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Outcome of reconstruction of cutaneous limb defects in dogs

using self-inflating tissue expanders

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Conflict of interest statement

Marc C. Swan FRCS Consultant plastic surgeon – Founding director of Oxtex, with founding shares in the company. Marc was involved only indirectly with cases for advice on placement and case management

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Structured summary

Objectives- To describe the technique of placement and clinical outcome following use of self-inflating tissue expanders (STE) in twelve consecutive cases of reconstruction of distal cutaneous limb defects in dogs.

Methods- Cases of distal cutaneous limb defect were included. Cases were divided into 3 groups based on location of the placement of the STEs: Group A (4 dogs) : on, or proximal to the elbow and stifle; Group B (4 dogs), distal to the elbow/stifle and proximal to the carpus/ tarsus ; Group C (4 dogs) distal to the carpus and tarsus. Owner's satisfaction and clinical outcome were documented.

Results- Thirteen cases were originally included but one was excluded because of incomplete follow-up. One case experienced premature removal of the STEs before expansion started. A mean of 5 STEs were implanted per dog (range 2-9). Devices were explanted after a mean of 24 days (range 13-42 days). Primary closure was achieved in 8/11 cases including all cases from Group A, and 75% and 33% of cases from Group B and C respectively. All incompletely reconstructed defects or cases of wound dehiscence healed by second intention. Eight out of 12 owners were satisfied.

Impact of the work - Skin expansion using STE can be used as an alternative for the reconstruction of limb defects in dogs where direct primary closure would otherwise not be achievable. Defects below the carpus and tarsus are more challenging to treat with STEs.

Key words

Soft Tissue Surgery, Reconstructive surgery, Skin expansion

Introduction

Tissue expansion was first described for soft tissue in the mid 20th century (Neumann, 1957). It is now an established reconstructive technique in human surgery (Swan, 2007) and has a host of potential applications in veterinary surgery (Pavletic, 2010), in particular in the field of reconstructing limb cutaneous defects.

Tissue expansion works by inducing 'biological creep' (generation of new tissue secondary to a chronic stretching forces) to the skin as opposed to producing tissue elongation beyond inherent extensibility, which is defined as "mechanical creep". Mechanical creep induces a straightening of the convoluted collagen fibres, microfragmentation of the elastic fibres and mouvement of water from the collagen network. Conversely, the new tissue generated by "biological creep" (similar to events such as pregnancy, skin growth over tumours or obesity) undergoes completely different molecular and cellular changes with epidermal thickening and angiogenesis (Wilhelmi et al., 1998).

Soft tissue expansion in the limbs of dogs has the advantage of additional skin for use in reconstructive procedures where there is otherwise limited local tissue available for the rotation or advancement of a skin flap (Swaim, 1980). It is widely regarded that large skin defects of the limb, especially the distal limb are often difficult to manage (Spodnick et al., 1993); treatment often requires prolonged open wound care, second intention healing (Bright RM, 1985, Prpich et al., 2014) and/or the use of free skin grafts (Riggs et al., 2015).

Since its inception, tissue expansion has been achieved by inflating a silicone balloon placed subcutaneously, using saline to fill the balloon through a subcutaneous (or occasionally an external) port. The technique was first reported in veterinary medicine in 1989, in three horses, one heifer and one dog (Madison et al., 1989). Subsequently the technique was refined more specifically to expand distal extremities in dogs (mid crus and mid ante brachium) in both experimental (Keller et al., 1994) and clinical settings (Spodnick et al., 1993, Keller et al., 1994).

It was noted that even if the expanders were well tolerated with few complications, mild discomfort following percutaneous injections to fill the balloon was reported (Keller et al., 1994). Moreover the physical bulk of traditional balloon-type expanders often precluded their use in discrete anatomical locations (Swan et al., 2012). Furthermore the need for weekly expansion through a buried port can be painful and time consuming, may lead to an increased rate of port site infection with potentially greatly increased cost to the owner. These limitations have led to the development of self-inflating tissue expanders.

