COLLECTION OF LECTURES

NEW OPTIONS AND PROCEDURES IN WOUND TREATMENT 2024

Professional veterinary seminar

DATE AND VENUE

On 23/03/2024 from 8:30 a.m. to 4:30 p.m

Education and information center FLORET, Kvýtnové námýstí 391, 252 43 Prýhonice

LECTURER

MVDr. Leona Rauserová, Ph.D.

MVDr. Roman Kvapil

MVDr. František Zahrádek

MVDr. Zdenýk Žert, CSc., Dipl. ECVS

The seminar is included in the KVL continuous education program - **22 credits.**

ORGANIZER

WERFFT, spol s ro, Kotláýská 53, Brno, 60200 ID 49433318

SPONSORS

Abilar® 10%

Vet līmce

www.werft.cz

PROGRAM

8.30 - 9.00	*Registration*
9.00 - 9.45	**Stabilization of the patient with a wound** from simple cases (stopping bleeding) to complicated cases (polytrauma) MVDr. Leona Rauserová, Ph.D.
9.45 - 10.30	**Uncomplicated wound healing** physiological wound healing from a clinical point of view MVDr. Roman Kvapil
10.30 - 11.00	*Coffee break*
11.00 - 11.45	**Complications of wound healing** MVDr. Leona Rauserová, Ph.D.
11.45 - 12.30	**Cases from practice** MVDr. František Zahrádek
12.30 - 13.30	*Lunch*
13.30 - 14.15	**Debridement of secondary healing wounds and biofilm as complications of wound healing in horses** MVDr. Zdenÿk Žert, CSc., Dipl. ECVS
14.15-15.00	**Choice of secondarily healing wound cover and methods of skin transplantation in horses** MVDr. Zdenÿk Žert, CSc., Dipl. ECVS
15.00 – 16.30	*Discussion*

PROCEEDINGS

STABILIZATION OF THE PATIENT WITH A WOUND

from simple cases (stopping bleeding) to complicated cases (polytrauma)

MVDr. Leona Rauserová, Ph.D.
Vyvet Veterinary Clinic, Dÿdická 680/27A, Vyškov
rauserovaleona@gmail.com

NOTE

Stabilization of the patient with a wound

Wounds are usually caused by trauma and can lead to a serious alteration of the general state of health of varying extent. We regularly encounter patients for whom only local treatment of the injured area is sufficient. On the other hand, many patients arrive in a state of shock as a result of extensive trauma or as a result of the development of an infection (sepsis, septic shock). General health status, age and possible comorbidities significantly influence wound healing and the risk of complications. Therefore, a thorough clinical or laboratory examination is an integral part of the treatment of every patient with a wound.

1. Anamnesis

When determining the medical history, we should, among other things, focus on the time of onset and possible mechanism of injury, the occurrence of comorbidities and long-term medication. Currently, in connection with the import of animals from countries where rabies occurs, the date of vaccination against rabies must be recorded, especially in the case of a bite injury.

2. Clinical examination

Depending on the severity of the injury and the alteration of the general state of health, we will perform either a primary clinical examination focused on the vital systems - airways, breathing, bleeding, circulation (ABC system - A - airway, B - breathing, bleeding, C - circulation), which at the same time we are trying to stabilize.

After this primary examination and simultaneous stabilization, we continue with a complete clinical examination (ACRASH PLAN- A – *airway,* C – *circulation,* R – *respiration,* A – *abdomen,* S – *spinal* cord, skin, scrotum, H – *head, hyperthemia, hypothermia,* P – *pelvis, perineum, pain,* L - *limbs,* A – *arteries,* N – *nerves).*

3. Stabilization

As part of the primary examination and stabilization, we assess the severity of the condition and try to prevent its further deterioration. With the exception of states of cardiopulmonary arrest, when it is necessary to start cardiopulmonary resuscitation immediately, we usually introduce an intravenous catheter with simultaneous blood sampling and apply analgesics and start infusion therapy, possibly oxygen administration.

From the laboratory parameters, it is advisable to examine at least the hematocrit and total protein with regard to possible blood loss. Determining the values of kidney and liver parameters, glucose and basic electrolytes will give us a more objective picture of the patient's condition.

The goal of analgesic therapy is to suppress the patient's pain and fear and thereby improve his comfort during further manipulation and examination.
Intravenous application of analgesics leads to a rapid onset of action.
If the patient is too painful and stressed and does not tolerate

insertion of an IV catheter, analgesics can be administered intramuscularly. For less painful conditions, first-line analgesics include butorphanol administered at 0.1-0.4 mg/kg IV or IM in dogs and 0.1-0.6 mg/kg IV or IM in cats. In animals with a significant alteration of the general condition, we start with a lower dose and, as necessary, repeat the application or add additional analgesics. In the case of a more extensive injury, especially if we anticipate the need for more extensive surgical treatment, we choose methadone at a dose of 0.1 - 0.4 mg/kg IV or IM. Caution with intravenous administration of methadone in cats, histamine may be released with a subsequent drop in blood pressure. Among other analgesics, fentanyl at a dose of 2-5 mcg/kg IV or IM is a suitable choice. The disadvantage of fentanyl is its relatively short effect and the necessity of reapplying. Metamizole (25 – 50 mg/kg IV or IM) is another possible option, especially for the dog. The use of anti-inflammatory drugs can be risky during the stabilization of patients due to their negative effects on renal perfusion and the risk of ulceration of the gastrointestinal tract, so it is preferable to postpone their application.

Infusion therapy consists in the application of balanced alkaligenic infusion solutions (Plasmalyte, Ringerfundin, Hartmann's solution) in a dose of 5-10 ml/kg over 15 minutes in cats and 5-20 ml/kg over 15 minutes in dogs. Administer bolus infusions repeatedly until circulation is stabilized. In case of moderate to severe shock or in patients with head trauma or bleeding in the lungs, it is more appropriate to start infusion therapy with the application of 5.85% NaCl solution at a dose of 1 ml/kg over 10 minutes, if necessary and repeatedly up to a total dose of 4 ml/ kg in cats and 5 ml/kg in dogs. After the application of this hypertonic NaCl solution, we always continue with the administration of one of the balanced alkaline solutions (Plasmalyte, Ringerfundin or Hartmann's solution) until the circulation is fully stabilized (5 - 10 ml/kg/h) and then according to the hydration status (2 - 3 ml/kg/hu animals without signs of dehydration). Administration of blood transfusion is indicated in animals with manifestations of anemic syndrome (persistent tachycardia, tachypnea, weakness, hypotension) and with an acute drop in hematocrit below 0.25 l/l/or a drop in total protein below 50 g/l.

If we have oxygen available, it is advisable to start oxygen therapy, especially in patients with shortness of breath and shock. In the first phase, we most often use the *"flow by"* method , in which we hold the oxygen tube a few centimeters from the animal's nose.

4. Antibiotics

The need for antibiotics depends on the severity of the injury. Superficial injuries do not require antibiotic therapy. Conversely, deep injuries or injuries penetrating body cavities, especially those caused by bites, should be treated with intravenous antibiotics that work against the entire spectrum of bacteria (G-, G+, anaerobes).
Ampicillium sulbactam at a dose of 10 – 25 mg/kg IV over 6 – 8 h or

amoxicillin clavulanate at a dose of 15 – 20 mg/kg IV after 6 – 8 h cover the complete spectrum of bacteria. Another alternative is the combination of cefazolin 20 mg/kg IV or cefuroxime at a dose of 10-15 mg/kg IV after 6-8 h and metronidazole 15 mg/kg IV after 12 h. Metronidazole can be replaced in this combination by clindamycin at a dose of 11-15 mg /kg IV after 8 – 12 h. If we assume a possible infection with pseudomonads (especially in older heavily infected wounds affected by gangrene), it is also necessary to administer fluoroquinolones (enrofloxacin 10 mg/kg once a day in dogs, max 5 mg/kg once a day in cats , marbofloxacin 2 – 5 mg/kg IV once a day in dogs and cats) or aminoglycosides (gentamicin 6 mg/kg IV once a day, amikacin 15 mg/kg IV once a day). The duration of antibiotic therapy depends on the degree of contamination of the wound (a smear should be taken for microbiological examination), the general condition of the patient and the course of healing. Due to the risk of selection of resistant strains, it is recommended to de-escalate antibiotic therapy as soon as possible according to the results of microbiological examination and antibiotic sensitivity, and to administer antibiotics for the shortest possible time. Attention, the local administration of antibiotics leads to the emergence of resistance within 5 days and there is a risk that the antibiotic will not reach a sufficient concentration and thus the selection of resistant strains increases even more!

5. Wound treatment

If the patient is bleeding profusely from the wound, further blood loss should be limited by applying pressure to the bleeding site, a péan clamp on the bleeding vessel, or a pressure bandage. In case of protrusion of internal organs, we wrap them with a moistened sterile cloth to prevent further injury. Penetrating chest injuries are temporarily closed by applying an impermeable layer (plastic, gloves) and a bandage and monitoring the patient's breathing. Penetrating injuries to the chest and abdomen are indications for urgent surgical revision.

Self-treatment of the wound tends to be painful. The intensity of the pain depends on the invasiveness of the surgical treatment. Smaller injuries can be treated after the application of analgesics (butorphanol, methadone, fentanyl) or in combination with sedatives (midazolam 0.1-0.2 mg/kg + opioid + ketamine 1-2 mg/kg IV or medetomidine 10-20 mcg/kg IV or dexmedetomidine 3 – 5 mcg/kg IV) and local anesthesia (lidocaine max 4 – 5 mg/kg dog, 2 – 3 mg/kg cat) or in general anesthesia.

After stabilizing the patient, we will perform the final treatment of the wound consisting of a thorough cleaning of the wound area (hair clipping to a sufficient extent, removal of gross impurities from the wound, lavage). To prevent further contamination of the wound during clipping, we can cover the wound with moistened gauze or by applying an inert sonographic gel. We aseptically prepare the wound area as a surgical field.

Subsequent massive rinsing with sterile Ringer's solution washes away impurities and reduces bacterial contamination of the wound. Beware of the pressure application of solutions into the morning subcutaneous pockets, which may occur to distribute the solution and possible contamination into the subcutaneous tissue without the possibility of the solution draining back. Sterile Ringer's solution is especially suitable in cases where there is a risk of communication with body cavities and joints. The addition of 1-2 ml of 2% lidocaine solution to 500 ml of Ringer's solution has an analgesic effect and will increase the patient's comfort. A 1% solution of povidone iodide or 0.05% chlorhexidine can also be used for rinses and irrigations, but it must be remembered that these solutions show some cytotoxicity. More modern superoxidized antiseptic solutions can also be used when there is a risk of exposing tendons, joints, bones, or penetration into body cavities.

Among the other alternatives, we can apply solutions that reduce the surface tension of the wound and thus enable its more effective cleaning (Prontosan). These solutions are especially suitable for older heavily contaminated wounds. The previously often used unsaturated (pink) solution of hypermanganese is the only one that has antiseptic properties and at the same time stimulates healing. Hydrogen peroxide, soaps and disinfectant solutions are not suitable for application to wounds. The signal to stop rinsing is the whitening of the edges of the wound.

