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Authors
Potter, Christian T
Camargo, Anthony M
Cecere, Robert A
et al.

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The Twizzler: a modified primary closure for distal lower extremity wound reconstruction utilizing a dynamic winch stitch

Christian T Potter[1] MS, Anthony M Camargo[2] BA, Robert A Cecere[3] BS, Annie Wang[4] MD, Carl F Schanbacher[4] MD

Affiliations: [1]University of Guam, Mangilao, Guam, USA, [2]University of Massachusetts Medical School, Worcester, Massachusetts, USA, [3]Weill Cornell Medical College, New York, New York, USA, [4]Tufts School of Medicine, Tufts University, Boston, Massachusetts, USA

Corresponding Author: Carl F Schanbacher MD, 1 Maple Street, Milford, MA 01757, Tel: 617-869-0126, Email: cschanbacher@gmail.com

Abstract
Management of lower extremity wounds following successful tumor excision presents multiple challenges. Distal lower extremity integument is highly prone to edema often lacks adequate skin laxity for standard primary closures. The closure must be resilient enough to withstand mobility. As a result, optimal reconstruction may include skin grafting, rotational flaps, free tissue transfers, healing by second intention, or some combination. These methods may involve multiple steps in reconstruction, a prolonged recovery period, increased cost, and higher infection risk. We propose a modified primary closure that takes advantage of the visco-elastic properties of the skin without introducing additional components or steps. This technique is initiated with percutaneous suture in order to intermittently stretch the skin with constant tension. This load cycling allows for lower extremity skin to stretch over time and ultimately reduce wound edge tension, allowing for ease of absorbable suture placement. The Twizzler technique is cost-effective, uses readily available supplies, and effectively closes relatively large defects on the lower extremities.

Keywords: dermatotraction, lower extremity primary closure, skin cancer reconstruction

Introduction
Following successful lower extremity skin cancer ablation, the surgeon often encounters the challenge of achieving optimal wound closure in an area prone to edema, ambulation, and poor skin laxity. When defects are small, primary closures are attainable; however, larger surgical wounds often require more involved reconstructions such as skin grafts, flaps, and free tissue transfer [1,2]. Alternative wound management includes second intention wound healing, which exposes patients to at least a two-fold increase in infection rate [3]. These methods may introduce unnecessary risks to the patient and add considerable cost, time, and morbidity [3-5]. Therefore, primary closures are often preferred to minimize these risks.

Achieving primary closure in larger wounds often requires intraoperative tissue expansion, a method that capitalizes on the skin's ability to stretch under stress. However, many methods described in the literature require the use of devices such as balloons and the Sure-Closure® (Zimmer Inc, Warsaw, IN), [5]. Such devices not only prove costly, but also require specialized equipment not readily available to surgeons. Surgeons have advocated serial excision as a way of leveraging mechanical and biologic creep to manage large cutaneous cancers [6]. Through the use of a permanent modified winch stitch, we introduce a cost-effective modification to the primary closure that allows for the immediate reconstruction of relatively large defects on the lower extremities.

Case Synopsis
Case 1
A 79-year-old woman presented with a squamous cell carcinoma on the right lower leg. Using Mohs micrographic surgery (MMS) the tumor was removed in one stage, leaving a final defect measuring 3.3×2.6cm, extended to superficial fascia. The patient

Figure 1. *Intraoperative images of right lower leg with patient in supine position:* ***A)*** *Post MMS elliptical defect measuring 3.3×2.6cm.* ***B)*** *Excess tissue is removed in the distal and proximal directions to form a lenticular shape.* ***C)*** *Percutaneous running sutures applied in a relaxed fashion, with excess material present at distal and proximal ends.* ***D)*** *Closure of skin edges by slowly applying a uniform force in opposing directions.*

