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The Vertical Contour Calcanectomy: An Alternative Surgical Technique to the Conventional Partial Calcanectomy



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ABSTRACT

Heel ulcers have a significant impact on lower extremity morbidity and confer a high risk for major amputations. Although there are many conservative treatment options, once calcaneal osteomyelitis occurs or a heel ulcer becomes chronic or recalcitrant, more invasive management is required. The partial calcanectomy is a surgical solution that can address both pathologies—the ulceration and the infected bone. The conventional partial calcanectomy, however, does not ensure complete soft tissue closure. Often, closure under tension is required for primary closure of the soft tissue deficit or the wound must be closed by secondary intention. This process occurs, in part, when the proportion of bone resected is insufficient in relation to the size of the wound. Closure under tension increases the possibility of dehiscence and subsequent postoperative surgical site complications that lead to the same risks for major amputation as the index heel ulcer. This article introduces and describes a novel modification to the conventional partial calcanectomy and addresses these aforementioned concerns. The vertical contour calcanectomy incorporates improvements to an already accepted limb salvage technique. The purpose of this article was to describe the indications, contraindications, intraoperative technique and postoperative management of the vertical contour calcanectomy for patients who present with heel ulcers in the limb salvage setting.

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Heel ulcers are a major cause of morbidity worldwide, comprising 23.6% of all pressure ulcers. Those at the highest risk for developing a heel ulcer are those requiring prolonged immobilization or hospitalization (1), and those with advanced age, complex comorbidities, and hypercatabolic nutritional states (2). Patients with peripheral arterial disease (PAD) represent the second largest at-risk population for developing heel ulcers (3). Additionally, patients with diabetes mellitus and diabetes-related lower extremity complications are also at high risk for developing heel ulcers (4). Diabetic foot ulcers precede >80% of lower extremity amputations, (5) and the heel is the second most common ulcer of the foot (6).

There is a significant distinction between plantar and posterior heel ulcer locations. Posterior heel ulcerations are generally caused from pressure and ischemia in patients who are nonambulatory, whereas plantar heel ulcers are generally the result of biomechanical abnormalities in the gait pattern of ambulatory patients. Although the procedure described in this article can address both heel wound etiologies, there should be additional attention paid to the ischemia and biomechanical factors that were

the origin of the skin breakdown and could complicate the healing course. In ambulatory patients, the heel is subjected to the pressures of weight and shear forces during gait, which can result in or exacerbate a plantar heel ulcer. Bedridden patients, usually medically complex and fragile, develop decubitus ulcers which occur to the posterior aspect of the heel. The challenges of addressing concomitant osteomyelitis (OM), providing adequate soft tissue coverage, and establishing sufficient offloading in a population with a high prevalence of peripheral polyneuropathy and PAD, make this location a major clinical problem (7). Heel ulcers have a high propensity for major lower extremity amputation (8,9). Although conservative treatment options exist, heel ulcers are often resistant to such modalities and recalcitrant when the underlying pathomechanics and ischemia are not addressed appropriately. Nonsurgical treatments remain time intensive and do not address the underlying etiology.

Despite its frequent use, the conventional partial calcanectomy has several important pitfalls. Two vital disadvantages relate to its lack of reproducibility and the high risk of recurrent plantar ulceration owing to residual calcaneal bone prominence. The literature does not provide guidance on how much bone must be resected to ensure primary soft tissue closure. Although there is an infinite subset of presentations of ulcer sizes, locations on the heel, and degree of related OM of the calcaneus, inconsistencies in performing the procedure have contributed to clinician frustration and suboptimal postoperative outcomes.

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The vertical contour calcanectomy (VCC) is a novel modification to the conventional partial calcanectomy, developed by surgeons at an institution dedicated to limb salvage. The VCC is an aggressive partial resection of the os calcis designed to ensure primary soft tissue closure and mitigate the risk of reoperation while respecting the basic tenets of surgical closure and wound healing. The purpose of this article is to discuss the clinical indications and contraindications, describe the intraoperative technique, and provide a general postoperative plan for patients undergoing this procedure.

