**Wound Management in Exotic Species**  
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**Introduction**  
A broken beak tip, rabbit pododermatitis, and the large burn across the ventrum of the snake. They all have one thing in common and that is they may appear to heal differently no matter what you do. The good news is that despite the species diversity, some of the same tenants hold true across species when developing a wound management plan. Several models of wound healing have been explored, and luckily most of the species we see in practice have been extensively studied, histologically, to qualify timelines and tissue characteristics of wound healing. The same tissue is involved, epidermis, dermis and subcutis. Amphibians and fish have a mucus layer that forms over the epidermis. Mammals, avian, herptile, and fish species have the same phases of wound healing, the timelines for each phase is just a little different. To review briefly, wound healing occurs in 4 stages, (1) immediate response, (2) inflammatory phase, (3) proliferation, and (4) maturation.

Comparative cutaneous wound phase healing times are listed in the table below. These timelines are carry the huge caveat that no other factors are affecting the process. For our clinical patients, underlying nutritional deficiencies, metabolic disorders, diet, stress, photoperiod and season, endocrine disorders, systemic inflammation and infection are all factors that can alter these timelines and the very nature and progression of wound healing.

<table>
<thead>
<tr>
<th></th>
<th>Immediate Response Hemostasis and Clot Formation</th>
<th>Inflammatory Phase Leukocyte migration</th>
<th>Proliferation Collagen and Fibroblast Migration, Granulation tissue</th>
<th>Maturation Re-epithelization, contracture</th>
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<tbody>
<tr>
<td><strong>Mammals</strong></td>
<td>Within seconds to minutes</td>
<td>24-48 hours, Lasts 1-3 days</td>
<td>24 hr to Day 4</td>
<td>Day 21-2 years</td>
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<tr>
<td><strong>Most Avian Species</strong></td>
<td>Within seconds, lasts 20-30 minutes, avascular epidermis</td>
<td>12 -36 hours, lasts up to 72 hours</td>
<td>Day 3-4</td>
<td>Weeks to Months</td>
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<td><strong>Reptiles</strong></td>
<td>Lizards: variable time, if a clot forms</td>
<td>Lizards: Variable, begins 6 hrs, lasts up to 30 hrs</td>
<td>Snakes: 30-40hr to Day 10</td>
<td>Snakes: Day 21-42</td>
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<tr>
<td></td>
<td>Snakes: immediate clot</td>
<td>Snakes: 24 hrs, lasts up to 5-10 days</td>
<td>Lizards: Day 5-10</td>
<td>Lizards: Day 84</td>
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<tr>
<td><strong>Amphibians</strong></td>
<td>Within seconds to minutes</td>
<td>1-3 days, faster in younger anurans and urodeles</td>
<td>Day 5-7</td>
<td>Day 7-14, Remodelling up to 2 months</td>
</tr>
<tr>
<td><strong>Fish (teleosts)</strong></td>
<td>Clotting may not have a role, avascular epidermis</td>
<td>Inflammatory starts in 1-3 hours</td>
<td>Rapid re-epithelization: 1.5 h Proliferation: 29 – 48 hours</td>
<td>Day 3-4</td>
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**Wound Presentations**  
**Small Mammals**  
Lacerations, puncture wounds, and pododermatitis are common wound presentations for small herbivores. Traumatic lacerations, self-mutilation, and neoplastic conditions are also common in ferrets,
myomorphic rodents, hedgehogs, and sugar gliders. Traumatic bite wounds from conspecifics, or other pets (birds, dogs, cats) are also common, and their oral flora should be considered where selecting systemic and topical antimicrobial therapy. Uncontaminated, large wound defects are amendable to copious lavage and primary closure. Grossly contaminated wounds may require extensive micro and macro debridement prior to attempted delayed primary closure or healing by second intention. For primary closures, using monofilament suture types appear to result in the best tissue closure and tensile strength durability during wound healing. Most have success with closing subcutaneous layers with 3-0 to 8-0 monofilament in a continuous pattern to reduce dead space and pocket formation. The skin should be closed in an intradermal pattern to prevent the patient from removing visible sutures. The same suture type on a reverse cutting needle helps to close the skin without using extreme pressure to advance the needle through the dermis, which can lead to severe bruising and pain after closure. Surgical glue may also be used for small skin defects and along surgical incisions in small amounts. Copious amounts of surgical glue may not only impede wound healing, but also incite wound exploration by the patient and self-mutilation. For large wound defects, flaps have been described experimentally and clinically in rats, rabbits, ferrets. Skin flap necrosis has been described in guinea pigs, and is clinically appreciated often when sites of extreme tension are closed without a tension-relieving suture pattern (horizontal or vertical mattress) tension relieving stents (easily made from IV suture line).