A self-inflating tissue expander is an osmotic expander formed of a hydrogel core (inert hygroscopic polymer) and external silicone coating. Once implanted, water is drawn by osmosis from the surrounding tissues into the device, which can spontaneously expand. The rate and extent of expansion is controlled by the external Silicone coating (Chummun et al., 2010). A self-inflating tissue expander has many advantages over the traditional balloon devices. The absence of a filling port and the ability of the hydrogel to conform to almost any configuration (Swan et al., 2011) enables this novel type of tissue expander to be used in anatomical locations that would otherwise be very difficult to utilise traditional expansion techniques using balloon devices. The indications for self-inflating tissue expander in skin reconstruction from the human literature include: the expansion of a flap to resurface an adjacent defect; the expansion of tissue prior to placement of an implant; and the pre-expansion of a flap or graft donor site (Sharpe, 1992). Among others they have been used for breast reconstruction, cleft palate repair, scar and burn resection (Ronert et al., 2004, Chummun et al., 2010, Lohana et al., 2012, Berge et al., 2001).

The use of self-inflating tissue expanders has never before been reported in veterinary clinical species. The purpose of this prospective study is therefore to report the technique of placement and clinical outcome in dogs with limb defects that were managed using self-inflating tissue expanders across North America, UK and Europe. This case series reports the use of a novel

self-inflating anisotropic hydrogel tissue expander, which consists of a hydrogel core coated in medical grade silicone, manufactured to ISO 13485 standards for prospective human usage.

Materials and Methods

The study received ethical approval from the Institutional Ethical Review Committee of XXXXX.

Cases managed with the a self-inflating tissue expander (STE) (Expaniderm, Oxtex Ltd , Oxford UK) (Figure 1) were prospectively included and signalment, clinical history, reason for expander use, surgical technique, owner satisfaction, expander ease of use and clinical outcome including complications were recorded.

The device expands in three phases: a delay phase for 3-4 days after implantation when no expansion occurs to enable initial wound healing, then a controlled phase of linear expansion, followed by a plateau phase (reached within 2-4 weeks) when the device is fully expanded and will remain so until removed for the second-stage reconstruction.

Dogs were included if they presented with a skin defect on a limb that could not be closed without a skin graft, flap or tissue expansion. The presence of active infection (evidenced by culture results and/or visual inspection) was a contra-indication. In the case of tumour resection, the preliminary cytology or histopathology results was first confirmed. All therapeutic options were presented to owners; some guidance was offered but the decision to proceed with skin expansion was based on the owners' decision. Informed consent form was obtained from the owners. Cases were excluded if follow-up was not available or if the information with regards to tumour grading and / or staging was insufficient.

Cases were divided into 3 groups based on anatomical positioning of the expanders. Group A (4 dogs) comprised of cases where the expanders were placed on, or proximal to, the elbow and

stifle in the forelimb and hindlimb respectively. Group B (4 dogs) comprised of cases where expanders were placed distal to the elbow and proximal to the carpus in the forelimb and distal to the stifle but proximal to the tarsus in the hindlimb. Group C (4 dogs) comprised cases where expanders were placed distal to the carpus and tarsus.

Indications for placing the expanders were as follows: prior to neoplastic tumour resection (n=5), prior to non-neoplastic tumour resection (n=3) and to aid primary wound closure of non-healing wounds (n=4). Table 1 documents case descriptions and indications for expansion for all cases included in the study.

Owner satisfaction was obtained by the veterinary surgeon performing the surgery once the wound had fully healed and was graded as either satisfied or not satisfied.

Expander ease of use, as assessed by the veterinary surgeon, was graded as good (expanders implanted as planned including location and number of devices), fair (expanders not implanted as planned either location and numbers but leading to satisfactory / complete reconstruction) or poor (expanders not implanted as planned leading to partial reconstruction).

Clinical outcome was defined according to the quality of wound closure and complications.