The VCC

Preoperative Planning

The primary indications for the VCC are patients with ulcers to the plantar and/or posterior heel secondary to pressure, ischemia, and/or infection. The VCC is reserved for those patients with a heel ulcer who otherwise cannot be primarily closed without advanced methods and/or those complicated by OM of the calcaneal tubercle. Other indications include patients with calcaneal gait who are not candidates for hindfoot reconstruction. Such patients include those who have minimal ambulation requirements, those who use their lower limbs only to transfer, and nonambulatory patients. Contraindications for this procedure include patients with a forefoot, midfoot, or hindfoot pathology that decreases the likelihood for a functional outcome and may be better served with alternative treatments including the need for a proximal amputation.

A patient who presents with a heel ulcer is given a comprehensive evaluation aimed to stratify perioperative risk. A thorough discussion of the surgical plan and postoperative expectations are presented. Laboratory testing should include a complete blood count with differential, a chemistry panel, erythrocyte sedimentation rate, C-reactive protein, glycosylated hemoglobin level, international normalized ratio, and additional tests based on specific patient presentation. Radiographic imaging should include plain radiographs of the foot and ankle and, depending on the circumstance, advanced imaging to rule out OM. A thorough vascular assessment is required to identify and optimize those with PAD, and should only be delayed if an emergent decompression is obligatory. Endovascular angiography is encouraged and may delineate the need for a proximal amputation. Often, these patients will benefit from revascularization of the lower extremity via angioplasty techniques such that medial and lateral calcaneal arterial flow can be re-established.

A staged approach is recommended, because this strategy allows for postdebridement soft tissue and bone culture and histopathology results to guide the timing of closure. The initial surgical intervention is directed at the removal of infected and nonviable soft tissue and bone to healthy margins. Retention sutures should be used to approximate the wound edges to prevent loss of elasticity in the skin and soft tissue between operative débridement. Once intraoperative cultures ascertain eradication of infection and the clinical presentation of the patient and local tissues have improved, a completion VCC can be performed. In contrast with this staged approach, a single-stage approach can be used in patients with noninfected decubitus heel ulcers after revascularization and in high-risk surgical candidates.

Most patients can tolerate a regional nerve block with sedation for the initial débridement, although general anesthesia is required if the patient will undergo prone positioning for the VCC.

The Surgical Technique

The VCC technique involves 4 basic steps:

1. Incisional approach,
2. Detachment of the Achilles tendon and the plantar fascia,

3. Performing 3 cardinal osteotomies with contouring, and
4. Soft tissue closure without tension.

Placing the patient in the prone position provides optimal visualization and accessibility to the surgical site. Alternatively, the lateral decubitus position can be used. A supine position can be challenging, but is an option when aided with support triangles and leg holders. A thigh or high-calf tourniquet should be used at the discretion of the surgeon.

Incision Planning

The soft tissue deficit generally dictates the extent of the incisional approach required to perform the VCC. After the excision of devitalized tissue, a linear midline Gaenslen split heel incision is used to create full-thickness medial and lateral flaps, exposing the plantar and posterior calcaneus. This can be accomplished by creating elongated, semielliptical incisions with the proximal and distal arms made in the midline of the posterior heel extending proximally past the insertion of the Achilles tendon, and as far distally as required based on the topography of the postdebridement deficit. It is important to note that the original Gaenslen paper includes hemisection of the calcaneus, a step that is not performed in the VCC technique.

Detachment

Once the medial and lateral flaps are created, the Achilles tendon is then fully detached from its insertion and the plantar fascia is detached from its origin. This tendon debridement is of particular importance in patients with posterior heel ulcers. In patients with plantar heel ulcers, the plantar fascia may require débridement, which should also be completed to the level of healthy fascia. A properly sized incision aids in visualization and dissection. The total incision length of the authors is generally 15 to 20 cm. Detachment of these structures enables easy removal of the bone fragments.

Osteotomies and Contouring

The full-thickness medial and lateral soft tissue flaps are protected to avoid injury to the vital neurovascular structures isolated within. Using a sagittal bone saw with a wide blade, the first osteotomy is made from the posterior aspect of the calcaneus and directed distally parallel to the long axis of the foot. Care should be taken not to violate the plantar cuboid and navicular, which are not visualized. The starting point of the osteotomy on the posterior calcaneus should be placed in the lower half as to avoid this problem (Fig. 1). The blade should remain inferior to the sustentaculum tali, which are easily palpated. The osteotomy includes the medial and lateral tubercles of the plantar calcaneus.