Literature

Frey E, et al 2022: AAFP/AAHA Antimicrobial Stewardship Guidelines. 2022 American Animal Hospital Association; https://www.portalveterinaria.com/upload/202207121012212022-aafp_aaha-antimicrobial-stewardship-guidelines.pdf

Harold D, et al 2013: AAHA/AAFP fluid therapy guidelines for dogs and cats. *Am Anim Hosp Assoc* 49(3): 149–159.doi.org/10.5326/JAAHA-MS-5868

Lefman S, Prittie JE 2022: High-rise syndrome in cats and dogs. *J Vet Emerg Crit Care* 32: 571–581; DOI: 10.1111/vec.13206

Kleinbart S. et al. 2022: Dog bite wounds in cats: A retrospective study *J Feline Med Surg* 24 (2): 107–115. DOI: of 72 cases 10.1177/1098612X211010735

Lux CN et al. 2018: Risk factors and death in patients undergoing thoracic surgery after trauma. *Am Vet Med Assoc* 252:1097–1107

Peterson NW, Buote NJ, Barr JW 2015: The impact of surgical timing and intervention on outcome in traumatized dogs and cats. *J Vet Emerg Crit Care* 25(1): 63–75. DOI: 10.1111/vec.12279

Piaggesi A. et al.2010: A randomized controlled trial to examine the efficacy and safety of a new super-oxidized solution for the management of extensive postsurgical lesions of the diabetic foot. Int J Low Extrem Wounds 9 (1): 10–15. DOI: 10.1177/1534734610361945

PROCEEDINGS

UNCOMPLICATED WOUND HEALING

MVDr. Roman Kvapil

Veterinary clinic, Durerova 18, Prague 10

veterinaskalka@seznam.cz

NOTE

www.werft.cz

Wound - definition

Vulnus – any tissue damage associated with a violation of the connection of the skin, mucous membrane or surface of an organ

Wounds by cause
ÿezná - vulnus scissum

Secná - vulnus sectum
Tenderness - vulnus lacerum
Biting - vulnus morsum
Puncture - vulnus punctum
Gunshot wound - vulnus sclopetarium
Bruised - vulnus contusum

We describe at the wound

Localization
Size Depth
Shape

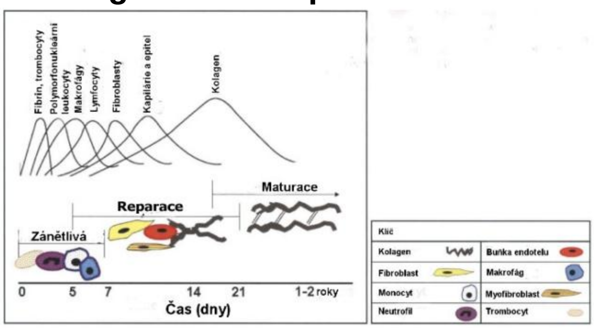
Direction
Edges
Secretion
Scum Type
of wound Ev.
smell Old

Healing - definition of
Sanatio = healing = repair of damage per

primam (intention) – wound healing for the first time, without complications
per secundam (intention) – wound healing secondary, occurs only after removal of destroyed wound edges, suppuration, etc. per tertiam
(intention) – delayed suture

- all vertebrates

Healing - a natural process



Healing - a natural process

https://www.edwardselfephotosafaris.com/its-not-all-cheerful-in

The doctor does not cause the wound to heal, but only facilitates and modulates the natural process.

Healing - the dog x cat difference

Dog		Cat
	Anatomy and physiology	
More	skin perfusion	Less
More		Less
Greater	subcutaneous collagen production	Smaller

Sanatio per primam

- 7th day with Fe less strength - pseudo-healing

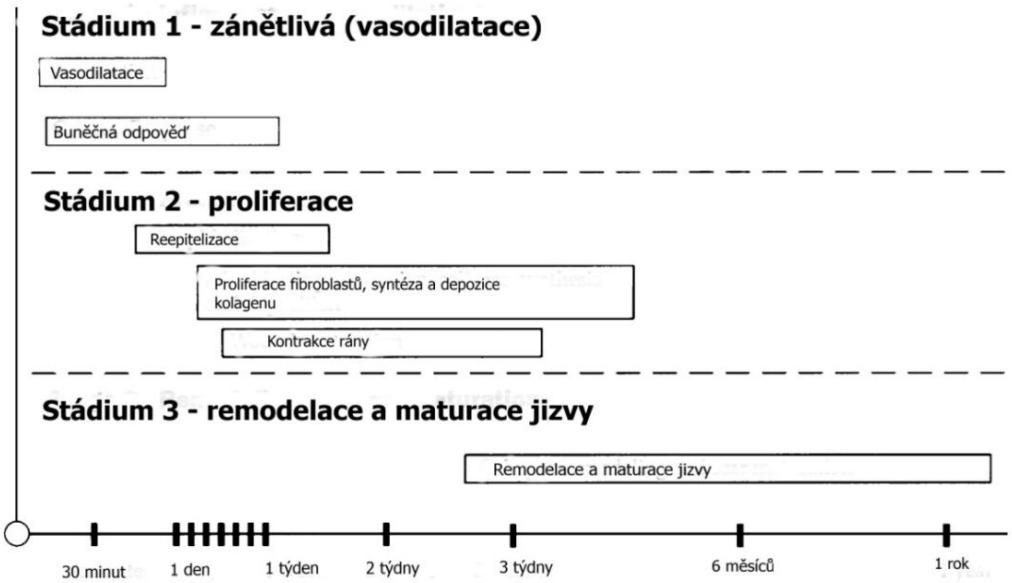
Sanatio per secundam

- Day 2 Ca – more fluid (edematous, redder)

-7. - Day 21 Ca – more granulation tissue (7.5 x 19)

- gran.tissue – Ca entire subcutaneous tissue x Fe wound edge

The healing phase



1 – inflammatory phase and debridement

Hemostasis

bleeding

paleness

clot formation

Inflammation

erythema

heat

edema

pain
exudation

2 – repair, proliferation

24-48 hours

necrosis (scab)

4-7 days

granulation tissue, visible epithelium at the edge of the wound

5. -9. day

visible contraction of the wound

3 - graduation

Day 21+

- visible contraction of the wound, complete epithelization
- reduced redness

Healing - time forecast

Plot	Beginning
Leukocyte migration	6 hours
Monocyte migration	48 – 72 hours
Fibroplasia	3-4 days
Angiogenesis	2 days
Epithelialization	1 – 2 days (proliferation)
Contraction	5 – 9 days

Improving healing

1. Inflammatory phase and debridement

Target

reducing wound contamination, supporting the host's defenses, preventing the development of infection

Method

Debridement, lavage

Debridement

DEBRIDEMENT = removal of non-viable tissue from a wound

Debridement		
neselektivní		selektivní
Laváž		Enzymatický
Chirurgická		Biochirurgický
Mechanická	Wet-to-dry	Autolytický (hydrocoloidy)
	Dry-to-dry	
Debridement polštářky		

Debridement – 7 – 8 psi - pound
force per square inch **lbf/in²**

- pressure corresponding to the gravitational force acting through a body of mass

one pound to the area of one square inch

- 1 psi = 1 lbf/in² ÿ 6,894.757 Pa

Standard atmospheric pressure at sea level is: Pa = 14.695948804 psi.

1) 18G catheter + 35cc syringe
2) 1 l bag – pressure 300 mm Hg

Debridement – preparations

Tabulka 3: Produkty pro enzymatický debridement dostupné na českém a světovém trhu.

Název	Enzym	Prodává se v ČR	Zdroj
Revamil® hydrofilní gel	med, který aktivuje pomocí peroxidu vodíku proteázy a obsahuje glukózaoxidázu bojující proti infekci	ano	(Wanszelbaum 2016)
Iruxol Mono	mast obsahující kolagenázu z *Clostridium histolyticum* a směs dalších proteáz	ano	(SÚKL 2019)
NexoBrid	čistý inertní gel obsahující bromelain	ano	(MediWound Ltd. 2018)
Pana-Veyxal® Salbe	mast s kombinací chymotrypsinu, trypsinu, papainu a vitamínů A a E	ano veterinární	(Weiron Dynamics, s.r.o. 2018a)
SunLitan® PA Zink	sprej s enzymy (trypsin, chymotrypsin, papain), vitamíny A a E, allantoinem a glycerinem	ano veterinární	(Weiron Dynamics, s.r.o. 2018b)
Xenaderm Ointment	mast obsahující trypsin a ricinový olej	ne	(Healthpoint, Ltd. 2019)
Collagenase SANTYL® Ointment	mast obsahující kolagenázu z *Clostridium histolyticum*	ne	(Smith & Nephew, Inc. 2008)
Accuzyme® Papain-Urea Debriding Ointment	hydrofilní mast obsahující papain a ureu	ne	(Wright a Shi 2003)
Varidase topical	mast obsahující streptokinázu a streptodornázu	ne	(Rutter et al. 2000)
Fibrinolysin W/DNASE – topical oitment	mast obsahující fibrinolyzin	ne	(DrugInfo 2007)

Possibility of wound closure

Options closure	**Wound classification**	**Wound treatment**
Primary closure Clean		Instant closing without voltage. It may require a suitable flap or skin graft.
Delayed primary closure - before the appearance of granulation tissue	clean – contaminated or contaminated wounds, or where tissue viability or swelling is questionable, or skin tension occurs during primary closure	Lavage and debridement of open wounds. Use of an appropriate dressing. Closure performed 2-3 days after injury. A suitable flap or skin graft may be required.
Secondary closure - after the appearance of granulation tissue	Contaminated or soiled wounds	Irrigation and debridement of an open wound. Use of an appropriate dressing. Closure is performed 5-7 days after the injury. May require appropriate flap technique or skin transplantation.
Secondary healing - phase of contraction and epithelization	Wound unsuitable for surgical closure: excessive contamination and devitalization. Do not weigh over the articular surface, as this may lead to joint contracture,	Lavage and debridement of open wounds. Use of a suitable dressing Let it heal by granulation, contraction and epithelization

Improvement of healing 2.
Reparation phase Goal

Contamination protection, stimulators and dressings to protect the deposition of vascular granulation tissue - moist surface, support contraction