Outcome was categorised into four groups:

Excellent: no complications during implantation or skin expansion and full reconstruction

Good: minor complications during implantation or expansion - full or partial reconstruction needing no further surgery post reconstruction

Fair: major complications during implantation or expansion - full or partial reconstruction – no further surgical intervention required post reconstruction

Poor: major complications during implantation or expansion requiring further care under sedation or anesthesia - partial or no reconstruction

All dogs had two general anesthetics, one for the initial implantation and a second for the subsequent explantation and wound reconstruction. Analgesia was provided with a combination

of opioids and non-steroidal anti-inflammatory drugs (NSAID) as appropriate. All dogs were induced, following premedication, using intravenous anaesthetic agents and maintained on Isofluane or Sevofluane. Prophylactic antimicrobials (including amoxicillin-clavulanic acid, second generation cephalosporin or metronidazole) were administered perioperatively to all dogs. Metronidazole was administered in only one dog based on culture and susceptibility testing. Dogs with open wounds were treated with antimicrobials based on culture and sensitivity testing wherever possible (2 cases). Postoperative infections were treated with antibiotics based on culture and sensitivity when possible. The use of bandages and wound drains was according to the veterinary surgeon's preference.

Implantation technique-The implantation technique followed a series of specific guidelines: (1) The incision for device insertion was made away from the proposed position of the device to minimise the risk of wound dehiscence during expansion; (2) The incision was made in normal skin, avoiding scar tissue, ulcerated or highly irradiated skin; (3) Care was taken so that the incision did not compromise the vascularity of the subsequent skin flap (Swan, 2007) and whenever possible the incision was made such that it preserved the proximal blood supply; (4) In oncological cases, the incision was made beyond the planned margins for tumour removal; (5) Blunt dissection was used to create a sub-cutaneous pocket and the pocket was made sufficiently large to accommodate the STEs. This was checked using a trial device of the same size as the STE before final implantation; (6) When inserting the STEs, care is taken not to damage the silicone membrane coating the expander (such as the use of toothed forceps is avoided); (7) Dead space was closed to prevent migration of the STEs; and (8) meticulous haemostasis is performed to reduce the risk of haematoma formation. Incisions were closed in a routine fashion (Figure 2 and 3).

Two expander types were used. They were both cylindrical with a diameter of 27mm. One expander device had a height of 5mm height and expanded to 18mm, whereas the alternative device had an initial height of 9mm and expanded to 25mm (Figure 1).

Explantation technique-Devices were removed through the incision created at the leading edge of the skin flap whenever possible, however this was dependent on anatomical location. When the presence of an expander created a fibrous capsule, scoring or excision of the capsule allowed the elasticity of the overlying skin flap to be restored. During scoring care was taken not to compromise the vascularity of the skin flap.

Following explantation, the skin defect was reconstructed fully or partially using the expanded skin either to aid direct primary closure or as an advancement flap.

Results

Thirteen consecutive cases of dogs with skin defects on the limb, managed with self-inflating tissue expanders between July 2014 and March 2016 were assessed. All cases were operated on by different veterinary surgeons in a number of institutions. One case was excluded from the present report due to loss of follow-up. For one further case, we could not report the outcome on reconstruction, expansion and wound closure following STE placement as the STEs had to be removed within 24 hours post placement (i.e. before any inflation had occurred). Therefore, outcome of implantation technique, rate and type of complications and procedure grading are reported on 12 cases whereas outcome of expansion, type of reconstruction techniques used, and wound closure are only reported on 11 cases.

Implantation and Expansion- A mean of 5 STEs were implanted per dog (range 2-9). Devices were explanted after a mean of 24 days (range 13-42 days). In 6 cases the STEs expanded as intended without complication. In 2 cases, both in Group C, major complications were seen during expansion: in one dog the STEs extruded through the skin and in the other case the devices were removed early due to skin necrosis overlying the devices. In another dog in group C, the devices were removed 24 hours post implantation (before expansion had started). In this case the un-expanded devices were placed on the palmar aspect of the carpal region and appeared to compromise blood supply to the distal forelimb, as evidenced by the profound change in colour of the leg distal to the STE placement site. Once the expanders were removed the leg returned to a completely normal colour. One STE in group A ruptured by explantation although there was no macroscopic damage to the skin and full expansion of the skin was achieved. Rupture was thought to be due to incorrect STE handling at implantation. In 3 cases minor complications occurred during expansion: 2 of these were incisional infections (suspected based on visual inspection) of which both dogs were being treated for an open wound. In 1 dog from group C there was minor tissue necrosis overlying one of the expanders, which did not affect the clinical outcome. 6 dogs were bandaged throughout expansion.

