CHAPTER SEVEN

Tension Relieving Techniques and Local Skin Flaps

David Fowler

INTRODUCTION

The elasticity of skin and, therefore, the ease with which large wounds may be reconstructed varies tremendously among species. Dogs and cats have highly elastic skin, which minimizes the difficulty of managing tensile forces affecting wounds. The free mobility of canine and feline skin is attributed to two factors. First, skin in these species is nourished by cutaneous arteries which supply relatively large regions of skin. Skin, therefore, can be moved freely on underlying tissues without compromising its vascular supply. Secondly, dogs and cats have a well developed system of cutaneous musculature, consisting of the platysma muscle (head and neck) and the cutaneous trunci muscle (thorax and abdomen). Cutaneous vasculature courses deep to this musculature, which is free of deep fascial attachments.

Intact skin is normally under the influence of tensile forces, and dermal collagen is remodelled accordingly. This is intuitively obvious because skin, when incised, retracts to form a gap. The magnitude of tensile forces, as well as their direction, varies according to location. Tension lines have been described previously and are orientated in a direction similar to the stripes on a zebra. The direction of maximum tension is easily determined by pinching folds of skin in multiple planes to see which offers the least resistance (Figure 7.1). The direction in which skin is most easily moved is termed the line of maximum distensibility and is usually perpendicular to the line of maximum tension.

Excessive tensile forces acting on wounds pose several problems for the surgeon:

- Direct wound closure may prove impossible if forces are of sufficient magnitude
- Excessive tension during wound closure may embarrass blood flow through surrounding skin, increasing the risk of incisional dehiscence
- Restricted movement and postoperative pain may be seen, especially in wounds situated near flexor or extensor surfaces

  Excessively taut closure of extremity wounds can cause a tourniquet effect, resulting in oedema or disruption of vascular flow to the distal limb (Figure 7.2).

Tension can result in hypertrophic scar formation, although this is of greater concern in people than in dogs and cats.

Surgical techniques that utilize local tissues for the management of tensile forces during wound closure include undermining of surrounding skin, walking sutures to redistribute tension throughout the wound, incisional "plasties' designed to redistribute tension in alternative directions, and local (random pattern or subdermal plexus) skin flaps used to move tissues from areas of relative excess into areas of relative need.

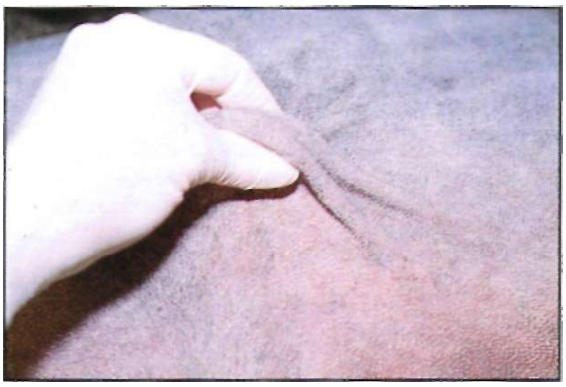

Figure 7.1: The elasticity of skin in different plants t assessed by pinching skinfolds in various directions.

Figure 7.2: Taut skin closure on an extremity has resulted in compromise of venous and lymphatic drainage, and swelling of the foot, in this cat with a metatarsal injury. Release of the closure is required to prevent secondary injury to distal tissues.

The decision as to which procedure is best depends on multiple factors, including location of the wound, regional availability of skin, magnitude of tensile forces or distensibility surrounding the wound, risk of delayed closure and preference of the surgeon. In general, the simplest and most cost-effective techniques should be used. However, it is important to identify in advance wounds that will benefit from more advanced or aggressive reconstructive techniques. Examples might include traumatic soft tissue wounds associated with open fractures or extensive oncological resections.

PATTERNS OF WOUND CLOSURE

Simple side-to-side closure is frequently not the most efficient or cosmetic method of wound reconstruction. Determining the ideal pattern of wound closure depends on assessing the magnitude and direction of planes of tension and distensibility surrounding the wound, as well as the shape of the defect. Wounds should be closed with the least tension and the best cosmetic appearance possible.

