Case Report

Surgical repair of a full-thickness ear pinna defect in a horse

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Summary
A 5-year-old gelding used for showing was presented for surgical repair of a full-thickness 15 mm diameter defect in the right pinna, which had occurred as a delayed complication following laser excision of a sarcoid. The defect had resulted in progressive deformity of the ear, and the horse was considered at risk of further injury if the defect became entrapped on a fixed object. Two artificial dermis meshes were inserted to encourage the formation of granulation tissue across the defect, and a commercially available skin expander was implanted adjacent to the site. Eighteen days later, a second surgery was performed to remove the skin expander and to mobilise a local rotational skin flap to close the defect. Both surgeries were performed under standing sedation and local anaesthesia. The site healed well, avoiding further potential trauma to the ear and deformity due to tissue contracture at the site, although some deformation of the lateral aspect of the cartilage remained.

Introduction
Indications for reconstructive surgery of the ear in horses are rare but include management of neoplastic lesions and repair of lacerations (Massoni et al. 2005; Skärлина et al. 2015). In comparison, numerous procedures of the ear in dogs and cats are well established (Lanz and Wood 2004) due to the higher prevalence of ear infections and wounds in these species. Management of injuries to the pinna is made difficult in many species by the range of motion of the external ear, which in the horse is nearly 270 degrees (Hendrickson 2019). However, in contrast to distal limb wounds in horses, the location of the ears and their good blood supply mean that contamination and slow healing are rare complications (Hendrickson 2019). Survival of the pinna is dependent on maintaining the integrity of this good vascular supply (Lanz and Wood 2004).

Where possible, primary closure of wounds is preferable to secondary intention healing in all species due to the likely superior cosmetic outcome, faster return to function and prevention of contractures. Where immediate or delayed closure of wounds by first intention healing is not possible, skin grafts or flaps can be employed to avoid the need for second intention healing. Both free skin grafts and pedicle flaps are used to manage ear defects in man and dogs (Pham et al. 2003; Lanz and Wood 2004; Papadiocho et al. 2017) and have been used to treat horse wounds at other anatomical locations (Stashak and Schumacher 2017; Yoshimura et al. 2020). The successful use of a skin graft in treating a cosmetic defect in the outer aspect of a horse’s pinna has also been described (Massoni et al. 2005), but there are limited descriptions of reconstructive surgery of the equine ear in the literature.

The shape of the external ear is determined by the supporting auricular cartilage (Dyce et al. 2002), which if damaged can cause collapsing or kinking of the pinna. The skin on both sides of the pinna is closely attached to the perichondrium of the cartilage, and the lack of free skin is another factor making repair of injuries in this location more difficult. In addition, cartilage is known to be a poor environment for acceptance of free skin grafts (Schumacher 2019). Defects of the pinna that involve the skin and cartilage (full-thickness defects) present a unique challenge to the surgeon, as there is no underlying structure at all to support a skin graft or pedicle flap.

In contrast to free skin grafts, pedicle flaps retain their original vascular supply or have their vascular pedicle anastomosed to vessels adjacent to the recipient site (Bristol 2005). In areas of poor blood supply or an incomplete bed of granulation tissue, this is an advantage over free skin grafts that rely on revascularisation for their survival. This case report documents the successful repair of a full-thickness defect in the pinna of an adult horse, using two artificial dermis meshes to encourage the formation of granulation tissue across the defect and a commercial skin expansion device to create the additional tissue required for closure of the defect using a rotational skin graft.

Case history
A 5-year-old Thoroughbred cross gelding was presented to the Philip Leverhulme Equine Hospital, University of Liverpool, for treatment of a full-thickness defect in the pinna of the right ear. This had occurred following diode laser excision of a sarcoid on the outer aspect of the ear 2 months previously at another clinic; details about the amount of laser energy applied were unknown. At the time of surgery, the sarcoid was reported to be closely adhered to the underlying cartilage and laser energy was applied to the surface of the cartilage. Following laser excision, the site was left to heal by second intention and at re-examination, 3 weeks after surgery, the region was reported to be infected and necrotic. At this stage, treatment with oral antimicrobials had been initiated, in addition to once daily topical application of a 50:50 mix of 0.1% betamethasone valerate (Betnovate) and
a sterile hydrogel (Intrasite). Progressive tissue necrosis continued resulting in a full-thickness circular defect in the pinna.