Reconstruction-All dogs underwent a second general anaesthetic for reconstruction. STEs were removed and in cases with a mass to be resected this was undertaken during the same anaesthetic episode. In 6 cases the expanded skin was used as an advancement flap and in 5 cases the expanded skin was used to aid direct primary closure.

Wound Closure- This was assessed in 11 of the 12 cases. Primary closure was achieved in 8/11 (73%) cases. In group A, all 4 cases achieved primary closure (100%). In group B 3 of the 4 (75%) cases achieved primary closure. In Group C 1 of the 3 (33%) cases achieved primary

closure. Two of the cases from group A that had initial primary closure, subsequently encountered complications. One case resulted in complete wound dehiscence due to improper device positioning leading to excessive tension in the area of the defect where no tissue expander had been placed. In the second case there was partial ischemia of the advancement flap caused by inappropriate location of the implantation incision, which disrupted a significant portion of the blood supply to the advancement flap, resulting in nearly 90% of the skin appearing non-viable. In 3 cases (1 from group B and 2 from group C) primary closure was not achieved; however in all cases the resultant defect required to heal by second intention was greatly reduced due to the additional skin.

Two of the three cases of group C failed to achieved primary closure due to tissue necrosis during expansion. In one case the STEs were removed prior to full expansion due to necrosis of the overlying tissue, this meant that there was insufficient skin generated for primary closure, however the skin that was expanded was viable and used to reduce the size of the defect. In the second case in group C the STEs extruded prior to explantation, however extra skin was still generated and this was used to aid primary closure of the original defect and only a small open wound was left at the donor site which healed, without complication, via secondary intention. In the one case from group B where primary closure was not achieved this was due to placement of the expanders. Rather than being placed laterally and medially around the wound to be reconstructed, half the devices were placed proximally, which significantly reduced the ability to clinically use the skin that had expanded.

Complications-Table 2 outlines all complications and procedure scoring outcomes. One of the 12 cases required additional surgery to remove the implants within 24 hrs after initial placement, as it was perceived that the implants were disrupting the blood supply to the leg. The 3 incompletely reconstructed defects and the 4 cases where dehiscence occurred all healed by second intention

without the need for further surgical intervention. Two dogs developed incisional infections, both of which were successfully treated with antibiosis (amoxicillin and clavulanic acid). The infections did not affect expansion of the STEs, reconstruction or clinical outcome.

Two dogs, both from group C, developed major complications during expansion. One had STEs removed early and reconstruction carried out with partially expanded skin. This resulted in a successful partial reconstruction that went on to heal without complication via secondary intention. The second case experienced device extrusion, however there was still expanded skin that was used to aid the reconstruction. The original defect was closed using the expanded skin and a small secondary donor defect was left to heal via second intention. This went on to heal without complication.

Procedure grading -On procedure grading 6/12 cases were scored as either excellent or good, 5/12 being scored as fair and 1/12 scored as poor. There were no complications seen at implantation and all surgeons scored the ease of use of the device as either good (7/12) or fair (5/12). Owners were asked to score their experience as being either satisfied or not satisfied, 8/12 owners reported that they were satisfied whereas 4/12 reported that they were not satisfied.

Discussion

This study is the first to present a range of indications, outcomes and complications associated with the use of self-inflating tissue expanders in a limited number of dogs. This type of tissue expander has never previously been used in veterinary clinical practice and this paper demonstrates an accurate and open documentation of the first 11 consecutive patients throughout Europe and North America. As a prospective study it shows the initial learning curve of this product.