Method

Cap, Cover, Moist Healing

Improving healing

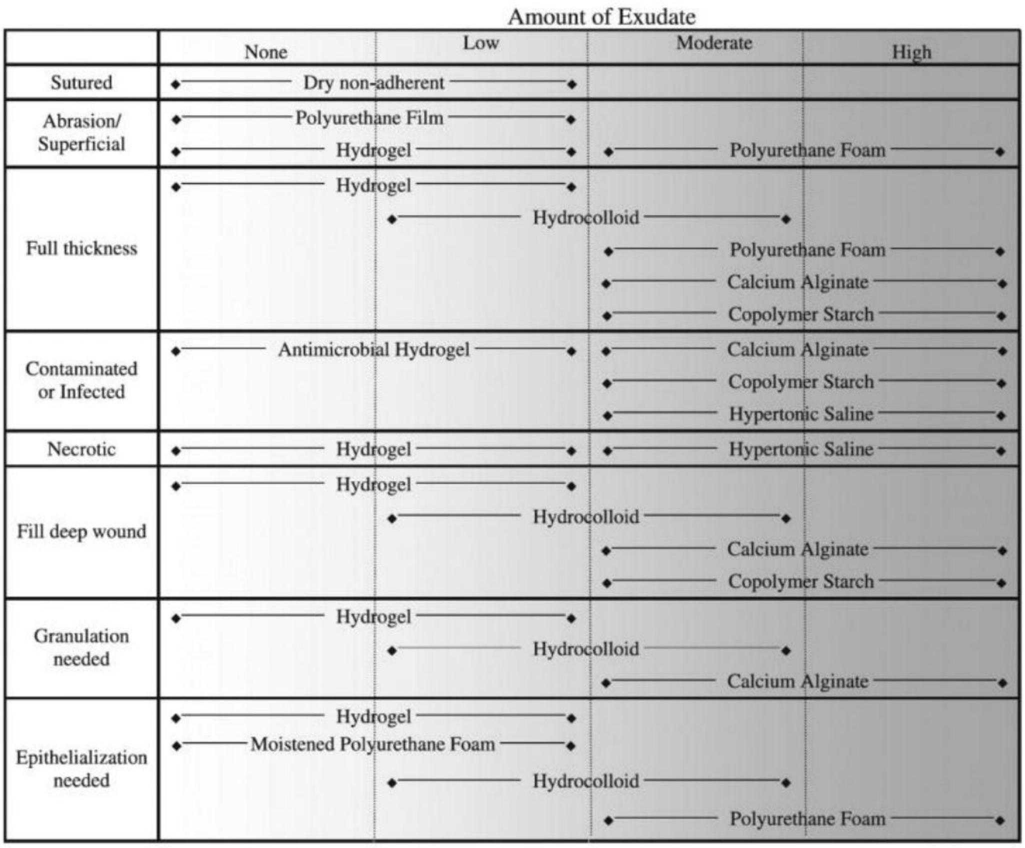
3. Maturation phase
Goal

Protect fragile skin

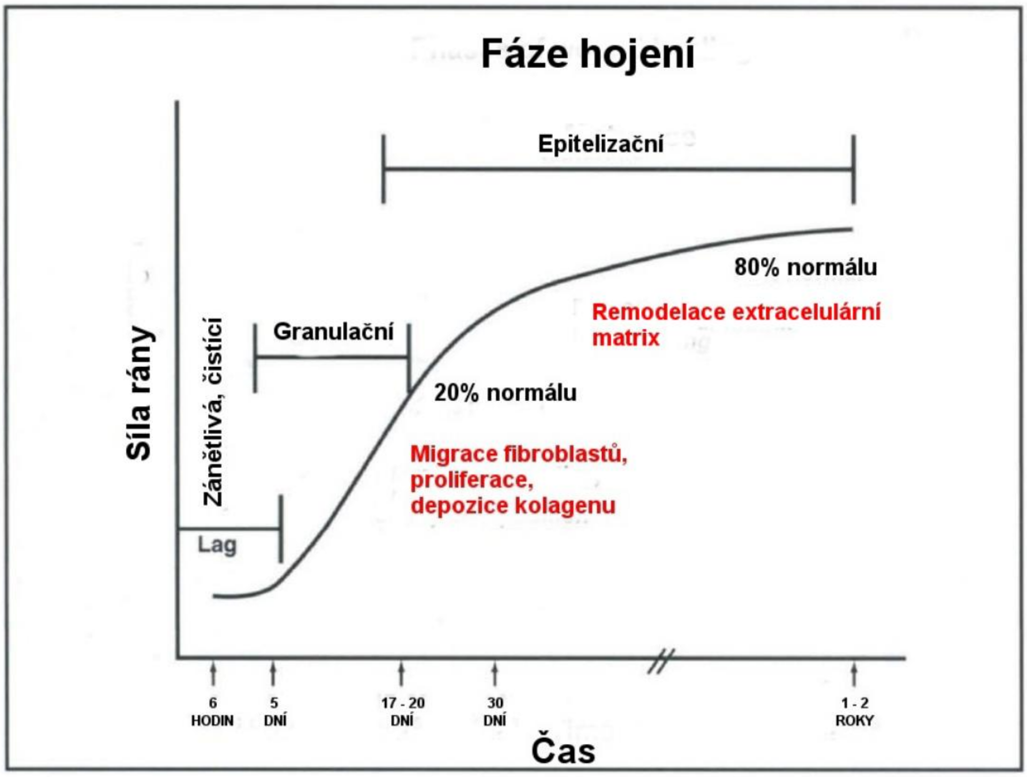
Method

Cover

Bandages



The force of the blow



Supporting the healing process

Goal = cleaning the wound, creating new tissue and closing the wound in an attempt to restore the skin barrier

Regenerative therapy of skin wounds

- application of growth factors, gene therapy, stem cell therapy, tissue engineering, reprogramming cells

Supporting the healing process

- mesenchymal germ cells (MSCs – mesenchymal stem cells)

- platelet-rich plasma (PRP – platelet-rich plasma)
  - reduction of inflammation and contraction, increased re-epithelialization and better maturation of granulomatous tissue, regulated expression of type I and III collagen
  - better maturation and organization of skin adnexa collagen fibers

Wound healing conditions

• Maintaining a moist environment • - hydrogels, hydrocolloids
Sufficient energy • - honey, sugar
Reducing swelling • - alginates, honey, sugar
Increasing the level of growth factors - acemannan, tripeptides + copper
• Source of substances for healing - collagen

• Increase inflammatory response • Infection control • Increase debridement • Increase O2 content • Increase blood flow

- maltodextrin
- antibiotics
- enzymes
- hyperbaric oxygen
- laser

Plant extracts in healing

Plant extracts

alkaloids, carbohydrases, glycosides, terpenoids, diterpenes, sesquiturpenes, phytosterols, phenolic compounds, tannins, flavonoids, saponins, lignins, alkaloids, essential oils

1. Antimicrobial activity
2. Antioxidants
3. Active enhancing ingredients
    1. Mitogenic activity – increased cell proliferation
    2. Angiogenesis
    3. Increase in collagen production
    4. Increased DNA synthesis

Abilar® VET

• Antimicrobial effect

- Methicillin-resistant *Staphylococcus aureus*, *Staphylococcus aureus* (MRSA), *Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis* and *Candida albicans.*

• Promotion of epithelization and reduction of scar formation
- in vitro

• Anti-inflammatory effect
- inhibition of interleukin 1-ÿ, metalloproteinase 3, tumor necrosis factor ÿ

• Prevention of biofilm formation
- preventing transition to chronicity

Case from practice

Komplikace hojení rány po odstranění a ošetření Abilar: Osrstěná kůže: mnohočetné prasknuté folikulární cysty (infundibulární cysty?) s chronickým pyogranulomatózním zánětem v periferní fibróze (IDEXX Laboratories), pes, německý boxer, 9 let

1.den 4.den 9.den 16.den

PROCEEDINGS

COMPLICATIONS IN WOUND HEALING

MVDr. Leona Rauserová, Ph.D.
Vyvet Veterinary Clinic, Dÿdická 680/27A, Vyškov
rauserovaleona@gmail.com

NOTE

Complications in wound healing

Complications in wound healing occur in 2.6-12% of cases, depending on etiology, animal species and method of treatment. There are many factors influencing healing and thus the risk of complications. We can divide them into local and global. Among the general factors influencing the course of healing are animal species (cats heal differently than dogs, horses are prone to hypergranulation especially in wounds on the limbs), age and complicating diseases and medication. E.g. in patients with diabetes, hyperadrenocorticism, liver, renal failure and tissue hypoperfusion, delayed healing and an increased risk of complications should be expected. A similar situation exists in patients with malnutrition, which is why high-quality and sufficient nutrition is a very important part of therapy for all patients.

Among the local factors of wound healing are the localization of the injury and the degree of tissue damage, which have a fundamental influence on the blood supply to the wound and thus the supply of oxygen and nutrients and the removal of metabolic products. Wounds located on the acral parts of the body are more susceptible to disruption of the vascular supply and thus poorer healing. The vascular supply to the wound can also be disturbed by the wound treatment technique (e.g. too tight a suture, excessive tension on the suture, ischemia caused by the dressing). The type and severity of the injury, along with the degree of contamination, are other important factors. Wounds contaminated with foreign material, microorganisms, or wounds containing necrotizing tissue (e.g. bone sequestration) take longer to heal and the wounds have an increased risk of complications. Very dangerous is the formation of biofilm on suture material and implants, which leads to impaired healing and repeated infection, because the bacteria of the biofilm are protected from the immune system and the effect of antimicrobial agents. For this reason, adherence to the principles of antisepsis and asepsis during surgical procedures and wound treatment is very important.

Complications in wound healing include:

Bleeding

Bleeding from the wound occurs immediately after the patient is injured.
Depending on the injury, bleeding varies in intensity from mild to life-threatening. After treatment of the wound with a primary suture, blood leakage from the suture may occur. There is an increased risk of postoperative bleeding in patients with coagulation (primary or secondary caused by e.g. excessive infusion therapy in combination with hypothermia and persistent metabolic acidosis). An increased risk of postoperative bleeding occurs in greyhounds, in which accelerated fibrinolysis has been described, leading to premature dissolution of blood clots and extensive postoperative bleeding, which can be life-threatening. Administration is recommended in these breeds to reduce the risk of postoperative bleeding

tranexanoic acid at a dose of 10-15 mg/kg IV every 8-12 hours for 3-5 days.

Application of etamsylate improves coagulation by increased platelet adhesiveness. Its interference with the effects of heparin has also been proven. Etamsylate (in a dose of 10 – 15 mg/kg IV after 6 h) can be applied not only overall but also locally.

Cold therapy (applying an ice pack) for 15-20 minutes will help stop bleeding and reduce post-operative pain.

Another option is to insert a suture deep into the surrounding tissue or a pressure bandage.

An integral part of reducing the risk of postoperative bleeding and stopping it is the patient's rest regime. Calm awakening and good analgesia reduce the risk of excitation and thus a sharp rise in blood pressure, which can lead to postoperative bleeding.

Edema

Swelling is another possible complication of wound treatment. Slight swelling of the injured area is common in the first days, as it is a symptom of inflammation, which is part of the physiological process of wound healing.
Extensive and persistent swelling, redness and soreness are associated with infection and the risk of abscess formation. To reduce swelling, we can generally administer anti-inflammatory substances (e.g. meloxicam, carprofen, coxib). Ice packs can be applied locally for 15-20 minutes 3-4 times a day. Other remedies can be recommended, for example, extracts from horse chestnut (Aescin tbl.) or Wobenzym.

Serum

It occurs in the case of a dead space in the wound, in which the protein-rich morning secretion accumulates. There is an increased risk of seroma formation in places where a larger cavity is formed, e.g. after the removal of larger masses or in dogs during a caudal laparotomy in the penis area. Prevention is careful closure of the subcutaneous tissue or placement of a drain with active suction.

Infection, abscess formation

Wound infection is one of the most serious complications of healing. There is an increased risk of infection in wounds caused by trauma, in which the wound is contaminated to a greater or lesser extent. In surgical wounds, if the principles of antisepsis and asepsis are followed, the risk of infection is low.
The presence of implants and non-absorbable suture material increases the risk of infection with biofilm formation. In this case, it can be a hematogenous infection, which is manifested by the formation of fistulas. Treatment tends to be quite difficult.

When a wound becomes infected, we usually cannot do without a general application of antibiotics. Therefore, it is very important for these infected wounds (bite wounds, fistulas) to take a sample for microbiological examination and

determination of antibiotic sensitivity. In patients with altered general health status caused by infection (sepsis), intravenous antibiotic therapy should be started as soon as possible and should cover the complete spectrum of pathogens (G+, G-, aerobes and anaerobes).
After receiving the results of the microbiological examination and sensitivity results, we reduce the antibiotic therapy so as not to promote the selection of resistant strains. In addition to general therapy, local therapy consisting of revision and thorough cleaning of the infected wound is also very important in this case. If possible, we remove all infected tissue, infected suture material, or implants. We then perform a thorough lavage and close the wound again either with a primary suture or by combining the suture with the introduction of a drain with an active aspiration system. Currently, a vacuum wound healing system is increasingly used in human medicine, which enables continuous drainage of morning secretions, or combines the lavage phase with the continuous suction phase. After cleaning the wound, the wound is closed with a suture. If we heal the wound as an open one, we can use rinsing solutions of povidone iodide, nanosilver, hypermanganese or superoxidized rinsing solutions and solutions containing singlet oxygen. We then apply non-antibiotic antibacterial gels to the wound (gel containing nanosilver, hydrogel, gel containing singlet oxygen, honey). We should always protect the wound with a suitable bandage.

Necrotizing fasciitis

This is a very serious and even life-threatening condition, where there is a rapid progression within a few hours from a local infection to gangrene, which is accompanied by a disruption of the general state of health. A minor injury can also be the cause.

The cause is the bacteria *Steptococcus canis, Escherichia coli,* bacteria from the genus *Clostridium* and *Pseudomonas.* An infection caused by *Streptococcus canis* is especially dangerous , in which exotoxins are produced after the application of fluoroquinolone antibiotics, which are the cause of the development of toxic shock syndrome. Subsequently, the overall condition of the patient significantly worsens, and may even lead to death.

Therapy consists of immediate surgical treatment - debridement, open wound healing (see wound infection) and general IV application of antibiotics, such as amoxicillin clavulanate in combination with aminoglycosides and clindamycin, which suppresses toxins. Based on the results of bacterial microbiological examinations, we reduce antibiotic therapy.

Intensive supportive therapy is an essential part of the treatment of these patients. It consists in infusion and analgesic therapy, possibly administration of vasopressors.

Wound dehiscence

It is another unpleasant complication in wound healing. The cause may be poor bleeding from the edges of the wound, excessive tension on the suture and infection. Wound dehiscence can also occur as a result of self-mutilation by the patient. An appropriate method of local treatment, possibly applying a bandage, can reduce the risk of this complication. If dehiscence occurs, further treatment of the wound depends on its location and severity. In all cases, we should take samples for microbiological examination. In case of dehiscence of the suture of the body cavity wall, revision and re-suture is necessary. In the case of surface defects, open wound healing is the method of choice. We can also consider negative pressure wound healing.

Hyperplastic scar - keloid

It occurs at the site of excessive irritation of a healing wound. Keloid formation is relatively rare in dogs and cats. Keloid tissue is stiff and more prone to injury.

Limitation of joint mobility and loss of muscle mass

The healing of extensive defects in the area of the joints can be accompanied by a limitation of their range of motion and loss of muscle tissue caused by long-term immobility. A separate chapter is the formation of extensive scars, especially after burns or devastating injuries with loss of soft tissues, tendons and damage to the bone base.

Tetanus

It is a relatively rare complication in wound healing, but this disease must be remembered especially in young animals. In terms of sensitivity, a dog is more susceptible to tetanus than a cat. Due to the seriousness of the disease and the limited possibility of therapy after the development of clinical symptoms, it is important to prevent this disease and, if suspected, to start adequate therapy.