**Clinical findings**

On examination, a 15 mm diameter, circular, full-thickness defect was evident in the central portion of the right pinna (Fig 1). Two small (<2 mm diameter) aural plaques were visible medial to the main defect, which were deemed to be of no clinical significance. There was a kinked appearance to the lateral aspect of the pinna as only a narrow strut of cartilage remained to provide support to this portion of the ear. Clinical examination was otherwise unremarkable and no sarcoids were evident elsewhere.

**Treatment**

In addition to the obvious existing cosmetic deformity, there were concerns that the ear would become progressively more deformed if left untreated, and that there was a risk of further trauma if a fixed object became caught in the defect. There were also concerns regarding tissue desiccation and failure of any attempted graft without suitable protection of the graft. Therefore, it was elected to perform a two-stage surgical procedure to bridge the defect with a rotational skin flap.

**First surgery**

Procaine penicillin (14 mg/kg bwt i.m.) and flunixin meglumine (1.1 mg/kg bwt i.v.) were administered preoperatively. The gelding was sedated with 0.01 mg/kg detomidine hydrochloride i.v. and 0.1 mg/kg methadone i.v., followed by a constant-rate infusion of detomidine hydrochloride i.v., administered to effect to maintain a suitable plane of sedation. A ring block was placed at the base of the right ear using mepivacaine hydrochloride (20 mg/mL, Dechra). Following clipping and aseptic preparation of the site, a 4 cm horizontal skin incision was created near the base of the ear on its caudal, convex surface. The subcutaneous tissues were dissected carefully using Metzenbaum scissors to create a tunnel into which a single, 27 mm diameter skin expander (Oxtex Expaniderm) could be placed, adjacent to the ventral edge of the defect (Fig 2). The skin incision was closed using 3.5 M polypropylene (0 USP) in a cruciate pattern.

Following this, the edges of the defect in the pinna were debrided using sharp excision (No. 15 blade). The area between the aural cartilage and skin was undermined on both the convex and concave surfaces of the pinna. Two artificial dermal substitute matrix dressings (PelnacTM) were applied, one to each side of the defect such that the dressing edge was slid between the skin and cartilage (Fig 3). The circular dressings were cut to size and placed ‘face-to-face’ with the silicone layer outermost. Both dressings were fixed in place using simple interrupted sutures of 3 M polyglactin 910 (2-0 USP). An ear dressing was placed but was not tolerated by the horse. Subsequently, glued-on foam dressings (Allevyn nonadhesive)2 were used to protect both surfaces of the ear, which the horse tolerated well. The foam dressings were cut to resemble the approximate shape of the pinna and secured using small amounts of ethyl cyanoacrylate glue at the base and tip of the ear. The glue was applied at least 1 cm away from any of the wound edges. Following surgery, the gelding received 5 days of nonsteroidal anti-inflammatory treatment (2.2 mg/kg phenylbutazone per os q. 12 h) and was maintained on systemic antimicrobials (30 mg/kg trimethoprim sulfadiazine per os q. 12 h) until the second surgery.