In rabbits, subcutaneous tracts due to puncture wounds are especially difficult to manage as drains are not effective the facilitating passive drainage from purulent debris from pocketed wounds. Rabbits, birds, and reptiles produce a caseous debris instead of a liquefied purulent discharge secondary to infection due to the presence of heterophils instead of neutrophils. Some report success with drains in chinchillas and guinea pigs, however perioperative maintenance may be tedious due to the patient’s nature to groom, chewing and remove the drain. For rabbits, macro-debridement, including complete surgical excision of abscess and abscess capsules, staged surgical debrideiments, and surgical removal of chronically infected, or necrotic tissue are warranted. In some cases, microdebridement via repeated irrigation can be performed to manage fresh, lightly contaminated and topical wound management aimed at enhancing autolytic enzymes activity and local concentration.

Neoplastic lesions often show poor response to topical treatments, and in these cases an impression smear, FNA or biopsy is warranted, as it can lead to a prompt diagnosis. Neoplastic conditions can vary from success with surgical excision (trichoepitheliomas, mastocytomas, etc) to requiring systemic therapy to modulate wound severity (T cell lymphoma).

Avian

Avian patients have the same skin structure as all vertebrates. The epidermis is avascular, extremely elastic, and very thin in comparison mammals. Birds also have keratinized epithelium (scales and keratin shields) along dorsal aspect of their feet. The rhinotheca and gnathotheca are also parts of a keratinized epithelial covering of the maxillary and mandibular bone, collectively known as the rhamphotheca. Clinically, wound management varies greatly among the three sites. Skin lacerations and beak defects (1) can be difficult to identify due to normal plumage, (2) easily invert and adhere to underlying muscle, and (3) lead to bone exposure (skull, distal metacarpal, beak). Provided site contamination is not severe, patient stabilization is preferred prior to delayed closure or bandage application.

Injuries that cause propatagial ligament contracture will impair flight. Fresh traumatic skin lacerations may be closed primarily with a monofilament suture type on a taper needle using a ford-interlocking or simple continuous tissue pattern. In some cases, tissue glue alone may suffice. Full thickness beak lesions along the rhinotheca are amendable to many stabilization treatments provided pain is controlled and any fractures over the maxilla does not compromise the patient’s ability to eat. Often local analgesia, systemic analgesics, and when possible, topical antibiotic impregnated polymers can be used for beak tip gnathotheca wounds and displacements are associated with a more guarded prognosis depending on the wound. Wing web injuries should be treated progressively to avoid systemic infection, as well as primary and secondary metacarpal wounds to prevent osteomyelitis. Pododermatitis should be staged in efforts to direct treatment approaches and to qualify prognosis. Regional antibiotic therapy, careful debridement, and careful foot bandaging can be used to treat severe cases. Reviews are available for difference bandaging techniques. Prosthetics have been described and developed for birds, foot webs, and is currently in development for hindlimbs for traumatic avulsions and amputees.
Reptiles
Comparatively, reptile wound healing follows similar stages but is strongly impacted by environmental factors that can significantly delay healing times in comparison to mammal and avian patients. In the healing process, epithelial cells and fibroblasts migrate from the skin edges, as opposed to the wound bed as seen in mammals, therefore large wound defects have result in significantly delayed closure. Traumatic wounds, thermal burns, lacerations, puncture wounds, carapacial and plastron ulceration, abscission and ulcerative dermatitis are not uncommon presentations. Debridement should be performed as indicated for all species. Primary closures can be closed with an evertting skin layer. Old references recommend the use of non-absorbable sutures, however recent studies reveal that monofilament sutures and in some cases, tissue glue, should be used for simple lacerations in snakes. Debridement and wound therapy principles follows the same guidelines as those outlines for mammals. Granulation beds may have a tan to brown coloration which should not be mistaken for necrosis. Additionally, green coloration is associated with bruising in reptiles because biliverdin as a primary byproduct of heme catabolism and this color should not be mistaken for tissue necrosis.