Managing 'dog-ears'

The term dog-ear refers to a bunching of tissue at the ends of a wound. Dog-ears are formed when fusiform defects with sides of unequal length are closed, or when wounds with a small length:width ratio are sutured side-to-side. Small dog-ears are frequently ignored, and resolve as redistribution of wound tension occurs over time. Larger dog-ears should be addressed at the time of wound reconstruction to provide a cosmetic closure. Many techniques have been described for the elimination or prevention of dog-ears:

- Dog-ear formation can be minimized by distributing length discrepancies between unequal sides of a fusiform defect throughout the suture line (Figure 7.3). This is most easily accomplished by first placing a suture at the mid-point of both sides, resulting in the formation of two smaller defects with unequal sides. Additional sutures are placed at the mid-points of each of these defects. Suturing continues until the defect is closed. By suturing in this fashion the length discrepancy between sides is distributed throughout the suture line rather than concentrated at one end.
- Larger dog-ears are more easily managed by excision (Figure 7.4). The simplest technique involves elevation of the dog-ear to form a triangular shape. Sharp incision is made through the skin on either side of the base of the triangle and the resulting defect is closed routinely.

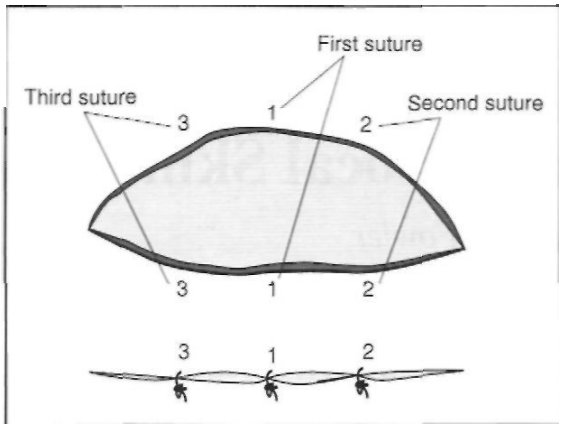

Figure 7.3: Tissue should be distributed evenly when closing ovoid excisions with unequal margins. This is accomplished by first placing a single suture at the mid-point of both sides. Remaining defects are closed by sequential placement of further 'dividing' sutures.

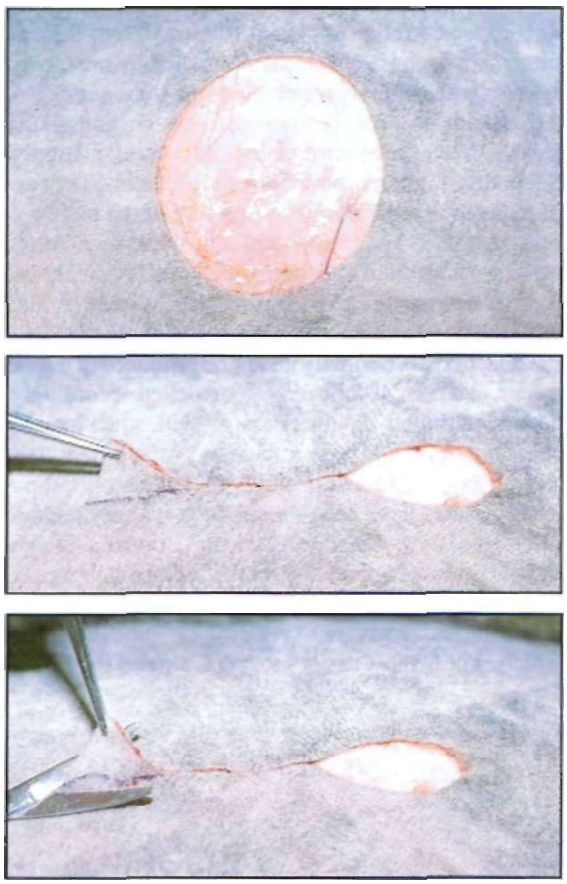

Figure 7.4: Closure of round or oval defects results in the formation of triangular 'dog-ears'. When excess tissue is available, dog-ears are most easily managed by simple excision of the redundant tissue.