**Second surgery**

The second surgery was performed 18 days later, when sufficient skin expansion was considered to have been achieved based on subjective visual assessment. Acepromazine (0.02 mg/kg bwt i.v.) and phenylbutazone (4.4 mg/kg bwt i.v.) were administered prior to preparation for surgery. The gelding was sedated with romifidine (0.04 mg/kg bwt i.v.) and morphine (0.1 mg/kg bwt i.v.). Mepivacaine hydrochloride (20 mg/mL, Dechra) was infiltrated at the base of the right ear in a ring block, as for

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the first surgery. The *Pelnac*™ dressing on the caudal, convex pinna surface was removed while the other dressing on the inner aspect was left in situ. There was evidence of granulation tissue and a healthy epithelial rim of tissue around the margins of the defect, which had reduced in size to approximately 11 mm in diameter. An incomplete circular incision was made between the ear defect and skin expander on the caudal, convex pinna surface, which would form the most rostral part of the skin flap (Fig 4). The skin expander was removed at which point it was noticed that its capsule had burst. However, no inflammation was visible at the site and sterile saline was used to flush out any material from the expander within the local tissues. The tissue that had been expanded was thicker than normal skin but was healthy in appearance and very well vascularised.

Further sharp and blunt dissection of the tissues was used to mobilise a local pedicle flap, incorporating the initial incision used to place the skin expander towards the base of the ear. The base of the pedicle was orientated caudomedially and was no less than half of the length of the flap created. The tip of the flap comprised of the skin immediately distal to the circular defect. The epithelial tissue extending 4 mm from the edge of the defect was carefully removed so that the skin flap could be advanced and rotated across the defect (Fig 5). The inner *Pelnac* dressing provided a barrier to prevent potential desiccation of the skin flap as it crossed the defect. The pedicle flap was secured using 3 M polyglactin 910 (2-0 USP) in a simple interrupted pattern. These full-thickness skin sutures were placed 4 mm beyond the cartilage defect, to avoid the suture line overlapping the defect. The resulting triangular skin defect that had been created towards the base of the ear was left to heal by secondary intention (Fig 6). A foam dressing (Allevyn nonadhesive) was sutured over the caudal aspect of the pinna to protect the surgical sites.

Post-operative care
Following the second surgery, the gelding received 10 days of nonsteroidal anti-inflammatory (2.2 mg/kg phenylbutazone per os q. 12 h) and 14 days of systemic antimicrobials (30 mg/kg trimethoprim sulfadiazine per os q. 12 h). The gelding remained hospitalised during this time to monitor healing and minimise the chance of trauma to the ear, particularly as assessment of the ear and dressing changes were markedly resented. Glued-on dressings were changed every 5 days during hospitalisation. The skin sutures were removed 14 days after surgery, and the horse was discharged the following day.

Outcome
The pedicle flap remained viable, and at discharge the surgical site had healed well. The small triangular defect towards the base of the ear was healing well by second
intention with healthy granulation tissue and evidence of progressive epithelialisation (Fig 7a,b). The ear continued to heal well, and the only deformity remaining was a kinked appearance to the lateral aspect of the right pinna. The gelding successfully returned to showing and at 2 years post-operatively, no further deformity of the ear had developed (Fig 8).

Discussion

This case presented a unique challenge of tissue reconstruction and illustrates some of the factors to consider when managing full-thickness defects of the pinna. Although the reason for cartilage loss in this case is unknown, it seems unlikely that infection alone would have been the cause. Ongoing thermal necrosis is known to occur following laser excision of tissue (Hawkins 2019) and was considered the most likely reason for cartilage loss in this case. This emphasises the need to minimise collateral damage to adjacent tissue during laser excision of skin masses to avoid the potential sequelae of delayed thermal necrosis. When using laser around the ear, particular care should be taken to minimise the amount of thermal energy delivered to auricular cartilage, particularly the cartilage in the main body of the pinna, to avoid loss of structural integrity of the ear which can be difficult or impossible to correct.