Amphibians
Only rivaled by fish, amphibians appear to have the strongest ability to heal not only cutaneous lesions, but are well known for digit and limb regeneration. Amphibians are well-studied and the presence of antimicrobial peptides, cell differentiation, regeneration, and cutaneous physiology. Unfortunately, because the skin has electrolyte regulation and respiratory function, lesions in the skin have unavoidable systemic consequences. Systemic treatment is warranted for skin lesions, and topical treatments can be challenging. “Red-leg” is a dated term to describe dermatosepticemia, which more accurately describes the severity of the disease process. This can be caused by bacterial, fungal, viral or neoplastic diseases. Medicated bathes can be provided based on suspected pathogens that can either cause or exacerbate disease. Localized mycobacterial infections require surgical excision, generalized infections warrant euthanasia due to zoonotic risk. The author has had success with Manuka honey on extensive palmer and plantar ulcers, impregnated honey hydrocolloids with tegaderms and surgical skin glue in large amphibians. Ultimately water quality and environmental accommodations will need to be optimized to support systemic health and to reduce wound bed contamination.

Fish
Fish have a mucus layer, thin epidermal layer that covers scales produced by the dermis. As with amphibians, the mucus layer helps protect the animal from electrolyte imbalances and osmotic shock, therefore wounds need to be assessed and addressed rapidly. As with reptile and amphibian wounds, Gram negative bacteria are a primary concern for wound contamination. Systemic treatment is warranted for skin lesions, and topical treatments can be challenging. Primary closures can be performed carefully when warranted, and suture selection is important. Chronic gut is reported to degrade quickly in aquatic environments. Polyglactin 910 has been reported to untie easily in saltwater ( ). Monofilament nylon was found to induce a superficial reaction in koi when the tags contacted the skin. More often, cutaneous ulcerations are common and optimal water quality is paramount to recovery. Microsurgical wound debridement and topical dressings, such as Ilex oitnments, biodress, polymer or bone cement antibiotic-impregnated implants, and on rare occasions, tegaderms may be used to support healing wounds.

Basic Principles of Wound Cleansing & Bandaging
Antiseptics & Irrigation: As with all species, antiseptics should be used to decontaminate wounds, not damage healing tissue. Sterile saline is the safest bet for irrigation across all species. Hypertonic saline is antimicrobial but will damage and desiccate the wound bed. Chlorhexidine >0.05% and povidone iodide >1% can be cytotoxic. Hydrogen peroxide >3% is cytotoxic and should not be used on fresh wound beds. It can, however, be used to liquefy caseous debris in small pockets and used once in pockets were anaerobic bacteria, such as Clostridial species, are suspected to contaminate the wound bed. In efforts to microdebride the wound during irrigation, a 18G needle affixed to a 30-cc syringe generates the necessary pressure (12-15 psi) to remove the surface epidermal cells without damaging the wound bed.