Due to the ease of use this product and its application in limb reconstruction, the majority of cases are seen and dealt with in first opinion practices. This is reflected by the fact that 11 different surgeons took part in this trial. There was extensive support given by both a board certified veterinary surgeon and a human consultant reconstructive plastic surgeon, highly experienced in tissue expansion. Therefore this product was trialed in a realistic setting for its intended use.

Of the 3 anatomical groups, group C had the least favorable outcomes and was the only group to have major complications. The reason for complications distal to the carpus and tarsus is not fully understood but one hypothesis is that the pressure of the tissue expander device on the overlying skin exceeds the tissue perfusion pressure in this location thus leading to local tissue ischaemia and subsequent skin necrosis. There was no evidence of skin necrosis when the devices were placed proximal to the carpus or tarsus (groups A and B). Therefore it would be recommended that current self-inflating expanders only be placed distal to carpus or tarsus under careful consideration. It is possible that a device that expands more gradually would potentially overcome the problem of tissue necrosis.

Of the 8 cases with devices placed proximal to the tarsus and carpus, 6 had no complications throughout expansion and 2 cases had minor complications, thus demonstrating that use of these devices in this region is safe and effective. The minor complications were incisional infections which both resolved completely with antibiotic treatment. None of the minor complications during expansion affected outcome.

Precise and correct anatomical placement of the device is crucial to the quality and quantity of the expanded skin required for reconstruction (Hudson and Grob, 2005). It is advised that an expander is placed a minimum distance from the defect and that the expander is 2.5-3.0 times the size of the defect to be reconstructed in order to succeed in primary closure (van Rappard et al.,

1988). This assumption is based on studies performed on human skin, however studies carried out by Bartell and Mustoe found that there was no statistical difference between human and dog skin when tested for elastic and biomechanical properties and has been established as the best animal for tissue expansion (Bartell and Mustoe, 1989). It is therefore not known whether the same principles should apply to canine skin expansion. However, incorrect placement was seen in 2 cases in which less than excellent outcomes were achieved. In one case, rather than the devices being placed along the lateral and medial edges of the defect to be reconstructed 5 of the 8 devices were placed proximal and medial. This meant that all though the devices expanded as expected the extra skin created was difficult to utilize distally. As previously stated in one case the incision for placing the STEs cut across the blood supply to the subsequent advancement flap, thereby resulting in its partial necrosis.

The expanders tested in this study are anisotropic (only expanding in one vertical direction), therefore the additional skin gained is through the increase in height of the device. Thus the most efficient way to site the STE's, in order to achieve the maximal amount of expanded skin is in a longitudinal configuration of STE's along the length of the defect, or, where possible, one row either side of the defect.

Complications arising from tissue expansion are relatively common, but the majority are of a minor nature (Malata *et al.*, 1995). In two retrospective studies by Casanova *et al.* (2001) and Pandya *et al*. (2001), the overall complication rates in lower limb tissue expansion in humans was cited as being 19.4% and 43% respectively, of which major complications were seen in 15.5% and 17% accordingly (Casanova *et al.*, 2001) (Pandya *et al.*, 2002).

In this study the only group in which major complications were seen during expansion was those where the STEs were implanted distally to the carpus / tarsus. It is hypothesized that due to the

distal location of the STEs the pressure exerted by the STEs exceeded the local tissue perfusion pressure thus resulting in tissue ischemia and subsequent tissue necrosis. This is similar to the human literature, which reports that complications of the extremities are generally higher than those of the trunk and scalp (Hallock, 1987). The reason why one case developed a suspected distal limb ischemia following STE placement is unknown. This dog was the only one for whom the STEs were placed on the palmar aspect of the carpal region so it could be hypothesized that the STE were interrupting the blood supply to the distal leg from the median artery, the reason why the dorsal blood supply form the cranial superficial antebrachial artery did not suffice is unknown. Following this complication, we are now recommending that STEs are not placed in the palmar region of the carpus.