Circular and ovoid wounds

Various techniques facilitate the cosmetic closure of circular defects (Swaim and Henderson, 1997). The technique of choice depends primarily on the amount of redundant skin surrounding the defect:

Direct closure of circular defects results in the formation of large dog-ears. This can be prevented by excising triangular pieces of skin from opposing ends of the defect, thereby converting a circular defect into a fusiform defect with a 4:1 length:width ratio (Figure 7.5). Skin surrounding the wound should be manipulated to determine the lines of greatest and least tension, and skin excision should be performed such that the resulting fusiform defect is orientated parallel to the line of greatest tension.

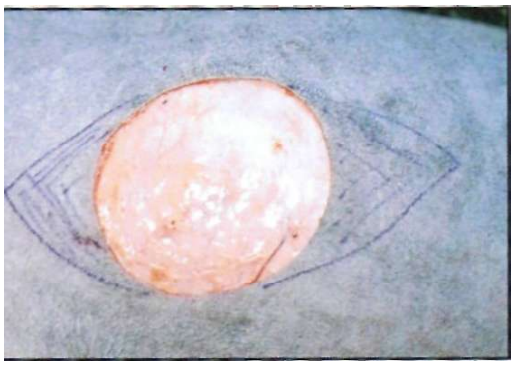

Figure 7.5: Dog-ear formation can be avoided by converting round or ovoid excisions into fusiform excisions with a 4:1 length:\vidth ratio. The shaded area indicates tissue to be excised. This technique is useful in areas with redundant or elastic skin.

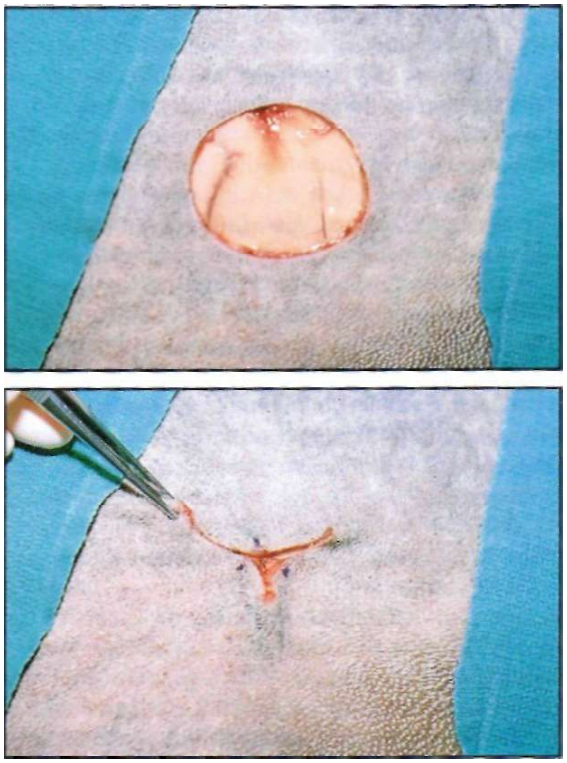

Figure 7.6: In areas with minimal skin elasticity, dog-ear formation can be minimized by triangulating the closure of round defects. Small dog-ears formed at the ends of each arm of the closure can be excised.

- The amount of tissue that needs to be excised to ensure a cosmetic closure can be reduced by performing a three-point closure of circular defects (Figure 7.6). A single subcutaneous or intradermal suture is placed into three equidistant points and tied, thereby converting the circular defect into three smaller fusiform defects. Dog-ears will be formed at the ends of all three fusiform defects; they should be sutured as described previously.
- When little or no elastic or redundant skin is available for reconstruction, a combined V closure should be considered (Figure 7.7). V-shaped incisions are made at opposing sides of the circular defect such that the arms of the V form two sides of an equilateral triangle pointing toward the centre of the defect. The height of this imaginary equilateral triangle equals the radius of the defect. Following incision, the flaps are undermined and transposed within the defect. The tips of the flaps are sutured such that five smaller fusiform defects result, all of which have roughly equal sides. Continued routine closure results in an irregularly shaped suture line with minimal dog-ear formation.