Literature

Bohling MW, et al. 2005: Wound Healing in the Cat: A Macroscopic Description and Comparison with Cutaneous Wound Healing in the Dog.
Veterinary Surgery, 33:579–587.

Brunnberg L., et al. 1997: Complications of wound healing in dogs and cats. A retrospective analysis (1990-1994). Wound healing disorders in dogs and cats. Retrospective Analyze 1990-1994. Kleintierpraxis, 1997, Vol. 42, No. 7, 535-553.

Frey, E., et al..2022 AAFP/AAHA Antimicrobial Stewardship Guidelines.
2022 by American Animal Hospital
Association; https://www.portalveterinaria.com/upload/202207121012212
022-aafp_aaha-antimicrobial-stewardship-guidelines.pdf

Kleinbart S. et al. 2022: Dog bite wounds in cats: a retrospective study of 72 cases *Journal of Feline Medicine and Surgery,* Vol. 24(2) 107–115; DOI: 10.1177/1098612X211010735

Piaggesi A. et al. 2010: A Randomized Controlled Trial to Examine the Efficacy and Safety of a New Super-Oxidized Solution for the Management of Wide Postsurgical Lesions of the Diabetic Foot. The International Journal of Lower Extremity Wounds, 9(1): 10–15, DOI: 10.1177/1534734610361945

Zitzl J., et al.2023: Survival in canine tetanus – retrospective analysis of 42 cases (2006–2020). *Queue. Vet. Sci.* 9:1015569.

doi: 10.3389/fvets.2022.1015569

PROCEEDINGS

Cases from practice

COMPARISON OF HEALING PROCESSES IN STANDARD SURGICAL WOUNDS - ABILAR VS. LASER

Case study

MVDr. František Zahrádek
Veterinary surgery, Pod Bruÿnÿ 1, Plzeÿ 2
frantisek.zahradka@vetplzen.cz

NOTE

COMPARISON OF HEALING PROCESSES IN STANDARD SURGICAL WOUNDS. - ABILAR VS. LASER

CASE STUDY

NEW PROCEDURES IN SURGICAL WOUND HEALING PROCESSES

In the field of surgery and wound care, we follow constant advances that bring new approaches and technologies to promote effective healing. In this revolutionary era, it is important to research and compare different treatment methods. We aimed to compare the standard surgical method using traditional procedures and the innovative drug Abilar and the biostimulation laser to better understand their benefits and possible improvements in the wound healing process.

OBJECTIVE OF THE STUDY

• -The aim of this study was to evaluate the course and speed of healing of standard surgical wounds by the sanatio per primam process through modified postoperative care. Abilar and biostimulation laser BTL – 4000 SMART were used as modification elements.

• As a model for comparison, a classical method was used without affecting the healing process of the surgical wound.

• -The aim of the study was to regulate the standard process of sanatio per primam wound healing at different stages and thereby shorten the surgical wound healing process, as well as assess the quality and functionality of the scar after the procedure.

• Patient comfort was one of the secondary factors monitored, as was the ability and difficulty for the owner to ensure an uncomplicated healing process after surgery.

CONDITIONS FOR ENROLLMENT IN THE STUDY

In order to eliminate differences and reduce the error of the results during the assessment, standardized patients were included in the study as far as possible.

• Healthy females of medium breed 5-20 kg
• The procedure was performed as a preventive OVH
• During the 5 months prior to the procedure, the bitches did not have any disease that required any medication (ATB, hormones, NAISD etc.)
• Age range of patients 3-5 years
• Patients were kept in a home environment with a 24-hour monitoring
• Female patients where self-mutilation dehiscence occurred or intervention by the breeder using another wound healing procedure chosen by him (human factor) were excluded.

• According to the standard, the surgical wound was closed with an intradermal suture with ex within 7-10 days after the procedure
• Wound assessment was performed at intervals of 0-1-3-7-10-21 days after the procedure.

PROCESS OF PHYSIOLOGICAL HEALING-REPAIR (SANATIO PER PRIMAM)

Healing – reparation can be divided into 3 overlapping stages:
• Exudation phase (inflammatory phase) – usually lasts 3-5 days.
• Proliferation phase – takes place over a period of 3 days to 3 weeks.
• Remodeling phase (maturation phase, self-repair phase) – takes place from a few weeks after the injury to several years.

SANATIO PER PRIMAM INTENTIONEM

In this way, sterile wounds, mostly cuts with smooth edges close together, heal without a major inflammatory reaction (the edges of the wound are first glued together with fibrin and then a reparative inflammation takes place with healing by a fibrous scar). Healing can be divided into several phases.

PHASE 1 – EXUDATION

• In the exudative phase, the edges of the wound are glued with fibrin from a small blood clot, a thin protective crust is formed on the surface. This has the function of a mechanical barrier to prevent further contamination and also prevents the loss of further fluids. After 2-3 hours, a light leukocyte infiltrate and mild hyperemia appear at the edges of the wound as manifestations of reparative inflammation.

2. PHASE OF PROLIFERATION

• During the proliferative phase, the basal layer of epithelial cells around the wound increases mitotic activity and its elements move to the edges of the wound and through it.
• After 2-3 days, the surface of the wound under the coagulum is re-epithelialized with a uniform basal layer of cells.

The subepithelial clot is gradually removed by macrophages and newly formed capillaries, fibroblasts and myofibroblasts take its place.

3. PHASE OF REMODELATION, DIFFERENTIATION

In this phase, after 10-14 days, the edges of the wound are connected by newly formed disordered fibrous tissue. There is normal epithelium on the surface, the rest of the surface coagulum has already separated. Remodeling of the fibrous scar takes place with the formation of ordered collagen fibers, ensuring adequate strength of the tissue, while this process lasts several weeks (even after this time, however, the normal representation of elastic fibers is missing, complete regeneration with the original strength and elasticity of the fibrous tissue occurs after months to years).

LASER THERAPY

• Laser treatment (laser therapy) is a part of light therapy, using repeated pulses of a narrow beam of monochromatic light. It is a life-stimulator for cells (improves cellular respiration, strengthens cell walls -
photon reaction, improves mineral balance, has strong anti-inflammatory, anti-pain, antibacterial and antiviral effects, soothing effects -
relieves spasms and reduces swelling)
• Laser therapy uses coherent monochromatic radiation in the range of visible radiation or microwaves. The laser beam is a carrier of energy, which it is able to release when it hits the irradiated surface.

• The laser is applied either continuously or pulsed. It has a significant biostimulating effect, especially collagen stimulation, support of tissue vascularization, acceleration of regeneration of blood vessels, lymphatic channels and epithelium, better use of oxygen and glucose, in general it is about speeding up the healing process.

BIOSTIMULATION LASER-4000 SMART

• The application was performed with a 685nm probe
• Dose 2.00 J/cm2
• Power 33mW
• Time according to the length of the scar 1.00 cm / 1 min
• Within 10 minutes after performing the suture in the interval 0-24-72 hours after the procedure

ABILAR VET

• Abilar Vet is a resin ointment designed to heal skin wounds.
• Contains 10% spruce resin (Picea abies) growing in Finnish Lapland.

• The combination of terpenes contained in the resin leads to a reduction of the microbial load.

• Abilar Vet leaves a protective film on the skin thanks to modified petroleum jelly, wax and stearic acid. It ensures a moisturizing effect (locks moisture in the skin and reduces the absorption of moisture from the atmosphere).
A film was created, as a carrier of active substances it also has a protective character.
• The bitter taste of the ointment reduces the animal's desire to lick the wound.

WHY USE ABILAR FOR WOUND HEALING – I.

• Natural ingredients with antimicrobial properties: Abilar uses the power of nature, containing natural ingredients with antimicrobial properties. This unique combination helps to limit the growth of bacteria and microbes in the wound, which is key to preventing infection and promoting clean and fast healing.
• Reduction of inflammation and swelling: effectively reduces inflammation and swelling around the wound. This not only minimizes pain, but also contributes to faster recovery of normal tissue.

• Support of the natural healing process: Abilar actively stimulates the formation of new cells and the regeneration of affected tissue. This results in faster wound closure and minimization of scarring complications.

WHY USE ABILAR FOR WOUND HEALING – II.

• Safety and ease of application: The product is known for its safety and ease of application, which is essential for patient comfort. Its suitability for various types of wounds and simple application contribute to a positive healthcare experience.

• Clinically proven effectiveness: Abilar has been subjected to a number of clinical studies that have confirmed its effectiveness in the wound healing process. This provides reassurance to both patients and doctors about its ability to achieve the desired results.

• Application interval: immediately after the suture has been performed and for the first 48 hours every 12 hours, then until ex suture 1 x every 24 hours. It was necessary to ensure air access, i.e. without a bandage and prevent self-mutilation (Vet collar)

COMPARISON OF LASER THERAPY AND ABILAR IN THE HEALING OF CLASSIC SURGICAL WOUNDS - I.

• Principle of action:
Laser therapy: Uses light energy to promote cell regeneration and reduce inflammation.

It works on a microscopic level, stimulating mitochondria and increasing ATP production.

Abilar: Contains natural ingredients with antimicrobial and anti-inflammatory properties. It acts directly on the surface of the wound, limiting the growth of bacteria and supporting the natural healing process
• Effectiveness in reducing inflammation:
Laser therapy: Helps reduce inflammation at the cellular level, which can lead to faster healing and minimized swelling.
Abilar: Actively reduces inflammation on the wound surface, which helps the healing process to be more comfortable and reduces the potential risk of infection.

COMPARISON OF LASER THERAPY AND ABILAR IN THE HEALING OF CLASSIC SURGICAL WOUNDS - II.

• Stimulation of cell regeneration:
Laser therapy: Stimulates cell regeneration and increases collagen production, which can

promote tissue regeneration.
Abilar: Actively supports the formation of new cells and the regeneration of affected tissue, which contributes to faster wound closure.
• Application time and comfort:
Laser therapy: Requires repeated sessions, although it can be considered painless.

Requires a trained professional to perform.
Abilar: Easy to apply and does not require specialized personnel.
Patients can use Abilar alone or under the supervision of a doctor, which contributes to their convenience.

COMPARISON OF LASER THERAPY AND ABILAR IN THE HEALING OF CLASSIC SURGICAL WOUNDS - III.

• Availability and cost:
Laser therapy: Can be expensive and not always available in all medical facilities.

Abilar: It is affordable, cost-effective, and readily available in a variety of forms, which can be beneficial for both patients and healthcare providers.

Both methods have their advantages and suitability depending on the specific situation and patient preferences. The choice between laser therapy and Abilar should be considered with regard to individual needs, the type of wound and the availability of the given therapy.

COMPARISON BETWEEN ABILAR, CLASSIC HEALING AND LASER THERAPY –

AND.

A comparison between Abilar, classical healing and laser therapy in the case of standard uncomplicated surgical wounds can be made from different points of view.

Here are three basic aspects to consider:
• Speed of healing:
Abilar: Actively supports the natural healing process and can contribute to faster wound closure.
Classical Healing: It depends on the individual conditions of the patient and careful nursing care. May require more time for wound closure.
Laser therapy: Can stimulate cell regeneration, which can go a long way toward speeding up healing.

COMPARISON BETWEEN ABILAR, CLASSIC HEALING AND LASER THERAPY – II.

• Reduction of inflammation:
Abilar: Contains antimicrobial and anti-inflammatory ingredients, which can help reduce inflammation in the wound.
Classic Healing: Depends on effective care and prevention of infection, but does not have specific anti-inflammatory substances.
Laser therapy: Has the ability to reduce inflammation at the cellular level.
• Pain:
Abilar: May help minimize pain and discomfort due to its anti-inflammatory properties.

Classical Healing: May be associated with pain, especially when it comes to wound care.

Laser therapy: Often considered painless, but requires specialized equipment and a trained professional.

COMPARISON BETWEEN ABILAR, CLASSIC HEALING AND LASER THERAPY – III.

The choice between these methods should be made individually, taking into account the specific needs of the patient, the type of surgical wound and the available medical equipment. Consultation with a doctor or specialist is key to deciding on the most appropriate approach to wound healing in a given case.