In cases of tumour resection, reconstruction was carried out before the margins were known. It is therefore possible that this method of reconstruction could be associated with cancer cells seeding, although we did not encounter this complication in our study. This issue might be more prevalent with tumours such as mast cell tumours and high grade STS , which typically require larger resection margins (Ryan et al., 2012). The very low occurrence of these tumours in our study population (no high grade STS and only one mast cell tumour) can explain why we did not encounter local recurrence due to cancer cells seeding. We however believe that cancer cell seeding is a potentially serious issue to consider whilst using STE and, would advise against using those in the management of feline fibrosarcoma for this reason. An alternative would be to resect the tumour at the time of STE placement. This was not advised as we estimated that the management of an open wound in addition to the management of the STE sites could potentially increase the risk of complications, including infection. We also felt that the presence of an open wound could act as a “path of least resistance” and could increase the risk of premature STE dislodgment through the open wound, considering that STE were always placed on the edge of

the proposed resection site. Ultimately the decision to not resect the tumour at the time of STE placement was based on subjective more than objective considerations.

Traditional tissue expansion is performed over several weeks to months. It was found that when skin was expanded proximal to the carpus and tarsus there were no detrimental effects of rapid two week expansion, compared with dogs where the device was expanded more gradually over four weeks (Keller et al., 1994). This is supported by Mustoe *et al*. who concluded that rapid tissue expansion (two weeks in dogs) did not demonstrate any deleterious effects when compared with a more conventional regimen (Mustoe *et al.*, 1987). This was confirmed in the present study. Mean expansion time in this study was 24 days. We started the study aiming for 28 days however it became apparent that there was little to be gained from leaving the expanders longer than 14 days, which is our current expansion time recommendation.

Even if the small number of included cases precludes drawing definitive conclusions, it does not presently appear that the incidence of complications is correlated with an increase number of STE placed. In fact, in two of the cases where the STEs were placed adjacent to open non-healing wounds, both wounds spontaneously started to contract. It is hypothesised that was due to two reasons. Firstly, the dissection of a subcutaneous pocket causes a delay phenomenon, which increases the rate of wound healing due to dilation of existing vessels (Taylor *et al.*, 1992); secondly the mechanical stress placed on the skin by the expanding STE may result in an increase in local angiogenesis. In a prospective soft tissue reconstruction study in humans using traditional balloon expanders, increased expression of vascular endothelial growth factors (VEGF), a major angiogenic cytokine, was demonstrated compared to non-expanded control patients (Lantieri *et al.*, 1998).

In dogs, several options can be used for reconstruction on the limb including allowing a wound to heal via second intention (with or without the adjunct of negative wound pressure therapy), surgical closure by skin grafting, distant direct skin flaps (pouch or hinged flaps), pre-suturing of tissue surrounding the wound, placement of devices achieves gradual closure of the wound (Velcro pads, etc..). Of all these techniques, second intention healing and skin grafting are amongst the commonest used. Second intention healing has the advantage of requiring less surgical knowledge and may be attractive to an owner due to the lack of a surgical fee. It can be very useful in contaminated or infected wounds. However secondary intention is often protracted, may provide poor cosmetic results, and might result in functional disability due to scar tissue. Owners often underestimate the costs of prolonged dressings. Prpich reported a 25.8% long-term complication in dogs that had secondary intention healing after wide local excisions of STS in the distal limb including intermittent disruption of the epidermis and decreased range of motion of the carpus due to scar contracture (Prpich *et al.*, 2014). Free skin grafts have the advantage of a single operation with quicker healing times, as well as potentially improved cosmetic and functional outcomes. They can however be technically more challenging with associated donor site morbidity. The success of the graft is mainly reliant on the establishment of a viable blood supply from the wound bed; and thus graft survival is more challenging, although possible, over exposed bone, joint, tendon or similarly poorly vascularized tissue. Tissue expansion offers an alternative to these; it is a simple technique to perform utilising adjacent skin with an established blood supply, which can therefore be used to resurface any defect regardless of the underlying vascularity. Riggs et al reported the outcome of free skin grafts on 32 dogs; outcome was deemed successful if ≥ 75% of the original skin graft was viable 1 and 2 weeks after surgery. They reported a success rate of 38% (Riggs *et al.*, 2015) but did not evaluate the associated complications.