Bandaging: The era of wet-to-dry bandages is over in human medicine and is following suit in veterinary medicine. Once the wound has been staged (fresh, contaminated, chronic, necrotic, burn), the appropriate bandaging approach can be selected. There are a few general rules to keep in mind with selecting
Avoid dehydrating the wound. Wound desiccation and limited oxygen availability will ultimately compromise the first and second stage of wound healing. Granulation tissue will only grow in the absence of infection. Protecting the wound should not include preventing it from receiving oxygen. Culture and biopsy may be indicated in complicated cases. It is important to remember that the primary layer will also change as wound healing progresses. Primary layer should be chosen to prevent wound desiccation, wick away purulent debris, stimulate autolytic processes, and prevent wound hypoxia. Hydrogels, absorbent foam, ilex ointment, hydrogel impregnated gauze, antimicrobial impregnated gauze, Manuka honey, hydrocolloids and tissue shields for clean wounds, such as tegaderm may be indicated depending on wound type and stage. For rhampothecal defects extending to the bone layer along the biting surface, doxycycline polymers can be used after irrigation of the site, which will need to be covered by other polymers or plumber’s putty. Hydrocolloids, manuka honey, and vaseline impregnated gauzes can be used as epithelial scaffolds during wound contraction after granulation. Secondary layers should be protective and absorbent. Tertiary layers should help stabilize additional bandaging materials, should ideally be water proof, but oxygen permeable. Completely occlusive bandages are not recommended.

**Product Review**

**Silver Sulfadiazene (SSD crème):** Extensively used in human medicine for third-degree burns, it is one of 5 medications that remains effective against a dangerous Gram negative rod that can become life-threatening for all species, *Pseudomonas aeruginosa*. SSD is also reported to be antifungal, antibiotic and the silver component is thought to support granulation tissue development. If it seems like it is too good to be true, one might question if it is not. There are some caveats. First, the way in which it is applied can alter its efficacy, as thick layering can suffocate wound beds and exacerbate disease. Additionally, as an occlusive, it has been shown to delay wound healing in reptiles- the very species at significant risk for *Pseudomonas* and gram-negative wound contamination. When used appropriately, a thin layer can be applied topically, and a contact time of 20 minutes is recommended to work effectively as an antimicrobial agent.

**Primary Layer Bandage Types:** Some primary layers are designed to support resident macrophages, which secrete matrix metalloproteinases (MMPs) and use calcium to degrade necrotic tissue. Alginate preparations entrap autolytic enzymes to stay at the affected site to improve wound healing. Ilex is a petrolatum and calcium-containing product that has been used successfully in aquatic environments in sea turtles for shell defects, and may have application in fish, particularly deep wounds.

**Manuka Honey:** After systemic review, this topical product appears to be one of the few topical dressings that works at each stage of wound healing for various types of wounds (necrotic, contaminated, chronically infected wounds, burns, ulcers), and unlike other biocides, is not cytotoxic. It has been shown to have clinically significant antimicrobial, anti-inflammatory and antioxidant activities, immune-stimulatory, tissue growth stimulatory, and debridement action in wound regeneration. The author has used Manuka honey, at the recommendation of an NIH wound specialist, in severe wounds across all species reported, with great success in healing chronic ulcers, chronic infections, especially in reptiles. Methylglyoxal is the active ingredient in Manuka honey responsible for antimicrobial efficacy.

**Negative Pressure Wound Therapy:** Vacuum-assisted wound closure has been reported in several cases for successful and expedited treatment for shell wounds and defects. The application of sub-atmospheric pressure to a wound has been shown to increase blood flow to the wound and immediate periwound environment, removed exudate, and stimulate granulation tissue formation, thus significantly reducing wound healing timelines. Small VAC units may be of use in mammals that tolerate it, however there are contraindications, which includes placement over open joints, over neoplastic lesions, over necrotic wounds, and placement over areas sensitive to pathologic fractures.

**Photobiomodulation (Low Level Laser Therapy):** There is mounting evidence that supports that LLT improves wound healing. Absorption of photons by mitochondria of photoresponsive cells stimulates an increase in ATP, which makes energy available for a variety of cellular processes, including angiogenesis, fibroblast proliferation, transition of fibroblasts to myofibroblasts, collagen synthesis, and anti-inflammatory processes. In mammals, this treatment effect is significant. Surgical sites are treated as standard of care post-operatively for all patients at the author’s veterinary hospital. In reptiles, the evidence is variable and may be due to difference in fibroblast location at the wound in classic wound healing, which differs in mammals, however increases in fibroblast migration and collagen density have been reported. In fish, anecdotal reports support its use to optimize chronic non-healing wounds. The
author has successfully used the LLT in avian wound management. Additional clinical trials are needed to help identify therapeutic effects in species with variations in wound healing characteristics.

References