As when managing sinocutaneous fistulae, failure to prevent movement of air around the dermal aspect of skin grafts placed over full-thickness defects may result in desiccation of skin and subsequent failure of repair. To avoid this, creation of a periosteal flap is an important component of successful sinocutaneous fistula repair (Schumacher et al. 1985; Barber and Stashak 2017). It was considered that simply performing a skin graft as the sole treatment would be at high risk of dehiscence and likely to be unsuccessful. Furthermore, it was felt that a perichondral flap could not be reliably created at this location. To attempt to reduce the size of the defect and enable protection of the dermal aspect of a subsequent skin graft, an artificial dermis mesh was used to provide a matrix scaffold which allowed invasion of fibroblasts and thus encouraged the formation of granulation tissue. The same type of dressing has been used successfully in man (Suzuki et al. 2013), and this case demonstrates its potential application in equine wound reconstruction. Following implantation, the Pelnac™ mesh is gradually replaced by host dermal tissue (Suzuki et al. 1990, 2000). Other skin substitutes and scaffolds have been used as biological dressings in horses (Bristol 2005) and to cover periosteal flaps used in the repair of nasocutaneous and sinocutaneous fistulae (Barber and Stashak 2017). In addition, the use of a commercial wound matrix and transpositional muscle flap to repair a sinocutaneous fistula has recently been reported (Yoshimura et al. 2020). Although the defect had not entirely filled with granulation tissue before the second surgery, one Pelnac™ mesh was left in situ, utilising the silicone outer layer to provide structural support and prevent dermal desiccation of the subsequent skin graft.

A pedicle skin graft was chosen over a free skin graft due to the intact blood supply, and the fact they are generally easier to immobilise, heal more consistently and give a better cosmetic outcome (Stashak and Schumacher 2017). The skin is taken locally to the defect so is of a similar appearance and thickness. However, equine skin is relatively inelastic compared to other species (White 1992) and the ear is a site with very little loose skin. Skin expanders have been used previously to create additional skin and facilitate the repair of cosmetic defects in horses (Madison et al. 1989) but are yet to become widespread in equine practice. The technique necessitates two surgeries and is a longer process than free skin grafting or use of conventional flaps, due to the time needed for tissue expansion to occur. However, successful use of tissue expansion can achieve more favourable cosmetic outcomes than free skin grafting (Stashak and Schumacher 2017). Furthermore, skin flaps using expanded skin have been shown to be significantly more likely to survive compared with acutely mobilised skin flaps, which has been attributed to their improved vascularity (Cherry et al. 1983).

Previous skin expander technology has utilised sequential injection of saline to achieve gradual growth of a balloon expander (Bristol 2005). The tissue expander used in this case comprises a hydrogel core encased in an external silicone coating creating a self-inflating device that osmotically draws in fluid from surrounding tissue (Swan 2007), negating the need for further intervention until removal of the expander. The device has been used successfully to repair cleft palate defects in children (Swan 2007) and in the reconstruction of cutaneous limb defects in dogs (De Lorenzi et al. 2018). The device expands at a controlled rate and in a unilateral direction (anisotropy), allowing greater precision in the planning of tissue expansion (Swan 2007). This also reduces the risk of ischaemic damage to tissues when skin expansion occurs too quickly (Stashak and Schumacher 2017). Sufficient tissue expansion was considered to have occurred by Day 17 following placement in this case. This was based on subjective visual assessment and on the manufacturer’s guidelines regarding the skin expander used. Maximal volume expansion was achieved between 2 and 3 weeks post-operatively when the same device was used in vivo in the porcine hard palate (Swan et al. 2012).

At the second surgery it was discovered that the outer membrane of the expander had burst. There was no obvious reason for this, and there had been no indication that this had occurred during the interoperative period. The silicone membrane controls the rate and extent of expansion (Chhummun et al. 2010). Both the outer membrane and hydrogel core are inert materials, manufactured in
accordance with ISO 13485 standards for human medical devices, and as such are not expected to cause local tissue reaction. There were no clinical signs to indicate at what stage the membrane may have ruptured. No adverse effects on the local tissues were evident, and the burst membrane caused no problems with removal of the expander.

