Use of an external skin-stretching device for wound closure in dogs and cats

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Surgery relies on inherent elastic properties of the skin to close wounds secondary to trauma or after removal of diseased tissues. The skin’s inherent elasticity can vary among species and individual animals; it also can vary on the basis of body region, age, body configuration, and pathologic conditions involving the cutaneous tissues. To minimize tension during basic wound closure, surgeons may attempt to place incisions parallel to lines of maximum tension. Undercutting skin margins can further mobilize skin, although the combined effects of undermining cutaneous tissues and attempting to close wounds under tension can result in variable degrees of circulatory compromise.

Several investigators have reported that skin is capable of extension beyond its inherent elasticity, as documented by use of a stretching or tension force applied over time. This phenomenon, termed mechanical creep, is complimented by stress relaxation (ie, the progressive reduction in force required to maintain the stretched dermal collagen fibers at a specific length). During the process, tissue fluid is slowly displaced from around the randomly arranged convoluted dermal collagen filaments as they straighten and compact longitudinally in the direction of the stretching force or load. This increase in cutaneous length can be measured within minutes after application of a load; the greater the force applied to the skin, the sooner maximal extension is achieved. The amount of time required for mechanical creep to achieve its desired effects varies on the basis of body location, direction of force application, patient age, and health status of the specific individual.

The basic concept of surgically expanding skin was described by Neumann in 1957, which led to the development of the modern tissue expander in the 1970s. Inserted in the hypodermis, intermittent injections of saline (0.9% NaCl) solution are used to slowly enlarge these silicone elastomeric devices. During a period of several days to weeks, enlargement of these ballooning expanders increases the surface area of the overlying skin to enable coverage of adjacent skin defects. Recruitment of skin by use of tissue expansion is the result of a combination of acute stretch, recruitment of adjacent elastic skin, and true expansion as a result of biomechanical properties of stress-relaxation described previously. However, limited intraoperative use of tissue expanders is reportedly less effective than undermining alone in mobilizing skin for wound closure.

In one study, investigators documented that variable gains detected in the recruitment of skin associated with tissue expanders is influenced by biomechanical, histologic, and expansion characteristics of skin in various species of animals. In that study, those investigators indicated that the skin of dogs is the best model for tissue expansion in humans, primarily on the basis of its biomechanical properties. On the basis of my surgical and anatomic observations, cutaneous tissues of domestic cats and dogs are quite similar in their general physical properties and distribution of direct cutaneous arteries. Results of circulatory mapping studies also suggest similarities between cutaneous tissues of humans and those of dogs and cats.

One surgical method described uses, in part, the biomechanical properties of mechanical creep and stress relaxation to facilitate closure of skin wounds. This method relies on the use of nonadjustable tension-mattress sutures to imbricate the skin on opposing sides of cutaneous lesions. The sutures primarily exert their effect on the healthy skin immediately adjacent to the proposed surgical site. The force required to close surgical wounds can be markedly reduced within 24 hours after suture application, as determined on the basis of studies performed in swine, with positive benefits evident as rapidly as 2.5 hours after application in humans and pigs. Similar techniques have been designed to facilitate wound closure of skin by stretching or load-cycling skin bordering a wound or surgical site, using skin hooks or a ratchet device.

An externally applied skin-stretching device was developed to harness the viscoelastic properties of the skin. In its current design, the basic device maintains continuous, adjustable tension to skin by means of adherent skin pads applied to opposing sides of a surgical site, which are coupled by adjustable, elastic tension straps or cables that engage the skin pads.

Use of this noninvasive continuous-tension skin-stretching device that rapidly mobilizes skin for wound closure, using viscoelastic properties of the dermis, is reported here. Problematic wounds in dogs and cats were used to assess the clinical advantages and disadvantages of this new device and technique to close skin defects.

Procedures

Dogs and cats with serious cutaneous wounds or lesions were evaluated, and use of the external skin-stretching device was considered. Animals with large wounds that were not amenable to closure without the use of extensive undermining of cutaneous tissues, skin grafts, axial pattern flaps, or a combination of reconstructive techniques were selected. Consent of owners was obtained for use of the skin-stretching device. Successful use of the device requires a reasonable source of donor skin that can be recruited for wound closure. After surgery, incisions considered at risk of disruption because of moderate tension for skin closure were managed with external stretchers to pre-
vent dehiscence. These included closures judged to be at substantial risk for sutures eroding through the skin to the incision border, as determined on the basis of tension necessary to appose the wound margins.

