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# Vessel Loop Closure Technique in Open Fractures and Other Complex Wounds in the Foot and Ankle

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*A gaping wound of the foot and ankle can be difficult to close. In cases in which wound margin mobility is suitable, the use of a vessel loop, or loops, to provide sufficient tension for wound margin reapproximation can be a useful adjunct to the surgical management of wounds that would otherwise be very difficult to close without the use of a skin graft or flap coverage. In this report, we describe the use of a vessel loop, or loops, for reapproximation of the margins of gaping wounds of the foot or ankle.* (The Journal of Foot & Ankle Surgery 48(6):692–699, 2009)

Key Words: ankle, foot, reapproximation, suture, wound margin

The condition of open fracture is often a harbinger of wound complications involving exposed hardware and the need for advanced closure techniques, which can include the need for skin grafting. The senior author has found that the vessel loop closure technique seems to expedite wound closure and has prevented serious wound contractures that can otherwise lead to higher morbidity and expense. Among the many tips, quips, and pearls that we have learned over the years, some techniques will stand the test of time better than others. Indeed, some techniques are more a matter of fad than function and will soon fall by the wayside. Valuable techniques, those that become a part of everyday practice, serve patients very well and become a part of the standard of care.

One such technique is the use of vessel loops for wound closures. This method of wound closure is simple, inexpensive, and easy to perform in just minutes. For large or otherwise complex wounds, this technique often serves to avoid the need for skin grafting techniques and potentially reduces the duration of hospital stay, risk of infection, and the need for local wound care regimens that may otherwise be required. Despite the fact that this technique was described more than 2 decades ago (1), some surgeons have never seen or used the procedure. Accordingly, we would like to take a closer look at this technique, and demonstrate its use in case reports that depict its effectiveness in achieving wound coaptation without undue tension for a variety of conditions.

## Surgical Technique

There are a host of conditions that may require delicate skin tensioning to achieve closure including open fractures

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**FIGURE 1** Child with lawnmower injury. (*A*) Dorsoplantar view, showing grass debris in the wound and traumatic amputation of the fifth toe. (*B*) Frontal view. (*C, D*) Vessel loop crisscrossing the wound, anchored through skin staples dorsally and plantarly, with nonadherent gauze placed under loops and over the open portion of the wound. (*E*) Vessel loop coaptation with antibiotic ointment before dressing application. (*F*) Residual dorsolateral granulation at weeks after the initial debridement.

(Figures 1 and 2), fasciotomy wounds (Figure 3), diabetic foot wounds, or amputations in which skin closure may be challenging. The chronic Charcot foot, with subsequent structural deformity, is often fraught with the development of bone and/or bursal projections that compromise the underlying skin and result in the development of abscess or ulceration (Figure 4). Often, skin or soft tissue atrophy or reduced vascularity may result in local soft tissue


**FIGURE 2** Open fracture dislocation of the ankle with (*A*) inspection showing a necrotic posterior wound margin. (*B*) The wound margins could not be reapproximated after ankle realignment and debridement. (*C*) Vessel loop closure used to gently reapproximate the wound while preventing further wound edge retraction. (*D*) Wound closure observed 2 weeks after open reduction and fixation.

insufficiency or ischemia, which necessitates a gentle but firm closure to allow the primary wound healing process to begin.

This technique can facilitate a delayed primary closure in the event that the index procedure results in a wound that may be otherwise challenging to close should one allow the wound to heal by secondary intention. The wound retraction that can naturally occur in a plantar wound, especially in the face of intrinsic muscle contracture, may prevent primary closure. Alternately, these wounds may require plastic surgery techniques or even skin grafting to achieve complete wound closure. This technique offers a viable alternative to more invasive approaches that involve greater risks such as host graft site morbidity.

The vessel loop closure involves large vessel loops and skin staples. To begin the closure, the surgeon folds the length of the vessel loop in half. The center of the vessel loop is then positioned just beyond the end of the wound (in this case, the most proximal end of the wound) and is secured with a skin staple (Figure 3B). The vessel loop is then directed along the medial and lateral aspects of the wound, creating a 60° angle. A skin staple is then placed on each side of the wound approximately 1 to 2 cm distal to the proximal end of the wound, thereby creating a triangular pattern to start the process. This serves as the pinnacle of the lace pattern. From here, the strands of the vessel loop are crossed over the wound, using staples to secure the vessel loops at least 1 cm or more away from the wound edge, in an effort to reduce stress on the wound margins. The loops are angled as they cross the wound and are secured in series along the wound margins, creating a shoelace pattern. Once the entire length