Fig. 1. First osteotomy landmark. Two imaginary lines can be made dividing the superior and inferior aspects of the calcaneus. The first cardinal osteotomy (long horizontal yellow line) should be placed just inferior to the bisecting (bold black line).



Fig. 2. Second osteotomy landmark. The second osteotomy (vertical red line) is made midway between the remaining posterior calcaneus and the axis of the malleoli. This line also corresponds with the lateral process of the talus on imaging. The osteotomy can be made at the bisection (bold black line) or adjusted depending on the size of the calcaneus. Larger calcanei can tolerate an osteotomy closer to the midline, but the osteotomy should never exit into the subtalar joint.

The second osteotomy is made parallel to the long axis of the leg and perpendicular to the first osteotomy. The osteotomy is initiated from the plantar aspect of the foot. The blade should exit on the superior aspect of the calcaneus and should be within the posterior half of the superior cortex. To locate this position, the surgeon should find the midpoint between the posterior calcaneus and the malleoli (Fig. 2). If imaging is available, this point corresponds with the lateral process of the talus. Alternatively, the osteotomy can be made from superior to plantar.

The final osteotomy is made at 45° tangential to the first and second bone cuts. On imaging, the cut is parallel to the posterior facet of the subtalar joint (Fig. 3). Generally, these osteotomies can be made without intraoperative imaging; however, fluoroscopy may aid in this regard. The final step of the osseous component of the VCC is calcaneal contouring. Contouring is aimed at creating a rounded final surface with smooth cortical borders. This goal can be accomplished with hand or power rasps (Table). A lateral intraoperative fluoroscopic image confirms bone resection, calcaneal contouring, and a flat weightbearing surface.

Closure

In preparation for closure, the surgical site is copiously lavaged with normal saline. If a tourniquet was used, it should be deflated before closure and hemostasis achieved. The calcaneus is a well-vascularized



Fig. 3. Third osteotomy landmark. The third osteotomy is made at 45° to the previous osteotomies or parallel to the posterior facet of the subtalar joint on imaging (represented in blue). This site, however, can be approximated and fluoroscopy is not required.

Table
Cierny Mader osteomyelitis classification (16)

Classification	Description
Anatomic type	
I	Medullary OM
II	Superficial OM
III	Localized OM
III	Diffuse OM
Physiologic class	
A–host	Good immune system and delivery
C–host	Compromised locally (B ^L) of systemically (B ^S)
D–host	Requires suppressive of no treatment minimal disability; treatment worse than disease; not a surgical candidate
Clinical stage*	
Example	Stage IVB ^S OM is a diffuse lesion in a systemically compromised host

Abbreviation: OM, osteomyelitis.

*Type + class = clinical stage.

bone, and may require extra attention to achieve full hemostasis. To prevent hematoma formation, the use of a surgical drain is encouraged, especially in patients receiving anticoagulation. After the osteotomies, soft tissue closure can usually be achieved without tension. Reattachment of the Achilles tendon is not performed. Most cases require revision of the incisional flaps created after completion of the osteotomies as there may be redundant tissue. Interrupted vertical mattress technique using a nonabsorbable #0 or #2 monofilament suture and intermittent skin staples is recommended. A posterior splint is applied in neutral to gravity equinus to decrease tension on the surgical incision, with robust padding and offloading of the heel. A soft roll is fashioned and placed between the heel and the posterior splint until the splint hardens to prevent pressure on the closure site, after which the roll is removed, which allows the heel to be suspended. Alternatively, a circular or delta frame can be used to suspend the heel for offloading of pressure.