Square, rectangular and triangular wounds

Square, rectangular and triangular defects are most easily closed using a technique of centripetal closure (Figure 7.8). Subcutaneous or intradermal closure begins at the four corners of the defect. Tissues are progressively apposed until all suture lines converge. When dealing with square defects, all four suture lines will converge at the centre of the defect. In rectangular defects, suture lines at opposing ends of the rectangle will converge with each other and the remaining defect is closed side-to-side in a routine maimer. Dehiscence is not uncommon at the junction of multiple suture lines. Tissues in these regions should be manipulated with care, and sutures placed precisely to minimize vascular disruption.

MOBILIZATION TECHMQUES

Direct closure techniques are often inadequate when dealing with large wounds, or wounds located in areas with little redundant skin. By using techniques that capitalize on the viscoelastic properties of skin, however, the surgeon is often able to achieve wound closure without resorting to more advanced reconstructive options, such as skin flaps or skin grafts. Options to enhance mobilization of skin include undermining, walking sutures, presuturing, multiple punctate relaxing incisions and acute or subacute skin expansion.

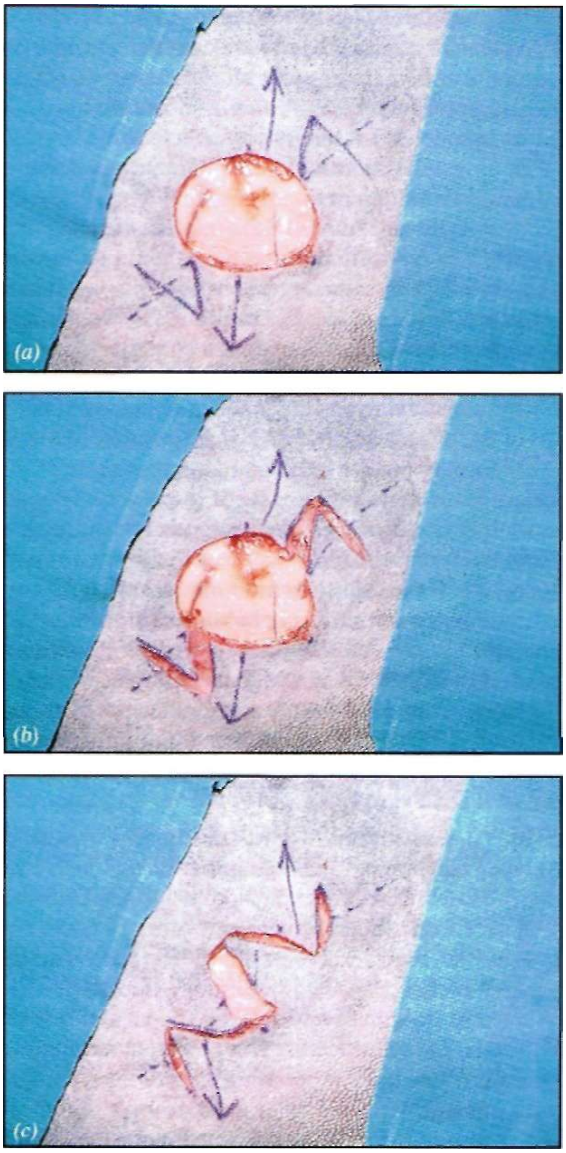

Figure 7.7: Combined Vclosure can be used in areas with little or no elastic skin surrounding a round excision, (a) The arms of the V to be incised are indicated. Arrows indicate the direction of maximal tension, (b) The arms of the V have been incised, (c) Undermining and transposition of the flaps results in a redistribution of tension.