**FIGURE 3** Persistent compartment syndrome of the foot presented in an adolescent woman just 2 days after a 4-compartment decompression. (*A*) Notice the macerated and retracted plantar wound margins with pedal edema just 2 days after medial arch decompression was undertaken. (*B*) Vessel loop closure used to facilitate gradual reapproximation of the margins. (*C*, *D*, *E*) The patient's appearance during stance maneuvers at 3 months after the delayed primary closure.

of the wound has been coapted under physiologic tension, the vessel loop ends are hand-tied over a drain sponge to prevent pressure necrosis. Doing so creates a long chain that prevents unraveling of the slick rubber material of the vessel loop. Figure 3B shows that the end of the vessel loop is secured with a series of 4 to 5 knots and then stapled down and turned back on itself to prevent slippage. Nonabsorbable sutures can be interspersed throughout this closure to provide enhanced support of the wound, if desired. We feel that it is best to prepare this closure with a nonadherent mesh dressing with the benefit of a topical antibacterial ointment or cream, because this closure allows exudates to escape from the wound. This method tensions the wound edges, preventing untoward dermal retraction while providing excellent wound coverage. Non-weight bearing is required in most cases, and the staples and vessel loops can be removed at 2 to 3 weeks depending on the location of the injury and the condition of the wound. If nonabsorbable sutures are used, they can be removed in a second setting once the patient has begun protected weight bearing and the wound has proven to remain well consolidated.


**FIGURE 4** Plantar protrusion and wound in a patient with Charcot neuroarthropathy. (*A*) Prominent plantar protrusion and cutaneous compromise due to an abscess overlying a subluxed cuboid bone. (*B*) After a complex incision and drainage with excision of aberrant inflammatory soft tissues and an enlarged bursal projection, a large plantar wound was present, with the cuboid displacing the deep plantar fascia medially. (*C*) A V-Y skin plasty and vessel loop closure was supplemented by prolene bolster sutures. The bolster sutures are retained for numerous weeks, seen here just 2 weeks after removal of the vessel loops (4 weeks postclosure). (*D*) At 8 weeks postoperatively, a trace remnant of plantar wound and V-to-Y skin plasty remain evident.

## Discussion

It is interesting to note that the concept of using a shoelace-pattern suturing technique was developed to adjust astigmatism after cataract removal (1–4). This novel suture technique was found to provide gentle coaptation of tissue layers without constriction, and it could be adjusted to create the desired tension. Cohn et al (5) described the technique of the vessel loop wound closure in 1986, in cases of forearm fasciotomies for the treatment of acute compartment syndrome. Their theory was that the use of vessel loops would not only keep the skin reapproximated, avoiding the need for later skin grafting, but that it would also reduce the length of hospital stay and minimize the risk for infection. Their technique involved placing staples around a wound and then threading a vessel loop through the staples in a crisscross fashion. The ends would then be tied after placing physiological tension across the wound edges. The wound was then dressed with saline solution–soaked gauze, which was kept moist by adding sterile saline solution as needed. The vessel loop would be tightened in the operating room approximately 48 hours after its initial placement, at the same time that the sterile dressing was changed, and the process was repeated at regular 48-hour intervals until the wound was closed. The skin and wound edges were checked regularly for any discoloration, and the tension was adjusted accordingly. Using this method not only decreased wound infection rates by leaving the wound partially open, it also allowed for a more cosmetic closure because grafting was no longer needed in many cases. Hospital stays were also decreased as the problems associated with skin grafts, such as pain, incomplete graft incorporation, and infection at donor and recipient sites, were less prevalent. In addition, the significant swelling that most often accompanies compartment syndrome was kept to a minimum because of the constant tension of the vessel loop.

Harris (6) later modified this technique by placing the staples 48 hours after the initial fasciotomy and spacing them at 1.5- to 2.0-cm intervals along the wound edges, weaving the 2 vessel loops shoelace fashion across the wound itself. The opposing ends were tied end to end, and mild constant tension was achieved. The loops were tightened on 1 or 2 subsequent occasions, and only 1 patient required anesthesia. The patients were kept non-weight bearing until the wound had been closed, and the wound was examined daily for signs of skin necrosis, local inflammation, and compartment syndrome.