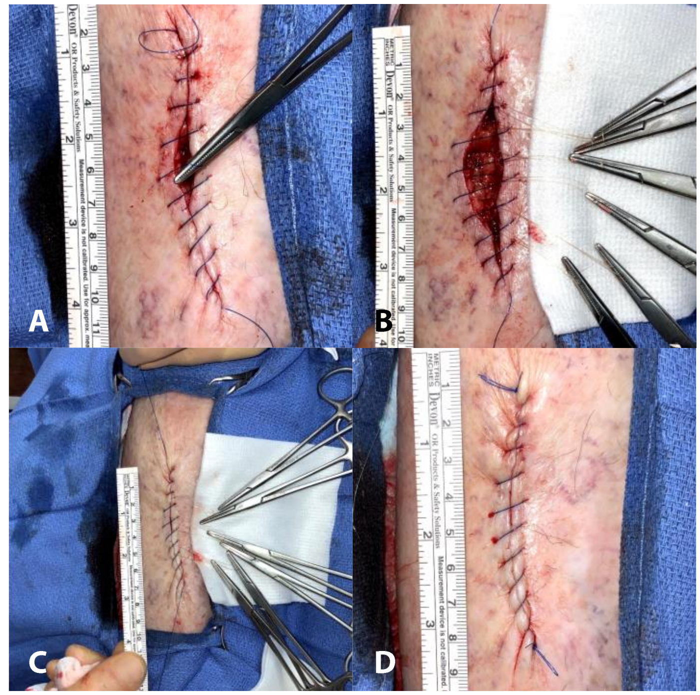

Figure 2. *Intraoperative images of right lower leg with patient in supine position:* ***A)*** *Percutaneous suture being loosened using a needle driver.* ***B)*** *Lenticular wound after application of deep dermal sutures (clamped with hemostats).* ***C)*** *Closure of skin edges by application of force to excess percutaneous suture material. Note the clamped deep dermal sutures off to the side.* ***D)*** *The final wound appearance following fastening of the percutaneous sutures using a surgeon's slip and tying of deep dermal sutures.*

preferred wound closure because of her moderately active lifestyle and concern for infection. A traditional primary closure would be likely to fail related to the high wound closure tension and surrounding edema (**Figure 1A**).

The reconstruction of the elliptical defect was carried out by first creating a lenticular wound (**Figure 1B**) using a No. 15 scalpel blade along longitudinally oriented maximal skin tension lines. In planning the final wound shape, the goal was to achieve a length to width ratio between 3:1 to 4:1, with apical tissue cones measuring approximately 30°. The integument was then approximated with 3-0 polypropylene (Prolene™ Ethicon Inc, Somerville, NJ) in a relaxed percutaneous running suture pattern, leaving adequate suture material at both ends (**Figure 1C**). Distance was approximately 7mm between bites, with a bite depth of 5-7mm from the wound edges. With the suture material in place, uniform force was applied to the excess suture material at the distal and proximal ends in opposition to stretch the skin margins closed (**Figure 1D**). Tension was applied intermittently for approximately 30-60 seconds.

Following the load period needed for sufficient skin stretching, the wound was reopened, allowing deep dermal sutures to be placed. Using the head of a needle driver, the percutaneous suture was loosened sequentially (**Figure 2A**) to expose wound edges for deep suture placement. Next, deep dermal 4-0 poliglecaprone 25 (Monocryl™, Ethicon Inc, Somerville, NJ), was applied but not yet tied and separately clamped with hemostats (**Figure 2B**). The reopened wound was then subjected to another load period by applying uniform force to the percutaneous suture ends (**Figure 2C**), followed by the fastening of this suture at each end using a surgeon's slip knot. During this step, it is imperative to avoid securing the percutaneous suture with excessive force or tension, which may result in strangulation. The deep dermal sutures were then unclamped, tied and cut successively. These sutures serve to further relieve tension and provide long-term structural support after the percutaneous suture is removed in two weeks. The final incision measured 7.8cm (**Figure 2D**). After receiving fastidious wound care instructions (**Table 1**), the patient's surgical site was dressed with a non-adherent dressing (Telfa pad, Curad®, Chicago, IL), gauze, and a transparent occlusive film (Tegaderm™ 3M St. Paul, MN). After two weeks, the patient was evaluated and the percutaneous sutures were removed. At this time the patient was cleared to resume light physical activity (jogging, and bike riding). At seven weeks post-reconstruction the wound is fully healed (**Figure 3**).