CASE STUDY 1

• German boxer female, age 2 years, weight 24 kg, 3 months after oestrus
• The classic method of healing sanatio per primam
• From the 2nd day, rapeseed toilet
• Suture on the 10th day after the procedure

Photo 3rd day after procedure 1

CASE STUDY 2

• Crossbreed female, age 2 years, weight 16 kg, 4 months after oestrus
• Laser – reduction of hyperemia around the incision
• Shortening the exudation phase to 1-2 days
• Start of reepithelialization after only 48 hours
• Strength of the scar per digit. pressure 4th day
• Ex suture on day 5, need more traction force

Photo 3rd day after procedure 2

CASE STUDY 3

• Female Shi-tzu 1.5 years weight 5 kg 3 months after estrus
• Abilar prolongation of the exudation phase and hyperemia for about 4 days
• Optical fragility of the edges of the wound
• Visible re-epithelialization process from day 5
• Scar strength due to better elasticity per digit. pressure
• Stitch ex 6th day very easily

Photo 3rd day after the procedure 3

OPERANT WOUND EVALUATION

• Evaluated criteria 1) ex-
stitch time 2) digital
control of suture strength 3) ease of ex-stitch:

Ad 1)Ex stitch laser 5th day after the procedure Abilar 6 days after the procedure Standard 10 days after the procedure
Ad 2) Laser scar strength 4th day Abilar scar strength 5th -6th day day Standard scar strength 7. -9. day
Ad 3) Laser required greater traction force Abilar very easily Standard moderately strong

RECOMMENDATIONS FOR MORE WIDE USE OF ABILAR IN VETERINARY PRACTICE IN THE CARE OF STANDARD SURGICAL POSTOPERATIVE WOUNDS - I.:

• In the field of veterinary care, modern approaches are increasingly being applied to improve the wound healing process and post-operative wound care. Abilar, with its natural ingredients and antimicrobial properties, offers veterinarians an innovative treatment with the potential to increase the effectiveness of surgical wound care.

• The following recommendations focus on the widespread use of Abilar in veterinary practice:

•

RECOMMENDATIONS FOR MORE WIDE USE OF ABILAR IN VETERINARY PRACTICE IN THE CARE OF STANDARD SURGICAL POSTOPERATIVE WOUNDS - II.:

• Preventive application:
For planned surgical interventions, consider preventive application of Abilar to the area of the surgical wound. Its antimicrobial effects can prevent infections and promote clean and quick healing.
• Support for faster healing:
Apply Abilar to post-operative wounds to promote faster healing. Its ability to actively support the formation of new cells and tissue regeneration can contribute to speeding up the recovery process.
• Reduction of inflammation and swelling:
Use the anti-inflammatory properties of Abilar to minimize swelling and reduce inflammation around the surgical wound. This can bring significant comfort to patients.

RECOMMENDATIONS FOR MORE WIDE USE OF ABILAR IN VETERINARY PRACTICE IN THE CARE OF STANDARD SURGICAL POSTOPERATIVE WOUNDS - III.:

• Safe and easy to use:
Abilar is usually easy to apply and does not require complex procedures.
Veterinary technicians and animal owners can use Abilar for post-operative wound care with relative ease, increasing the wide availability of care.
• Individual cases and species of animals:
Abilar can be applied to different animal species according to individual needs and in different veterinary areas, from small pets to larger farm animals.

• Consultation with animal owners:
Provide information to pet owners about postoperative wound care options with Abilar. Explain to them the benefits of this modern method and how they can actively contribute to their pet's healing process.

ABILAR VET – IN VETERINARY PRACTICE, ABILAR CAN PROVIDE VETERS WITH A USEFUL TOOL FOR EFFECTIVE CARE OF SURGICAL WOUNDS.

PROCEEDINGS

DEBRIDEMENT SECONDARY HEALING WOUNDS AND BIOFILM
AS A COMPLICATION OF WOUND HEALING IN HORSES

MVDr. Zdenÿk Žert, CSc., Dipl. ECVS

Clinic for diseases of horses, Petÿvald 27

zdzert@gmail.com

NOTE

www.werft.cz

Wound debridement technique

1. Introduction

Contusion of tissues in wounds in horses leads to their gradual death, which is the source of prolonged healing. Accidental injuries to horses commonly contain devitalized tissue, biofilm colonized by many types of microorganisms, exudate, and debris.
The devitalized tissue slows healing by providing a breeding ground for infection and exacerbating the inflammatory response. Removal of nonliving tissue or foreign material by debridement reduces the bacterial population on the wound surface, which improves healing. However, in order for healing to occur quickly, as much viable tissue as possible must be preserved. Debridement should be performed during the first examination of the wound, which must be repeated during healing in order to reduce necrosis and infection in the wound as quickly as possible. Although debris and loose debris can be washed away using copious sterile irrigation, wound debridement is combined with irrigation to ensure optimal wound healing. In clinical practice, various techniques are available for removing damaged tissue, biofilm, dirt and foreign objects from the wound - autolytic, mechanical, enzymatic, surgical, biological and negative pressure therapy. The method chosen depends on various factors such as the type, size, location and age of the wound; extent of tissue damage and contamination; patient tolerance; economy; the expertise of the attendant and the equipment available. More than one type of debridement is often required to optimally prepare a wound for healing. The following subsections discuss the more common debridement techniques available to the equine practitioner in order to provide an overview of the indications, cautions, and contraindications of each technique.

2. Autolytic debridement

In wounds, debridement occurs naturally by autolysis, a process by which devitalized tissue is softened or liquefied by enzymes released by macrophages, mast cells, endothelial cells, keratocytes, and fibroblasts. Autolytic debridement is slow, selective (i.e., only devitalized tissue is liquefied) and virtually painless. This method uses the body's own enzymes and moisture under the dressing, and the dead tissue is liquefied and sucked into the wound cover and dressing and removed from the wound. Commonly used types of wound coverings are hydrocolloids, hydrogels and transparent foils (semi-occlusive and occlusive), the most common dressing is a padded cover dressing, the underlying material of which - the dressing cotton wool - is used to absorb early secretions.

3. Mechanical debridement

Mechanical debridement includes wound coverage with adhesive gauze, antimicrobial gauze dressing, hypertonic saline gauze dressing, alginate dressings calcium and occlusive wound covers. Adherent open mesh gauze can be applied to the wound, either dry for an exudative wound or moistened (usually with sterile saline) for a dry wound. This wound cover is secured with a clean covering bandage. Gas

the dressing adheres to the surface of the wound when it dries, so when it is removed, the tissue attached to the gauze is also removed from the wound. Mechanical debridement with gauze is non-selective as both healthy and unhealthy tissue is removed indiscriminately. Gauze wound covers can disrupt angiogenesis, fibroplasia, and epithelialization, and therefore should be used exclusively for debridement and never beyond the inflammatory phase of wound healing. An in vitro study comparing the effectiveness of different dressings for removing fibrin and blood clots in equine wounds found that dressings hydrated with saline were better for debridement than those hydrated with water because of their greater osmolarity. Saline-hydrated gauze and hydrophilic wound dressings were significantly (47%) more effective at breaking down proteins (mainly fibrin) than collagenase- or papain/urea-impregnated dressings or hydrogel dressings. In this study, saline dressings reached a plateau in the rate of protein degradation within 24 hours. Although this study did not consider the in vivo cellular effect on the removal of dead tissue, it suggested that gauze, hydrophilic, and alginate dressings moistened with saline were more effective in debriding wounds with protein coagulum or with crust (scab). The Antimicrobial Gauze Dressing is an excellent dressing for the treatment of heavily contaminated areas because it is impregnated with polyhexamethylene biguanide (PHMB), a strong but safe antiseptic with a wide range of effectiveness, which has been shown to kill bacteria on the wound surface and reduce the amount of exudate formation. Gauze soaked in hypertonic solution is ideal for the treatment of necrotic, heavily infected, exuding wounds.

wounds Yippee

Calcium alginate dressings exert their bioactivity by stimulating macrophages in the chronic wound. In addition to providing a moist environment that facilitates cell growth and migration, these sheaths generate a proinflammatory signal that promotes fibroplasia through a cascade of mediators released from activated macrophages.

Occlusive dressings are used to seal certain types of wounds, and their covering causes isolation of the wound from air, fluids, and harmful contaminants. Occlusive dressings promote moist wound healing and "autolytic cellular debridement" and are best used on clean, primarily exudate-free wounds.

4. Enzymatic debridement

Enzymatic debridement uses an ointment or gel with enzymes that soften and dissolve damaged tissue. Enzymes can be of animal, plant or bacterial origin. The combination of papain and urea is very effective in degrading fibrin in the wound.

Collagenase ointment derived from Clostridium histolyticum works by degrading collagen and elastin. Proteolytic enzymes dissolve collagen fibers and cause the breakdown of surface layers and devitalized tissue. Collagenase- or papain-urea-based agents can be used to accelerate the autolytic debridement process in areas where surgical removal is not possible or carries a risk, such as in wounds that closely approximate nerves and/or blood vessels. Factors that optimize enzymatic debridement include proper application facilitating contact between the enzyme and the area requiring debridement, sustained action of enzymatic activity in an optimal wound environment. Often, other topical agents are applied along with proteolytic enzymes to address additional goals, including equalizing moisture, controlling the amount of exudate, controlling the rate of microbial contamination, and enhancing tissue regeneration. Enzymatic debridement may be inhibited in combination with other wound dressings. For example, iodine-silver dressings have been shown to inhibit collagenase activity, leading to ineffective debridement. Because proteolytic enzymes cannot penetrate the thick, hard, dried crust of fibrin, they are more effective when the necrotic tissue is soft and moist. One study in horses evaluated the cleansing ability of enzymatic preparations. This study, using an in vitro model to simulate dry fibrinous chronic plaque, showed that traditional gauze dressings hydrated with isotonic saline or various forms of hydrophilic, hydrocolloid or alginate dressings (providing fluid) were more effective in removing fibrin and blood clots than enzymatic preparations. (collagenase, papain/urea and streptokinase-streptodornase). Enzymatic wound debridement has limitations in the treatment of incidental equine wounds, which are often heavily contaminated and include large amounts of necrotic tissue; therefore, other forms of debridement are preferred.

5. Surgical debridement

Surgical uses of debridement include excision, hydrosurgical debridement and low-frequency ultrasound. Surgical debridement with scissors and scalpel is the optimal method for rapid debridement of wounds containing large amounts of contused tissue and microbial tissue contamination. This method of debridement is selective because the surgeon has good control over which tissue to remove and which to leave. The goal of debridement is to create a well-vascularized wound that will support either primary suture or secondary healing and possibly skin grafting. It is essential to correctly identify the types of damaged tissues and important anatomical structures in the wound, so that surgical debridement does not cause further damage.

Aseptic technique prevents iatrogenic contamination. Repeat surgical debridement is in place or alternatively may be followed by another form of debridement such as autolytic debridement with increased dressing frequency. Different methods of surgical debridement include excisional, en bloc, partial, and progressive debridement. Excisional debridement can be performed 3/14 according to the affected layers in the wound, which represents the sequential removal of devitalized tissue, proceeding from the surface of the wound to its depth, or en bloc, which means excision of the entire wound including its edge, so proceeding from the edge of the wound to the end, all devitalized tissue is removed in parts while preserving important anatomical structures. Gradual debridement is performed over several days to avoid inadvertent removal of viable tissue. This approach is appropriate for most distal extremity wounds where improper removal of healthy tissue could have fatal consequences. When surgical debridement is performed, the two decisive criteria are the color and the degree of connection of the tissues to the substrate. White, tan, black and green tissues should be removed, as well as those that are poorly attached. Tissues that are pink to deep purple and that are well attached should be treated. The devitalized bone is removed, while the well-perfused bone with firm soft tissue attachments should be left in the wound. Bone fragments with questionable viability or bone that has lost periosteum should be aggressively removed to reduce the risk of sequestration and improve blood supply to the bone surface. Cortical bone debridement is best performed with a bone rasp; however, a curette, bone chisel, drill, or osteotome may be used. Hydrosurgical debridement involves the use of pressurized water or saline as a cutting/cleaning tool to rapidly and selectively remove debris and damaged tissue from the wound. A commercial hydrosurgical device generates a high-pressure (ÿ 15,000 psi) stream of fluid (sterile saline) that exits through a 0.127 mm handpiece orifice. The outflow of fluid from the outlet causes suction (Venturi effect) which draws the devitalized tissue into the cutting chamber where it is accumulated and evacuated. After debridement en bloc often

he uses a drain in the wound and the wound is sutured. Partial debridement is used for large wounds, usually on the trunk.