Several other variations of the original technique described by Cohn have been cited as well (7–14). Sandiford (7) used a size 12 Foley catheter in shoelace fashion instead of the vessel loop that was originally described. The catheter was placed 1 cm from the wound edge and the staples were approximately 2 to 3 cm from each other along the wound edges. Adequate closure was achieved, but evidence of pressure from the catheter was seen at the staple sites in several patients. The author (M.S.J.) has used this modified technique using an 8-french foley catheter with good results in open ankle fractures and compartment syndrome of the leg with good results and no complications of pressure necrosis. Zorilla et al (8) used the original technique of Cohn but modified the time at which the loop ends were tightened by tightening the loops 48 hours after the initial surgery, and then the loop ends were tightened at regular 48-hour intervals, with the use of local anesthesia. McKenney et al (9) achieved more rapid wound closure with a #2 nylon suture device, used in a similar fashion. Despite these reported modifications, we have found the shoelace technique with the vessel loop to be advantageous because of its ready availability and relative cost effectiveness. We have also used other closure devices, including adhesive skin strips and drainage tubes, but the vessel loop is the only item that provides continuous wound edge tensioning without excessive pressure. Below, we will depict several cases wherein the vessel loop was used as an adjunct to gaping wound closure in the foot.

## Case 1: Lawn Mower Injury

Traumatic amputation of the fifth digit and multiple metatarsal fractures were sustained as a result of a lawn mower injury to the left foot of a 5-year-old boy. The child had been transported to 2 different facilities before arrival at our institution. These facilities declined the case because it involved pediatric trauma. Figure 1 depicts the clinical appearance of the wound 8 hours after the injury. There was a large degloving wound across the dorsum of the left foot, and the extensor tendon to the fourth digit remained intact within the lateral wound bed. In the frontal plane view, there was a large defect at the site of traumatic amputation at the fifth metatarsophalangeal joint (MTPJ), with the fifth metatarsal head exposed and intact in the inferior lateral wound. The second digit had a large, serrated dermal defect overlying the distal ray with ample soft tissue for coverage. The wound edges on the dorsum were rolled and retracted, and the wound was laden with grass and debris. With the patient under general anesthesia, without a tourniquet, a pulsed lavage system was used to debride the wound with 9 L of normal saline solution. The power lavage was adjusted to reduce the pressure, taking into the consideration the condition of the skin and wound bed. A thorough exploration of the wounds was completed, and associated fractures of the fourth and fifth metatarsal shafts were identified. There was no evidence of neurovascular compromise, and the wound exhibited healthy bleeding potential. Deep wound cultures were taken, and the wound was prepared with a vessel loop skin closure while awaiting culture and sensitivity reports. Figure 1C depicts coaptation of the dorsal foot wound with gentle tension applied by the vessel loops. With this technique, physiological tension was achieved without overconstriction of the tissues. The vessel loop closure can be readjusted over time if needed to accommodate any change in the status of the edema in the extremity and wound margin tension. The dorsal foot wound was coapted, and a nonadherent mesh was used to cover the fifth MTPJ wound. The fifth MTPJ region was coapted by crossing the vessel loops over the mesh and supplementing the dorsal wound closure (Figure 1D). A second layer of vessel loops was placed over the mesh to enhance closure of the fifth MTPJ defect (Figure 1E). The entire closure was covered in antibiotic ointment in preparation for application of dry, sterile gauze dressing. The child tolerated the vessel loop technique well, requiring surprisingly little oral analgesic medication throughout the postoperative course. A second wound debridement was ultimately performed before delayed primary closure of the wounds. Over an 8-week period, the wound healed well with only a small, superficial zone of hypertrophic granulation tissue at the dorsolateral aspect of the foot (Figure 1F).

## Case 2: Open Ankle Fracture

A 60-year-old man presented 6 hours after sustaining an open fracture of the right ankle. The distal tibia was exposed, and the patient prepared for emergent wound debridement and stabilization of the fracture (Figure 2). Inspection showed necrosis of the posterior distal wound edge. After the fracture-dislocation was reduced and the wound debrided with pulsed lavage and 9 L of normal saline solution, the soft tissue sleeve appeared shrunken in comparison with the cubic content of bone present under the skin. In fact, after realignment of the dislocated and fractured ankle, we were not able to reapproximate the wound margins with typical suture techniques (Figure 2B). Therefore, the vessel loop closure method was used to gently reapproximate the wound while preventing further wound edge retraction. The vessel loop closure was completed before stabilization with an external fixator and would be maintained until culture and sensitivity reports became available (Figure 2C). After the open reduction and internal fixation was completed, the wound was easily coapted with the benefit of simple skin staples, and the patient recovered promptly with the wound appearing dry and well coapted in just 2 weeks after the open reduction and internal fixation procedure (Figure 2D). There was no episode of dehiscence or infection throughout the postoperative course, and the resultant scar was of satisfactory appearance and asymptomatic.