Hair is clipped from predetermined cutaneous sites for pad application, and the skin is cleaned with surgical soap and swabs containing isopropyl alcohol. The skin is allowed to dry completely before pad application. Multiple adherent pads can be applied to the skin adjacent and distant to the surgical site, depending on the amount of skin available or required for recruitment. Placement of pads at a greater distance from the surgical site was used to recruit additional elastic skin for closure of larger skin defects. In general, pad borders are placed a minimum of 5 to 10 cm from the wound margin, depending on size of the animal. An additional row of pads can be applied for dual-tiered recruitment of more distant elastic skin for larger problematic defects. Skin pads can be manually contoured to the natural curvature of the body region; alternatively, scissors can be used to make small cuts in the pads to improve contact with the skin’s surface.

Skin pads and the cable devices have a number of embodiments depending on the size of the wound, amount of skin recruitment desired, and intended use of the skin-stretching device. The prototypes reported here used a hook-and-loop fastener as the coupling mechanism between the skin pads and elastic cables (Fig 1).

Cyanoacrylate adhesive is used for all applications of skin pads to enhance pad adherence to the skin.

Figure 1—Components of the skin-stretching kit, including self-adherent skin pads (A), elastic connecting cable (B), cyanoacrylate adhesive (C), and adhesive applicator (D). (Reprinted with permission from Pavletic MM. Skin stretching techniques. In: Pavletic MM, ed. Atlas of small animal reconstructive surgery. 2nd ed. Philadelphia: WB Saunders Co, 1999;175.)

Figure 2—Use of the skin-stretching device in an experimental dog. An indelible marking pen was used to create a symmetric grid of 2-cm circles on both sides of the dog (upper left). Skin located between the line (arrow) on the left side of the dog and a corresponding line on the right side represents the inherent elasticity of the trunk skin, as determined by traction of the dorsal cutaneous surface. Three skin pads were positioned on each side of the dog. S = scapula. I = wing of the ilium. Initial application of the elastic cables, which are attached to corresponding skin pads on each side of the dog (upper middle). Notice the distortion of the circles to form elliptical shapes, indicating the source and direction of skin movement. The dog 72 hours after application of the device (upper right). Cable tension was readjusted (increased) every 8 hours. Dorsal advancement of the rows of circles is evident. Evaluation of skin tension in the ventral part of the abdomen suggested that a second tier of skin pads could have been used to accelerate recruitment of skin. Dorsal view of the dog at 72 hours (lower left). Notice that the recruited skin is retained in folds between the 3 sets of skin pads and elastic cables. After removal of the cables at 72 hours, > 20 cm of additional skin was recruited bilaterally (lower right). Notice the original limits of the inherent skin elasticity (arrowheads). In these pictures, which are of an early prototype of the skin-stretching device, notice that the attachment areas were riveted to the elastic cables at specific intervals.
Paired skin pads are glued on opposite sides of the wound; the surface of the skin pads provides the hook portion of the fastener. The pile surface of the elastic cables provides the loop portion of the fastener, which attaches to the hook surface of the skin pads. The elastic cable is attached to one pad, stretched across the surgical site, and attached to the opposing skin pad. The cable is stretched only to a submaximal length, which results in application of moderate tension and also reduces the risk of early displacement of the skin pads. As the skin areas progressively stretch as a result of the force applied, cable tension is adjusted (increased) every 6 to 8 hours to generate optimal tension forces during the period of application (Fig 2). Elastic cables also help maintain the position of any dressings or bandages placed over the surgical site, and wounds can be inspected easily at the time of cable adjustment. Recruitment of sufficient skin may be achieved within 48 hours after application, although it may be necessary to apply the devices for up to 96 hours to recruit sufficient skin in some subjects.

After completion of the stretching procedure, the elastic cables are removed. Animals then are anesthetized, and the pads are removed by peeling them from the skin or by use of a glue solvent. Pads allowed to remain on the skin will begin to separate within a few days after removal of the cables, concurrent with desquamation of the outer dermal layer. After surgical preparation of the animal, the recruited skin is advanced, and the skin wound is closed.

The skin-stretching device also can be used after wound closure. In some animals, skin pads and cables can be used for a 2- to 4-day period after surgery to offset moderate incisional tension.

**Results**

The skin-stretching device was used in 24 animals (20 dogs, 4 cats). The device was used to facilitate wound closure in 16 animals and was applied after wound closure to prevent postoperative dehiscence in 9 animals with moderate postoperative incisional tension; thus, it was applied before and after wound closure in 1 dog.

In the 16 animals in which the device was used before surgery to facilitate wound closure, wounds were mainly on the trunk but also included wounds on the flank, pelvic area, and limbs. The device was used before surgery on wounds that ranged from $3 \times 5$ cm on the carpus of one dog to $24 \times 30$ cm on the sternum of another dog. A $21 \times 61$-cm cutaneous defect extending from the dorsal cervical area to the pelvis also was closed by use of this device.