Hydrosurgery can often be performed on a standing horse under sedation and/or regional anesthesia. Hydrosurgical débridement is reported to be well tolerated because it is less painful than sharp débridement.
If hydrosurgery is used to debride a fresh wound to be sutured, some form of local anesthesia is required; conversely, local anesthesia is not usually required when hydrosurgical debridement is used to debride a granulation tissue-covered wound that has been left unsutured to heal secondarily. A recent ex vivo study comparing the effectiveness of different debridement methods in reducing Staphylococcus aureus burden from contaminated equine muscle showed that hydrosurgical debridement was more effective than isotonic saline irrigation, scalpel blade scraping. or a combination of lavage and curettage. Low-frequency ultrasound debridement uses low-frequency ultrasound waves (20–60 Hz), transmitted in contact or non-contact mode, produced

by a stream of saline solution through a tube into the head of the sonotrobe. Microcavitation, which results from the oscillation of salt gas bubbles, detaches necrotic tissue from healthy tissue, resulting in wound debridement and biofilm disruption; the necrotic tissue is suctioned or washed away. Healthy, more elastic tissue is preserved and stimulated to epithelize. Because the recommended treatment time is 20 to 30 s/cm2 of surface area, ultrasonic debridement is more suitable for the treatment of large wounds commonly found in horses.

6. Biological debridement

Biological debridement involves the use of Lucilia sericata (greenfly) maggots, which are grown in a sterile environment and digest dead tissue and pathogens. Biological debridement is recommended for use in horses to improve the healing of subacute and chronic, non-healing wounds when complete surgical debridement is difficult and to improve the healing of overtly infected wounds. The beneficial effect of worms on wound healing is attributed to the production of powerful proteolytic enzymes, upregulation of the expression of genes involved in wound healing, the creation of an antiseptic effect and the inhibition of biofilm formation. During the process of dissolving fibrin and necrotic tissue, the worms also destroy and digest bacteria, and L. sericata excreta have significant antifungal properties. In connection with the increasing incidence of antibiotic resistance, excreta of the fly L. sericata show strong, heat-stable, protease-resistant antibacterial activity against methicillin-resistant Staphylococcus aureus in vitro. Sterile worms can be applied to the wound by a direct method (free range) or indirectly without direct contact with the wound tissue. In the direct contact method, worms are applied to the wound under a bandage attached to the surrounding healthy tissue. After the maggots are placed on the wound, a nylon mesh is attached to the dressing to confine the maggots in the wound. In the indirect contact method, the worms are delivered in a closed polyester mesh filled with absorbent hydrophilic polyurethane foam and applied to the wound. Biological debridement by direct contact method is better in horses. The direct method of applying worms is also cheaper than the indirect method. In horses, biological debridement is described as an alternative approach to the treatment of septic navicular bursitis, laminar necrosis associated with complicated laminitis, and hoof bone osteomyelitis associated with subsolar infection. Biological debridement can also contribute to the successful healing of chronic nonhealing extremity lacerations, orthopedic infections without bony sequestrations, various soft tissue abscesses, supraspinal bursitis, and linea alba dehiscence after exploratory celiotomy. In a retrospective study of 41 horses treated with biological debridement, a favorable response was noted as early as one week after initiation of therapy. The lesions of the horses included in this study were subacute or chronic and were treated in various ways before biological debridement. In some cases, after 3 to 4 days of biological debridement, a second treatment is required to achieve the desired effect, cleaning the wound and starting fibroplasia (i.e. the formation of healthy granulation tissue filling the wound). Orthopedic shoeing, a non-occlusive dressing typical for biological debridement, must be adapted for each type of wound and anatomical location. For biological debridement to work effectively, free flow of exudate is necessary and the larvae must have a sufficient supply of oxygen.

7. Negative pressure wound therapy

Negative pressure wound therapy (NPWT) is a very effective way to control wound infection and accelerate wound healing.
Indications for the use of NPWT in veterinary medicine include traumatic wounds (wounds with loss of substance, extensive devastating and contusion wounds), deep burns, surgical wound dehiscence, wounds after treatment of myofascial compartment syndrome, and chronic non-healing wounds. NPWT is also excellent for increasing graft acceptance and can be used effectively over sutured wounds to loosen the suture and to prevent seroma formation in an incompletely closed wound with significant dead space and to minimize edema. NPWT stimulates the rapid formation of granulation tissue, shrinks the wound and sucks fluid from the wound, promotes fibroblast activity and angiogenesis. NPWT should not replace basic wound care steps such as cleaning, debridement, irrigation, and treatment of infection, although its use to debride an infected wound likely stimulates fibroplasia and increases resistance to infection in the early postinjury period. Other identified and validated mechanisms of NPWT include removal of interstitial fluid; thereby reducing edema; altered blood flow to the wound; and upregulated gene expression of cytokines related to wound healing. NPWT involves sealing the wound from the surrounding environment and delivering controlled negative pressure, typically not exceeding -125 mmHg, to the entire wound. The fluid produced by the wound is collected in a disposable reservoir connected to the pump. The open cell nature of the foam, which is placed under the film, ensures an even distribution of negative pressure over the entire surface of the wound. NPWT can be particularly useful in the treatment of equine wounds that undergo secondary healing. NPWT prevents retraction of wound edges, reduces wound size, reduces wound edema, and stimulates early onset of fibroplasia. In injured tissue treated with NPWT, granulation tissue forms earlier and is smoother, less exuberant, and has well-organized collagen fibers as demonstrated histologically.

Thanks to this, wounds treated with NPWT are less likely to overgrow granulation tissue and more amenable to early reconstruction, e.g. by skin grafting. In addition, NPWT increases the likelihood of free skin graft acceptance by immobilizing the grafts in the wound.

8. Conclusion

In order to promote wound healing in horses, reduce the risk of infection and improve the cosmetic outcome of the patient's treatment, it may be wound care included a variety of debridement methods. Using more than one debridement method will ensure better healing conditions.

Controlling bacterial contamination of wounds and limiting the effect of biofilm on wound healing

1. Introduction

The role of biofilm in chronic wound persistence and poor response to wound therapy in horses is of increasing clinical importance. Prevention of biofilm development involves the following three main strategies:

- effective wound cleaning and removal of bacterial infections in wounds,
- appropriate use of modern wound covers,
- use of local antimicrobial agents.

Once a biofilm has formed, its eradication involves achieving a balance between improving the wound environment and minimizing damage to the native cells that are integral to the healing process, primarily by repeated lavage and debridement in combination with topical antimicrobial therapy. It is important to be able to recognize:

- why and how biofilms form,
- recognize the clinical indicators that a biofilm has formed in a horse's wound,
- familiarize yourself with current biofilm diagnostics,
- learn treatment strategies for wounds affected by biofilm.

2. Understanding biofilm

A bacterial biofilm is an organized community of bacteria that are attached to the wound surface and enveloped by a 3-dimensional extracellular polymeric substance (EPS) that includes water, proteins,

polysaccharides, glycolipids, bacterial DNA and potentially other microbes that thrive in a protected environment. Bacteria that produce biofilm are able to survive and grow more slowly in a local environment depleted of nutrients and oxygen, which is called phenotypic heterogeneity. Biofilm formation is divided into the following three main phases:

- attachment of bacteria,
- grow,
- separation.

Planktonic (free-floating in the environment) bacteria adhere to the surface within a few minutes (stage 1) and individual bacteria change their phenotype, secrete an extracellular matrix and multiply after 6 to 12 hours and the biofilm matures based on signaling between

by cells called "quorum - sensing" (2nd stage). The biofilm reaches maturity within 2 to 4 days and then they begin to shed until
environment of floating planktonic cells (3rd stage) that disperse and attach to other areas of the wound bed. This distribution of cells activates the immune response of the host animal, stimulates the production of exudate, which provides additional nutrients and promotes the survival of the biofilm. Once a biofilm is formed, the bacteria differentiate into a complex community with increased resistance to the effect of antibiotics, disinfection, desiccation and the influence of the organism's immune defenses.

Obstacles in the fight against bacteria in the biofilm can only be overcome if the antimicrobial substances to which the bacteria are sensitive can act in appropriate concentrations for a long enough time.

3. Problems caused by biofilm

Polymicrobial biofilm can affect different types of wounds in horses (acute and chronic, traumatic and surgical). Factors that may predispose patients to biofilm formation in wounds include:

- immunocompetence of the patient (age, malnutrition, sepsis, corticosteroid administration, lack of antibodies, chronic stress, or diseases affecting the pituitary-adrenal axis, such as pituitary pars intermedia dysfunction [PPID]),
- inappropriate sensitivity to antibiotics,
- reduced vascular perfusion,
- extensive wound contamination,
- presence of foreign bodies, surgical implants or bone sequestration.

Prevention of biofilm development in acute wounds involves effective wound debridement, debridement to reduce bacterial counts, and appropriate use of modern wound dressings and topical antimicrobial agents.
The development of wound infection caused by biofilm has implications for the management of chronic wounds in horses, as it presents challenges in diagnosis and resistance to conventional treatment methods. A biofilm-complicated wound may not show signs of infection, but merely prolongs and impairs healing as bacteria compete for metabolic resources and suppress the host's inflammatory response during healing. The presence of biofilm has been shown to delay epithelialization and induce a chronic non-healing inflammatory phase in wounds. In addition, bacteria in a biofilm are more tolerant to antimicrobial therapy administered locally (antiseptics) or systemically (antibiotics), as well as to the animal's natural immune phagocytic response and environmental stresses because they are protected by their extracellular polymeric

matrix. For example, Staphyloccoccus aureus has been shown to be up to 100 times more resistant to antimicrobial treatment when growing in a biofilm versus a planktonic state. A mature biofilm is impermeable to commonly used antiseptics such as hydrogen peroxide, alcohols, bleaches, acids and oxygen radical scavengers, unless these products are used in concentrations toxic to the patient's cells, which is not recommended. Additionally, the ability of the animal's immune response to effectively control microbes declines as the biofilm matures.
As a result, infections involving biofilm often recur after antibiotics are discontinued. Early recognition of the presence of biofilm in non-healing wounds and targeted treatment are the keys to successful treatment of such wounds in equine practice.

4. Diagnostics of biofilm (clinical indications and laboratory examination)

Recent studies have shown that the wound biofilm is a polymicrobial bacterial community that includes more bacterial species than can be detected by routine culture and antibiotic susceptibility testing methods. Traditional culture techniques are often insufficient to comprehensively identify the bacterial species associated with biofilm. Biofilm in wounds can only be definitively diagnosed using scanning electron or confocal micrography or molecular techniques identifying the bacterial components of the biofilm, but these are not available for clinical practice. Biofilm was identified in 60% of chronic wounds and 6% of acute wounds in one study. More recent work suggests that biofilm occurs in most, if not all, chronic wounds.

Common methods of assessing bacterial load in wounds can be performed qualitatively or quantitatively. Qualitative assessment involves determining the types of bacteria and their sensitivity to antibiotics.
Quantitative bacteriology is rarely performed in veterinary medicine, but could be helpful in some cases, such as when wound healing is not progressing as expected or a skin graft fails.
Bacterial counts greater than 105 per gram of tissue or mL of exudate have historically been considered indicative of active infection, although the number of virulent bacteria causing the infection may be lower when foreign material (suture, necrotic tissue, foreign body, and implant) is present or reduced in the wound host resistance. Although a biofilm may be composed of only one species, recent publications demonstrate that bacterial findings from chronic equine wounds are often polymicrobial. The most common organisms in human chronic wound biofilms are the genera Pseudomonas, Enterococcus, and Staphylococcus.
It follows that conventional culture methods are inaccurate, as molecular analyzes of chronic wound samples revealed a much more diverse polymicrobial community (up to 17 genera per wound), including anaerobic species that are not normally demonstrated.

Currently, the best diagnostic method available to equine practitioners when biofilm is suspected is to perform a deep wound biopsy, or swab from the deepest available tissues, or both.
After wound debridement, samples should be collected from multiple sites, especially from the deepest areas of the wound (eg, pockets and fissures). When practitioners swab wounds to collect a sample, the swab should be drawn across the surface of the wound with sufficient pressure to collect a sample of the biofilm itself. Contamination with blood should be avoided during specimen collection, as blood itself contains antimicrobial elements that may affect culture results. Although sampling tissue from a wound is more invasive, culture is likely to provide more reliable results. Ideally, wound specimens should be collected before initiating or changing antimicrobial protocols. If it is considered necessary to collect samples while horses are on antibiotics, it is recommended that the laboratory be informed of the horse's antibiotic regimen and when the last dose was taken in connection with the collection of the sample. Positive culture results should be interpreted with the knowledge that the entire microbial spectrum present in the biofilm may be underestimated. In addition to a positive culture result, the presence of a biofilm can be suspected based on the clinical appearance of the wound. Clinical indicators of biofilm in a wound include:

- excessive humidity,
- low-quality granulation tissue,
- indicators of inflammation (temperance, edema, soreness and redness),
- history of persistent or recurrent infection despite antimicrobial treatment,
- negative culture results despite clinical suspicion of infection,
- wounds that remain in an unrelenting chronic inflammatory state despite the resolution of comorbidities (e.g. immunosuppression).