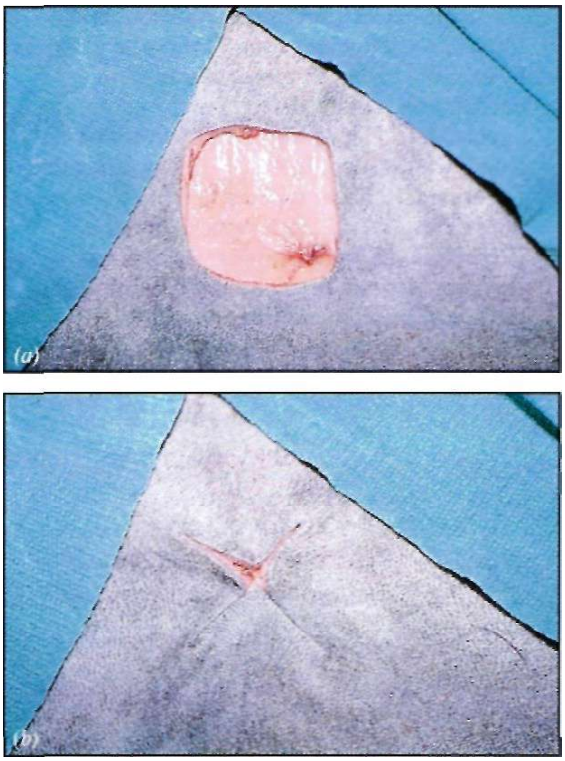

Figure 7.8: Square or rectangular defects are most easily closed using a centripetal closure beginning at each corner of the defect and extending toward the centre.

Undermining

Undermining skin surrounding a wound is one of the simplest and most effective methods of reducing tension during wound closure. Loose connective tissue attachments are severed between the skin and deeper tissues, thereby facilitating cutaneous advancement over the wound. Extensive undermining should be performed deep to cutaneous musculature, in areas where such exists, to preserve the vascular integrity of the skin.

There is no absolute formula to determine the extent to which surrounding tissue must be undermined. The directions of tensile forces acting on the wound are first determined by grasping and manipulating surrounding skin. Skin is then undermined parallel to the proposed direction of advancement (Figure 7.9). Skin edges are periodically assessed for ease of advancement over the wound and undermining is discontinued when opposing skin margins are brought into apposition with minimal tension.

Undermining, while reducing tension and facilitating wound closure, also increases wound dead space. In most instances, drains should be used for dead space management after extensive tissue undermining. Either passive latex drains or activ.e closed-suction drains can be used successfully. Drains may be unnecessary in locations where the application of a bandage assists in maintaining apposition of tissue planes and in reducing shearing forces acting upon tissue layers within the wound.

Walking sutures

Walking sutures have a two-fold purpose:

- They serve to obliterate dead space after undermining and distribute tensile forces throughout the wound surface, as opposed to concentrating forces at the skin margins
- They facilitate the progressive advancement of undermined skin into the wound defect.

Initial sutures are placed between the dermis, at the deepest portions of undermined skin, and fascia within

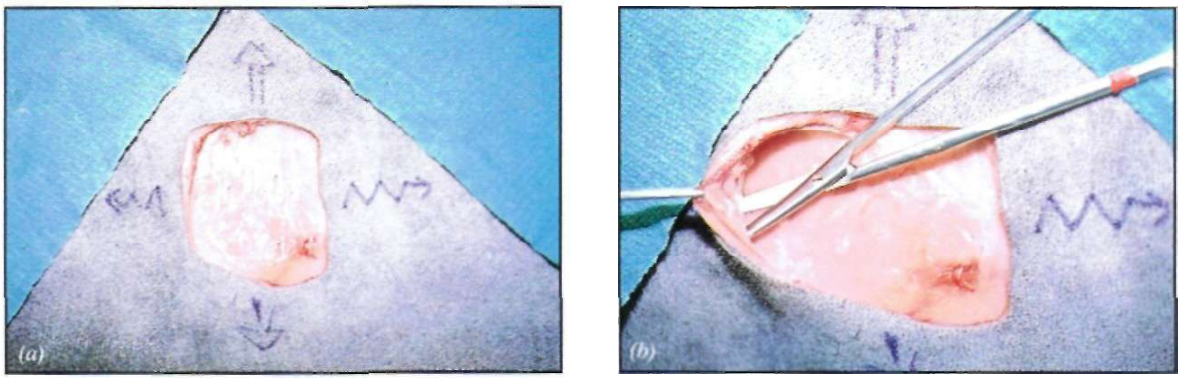

Figure 7.9: (a) Open arrows indicate the direction of maximal tension acting on this wound, (b) Tissue undermining is used to facilitate skin advancement over the defect. Tissue is undermined parallel to the direction of anticipated skin advancement.

the wound bed relatively nearer its centre (Figure 7.10). Proper suture placement into the dermis is confirmed by the formation of a dimple when the suture is tied or placed under tension. As the suture is tied, the 'base' of the undermined skin is advanced slightly towards the wound's centre. A second tier of walking sutures is then placed to provide further tissue advancement. Each tier of walking sutures thereby serves progressively to advance the skin edge toward the centre of the defect. Skin margins should lie in close apposition, with little tension, after completing the placement of walking sutures.