Postoperative Management

The postoperative course requires strict offloading and the patient must remain non-weightbearing if ambulatory. Patients who are bedridden should be provided with a means to keep the heel suspended during the healing process. Once healed, they will need an offloading device to protect against recurrent ulceration. Anticoagulation therapy for deep venous thrombosis prophylaxis should be determined in relation to each patient's risk-benefit analysis. Patients may require physical rehabilitation, which should be provided as needed. Weekly postoperative surgical site surveillance is continued until staples and sutures are removed. Continued offloading is required several weeks after suture removal to ensure incision healing. Transition to weightbearing generally includes the Charcot restraint orthotic walker upon healing. After 6 months of ambulation in the Charcot restraint orthotic walker, progression into a custom ankle foot orthosis may be considered.

Case Report

A 62-year-old male with a past medical history of diabetes, dyslipidemia, peripheral vascular disease, and chronic bilateral heel ulcerations underwent multiple right heel débridement, percutaneous tendo-Achilles lengthening before presenting to our institution with a nonhealing plantar ulceration to right heel. His body mass index was 21.4 kg/m² and hemoglobin A1c was 8.7%. The patient minimally ambulated with diabetic offloading walker assisted with crutches. The patient was admitted to the hospital to receive medical and surgical intervention to address soft tissue infection and underlying OM of the calcaneus as evident on and computed