From this study it can be concluded that soft tissue expansion can be used successfully as an alternative treatment for the reconstruction of limb defects in dogs where direct primary closure would otherwise not be achievable. Further research into the uses of tissue expansion in veterinary species is warranted, both with respect to distal limb defects, but also in alternative surgical indications including potentially increasing the viability of random and axial pattern flaps by pre-expansion (Cherry *et al.,* 1983) using the angiogenic properties of the "biological creep" induced by STEs . The use of pre-expanded flaps would be attractive for veterinary patients to potentially make them stronger to resist necrosis at their extremities, which is one very common problem with these flaps (Aper *et al*., 2003).

Statement of conflict of interest

The devices used in the study (Self-inflating Expanding Devices) are created and manufactured by a start-up company called Oxtex

One of the co-authors is a founding director of Oxtex, with founding shares in the company. He was involved only indirectly with cases for advice on placement and case management

One other co-author is a clinical specialist at Oxtex – full time employee of the company

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Figure legends

Figure 1: Oxtex 27mm self-inflating tissue expander. Left : before expansion ; right: after expansion

Figure 2a. Image of the metatarsal area of a dog presented for a lick granuloma (blue circle). The yellow dotted line represents the proposed incision to place the expanders (2 full circles). The two purple lines are the proposed incisions at the end of the expansion period. The purple line indicates the incision needed to create an advancement flap from the expanded skin. Alternatively a rotation flap (red line with two green arrows) could be undertaken

Figure 2b. Placement of two expanders within a subcutaneous pocket, as per planned diagram in Figure 2a

Figure 3: Step by step procedure from implantation to explanation of the STEs
a: Incision along lateral margin, b: Implantation of 2 STEs, c: STE's *in situ* post implantation, d: 14 days post implantation, e: Explantation of STEs, f: Removal of STS and lateral margins, g: Advancement flap created, h: Sutures removed 14 days post reconstruction. STE = Self-inflating Tissue Expanders

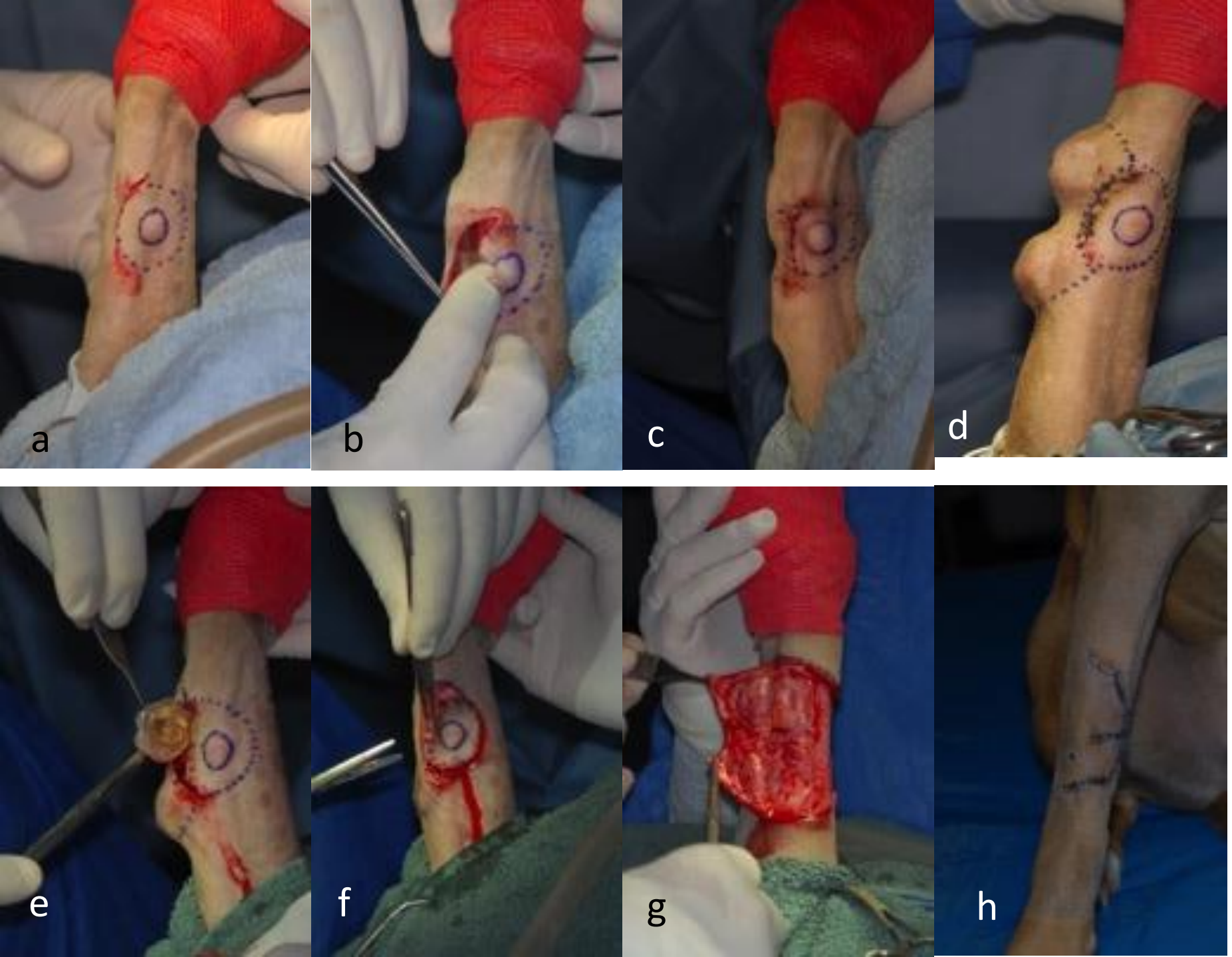
Table 1: Case description and reason for skin expansion