Because culture results are unreliable in the diagnosis of biofilm, assessment of clinical signs should guide the use of wound care techniques that anticipate the presence of biofilm.

5. Biofilm wound treatment strategies

Biofilm based wound care (BBWC) strategies are well described in human wound care to provide practical guidelines for clinical management in cases where biofilm is suspected. These strategies emphasize repeated debridement to physically disrupt the biofilm matrix and remove devitalized tissues that serve as nutrients for microbes.

Debridement disrupts biofilm structure, allowing increased sensitivity to antimicrobial therapy for a period that prevents reattachment of bacteria, as immature biofilm is more vulnerable to antibiotics. The two principles of debridement in human wound care described by Wolcott et al. they include debridement to change the conditions in the wound by removing all tissue surfaces that are in contact with each other and removing devitalized tissue down to normal bleeding tissue. Topical treatment is recommended to be applied within 4 hours of debridement, before biofilm re-forms.

An example of successful treatment of biofilms (and how quickly they regenerate in the absence of consistent therapy) is the removal of plaque from tooth enamel by a combination of brushing (ie, debridement) combined with topical antiseptic mouthwashes. In addition, antiseptic mouthwashes are minimally effective without prior flossing and brushing. With this in mind, it is recommended to treat biofilm in wounds in three stages:

- biofilm removal,
- delaying biofilm recovery,
- repeat until the biofilm is resolved.

Debridement of biofilms can be performed sharply with a scalpel, pulsed water jet, low-frequency ultrasound or mechanically with a gauze pad applied to the wound surface. To minimize patient discomfort during this step, it is recommended to sedate the horse and anesthetize the wound with local or regional anesthesia. If the patient's temperament requires it, or if the wound is extensive or not easily accessible, general anesthesia may be necessary for the first debridement. For protection against multidrug-resistant infectious organisms or when using a pulsed water regimen that may aerosolize microorganisms to a greater extent, a face shield or surgical mask may be recommended by the veterinarian. The goal of debridement is to remove as much biofilm, extracellular matrix, and devitalized tissue as possible to expose the remaining bacteria to antimicrobial agents. Reducing or preventing the re-establishment of biofilms after debridement can be achieved in several ways. Surfactants (polyhexamethylenebiguanide [PHMB] or polyhexanide) can be used as adjunctive therapies because they reduce the surface tension of the biofilm, facilitating its degradation and removal. Antiseptics do not penetrate necrotic debris and are unlikely to reduce bacterial populations deep in the wound bed without debridement. They should generally be reserved for use on normal skin and not on the wound bed. Agents that should not be applied to the wound because they are cytotoxic include acetic acid, alcohols, aluminum salts, boric acid, chlorhexidine, formaldehyde, gentian violet, hexachlorophene, hydrogen peroxide, hypochlorite, iodine, povidine-iodine, merthiolate, potassium permanganate, and silver nitrate. Unlike antiseptics, topical antimicrobials are effective against bacteria in the wound bed and have minimal side effects on wound healing (depending on the vehicle). Ideally, antimicrobial agents are selected based on culture results and sensitivity, and because of concerns about resistance, topical antibiotics should be different from those given systemically.

Topical wound dressings including silver sulfadiazine (1%) as silver-impregnated wound dressings are currently used to combat biofilm in humans and can also be used in horses if antibiotic sensitivity is not available. However, their effectiveness is limited to the first 24 hours, so it is necessary to change these bandages frequently to maintain their effect. If culture and sensitivity results are available, appropriate topically enhanced antibiotics can be applied.

In addition, topical application of plasma (natural or hyperimmune to a specific target pathogen) may be beneficial, as plasma inhibits bacterial adhesion and growth. The efficacy of regionally administered antibiotics (eg, regional limb perfusion) is also greater immediately after biofilm degradation, so timing perfusion after surgical removal may improve outcomes. In situations where a positive antibiotic culture is not obtained, or for temporary coverage of heavily infected wounds, broad-spectrum antibiotic therapy is indicated. Combinations of penicillin G (procaine penicillin or crystalline) or cephalosporins (ceftiofur, cefazolin, or cephalothin) and gentamicin are commonly used. A Gram-stained wound swab can also help guide interim antibiotic therapy. In general, heavily contaminated wounds or wounds with biofilms are more effectively treated with bactericidal antibiotics (vs. cephalosporins, bacteriostatic), aminoglycosides, metronidazole, quinolones, or rifampin. Biofilm occurring in the wound together with orthopedic implants often leads to their removal. In these situations, ideally, the infection is controlled with systemic and topical antimicrobial therapy until sufficient fracture healing or arthrodesis has occurred. In situations where both infection are present, including penicillins, instability and implants may be replaced or removed, cleaned, autoclaved, and reimplanted with new screws and holes if financially and technically feasible. Alternatively, the implants can be removed and the nonunion fractures treated with a cast, transfixation cast, or external fixator. The screw holes and the surrounding area can be filled with absorbable antibiotic elution materials. The use of surgical drains or leaving the distal portion of the incision open may facilitate drainage in these cases. Debridement and efforts to prevent biofilm reconstitution in the wound should be repeated as often (daily or at least every other day) until the infection resolves. Mature biofilms reform in as little as 24 hours (up to 72 hours) after debridement, providing opportunities in which bactericidal drugs can be more effective. It is recommended to monitor the horse frequently and continue antibiotic treatment until the signs of infection have resolved and the wounds have healed not progressing as expected. If there is no improvement within 3 to 4 days after initiation of treatment, it is recommended to review all aspects of the case, including repeated clinical examination, blood count, evaluation of the appropriateness of antibiotics given, and further debridement of the wound. Repeat bacterial culture and susceptibility testing are also indicated if symptoms of infection recur, the response to treatment is poor, or antibiotics are discontinued after long-term antibiotic therapy, and if the infection involves a multidrug-resistant or polymicrobial agent. When communicating with clients about the cost of care, it is important to emphasize that the higher cost of aggressive debridement in the early stages of wound management typically reduces the duration of treatment and the overall cost of long-term treatment. The limited yield of laboratory tests and the lack of clinical symptoms indicative of biofilm make it impossible to categorically determine whether a wound contains biofilm. Thus, until a test is available to identify the presence of biofilm in a wound, the clinical progression of wound healing with reduced spontaneous debridement and less exudation are the most effective methods of determining response to therapy and distinguishing biofilms in tissues.

6. Principles of treating wounds whose healing is complicated biofilm

- **Biofilm is present in most chronic wounds and is likely to be present both on the surface and in the deeper layers of the wound, its distribution may not be uniform.**
- **Biofilm is difficult to visualize macroscopically and exudate, dead tissue or pus can be mistaken for biofilm.**
- **Wounds that contain biofilm and are not recognized are usually treated ineffectively and their healing is delayed.**
- **An indication of the presence of a biofilm in a wound is a slow response to treatment with antibiotics or antiseptics.**
- **Debridement is the most important treatment strategy against biofilm; however, biofilms reform rapidly, so it should be used together with topical antiseptics and surfactants.**

7. Prospective diagnostic techniques and treatment strategies biofilm

For a targeted treatment of a wound occupied by biofilm and inhibiting its healing, diagnostic tests capable of detecting the presence and localization of biofilm in the wound would be useful. Since the activity of proteases correlates with the amount of active biofilm, field tests to quantify the protease activity of the wound bed could be one method of its indirect quantification and viability. New reduction techniques are currently being researched and further developed infections associated with biofilms. These include quorum-sensing inhibitors (RNAIII-inhibiting peptide [RIP]), surfactants, hydrophobic polycationic coatings, sol-gel coatings, covalent antimicrobial bonds, lactoferrin, xylitol, dispersin B, gallium, acetylsalicylic acid, bacteriophages (antibacterial viruses), ultraviolet light, low-voltage pulsed electric fields, and cell therapy options including platelet-rich plasma and mesenchymal stromal cells. Further research into biofilm management methods in randomized controlled clinical trials is needed.

8. Conclusion

The key to successful treatment is recognizing that a bacterial biofilm is likely to be present in most chronic wounds. Clinical signs of wound biofilm include exudate, poor-quality granulation tissue, local infection, negative bacterial culture results despite clinical suspicion of infection, and wounds that remain in a chronic inflammatory state and do not heal. The basis of therapy to reduce the bacterial load of biofilm in wounds is repeated debridement and the timely use of targeted local antimicrobial substances and surfactants that have minimal cytotoxicity towards native tissues. In the future, improved diagnosis of the presence of biofilm and more sensitive monitoring of response to treatment, as well as complementary therapies for its degradation, may have a positive effect on wound healing.

PROCEEDINGS

SECONDARY HEALING WOUND COVER SELECTION AND METHODS SKIN TRANSPLANTATION IN HORSES

MVDr. Zdenÿk Žert, CSc., Dipl. ECVS

Clinic for diseases of horses, Petÿvald 27

zdzert@gmail.com

NOTE

Wound covers

1. Introduction

Secondary wound healing takes place best under a cover that keeps the wound environment moist. In the literature, covers used to treat wounds are often referred to as "dressings" and in Czech literature, according to the author, they are mistakenly considered bandages. For this treatise the author considers a bandage to be a complete measure protecting the limb from contamination or excessive movement, and it consists of a wound cover that is in direct contact with the wound, a base material usually made of cotton or synthetic wadding, and appropriate bandages. Modern wound dressings are designed to provide moisture retention for a specific stage of wound healing. Moist wound healing occurs when wound exudate is left in contact with the wound bed. Human studies have shown that full-thickness skin wounds kept in a moist environment re-epithelialize in approximately 12-15 days, while the same wounds exposed to air take 25-30 days to heal. Wounds are less inflamed, less itchy, less crusty and more likely to heal without scarring. Wound exudate in the absence of infection provides a substrate rich in enzymes, growth factors, and chemotactic factors. Enzymes are a by-product of the breakdown of polymorphonuclear cells and macrophages. Enzymes enable debridement of devitalized tissue and improve the "base" for continued wound healing. This is the so-called autolytic debridement.

Autolytic debridement occurs between 72 and 96 hours and is accelerated by an occlusive dressing provided the dressing remains in contact with the wound secretion. Growth factors provide a stimulus for fibroblasts and epithelial cells. Chemotactic factors stimulate the migration of more neutrophils and macrophages to phagocytose bacteria and debris while releasing enzymes that further promote autolytic processes. A moist environment allows better migration of neutrophils and macrophages than a dry wound environment. Occlusion provides a constant thermally regulated environment for the cells, and if an appropriate wound cover and dressing is chosen, then bacterial penetration is reduced or prevented. Disadvantages of wet healing include bacterial colonization, folliculitis, the possibility of maceration of the surrounding skin and, in humans, allergy to the dressing material. There must be a fine balance between drying the wound and macerating the surrounding tissue. Fortunately, new covers are available that dictate the nature of wound development to provide an optimal environment for healing. In the secondary healing of lacerations and abrasions in horses, many guaranteed methods of their solution were used. Most often, the wound is covered with gauze and a covering bandage is applied to the limb. Both components of this dressing are porous and allow air to pass through the dressing and cover the wound to its surface. When a woven gauze cover is used, exudate from the wound is quickly absorbed through the gauze and into the dressing - vertical ascent. When using non-woven gauze and an occlusive dressing, wound exudate tends to drain quickly flow to the edge of the gauze and then it is absorbed into the dressing - horizontal wick effect. The degree of moisture retention depends on many factors, including the amount of exudate and type of gauze, the secondary covering, and the frequency of covering changes. When using a gauze cover, it is difficult to maintain a moist environment for wound healing. Occlusive dressings isolate the wound from the outside environment and provide many advantages over a simple gauze dressing. The occlusiveness of the dressing is measured by the evaporation of fluids from the surface of the wound through the cover and ranges from minimally occlusive to completely occluded. Advantages of occlusion include rapid autolytic debridement with less necrotic tissue, bacterial and waterproof barrier, reduced wound/dressing pain, ease of use, fewer dressing changes, and shorter healing time. Concerns about occlusion are mainly centered around infection. All wounds are colonized with bacteria, although they may not actually be infected. Infection means the invasion of bacteria in numbers >105/g in living healthy tissue. Signs of infection include edema, erythema, induration, and fever. Although there are concerns, studies have shown that occlusal caps are not associated with an increased rate of infection. An ideal dressing should keep the wound bed constantly moist and the surrounding skin dry, or in simpler terms, a complete dressing should handle the amount of exudate produced.