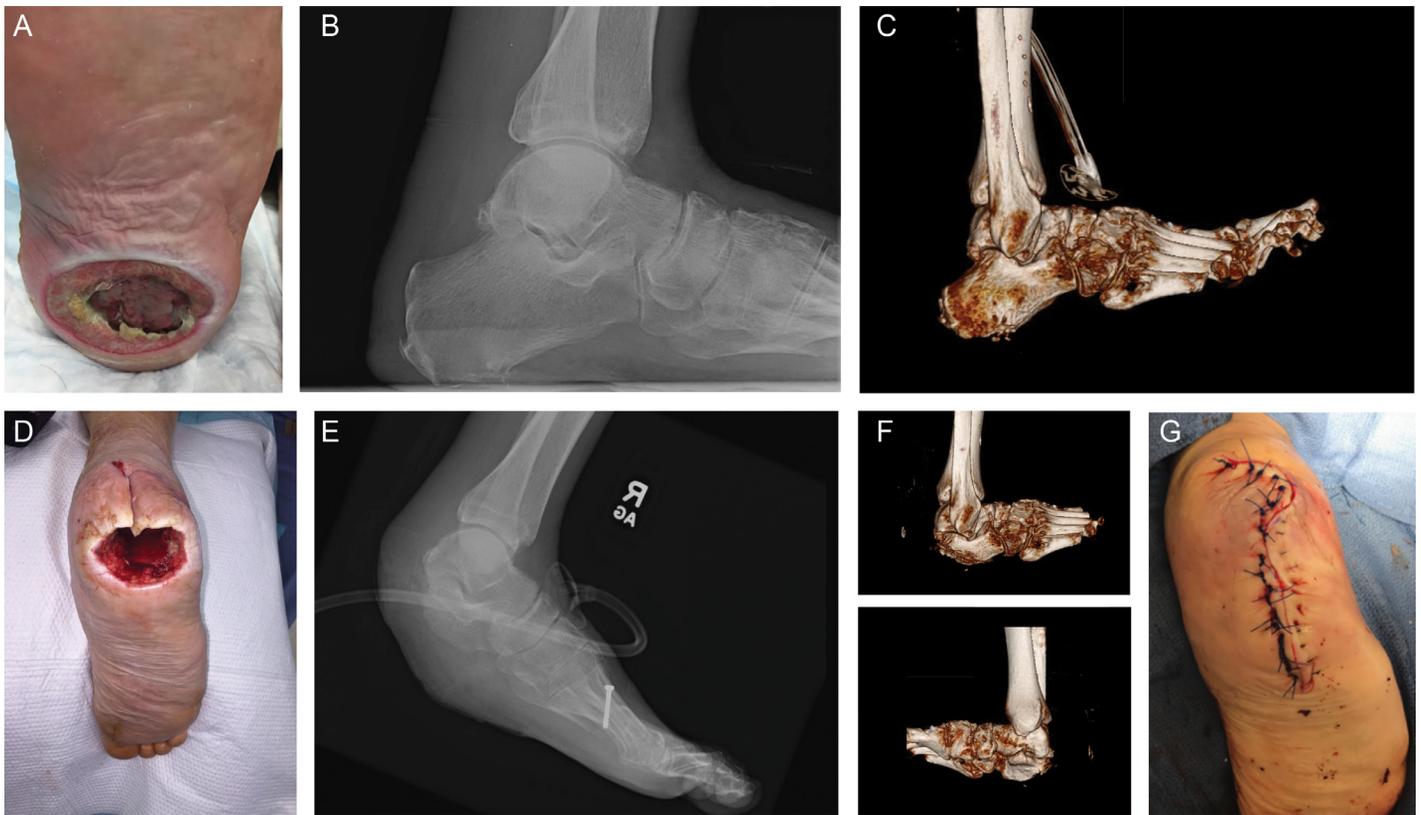


Fig. 4. (A) Preoperative clinical picture. (B) Preoperative radiograph. (C) Preoperative computed tomographic (CT) scan 3-dimensional (3D) reconstruction. (D) Interim operative clinical picture. (E) Postoperative radiograph. (F) Postoperative CT 3D reconstruction. (G) Postoperative clinical picture.

tomographic imaging (Fig. 4, A–C). Initial presenting laboratory tests included a white blood cell count of 10 and a temperature of 36.2°C. The patient underwent a previous right lower extremity arterial angioplasty a year earlier, with palpable dorsalis pedis and posterior tibial artery pulses. All other laboratory tests and vital signs were unremarkable. The patient underwent 2 débridements, including initial partial resection of the calcaneus to address infection (Fig. 4, D). Predébridement and postdébridement cultures were obtained during each operation. Once postdébridement cultures were negative, the VCC was performed and the wound primarily closed (Fig. 4, E–G). At the time of this article, the patients has completed 17 months of follow-up.

Discussion

Since the original operative technique was described by Gaenslen in 1931 (10) to treat heel ulcers complicated by OM, many other surgical procedures have been described. The conventional partial calcaneotomy has been portrayed as a viable alternative to the below knee amputation (11–14). Currently, however, the literature on the conventional partial calcaneotomy report a wide degree of variance regarding healing rates, reulceration rates, major amputation rates, and surgical site morbidity (12,15).

Of note, from the available literature, no technique papers or retrospective reports specify how much bone should be excised. Additionally, most articles that discuss the surgical management of calcaneal OM do not quantify the amount of bone that is involved. Without a clear delineation of the degree of infection and excised bone, it becomes impossible to extrapolate meaningful comparison or guidance in the treatment of this pathology from the literature. The critical component—the bone to soft tissue ratio at the heel after débridement—must serve in favor of the soft tissue to ensure primary closure without tension. The conventional

partial calcaneotomy does not define the mass of calcaneus required for resection. This finding may partially explain the high degree of outcome variability reported in the literature.

In these authors' opinion, the most important factor to postoperative success after patient optimization is to obtain early primary soft tissue closure without surgical site tension. There are several important questions the conventional partial calcaneotomy does not address in this regard: When OM is present, how much osseous resection is adequate to facilitate primary closure without tension? When OM is not present, how much osseous resection is adequate to facilitate primary closure without tension?

When calcaneal OM coexists with a heel ulcer, surgical osseous resection of the infected bone is important. The degree of anatomic involvement to the calcaneus can predictably guide the surgical aggressiveness of the resection based on the Cierny-Mader classification for adult OM (16). Cierny-Mader type III OM, and more so type II OM, may only require minimal resection to ensure surgical eradication of calcaneal infection (Fig. 4). In such cases, the remaining calcaneus may impede closure. The degree of tension required to approximate the wound edges for primary closure may be too excessive and can result in suboptimal postoperative results. Closure under tension, even if minimal, can become clinically problematic when postoperative edema occurs (8). In contrast, an aggressive resection of the calcaneus as described in the VCC can ensure definitive eradication of OM, decrease recurrence of OM and ulcerations, and allow the available postdébridement full-thickness soft tissue envelope to wrap around the remaining bone with tension free apposition of the skin edges.