Case number:	Group	Age (years)	No. of devices implanted	Reason for reconstruction	Size of defect to be reconstructed
1	C	7	2	MCT	3.0 3.5 cm
2	B	7	2	STS	2.5cm diameter
3	C	7	2	NNM	3.0 x 3.5 cm
4	A	13	2	NHW	4.0 cm diameter
5	B	7	6	NHW	10.0 x 8.0 cm
6	B	7	6	NHW	Not recorded
7	B	Not recorded	8	STS	6.0 x 5.0 cm
8	A	6	9	NNM	6.5 x 6.0 cm
9	A	5	6	STS	2.5 x4.0 cm
10	A	8	6	NHW	3.5 x 3.5 cm
11	C	Not known	2	STS	3.0 x 2.5cm
12	C	13	2	~~Benign sebaceous adenoma~~NNM	2.0cm diameter

MCT (mast cell tumour), STS (soft tissue sarcoma), NNM (Non neoplastic mass), NHW (non healing wound), TN (tissue necrosis)

Table 2: Complications and Outcomes following skin expansion

Dog case Number:	Complications during expansion Reasons Major/Minor	Primary closure achieved	Complications post reconstruction (Y/N)	Procedure grading	Owner outcome
1	Major – Tissue necrosis	N	N – Healed via 2nd intention	Fair	Not Satisfied
2	None	Y	N	Excellent	Satisfied
3	Major – Tissue Necrosis	N	N – Healed via second intention	Fair	Satisfied
4	None	Y	Y – 50% ischemic flap – Healed via second intention	Fair	Satisfied
5	Minor - infection of wound	Y	N	Good	Satisfied
6	None	Y	Y – 0.4cm tip of advancement flap ischemia – Healed via second intention	Good	Satisfied
7	Minor – incisional infection	N	N – partial closure healed via second intention	Good	Not Satisfied
8	None	Y	N	Excellent	Satisfied
9	None	Y	Y – Wound dehiscence– Healed via secondary intention	Fair	Satisfied
10	None	Y	Y – Wound dehiscence healed via secondary intention	Fair	Not Satisfied
11	Minor – Tissue Necrosis	Y	N	Good	Satisfied
12	Major- vascular compromise	N/A	N/A	Poor	N/A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