2. Types of wound covers

There are probably as many different types of wound dressings as there are ways to clean them. This paper is focused on the means with which the author has the best experience. Wound dressings should be chosen according to the stage of healing the wound is in. The author is not aware of any single type of dressing that is appropriate at all stages of the wound healing process. As a result, wound coverage will vary depending on how the wound is treated. In general, methods of treatment of secondary healing wounds can be divided into: debridement, antimicrobial action, control of the development of granulation tissue, stimulation of wound contraction and promotion of epithelization. The wound should be kept moist during all these stages, as moist wounds generally heal in half the time of wounds exposed to air, but it is necessary that they be properly covered.

3. Wound covers ensuring debridement

Cleansing wound covers are designed to remove bacteria and necrotic tissue from a wound. Debridement dressings should often be combined with some type of surgical debridement, where the bulk of the necrotic tissue is removed from the wound before a dressing is applied.

4. Hypertonic saline solution

Hypertonic covers are woven gauze bandages impregnated with 20% saline solution. They provide very aggressive, non-selective debridement. They work by drawing fluid from bacteria and diseased cells, reducing their adhesion to the wound bed, and are used to remove detached tissue from the wound when dressing. According to the author they are the most effective debridement dressings available. Hypertonic saline can be made by dissolving 200 g of salt in 1 L of boiling water. Lower concentrations of hypertonic saline do not appear to be as effective. Hypertonic wound dressings should be changed every day, in humans they are changed up to six times a day, because the high concentration of salt in the wound burns a person. This debridement dressing should be discontinued as soon as the wound no longer appears infected.

5. Honey and sugar

Honey has been used for centuries to improve wound healing. Certain types of honey, such as honey from specific plants such as the Manuka bush, appear to have an even greater antimicrobial effect than would be seen with the natural hyperosmolality present in all honeys. Not every honey has similar antimicrobial effects as Manuka honey, but according to the author's experience, the osmotic effects of any honey can be applied to large wounds in horses.

6. Antimicrobial wound cover

One of the widely used antimicrobial coverings is loosely woven gauze impregnated with polyhexamethylene biquanide (PHMB). PHMB is an antimicrobial substance that disrupts the cell walls of microorganisms, it is not cytotoxic to the cells of the wound tissues. The cover was originally developed to be applied to a wound to stop bacteria from entering (also used in baby wipes and contact lens cleaning solutions). It is now recognized that the dressing kills bacteria even when placed in a wound. It is supplied as a dry dressing and should be moistened with saline before application to the wound. Unlike hypertonic saline, this dressing should not be used as the primary wound treatment and should only be applied to the wound after the wound has been effectively debrideted and the bacterial count has been appropriately reduced. However, it can be used as a secondary dressing to limit the penetration of bacteria into the wound bed.

7. Moisturizing wound dressings

Although most wounds presented to the veterinarian for treatment are contused and contaminated, some wounds are dry, often as a result of improper care. A gel cover should be applied to these wounds to moisturize and improve the wound healing process. Gel caps commonly contain water, glycerin and polymer. Some gel caps contain gauze to help them maintain their normal shape. Amorphous dressings can be used to add moisture to a dry wound. Once the wound is moist, another dressing should be applied.

8. Covers supporting wound granulation and contraction

Calcium alginate

In the past, exuberant granulation tissue was the bane of equine doctors, and to think that someone could develop a wound dressing specifically to promote the growth of granulation tissue would be reprehensible. However, one of the complications of wound healing in horses is an insufficient local inflammatory response. A cover containing calcium alginate induces an effective inflammatory process, which is beneficial for starting wound healing per secundam. Another positive effect of the calcium alginate cover is that it supplies the wound with an excess of calcium and thus promotes wound contraction. This cover can also be applied directly to exposed bone tissue that has been disturbed on the surface, e.g. by a bone rasp, thereby minimizing the formation of a sequester and covering the bone with granulation tissue. As soon as the wound is covered with granulation tissue, it is necessary to stop using this cover.

9. Epithelization supporting covers

Semi-occlusive foam wound dressings help complete the secondary wound healing process. The foam slightly increases the surface temperature by one to two degrees, which significantly aids the epithelization process. The holes in the foam are very small, so the granulation tissue does not tend to overgrow. In addition, the foam contains PHMB, which limits the multiplication of bacteria without a negative effect on fibroblasts and epithelia. No other type of wound dressing should be applied to the wound at this stage.

10. Conclusion

In conclusion, there are many ways to treat secondary healing wounds in horses. The author prefers moist wound healing and the choice of coverings according to the effect on the wound in order to achieve the best possible cosmetic healing effect.

Skin transplantation in horses

1. Introduction

Skin transplantation is reserved for wounds with a very extensive skin defect that could not heal functionally or satisfactorily cosmetically with standard wound therapy. Skin grafts not only cover granulation tissue and result in a more cosmetic end result, but have also been shown to promote wound contraction and epithelialization while reducing excess granulation tissue. Skin grafting itself is not a difficult procedure. Most efforts involve appropriate preparation of the wound bed and skin graft before placement and effective immobilization after skin graft placement. Wounds should be treated using moist wound healing concepts to prepare the wound bed to accept a skin graft. The most common

circumstances that will lead to skin graft failure are infection, poor granulation tissue, and excessive movement at the graft site.
Consequently, the wound bed must be free of infection and have a healthy bed of granulation tissue before transplantation. If the previous graft failed, a quantitative bacterial analysis should be performed before placement of the second graft. If the wound is in an area of excessive motion, some type of wound immobilization should be performed, such as splinting or applying a cast. Regardless of wound location, it is recommended that the original dressing be left in place for 7 days before redressing. This will reduce the possibility of loosening of the grafts. There are three main types of skin grafts used in horses: autografts, allografts, and xenografts. Autografts are from the same animals, allografts are from the same species, and xenografts are from different species.

Xenografts such as pig skin and fish skin are not actually integrated into the host animal; they are really only used as biological wound coverings.

2. The healing phase of skin grafts

The healing stages of skin grafts are generally divided into four main categories: adherence, plasma imbibition, revascularization, and final organization. Adherence occurs on day 1, before any further stages of healing can occur. Graft adhesion is usually formed by fibrin between the graft and the wound bed. This distance between the graft and the bed should be small to minimize later difficulties in the healing process. Movement at this stage often leads to graft failure. Plasma imbibition occurs from days 1 to 4, when nutrition for the graft comes from the fibrin clot around the graft. At this stage, cyanosis of the transplanted tissue is expected. Revascularization occurs between days 3 and 7. There are at least three different methods of revascularization. Inosculation occurs when vessels in the graft anastomose with vessels in the recipient bed and is the fastest method of revascularization. Capillary buds can penetrate from the recipient bed into the vessels of the graft and use them as a conduit to revascularize the graft.

Capillary buds can penetrate the graft to areas other than old vessels to revascularize the graft. This is the slowest revascularization because the capillary bud growth rate is approximately 1 mm/day. The greater the distance between the graft and the recipient bed, the more likely it is that the capillary buds will have to form a completely new vascular network, and the greater the likelihood of graft failure. The final stage of healing is organization, when the fibrin of the original clot replaces the ligament to hold the graft permanently in place. Fibroblasts are responsible for collagen deposition during organization. Collagen fibers and neovascularization ensure a firm attachment of the graft to the recipient's bed within 9 days after transplantation.

3. Graft thickness

Full-thickness grafts consist of both dermis and epidermis. Partial-thickness grafts consist of the epidermis and part of the dermis. Full and partial thickness grafts can be used in horses. Full thickness grafts tend to provide more cosmetic end results because they have all the adnexal structures such as hair follicles and skin glands. However, their successful application is more difficult because they are thicker and take longer to bleed. Partial-thickness grafts are better anchored in the wound, but the final cosmetic result is poorer. When choosing a donor site, it is best to choose a site that will not leave a significant cosmetic defect. Either the side of the neck under the mane or the ventral belly or chest area where there is excess skin

4. Graft types/techniques

The graft can be removed manually or using a motorized device. Most practitioners take grafts using a manual technique. The benefit of uniform graft thickness when using a dermatome is often outweighed by the cost of this motorized device. Regardless of the method, the transplanted tissue must have adequate capillary exposure by keeping the graft in close proximity to the granulation bed to allow blood vessel ingrowth. The recipient's bed must have adequate capillary supply and the physician must provide protection against mechanical damage, hematoma formation, and infection. Skin grafting can be done using many different techniques. The techniques will be listed in order from simplest to most complex.

“Pinch” graft

For "pinch" grafting, the simplest equipment of all the mentioned techniques is needed. Grafting can be done with a number 12 scalpel blade, pean and fine scissors. The skin is stretched with forceps and a small piece of it is cut off with a scalpel blade. Grafts should not be larger than 8 to 10 mm in diameter. The subcutaneous tissue is removed with scissors. A scalpel is used to create pockets approximately 1 cm apart in the granulation tissue, and the grafts are placed in the shallow pockets. The graft site is covered with a non-adherent cover or oily gauze and a pressure dressing is applied. This technique can be performed on a standing horse.

“Punch” graft

“Punch” grafting requires similar instrumentation as the previous method, in addition, 6 mm and 8 mm skin biopsy needles are necessary. An 8mm needle is used to remove the graft involving the epidermis and dermis. The subcutaneous tissue is removed from the graft and the graft is placed on saline-soaked gauze. For the best possible cosmetic result, it is good to keep the normal orientation of the hair on the grafts. A 6mm needle is used to remove the roller from the granulation tissue of the wound. After the hole for the graft is created, the excess blood is aspirated and the graft is inserted into it. The wound is covered with a non-stick cover or oily tulle and a pressure bandage is applied. This technique can also be performed on a standing horse.

5. Tunnel grafting

Tunnel grafting requires the removal of long, narrow strips of skin from the donor site. The granulation tissue is undermined with a long pean and the graft is passed under it and attached to the skin with a suture at the edges of the wound. The wound is treated in the same way as in the previous two methods.
After approximately 6 to 10 days, the granulation tissue above the skin grafts is surgically removed. More skin is placed into the wound than pinch or punch grafts, and less specialized equipment is required compared to a mesh graft. This technique usually requires general anesthesia.

“Mesh” graft

A mesh graft of full or partial thickness of the skin will probably provide the best cosmetic result, but requires relatively expensive specialized instrumentation and is the easiest to fail. The most common cause of failure is movement of the graft above the base of the wound, which inhibits capillary growth. One way to reduce problems with graft movement is to "mesh" the graft. Graft meshing is advantageous for two main reasons. It allows the evacuation of exudate from the space between the graft and the wound bed and allows a larger area to be covered without the need to harvest a large graft from the donor site. Collection from the donor site is best done with a dermatome, which removes a slice of skin of uniform thickness. The dermatome can be set to cut a partial or full thickness graft. The removed graft is cut on the mesher, so that an expandable mesh is created, which is sewn to the wound and placed under the bandage.

“MEEK” grafting

MEEK grafts are small islands of skin cut with a MEEK device from a strip of partial-thickness skin (containing the epidermis and a weak layer of the joint, without traces of subcutaneous tissue), which are glued on the epidermal side to a special foil and the dermal side are attached to perfectly prepared granulation tissue. This type of grafting makes it possible to easily respect the direction of hair growth, covers the area with granulations the tightest of all transplant techniques and is also the best rated in terms of cosmetic effect.

6. Transposition of the skin flap

There is relatively little use of skin pedicle transposition in horses because it requires that there be sufficient skin adjacent to the wound defect and that the skin can be rotated into the area while leaving at least some of the vascular supply intact. In most cases, this technique is used in the head area of horses, especially to cover fistulas above the maxillary sinus. The donor site can be left open to healed secondarily. Distal limbs in most cases do not have enough skin in addition to tissue rotation and the skin on the limbs is not well blooded. This technique requires general anesthesia.

7. Conclusion

Skin transplantation in horses can be performed in field conditions, but usually requires such intensive care that it is better to deal with it in institutional facilities. Techniques are used that are mainly applied to people in the treatment of burns. The final cosmetic result is often better than a scar after secondary wound healing. Care must be taken to minimize the movement and number of bacteria to achieve satisfactory results.