In select cases, particularly those who are minimally ambulatory, a VCC partial calcaneotomy can facilitate primary closure even in the absence of infection. In the past, this procedure has been reserved for those wounds complicated by OM. Nonsurgical alternatives include

negative pressure wound therapy, the use of bioengineered tissue allografts, and standard of care with offloading. However, increasing evidence encourages early soft tissue closure or coverage as a key element in preventing OM (17).

It is important to note that the heel is composed of unique tissue that cannot be easily replicated. The heel pad is a dense fibrofatty network with a sophisticated morphology that allows for shock absorption and weight dispersion. Collagen bands form septations known as chambers which that connect the skin to the periosteum of the calcaneus. Adipose tissue of varying densities populates these chambers. Preservation of the heel pad (even just the medial and lateral remaining borders) is an important surgical consideration.

The conventional partial calcaneotomy has been a successful limb salvage tool in the treatment of heel ulcers. A literature review in 2005 of 148 cases by Randall et al (6) reported an overall healing rate of 89%. Smith et al (11) reported that, in healed partial calcaneotomies, 90% maintained preoperative mobility. Smith et al (18) in a study of 50 heel ulcers divided patients into 3 groups: diabetes mellitus plus PAD, PAD, and diabetes mellitus with healing rates of 56.5%, 64.3%, and 83.3%, respectively. Han et al (19) in 2011 reported a healing rate of 58% and a major amputation rate of 42% in nursing home patients who developed heel ulcers and required a conventional partial calcaneotomy. In a systematic review, Schade et al (12) reported that <24% of patients had minor surgical site complications that went on to complete healing, and a major amputation rate of 10%. Interestingly, of those who did not require major amputations, they found that 85% of patients maintained or improved ambulatory status postoperatively after partial and total calcaneotomies with calcaneal OM.

Heel ulcers, with or without OM, are difficult to treat. Given the forces applied during walking, and the difficulty to offload, other treatment options such as the application of biologics, negative pressure wound therapy, and skin grafts are at high risk for failure. Complex soft tissue reconstruction such as free tissue transfer is a viable option, but careful patient selection and vascular evaluation are paramount given the additional donor site morbidity (20). The surgeon should recognize that the population at risk for developing heel ulceration shares common comorbidities and overlapping risk factors that result in suboptimal distal tissue perfusion. Preoperative vascular optimization becomes paramount to successful outcomes in all VCC cases. Intraoperative technique requires gentle tissue handling, minimal retraction, and an understanding of the vascular supply to the heel. The linear Gaenslen split midline heel incision respects the angiosomes that supply the posterior and plantar heel. The posterior tibial artery and the peroneal artery provide a dual supply to the heel. The medial calcaneal branch of the posterior tibial artery supplies the posterior medial heel and the plantar heel. The lateral calcaneal branch of the peroneal artery supplies the posterior lateral heel and can contribute to the lateral plantar heel (21).

In addition to optimizing and protecting vascular integrity, other important factors can contribute to postoperative outcomes. Cook et al (15) showed the presence of methicillin-resistant *Staphylococcus aureus*, vascular disease, suboptimal albumin levels, and high preoperative ulcer Wagner grades can decrease closure rates at 1 year from 83% to 51%. Other reported risk factors for heel ulcer failure include renal disease, low ejection fraction, and smoking. Therefore, promoting overall health quality is an important continuous component of postoperative care. A multidisciplinary team approach is advantageous in all limb salvage scenarios.

The fear of inducing an iatrogenic calcaneal gait may prevent the appropriate resection of infected calcaneus and detachment of the Achilles tendon by some surgeons. This complication can result in recurrent OM, reulceration, and an increased risk of major amputation. When residual or recurrent OM occurs, long-term antibiotics can be an alternative option. In the patient with diabetes, however, as a result of