Case 2

An active 59-year-old woman presented with a basal cell carcinoma on the right lateral shin. The tumor was removed in two stages of MMS, leaving a final defect measuring 1.4×1.5cm (**Figure 4A**). Wound reconstruction was initiated by transforming the defect into a 4.0×1.5cm fusiform wound along the length of the shin (**Figure 4B**). Using the previously described technique, termed the Twizzler, the defect was repaired by first placing running percutaneous 3-0 polypropylene along the length of the wound. The wound was then sequentially closed by pulling on the opposite ends of the percutaneous sutures before reopening the wound to place and tag deep dermal 4-0 poliglecaprone 25 sutures. After reclosing the wound by pulling on the percutaneous suture, both the percutaneous suture and deep dermal sutures were tied off. The final incision measured 5.0cm in length (**Figure 4C**), and the surgical site was dressed with a non-adherent dressing (Telfa pad, Curad®, Chicago, IL), gauze and a transparent occlusive film (Tegaderm™ 3M St. Paul, MN). After two weeks of fastidious wound care (**Table 1**), the percutaneous sutures were removed (**Figure 4D**) and the patient was cleared to resume her physical activities.

Figure 3. *The wound appearance at seven weeks post-reconstruction.*

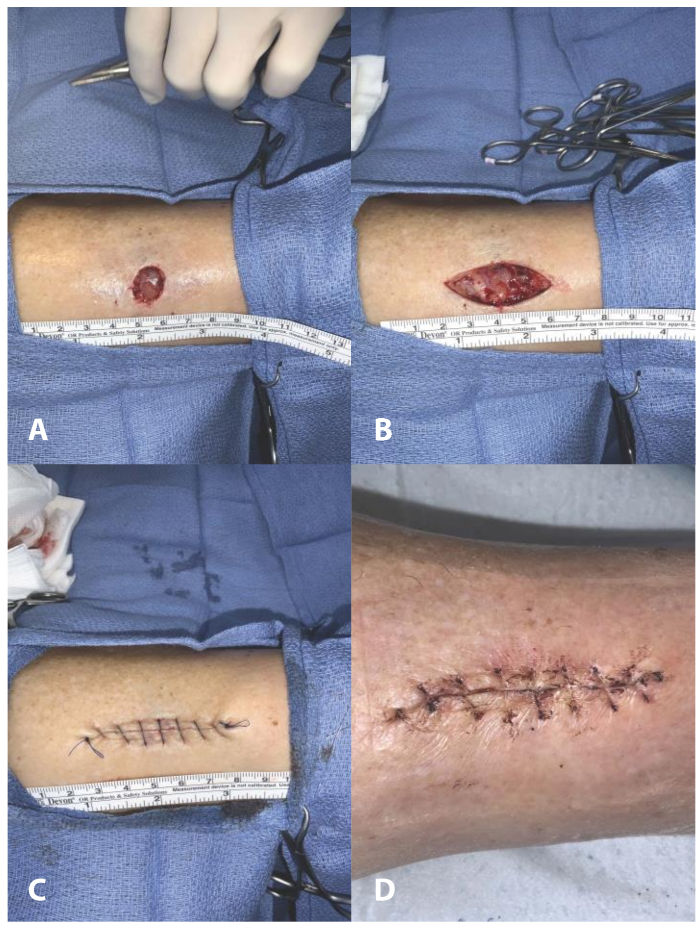

Figure 4. *Intraoperative and postoperative images of right lateral shin with patient in supine position:* ***A)*** *Post MMS elliptical defect measuring 1.4×1.5cm.* ***B)*** *Fusiform wound following the removal of distal and proximal excess tissue.* ***C)*** *The final wound appearance following reconstruction using the Twizzler technique.* ***D)*** *The wound appearance after suture removal at two weeks post reconstruction..*