Walking sutures have two significant disadvantages:

- When used for closure of clean-contaminated wounds, the incidence of infection may be increased due to the multiple ischaemic foci formed and the quantity of foreign material placed within the wound
- Walking sutures may also compromise cosmetic appearance and increase postoperative pain due to the fixation of normally moveable skin to relatively immobile underlying fascia. Because of these sequelae, the author only uses this technique to achieve wound closure if it is absolutely necessary.

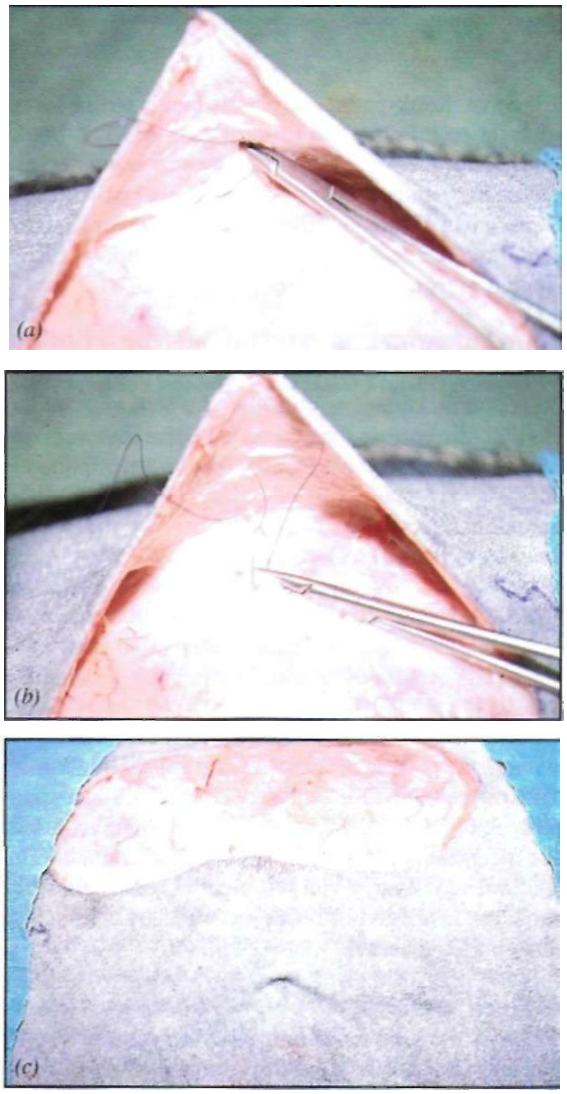

*Figure 7.10: Walking sutures can be used to facilitate skin advancement and to distribute tensile forces over a large surface area, (a) Skin is first undermined and a suture bite is taken into the dermis at the deep margin of undermined skin, (b) A second bite is taken into fascia, relatively closer to the wound's centre, (c) Tying this suture advances the dermis to the point of fascial fixation. A 'dimple * is formed in the skin when a suture is placed at an appropriate depth into the dermis.*

Presuturing

Presuturing is a means of mobilizing tissue in instances where advanced planning is feasible, such as surgical removal of a large lesion. This technique utilizes the properties of cutaneous viscoelasticity and mechanical creep to facilitate subsequent wound closure.

Plicating sutures are placed across the proposed area of excision 8-24 hours prior to surgery. Immediately prior to surgery, the sutures are removed and the lesion is excised. Subsequent closure is achieved with less tension and a reduced incidence of tissue strangulation and dehiscence.