microvascular compromise, antibiotics often only reach the target tissue in peak plasma concentrations that suppress rather than eradicate infection. Furthermore, diabetic tendinopathy results in shortening of the Achilles tendon and predisposes to many forefoot pressures and related pathomechanics. A common misconception argues that the Achilles insertion must be maintained at all costs. Patients are able to ambulate adequately as the flexors of the foot remain active and compensate for the loss of the Achilles tendon. This compensation is the same one that assists ambulation after an Achilles lengthening procedure. Proper orthoses and bracing promote functional ambulation after the detachment of the Achilles tendon as described in the VCC procedure. In a study by Baravarian et al (9), the loss of the Achilles tendon insertion often leads to weakness and gait dysfunction, but with proper ankle foot orthoses, patients felt no weakness in their posterior muscle groups and report similar ambulation status (9,12). We have found that, at 6 to 12 months postoperatively, there is significant and palpable attachment of posterior soft tissue scar mass to the posterior calcaneus, which mimics the function of the resected Achilles tendon. It is important to note, however, that, if the heel ulcer is a consequence of calcaneal gait, in addition to the VCC, an ankle arthrodesis or tibiotalar-calcaneal arthrodesis may be required to maintain a plantigrade functional foot.

Interestingly, the quantity of calcaneus removed for OM does not affect patient function as assessed by the Lower Extremity Function Scale. In a retrospective review by Oliver et al (22), patients who required aggressive resection with 13% remaining calcaneus had similar Lower Extremity Function Scale scores when compared to those with 74% of remaining calcaneus. Additionally, Attinger et al (23) suggest that limb length is directly related to life expectancy, provided patient expectations are met. In the diabetic sedentary patient with multiple comorbidities, preservation of limb length has a significantly lower morbidity than below-the-knee amputation (20). Patients who are less active have worse outcomes than those who remain active because of cardiopulmonary deconditioning and musculoskeletal atrophy. The VCC provides patients with an aggressive resection, which decreases the likelihood of recurrent OM and ulceration, a robust soft tissue closure without tension, and limb length that allows for continued ambulation at or better than baseline with proper bracing.

There are other investigators who have demonstrated success with modified partial calcaneotomies. These tend to only resect the calcaneal tuber at an oblique angle 1 to 2 cm posterior from the posterior subtalar joint facet and calcaneocuboid joint (8,9,11). Described as subtotal calcaneotomies, the angle created from a single osteotomy may be too acute to effectively disperse plantar pressure. The presence of an abrupt plantar border, and/or exposed cortical walls can lead to reulceration and increase the likelihood of a subsequent complications and morbidity, including limb loss. Faglia et al (24) emphasize the importance of mitigating reulceration: recurrent ulcerations secondary to surgical site dehiscence, inadequate resection of OM, or other host complications increase the risk of limb loss. When repeat operations are required secondary to unresolved OM, major amputation risk increases to 52.2% as compared with 18.5% for the midfoot and 0.33% in the forefoot (24). Ulcer recurrence has a major impact on patient quality of life, carries a high economic health burden, and places the patient at an increased risk for additional antibiotics, repeat hospital admissions, and the associated risks of surgical intervention. The VCC promotes aggressive resection with the advantage of ensuring all surfaces are quiescent thus mitigating this risk.

In conclusion, the goals of treatment are challenging to achieve, but remain standard; elimination of infection, prompt soft tissue coverage, and a functional outcome for the patient (25). As with all heel ulcers, and diabetic foot ulcers in particular, treatment requires accurate identification of OM, vascular evaluation and optimization, surgical débridement of devitalized and infected soft tissue and

bone, and a reconstructive effort cognizant of biomechanical implications.

The VCC is an innovative modification to the conventional partial calcaneotomy, which enhances the rates of primary closures. The VCC is a powerful alternative to major amputation and decreases morbidity and mortality related to postoperative surgical site complications. The procedure promotes the early closure without the need for complex soft tissue reconstruction. Functional outcomes after aggressive calcaneal resection has been shown to be equivalent to the Lower Extremity Function Scale assessments compared with those with minimal calcaneal resection. The ambulatory devices required postoperatively are readily available and well-tolerated by patients. The VCC provides the patient with a stable robust soft tissue envelope at the plantar heel and maintains a plantigrade functional lower extremity. Although this technique has been described to ensure reproducibility and ensure anatomic weightbearing surface contour, the osteotomy approach for VCC can be modified based on a patient's unique presentation to achieve similar results. These authors advocate this novel surgical technique as an alternative to the conventional partial calcaneotomy as a viable limb salvage tool and encourage further studies to assess its merit.

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