Other potential complications of skin expanders include dehiscence of the initial incision, implant migration, ischaemia of the skin over the expander or underlying tissues, and surgical site infection (Bristol 2005; Chummun et al. 2010). Dehiscence of the incision may occur if the expander is placed too close to its site of insertion, and the chances of this can be reduced by ensuring the incision is distant to the desired site of skin expansion. A subcutaneous tunnel should then be created to allow insertion of the expander to its correct location. This was attempted in the case described by placing the skin expander through an incision placed as close to the base of the ear as possible. However, the size of the tissue expander and the thin skin which was closely adherent to the underlying tissue limited the degree of subcutaneous tunnelling that could be performed at this location. Ischaemic damage and necrosis of tissues adjacent to the expander can result when expansion occurs too quickly (Stashak and Schumacher 2017). Careful monitoring of the site is required, though the controlled rate of expansion offered by the expander employed in this report should avoid this complication.

Surgical site infection is a potential problem in all surgical procedures, particularly when implanting a medical device. This risk may be minimised with careful aseptic technique and the use of perioperative antimicrobials. However, the risks of antimicrobial use and the importance of responsible antimicrobial stewardship should also be considered (Weese 2015). Prolonged antimicrobial courses were employed in this case due to concerns that the meshes and skin expander would increase the risk of infection. However, in retrospect we consider that antimicrobial use could have been more judicious, particularly following the second procedure. Prolonged systemic administration was probably unnecessary, particularly given the excellent vascularity of tissues in this region.

When using pedicle flaps there should be enough excess skin to cover both the site requiring reconstruction and the secondary defect created by mobilising the flap, without creating excess tension (Provost and Bailey 2019). In the case reported the skin flap mobilised was insufficient to cover both the defect and its site of origin. This meant a small triangular defect was left to heal by secondary intention. Insufficient tissue expansion has also been the experience of the authors during other clinical cases in which skin expanders have been used. In this case using two expanders may have produced enough skin to avoid the defect. However, the circular shape of the expander means there would be irregular expansion even if they were placed directly adjacent to each other. The creation of a range of shapes and sizes of skin expander would allow more complex planning of skin expansion although clinical experience of their use in horses is still limited.

The use of an artificial dermis scaffold and soft tissue expansion to repair the defect highlights the need for a dynamic and multimodal approach to successfully manage such cases. Tissue engineering is an exciting area of science.
in which rapid developments are being made (Theoret 2017), and future research in this area will be important to further advancements in equine wound management. However, a wide number of products are available with major inconsistencies in their production and action (Theoret 2017). Clinical trials of their use in equine wounds are indicated before specific products or therapeutic approaches can be recommended. Skin expansion is an area of growing interest to the veterinary profession, and the demonstration of a safe and commercially available tissue expander should increase the use of this technique (De Lorenzi et al. 2018). Further research into alternative uses is needed, and the development of optimum sizes and shapes for the equine market is warranted.

This case demonstrates the successful repair of a full-thickness defect in the ear and the challenges encountered when performing reconstructive surgery in this region in the horse. Deformation of the cartilage did remain and whilst repair avoided potential progression due to tissue contracture, correction of structural deformity in this area is more difficult to achieve. This highlights the importance of avoiding iatrogenic damage to cartilage in the ear, particularly when utilising medical laser devices to remove aural skin masses.

Authors’ declaration of interests

D. Archer has previously acted as a Veterinary Advisor to Oxtex Ltd.

Ethical animal research

Ethical approval for use of the skin expander was granted by the University of Liverpool Veterinary Research Ethics Committee (VREC257) as part of a clinical trial of the devices. Full informed consent for treatment and publication of this report was obtained from the owner of the horse.

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Authorship

D. Archer and A. Ehle contributed directly to case management and performed the surgeries. J. Wilmink provided advice on surgical management and dressings. S. Willson and M. Cullen prepared the manuscript. All authors contributed to revision of the manuscript and approved the final version.

Manufacturers’ addresses

1GlaxoSmithKline, Uxbridge, UK.
2Smith & Nephew Medical Ltd, Hull, East Yorkshire, UK.
3Dechra Veterinary Products, Shrewsbury, Shropshire, UK.
4Oxtex Limited, Witney, Oxfordshire, UK.
5Gunze Limited, Dusseldorf, Germany.

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