## Case 3: Compartment Syndrome

In this case, compartment syndrome of the foot persisted in an adolescent woman just 2 days after a 4-compartment decompression of the foot had been undertaken. The plantar wound was extensile and retracted as noted in Figure 3A. The muscle within the central wound bed had a waffle-weave impression, evidence of the nonadherent dressing previously applied. It was easy to appreciate the bulging appearance of the soft tissue structures protruding from the wound. This musculature in the plantar vault was difficult to reapproximate and close because of pronounced wound-edge retraction, maceration, and persistent soft tissue edema. A vessel loop closure was used to facilitate gradual reapproximation in this case. The vessel loop technique would be used to draw the wound edges close together, after which it was supplemented with the benefit of nonabsorbable suture once the edges were coapted free of tension (Figure 3B). The loops could be readjusted in the event of patient intolerance to the closure, and this was a particularly helpful aspect of this technique in a case that required delayed primary closure after trauma. The vessel loops were removed 2 weeks after surgery, and the patient was able to begin protected weight bearing at 3 weeks with the benefit of a soft cast and surgical shoe. Finally, the nonabsorbable sutures were removed at 5 weeks, and the patient was then advanced into a removable compression stocking and a firm-soled athletic shoe. At 12 weeks after the delayed primary closure, the patient was able to perform all of her usual daily activities without exception. Figures 3C and D depict her appearance during stance maneuvers at 3 months after the delayed primary closure. There was no incidence of wound dehiscence or infection, and the wound healed without evidence of painful or unsightly scar formation.

## Case 4: Charcot Neuroarthropathy

A 50-year-old insulin-dependent woman with diabetes with a longstanding history of stable Charcot neuroarthropathy developed an abscess in the midfoot. Given the rocker-bottom deformity of the foot, this region was predicted to have less than ample soft tissues available for a generous wound closure at the apex of the plantar foot deformity (Figure 4A). After a complex incision and drainage with excision of aberrant inflammatory soft tissues and an enlarged bursal projection, a large plantar wound was present. The cuboid was seen to have protruded through the plantar fascia, displacing the fascia medial-ward as seen in Figure 4B. A skin transport procedure performed in a V-to-Y fashion provided ample soft tissue for a vessel loop coaptation of the surgical site (Figure 4C). At 8 weeks after aggressive debridement and delayed primary closure using the vessel loop technique, there were only trace remnants of the incision and drainage site and only a faint residual scar indicative of the V-to-Y skin plasty. The patient returned to her Charcot Restraint Orthotic Walker at 8 weeks and continued her usual daily activities beginning at 3 months after the delayed wound closure.

In conclusion, open fracture and other traumatic injuries of the foot and ankle can be compounded by wound complications that often require complex wound care regimens or plastic surgery techniques to achieve a satisfactory closure. Complications such as severe wound margin retraction and dehiscence, as well as infection, can delay wound healing and stall the physical rehabilitation process. The vessel loop closure technique is a time-tested procedure that is easy to perform, readily available and inexpensive, and facilitates wound closure under physiological tension. This method can be used as an adjunct to serial wound debridements to eradicate debris and reduce the risk of infection. This gentle technique of soft tissue tensioning also encourages enhanced patient tolerance of the procedure and provides delicate manipulation of the associated neurovascular elements gradually over time. This is particularly helpful in cases of traumatic injury to the foot and ankle in which the soft tissue envelope has been seriously violated, such as in the crush injury resulting in compartment syndrome of the foot. In cases in which there has been significant wound margin retraction, this technique could be used to achieve gradual closure over time, thereby allowing the surrounding soft tissue and neurovascular elements to adapt until complete coaptation is achieved. It is the authors' opinion that this technique may reduce the incidence of wound dehiscence, infection, and/or neurovascular compromise in cases of open fracture in which wound complications are not infrequent. As with any technique of soft tissue tensioning, there is a learning curve regarding the decision to perform such a closure. Experience has shown that the technique can be modified to provide gradual wound coaptation in addition to serial wound debridements to ensure patient tolerance of the delayed primary closure. In cases in which serial wound debridements are required, this technique will facilitate continuous coaptation of the wound edges in a physiological manner, thereby allowing adaptation of the neurovascular elements and ultimately preventing wound retraction and dehiscence. In the case of open fracture, we feel that this technique may prove to reduce the incidence of serious posttraumatic wound complications.

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