Skin stretching is similar to presuturing in principle, but is used after the formation of an open wound. Skin stretchers consist of externally applied

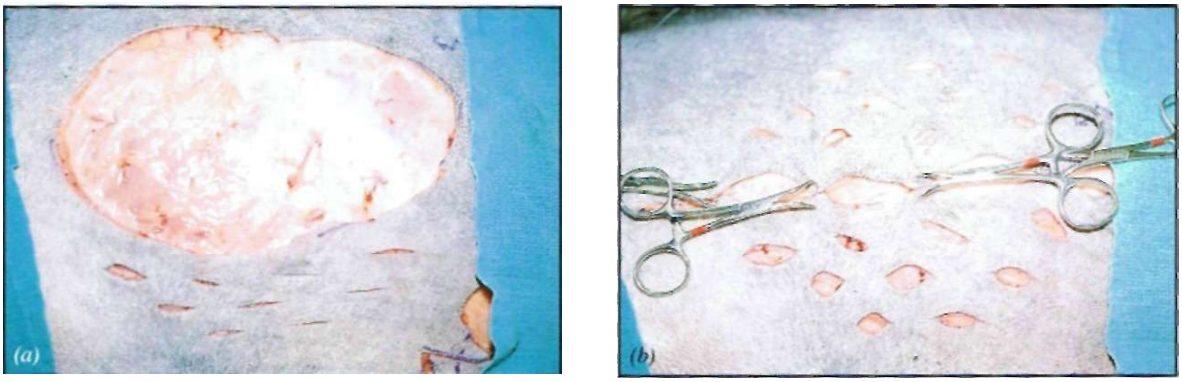

Figure 7.11: Mesh expansion is used to facilitate skin advancement over large open wounds, (a) Staggered parallel rows of 1-2 cm incisions are made on either side of the defect, (b) As skin is advanced, the small incisions expand, resulting in the formation of many small open wounds. Second intention healing of these smaller wounds progresses at a much more rapid rate than does second intention healing of a single large wound.

adhesive 'hook-pads' and elastic bands with a series of 'pile-pads' attached to their surface. The hook-pads are placed on either side of the wound and are connected under tension using the elastic bands. Tension is incrementally increased several times daily over a 2-4 day period until apposition of wound margins is achieved.

Multiple punctate relaxing incisions (mesh expansion)

Relaxing incisions are considered when, after undermining skin surrounding the wound, tension continues to preclude direct closure. Staggered rows of punctate incisions are made, full thickness, through skin surrounding the defect, beginning nearest the wound margin (Figure 7.11). Incisions may vary but are normally 1-2 cm in length. Incisions should be separated by several centimetres to ensure that adequate blood supply is maintained to the elevated skin. Multiple staggered rows of incisions are made on either side of the wound.

As the skin margins are advanced to cover the wound, the punctate incisions form gaps, allowing the undermined skin to expand. The amount of skin expansion obtained is directly proportional to the length of the incisions and the number of incisions made. The multiple small open wounds created using this technique are bandaged and allowed to heal by contraction and epithelialization.

Skin expanders

There is very little literature describing the use of skin expanders in small animal surgery. Skin expanders consist of inflatable silastic chambers and are available in many different sizes and configurations. They are placed subcutancously, adjacent to the wound bed, or adjacent to lesions prior to surgical excision. It is important to plan the location of the expander relative to the wound, since the expanded skin must subsequently be in a strategically advantageous position for advancement or rotation over the defect. The incision for subcutaneous implantation of the expander also must be planned so that it is located at the leading edge of the advancement or rotation flap that will be formed at the time of wound reconstruction.

After implantation, the chamber is inflated over a course of days to weeks. Intraluminal pressure within the chamber is monitored and is maintained below normal capillary pressure. Expected tissue responses include epidermal hyperplasia, dermal collagen compression and the formation of granulation tissue and a fibrous capsule around the expander.

Skin expanders are associated with some problems:

- If pressures generated are too high, reduced vascular perfusion can cause necrosis of overlying skin
- Infection can occur, especially when expanders are used adjacent to contaminated wound beds
- Patient discomfort and pain during expansion has been reported in people, but has been difficult to evaluate in animals
- The fibrous capsule that forms around the tissue expander limits the pliability of overlying skin, making it difficult to mobilize over the wound
- Tissue expanders generally require staged reconstructive procedures separated by days to weeks, although acute intraoperative tissue expansion can be used to achieve an effect similar to presuturing.

REDISTRIBUTION OF TENSILE FORCES USING INCISIONAL 'PLASTIES'

V-Y plasty

The V-Y plasty is most commonly employed to correct functional consequences of wound contrac-