The device was used most commonly for wounds that resulted from trauma. For example, a Yorkshire Terrier sustained massive skin loss over the dorsolateral lumbar and thoracic area and fractured ribs as a result of an attack by a large dog (Fig 3). After 4 days of open wound management, skin pads were placed on the skin surface of the dorsal aspect of the pelvis, left lateral and dorsal aspects of the thorax, and right lower abdominal wall. Cables were coupled to pads placed on opposing sides of the wound, and tension was adjusted every 6 hours to stretch the skin prior to suturing. Cables also helped maintain the position of sterile wound dressings. After use of the device for 72 hours, the dog was anesthetized, skin pads were removed, and the $15 \times 20$-cm wound was closed. Skin pads and a short segment of elastic cable were used postoperatively to reduce skin tension on the dorsal aspect of the suture site for an additional 3-day period.

The device also was used for wounds that resulted from previously planned surgical procedures. For example, surgery was performed on a Beagle to remove scar tissue from the dorsal lumbar and pelvic areas that had developed after the dog was burned (Fig 4). The hairless scar ($13 \times 22$ cm) was prone to ulcers secondary to actinic radiation and external trauma. Two pads ($4 \times 8$ cm) were placed on the skin on the lateral aspect of the abdomen; 2 additional pads were placed cranial and caudal to the wound in the dorsal lumbar and pelvic regions. A protective cotton pad was placed on the delicate scar tissue prior to application of the cables. At 72 hours after application of the cables, the scar was surgically removed, and the wound was closed with sutures.

Skin stretching for wound closure began immediately at the time of application of the tension cables to the attached skin pads. Cable tension was increased periodically, and substantial skin stretching was accomplished in 48 to 96 hours, depending on the skin available for recruitment. It is the author’s impression that the greatest gains in skin stretching were achieved 48 to 72 hours after initiation of tension application. Smaller incremental gains were evident after that period.

![Figure 3—Results for use of the skin-stretching device in a Yorkshire Terrier that had a traumatic injury (bite wound). Extensive skin loss is evident on the dorsal and lateral aspects of the thorax and abdomen (left). Application of the device for 72 hours, during which cable tension was adjusted every 6 hours, resulted in recruitment of a sufficient quantity of skin (arrow) to allow surgical closure of the wound (middle). Notice that the elastic cables did not interfere with the formation of healthy granulation tissue. The dog in dorsal recumbency, wound closure was primarily accomplished by advancement of the skin from the left aspect of the thorax, right flank, and right side of the abdomen (right). Because of tension on the sutures in the caudal part of the incision (arrow), the skin-stretching device was reapplied after surgery for 3 additional days.](image-url)
A few animals curled their body when resting, resulting in a decrease in cable tension on one side of the trunk (inner curvature of the trunk). This necessitated an increase in cable tension to accommodate that body position. When those animals subsequently stood or became recumbent with their body in a straight position, tension of each elastic cable was readjusted as necessary.

In the 9 animals in which the skin-stretching device was used to offset incisional tension, skin stretchers were used for 72 to 96 hours after surgery. Similar to the situation for open wounds before surgical closure, elastic cables were useful in maintaining dressings or bandages applied to the underlying incision site.

The primary complication in these animals was an occasional partial or complete separation of a skin pad from the underlying cutaneous surface, necessitating reapplication or replacement, using cyanoacrylate glue. Displacement usually was the result of improper skin preparation prior to glue application, an excessive amount of glue with poor polymerization, or overzealous application of tension on the cables, especially during the early phase of skin stretching. The skin of some animals also may have been more prone to pad separation, probably as a result of active sebaceous glands or moisture accumulation beneath the skin pads. To improve pad contact with the skin, pads were slightly molded to better conform to the regional body contours. Removal or separation of pads prior to surgery occasionally stripped a portion of the stratum corneum of the epidermis; however, these areas reepithelialized within a week.

In animals in which the skin was stretched prior to surgery, residual glue and pad remnants on the skin after initial attempted pad removal by clinicians usually was removed during presurgical scrubbing. In all animals, skin pads that were not intentionally removed began to separate from the skin within a week after application.

Skin pads and use of the elastic cables did not cause signs of pain in these animals. To minimize discomfort during adjustment of the elastic cables, one hand immobilizes the skin pad, and the other hand uncouples the cable from the pad’s surface. Two dogs used their mouth to uncouple the elastic cables, probably because of the restrictive effect felt as the skin stretched during the latter phase of skin mobilization. Elizabethan collars were applied to these 2 dogs.

Discussion

The presuturing technique and other mechanical means described in the literature facilitate wound closure by manipulating the skin that is in close proximity or adjacent to the margins of a wound or proposed surgical site. Each of those methods requires a component to be inserted into or beneath the skin to achieve the desired effect. The condition of the bordering cutaneous tissues and size of the defect are primary factors that will influence their efficacy. Insertion of pins into compromised skin, followed by application of a variable degree of tension, has the potential to impair circulation, traumatize tissues, potentiate infection, and cause discomfort to an affected animal. Moreover, their effective use is limited to application in smaller wounds.