Table 1. *Preoperative and postoperative patient instructions and activity limitations for Mohs micrographic surgery defects repaired using the Twizzler technique.*

Surgical Timeline	Patient Instructions
1 week pre-surgery	Wash below the waist with 4% chlorhexidine gluconate wash once daily
Weeks 1 & 2 post-surgery	Keep original surgical site dressing dry and do not remove it or change it until suture removal (2 weeks post-surgery) Elevate leg whenever possible and apply a heating pad to surgical site 5-10 times/day (20 minutes on, 20 minutes off) Do not engage in strenuous activities or perform isometric exercises
Week 3 post-surgery	Keep surgical site dry and do not apply any ointment(s) Change bandage as needed Resume light physical activity (e.g., jogging and biking)
Week 4 post-surgery	Leave surgical site uncovered Clean with mild soap and water or 4% chlorhexidine gluconate wash once daily Resume normal physical activity

Discussion

In cutaneous surgery, traditional primary closures are typically initiated with the placement of deep dermal and subcutaneous sutures followed by percutaneous skin edge approximating sutures. The inherent problem with this conventional approach on lower limb wounds is that high tension between skin edges precludes the placement of isolated deep dermal sutures without tissue tearing. The surgical technique presented herein, the Twizzler, reverses this dogma by taking advantage of dermatotraction, allowing deep dermal sutures to be placed successfully.

The literature surrounding dermatotraction, a form of tissue expansion, documents its use as an effective method for closing large fasciotomy wounds, usually with costly specialized traction devices. However, in 2000, Chiverton and Redden demonstrated the success of a unique surgical reconstruction on the lower limbs using purely subcuticular 2-0 polypropylene suture to attain delayed primary closures on six patients following fasciotomies [4]. Other methods using non-specialized equipment include corrugated drains fastened by running sutures looped around spinal needles in conjunction with towel clamps, which can produce unnecessary trauma [7,8].

These techniques rely on the skin's visco-elastic property of mechanical creep allowing tissue to stretch over a given time when a constant force is applied without any increase in its tension. This expansion over time results in the progressive reduction in force required to maintain constant skin length resulting in stress relaxation [5]. In practice, both mechanical creep and stress relaxation are achieved by subjecting the skin to a constant load or by intermittently stretching the skin, a process called load cycling [7,8]. By intermittently applying tension, an incremental elongation of the skin is achieved.

Unlike fasciotomy wounds, the repair of skin cancer defects involves the loss of skin and thus results in increased tension along the wound. In the early 2000s, cutaneous surgeons accounted for this by utilizing a temporary intraoperative winch (multiple pulley) and modified winch (dynamic winch) sutures to successfully achieve tissue expansion and eventually primary closure [9,10]. Specifically, this type of stitch is a running suture utilizing multiple loops or pulleys with both free ends tied diagonally. When tightened by pulling on the diagonal component, skin is stretched by means of mechanical creep. Because of the inverse relationship between force and distance, an increase in number of throws results in a larger mechanical advantage, thereby requiring less force to close the wound.

The true utility of the winch stitch is its ability to gradually stretch tissue, resulting in a dramatic reduction in tension between skin edges. Such reduction allows the surgeon to successfully place tension-relieving deep dermal sutures across the wound. However, one disadvantage of the suture is that the free ends are traditionally tied together, resulting in a diagonal force that can complicate the placement of deep dermal sutures once tissue expansion is achieved. Caspian et al. recommended using hemostats to clamp the free suture ends along the wound, termed the dynamic winch stitch [10].