Unlike other devices, the skin-stretching device described here was designed to mobilize large areas of skin adjacent and more distant to the surgical site in a cumulative fashion. Consequently, skin can be stretched from more than one region and direction in relation to the surgical site. The elastic cables exert continuous tension, and cable width, thickness, length, and elasticity can be altered to accommodate specific needs of an affected animal. However, on the basis of normal movement and ambulation in animals, cables can vary in a fashion similar to load-cycling of skin. Recruitment of skin was evident within 24 hours after application, with additional incremental gains thereafter. Stretched skin was primarily held in static folds between paired opposing skin pads.

Stretching of skin is the result of a combination of several factors. Early during force application, net gains are likely the result of progressive extension of dermal collagen and elastin fibers. As skin stretches farther under continuous tension, gains are the result of mechanical creep and stress relaxation. A primary advantage of this device is its ability to quickly recruit elastic skin from a large surface area in a noninvasive manner. Unlike other devices, the elastic cables apply continuous, adjustable tension to promote skin stretching. Because of its light-weight, low-profile ability to follow natural body contours and simplicity in design and function, the external stretching device could easily be adapted for use in humans.

For additional skin recruitment from a large area of donor skin, a series of skin pads and cables can be staggered in a tiered arrangement to simultaneously
stretch and recruit skin at variable distances and from various sides of a particular surgical site. During management of open wounds, the elastic cables help maintain the position of bandages or dressings covering the wound surface. Bandages or pads placed over the surgical area are used to cover the wound as well as to protect these areas from cable-induced irritation or possible compression trauma. Uncoupling the cables allows a clinician to easily inspect the wound during the process of stretching the skin.

Tension generated by the elastic cables is dispersed at the site of skin pads, radiating in an outward direction. Indeed, the fact that the pads used with this device have a comparatively large footprint of contact with the skin is a major advantage over methods and devices inserted into or underneath the skin. A wide distribution of the superficial tangential force generated by the elastic cables (ie, from the pads to the skin) would explain the reason that ischemic necrosis has not been a complication. This is to say that if an adhesive to apply pads to the skin surface eliminates risk associated with devices transmitting force over a finite surface area delineated by pins or anchor sutures inserted into the skin. Excessive application of tension secondary to overzealous tightening of the elastic cables can result in separation of pads from the skin, necessitating reappllication. In those cases in which the cornified surface of the skin was partially removed secondary to pad avulsion, the stratum corneum rapidly healed without incident.

Separation of a pad from the skin during the process of stretching the skin was the most common complication in the dogs and cats described here. Loss of 1 or 2 pads was recorded in 6 animals and was remedied by reappllication of the pads with additional cyanoacrylate adhesive. Pad separation may be attributable, in part, to the relative activity of sebaceous and coiled tubular sweat glands in a subject's skin. Overzealous application of cable tension by stretching the cable to its maximum length before attaching it to the skin pads also can precipitate pad separation, especially during the first day of application. Skin must be free of debris, clean, and dry before pad application. Cyanoacrylate adhesive or other biocompatible skin adhesives, when used sparingly, can be effective in supplementing adherence of the medical-grade bonding agent used in the animals reported here.

A number of elastic materials have been examined for their use as elastic cables, all of which are capable of generating differing amounts of tension. In turn, the amount of tension generated by a specific elastic band can be altered by the length of the cable and degree of manual force used to stretch the cable before attaching it to the paired skin pads. Normal body motion or alterations of body position in mobile patients can transiently vary cable tension. This, in turn, may cause a load-cycling effect that could contribute to mechanical creep and stress relaxation of the skin. The most appropriate tension used to optimize skin deformation in these dogs and cats was determined largely by subjective estimation. The approach used was to apply a moderate amount of continuous tension to the cables, adjusting the cables every 6 to 8 hours to ensure maximum skin recruitment could be achieved within a short time frame. Because necrosis of the skin was not observed, the primary reason to avoid excessive cable tension in this study was to reduce the likelihood of pad separation from the skin. Although skin stretching can be assessed subjectively by visual and manual means, a tangible reduction in cable tension was the primary indicator for the need to increase cable tension.

Results from the cats and dogs reported here document that this externally applied skin stretcher has several potential advantages over other devices currently used for wound closure in humans and domestic animals and, in some cases, may eliminate the need for more costly flap, grafting, or tissue-expansion techniques. In an era of escalating veterinary medical expenses and increasing emphasis on cost containment, this device is especially attractive because its application and use does not require that an animal be anesthetized or undergo additional surgery.

References


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