The Twizzler utilizes the dynamic winch stitch as a mechanism to achieve tissue expansion and eventually primary closure. Normally, the winch stitch only spans a portion of the wound with three to five throws. However, the Twizzler's modified dynamic winch stitch spans the full length of the wound, often in excess of five throws, depending on the wound size. Because the suture spans the full length of the lenticular wound, tension is applied by pulling the suture's free ends away from each other. Although this may seem like excess work to the surgeon, the mechanical advantage gained by utilizing five or greater throws greatly reduces the necessary force to close the wound.

Fundamentally, the biggest difference between the traditional application of the dynamic winch stitch and the Twizzler is that the winch stitch is fastened after the successful placement of deep dermal sutures and remains in place for approximately two weeks. Normally, winch stitches are used intraoperatively, as the diagonal component is speculated to contribute to suture track marks. The Twizzler secures its modified winch stitch at both ends of the wound using a surgeon's slip knot and thereby avoids a diagonal force. Rather than avoiding suture track marks, the main advantage for the Twizzler is successful wound closure and expedient wound healing.

In defects where significant tissue is excised or excess edema is present, high skin tension can preclude primary closure. Because the dermis thins at a rate of six percent per decade, elderly patients may present with a paucity of integument collagen rendering successful defect closure unlikely [10]. Other comorbidities such as protein malnutrition, severe photo-damage, and history of corticosteroid use make this and other wound closure techniques difficult, at best.

Significant tension and friability can result in tissue tearing. A previous experiment utilizing skin substitutes showed that 3-0 polypropylene suture tears through the dermis when an excess force of 6N is exerted [12]. The amount of force a surgeon can exert before tearing through skin is directly proportional to the number of throws. The cutaneous surgeon can minimize tissue tearing by increasing the number of throws, allowing for the successful closure of high-tension wounds. However, the surgeon may find it more difficult to pull the wound closed with higher numbers of throws (eight or greater) as the friction coefficient of even polypropylene suture material may not be sufficient to overcome tissue resistance. To adapt to such a situation, the surgeon may need to sequentially extract excess suture from the midpoint of the wound with blunt end instruments such as needle driver tips.

An additional potential complication of the Twizzler technique includes wound tension ischemia. Overt strangulation can occur when excessive force is applied to close the wound. It is vital for the surgeon to slowly stretch the wound closed as well as fasten the percutaneous suture with sufficient tension to keep the wound edges together. Undue wound edge tension can result in strangulation and wound edge necrosis. In the literature, other authors do not recommend that winch stitches be utilized as long-term (14 days or longer) sutures due to ischemic complications associated with the multiple loop structure. However, in the past four years, we report no ischemic complications in the successful repair of numerous lower extremity defects using the Twizzler technique.

Conclusion

The Twizzler closure, utilizing a modified winch stitch, presents numerous advantages over traditional methods for managing lower extremity defects. By utilizing 3-0 or 4-0 polypropylene suture material in a running fashion across a lenticular wound as an apparatus for dermatotraction, the Twizzler closure provides a simple, immediate, and efficient method for managing otherwise difficult wounds. Specifically, percutaneous sutures are used to relieve tension across the wound, thereby allowing absorbable deep dermal sutures to be placed almost tension-free, facilitating successful wound edge approximation. The final fastening of the percutaneous non-absorbable suture serves to further approximate the skin edges while enhancing mechanical creep and stress relaxation.

This wound closure method has been used with great success and can serve as a helpful technique in managing lower extremity wounds and others under high tension. To date, we have utilized the Twizzler to achieve primary closure in over 180 MMS lower extremity defects ($\bar{x}$ MMS defect size 2.84cm^2, $\bar{x}$ primary closure length 5.25cm). Anecdotally, by using the Twizzler technique in place of complicated reconstructions and second intention wound healing, we have documented a decrease in lower extremity infections following MMS. More recently, we have expanded the anatomical use of this technique to achieve primary closures in high tension wounds on the scalp and trunk. In doing so, we find this technique to work best on skin with a thicker dermis to expand the skin and that the use of a taper needle provides a greater advantage than a cutting needle, preventing skin tears.

Potential conflicts of interest

The authors declare no conflicts of interest.

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