

Therapeutic Management of Pododermatitis in Falcon Medicine: Historical and Modern Perspective

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Received: July 11, 2021; **Published:** July 27, 2021

Pododermatitis, also known as bumblefoot, is the inflammation of the skin of the foot. Pododermatitis is considered a gradual degenerative and inflammatory condition of the plantar surface of the foot involving most commonly the plantar metatarsal pad, but also the plantar digital pads and, more seldom, the interdigital spaces. The most commonly and widely used classification of pododermatitis in falcon medicine is the grading from 1 - 5 depending on the severity of clinical symptoms, pathological changes, and prognosis. Factors that could predispose falcons to develop pododermatitis include, inadequate all-meat diets, suboptimal or inadequate hygiene on perching surfaces, immune compromised falcons due to stress or disease, excessive weight bearing on the feet due to overweight, asymmetrical weight bearing on the feet, inactivity, unsuitable perches and perching surfaces, and sudden cessation of exercise. Members of the Falconiformes, but in particular the gyrfalcon (*Falco rusticolus*) falcon, and saker (*Falco cherrug*) falcon are more likely to develop pododermatitis. This medical condition affecting the feet of birds of prey used for falconry has been recognized and widely cited in medieval literature and several remedies and treatments were proposed. However, the pathophysiology of the disease syndrome is unchanged in the way that ischemic insult to the tissue develops into necrosis and inflammation affecting the plantar epithelium and/or deeper structures of the feet. Husbandry adjustment is the most powerful, but also most cumbersome and laborious tool in the management and prevention of pododermatitis, and

often forces the angle of view away from falconry traditions. A series of therapeutic plans are available to treat the different degrees of pododermatitis. These includes combinations of husbandry changes, antibiotics and anti-inflammatory medication, bandages, radiography and surgery. A recent study assessed the effects of perching surfaces and foot bandaging on central metatarsal foot pad weight loading of the peregrine falcon. (*Falco peregrinus*).

PODODERMATITIS, also known as bumblefoot, is a compound medical term formed from the Greek words “pod” (foot), “derma” (skin), and “-itis” (inflammation), meaning the inflammation of the skin of the foot. Pododermatitis is considered a gradual degenerative and inflammatory condition of the plantar surface of the foot involving most commonly the plantar metatarsal pad, but also the plantar digital pads and, more seldom, the interdigital spaces (Zsivanovits, Monks 2016).

CLASSIFICATION OF PODODERMATITIS

A classification of the different clinical presentations of pododermatitis was first proposed over 40 years ago and were grouped into three categories (Cooper 1978). This system has been used as a base by other authors to propose a much wider and diverse classification. Currently, the most commonly and widely used classification of pododermatitis in falcon medicine is the grading from 1-5

Citation: J. SAMOUR, M. B. WERNICK and P. ZSIVANOVITS. (2021). “Therapeutic Management of Pododermatitis in Falcon Medicine: Historical and Modern Perspective”. *Archives of Veterinary and Animal Sciences* 3(1).

depending on the severity of clinical symptoms, pathological changes, and prognosis (Oaks 1993). The classification is as follows:

Grade 1: Erythema and smoothing of the skin on the plantar aspect of the feet including the metatarsal and digital pads. Flattening of the papillae. Slight discolouration can also be observed.

Grade 2: Mild to moderate hyperkeratosis and thickening of the plantar skin including the metatarsal and digital pads. Localised inflammation and the beginning of necrosis with the development of scabs. Distinct discolouration.

Grade 3: Moderate to severe hyperkeratosis. The feet will often feel warm to touch, with moderate to severe swelling and mild to moderate pain. The necrotic and hyperkeratotic core penetrate the skin full thickness with the formation of a caseous abscess. Mild pain.

Grade 4: Infection spreads to adjacent soft tissues. Tenosynovitis resulting in ascending infections and inflammation extending from the foot towards the tarsometatarsus. Swelling is commonly observed on the dorsal and plantar aspect of the feet. Mild to moderate pain.

Grade 5: Involvement of skeletal structures. Osteomyelitis and or septic arthropathies of one or more of the intertarsal joint, tarsometatarsal phalangeal joints or interphalangeal joints and, digital bones. Severe swelling with moderate to severe pain.

PREDISPOSING FACTORS

Factors that could predispose falcons to develop pododermatitis include:

- Inadequate all-meat diet characteristic of deficient vitamin A, vitamin D3, biotin, calcium, and other essential elements.
- Suboptimal or inadequate hygiene on perching surfaces.
- Immune compromised falcons due to stress or disease.
- Excessive weight bearing on the feet due to overweight.
- Asymmetrical weight bearing on the feet due to bone or joint deformities, trauma, or surgery.
- Inactivity. Blood supply to the feet is dependent on the level of exercise. Increment of blood flow and temperature of up to 10°C was observed in falcons after exercise, returning to normal after 20 min (Müller, Wernery, Kösters 2000).
- Unsuitable perches and perching surfaces. Perching for too long on small flat surfaces on falconry blocks may cause pressure on the plantar metatarsal pads leading to pressure sores, and avascular necrosis.

- Sudden cessation of exercise at the end of the hunting or racing seasons. Falcons are threefold more likely to develop pododermatitis if training stops suddenly compared to gradual reduction in the level of training (Lierz 2003).

Affected devitalized plantar tissue has a reduced immune response to opportunistic pathogens and limited healing capability. On histologic examination common findings include epithelium degeneration, the spread of bacteria, fungi and yeast, hyperkeratosis, necrotic foci, and thrombosis of capillary vessels (Harcourt-Brown 2000, Cooper 2002).

SPECIES SUSCEPTIBILITY

Birds of prey are classified under two large groups, diurnal and nocturnal species, based on hunting and feeding habits. The diurnal species comprise six different families including Accipitridae, Pandionidae, Sagittariidae, Falconidae, Cathartidae, and Cariamidae. These families used to be grouped together under the order Falconiformes, but current classification separate these species into two orders, the Falconiformes and the Accipitriformes (Del Hoyo, Elliot, Sargatal 1994). Members of the Falconiformes, but in particular the gyr (*Falco rusticolus*) falcon, and saker (*Falco cherrug*) falcon are more likely to develop pododermatitis (13% susceptibility) than smaller species such as the peregrine (*Falco peregrinus*) falcon (5% susceptibility) (Lierz 2003), and perhaps other smaller falcon species such as the lanner (*Falco biarmicus*) falcon, and the lugger (*Falco jugger*) falcon probably due to differences in size and weight. Members of the Falconiformes appear to be more susceptible to develop pododermatitis than Accipitriformes (Lierz 2003). The nocturnal species comprise two families, the Strigidae or typical owls, and the Tytonidae, including bay (*Phodilus spp*), and barn (*Tyto alba*) owls. These species, also seems to be less susceptible to develop pododermatitis.

HISTORICAL PERSPECTIVE ON THE TREATMENT OF PODODERMATITIS IN FALCON MEDICINE

An early treatise from the Korean peninsula on falconry mentions that moxibustion was used to treat swellings on the legs and feet of birds of prey used for falconry (Sun Chun 2009). Moxibustion, also called moxa treatment, is part of the traditional medicine practices originating in China and subsequently spreading to Japan, Tibet, Korea, Vietnam, and Mongolia. Moxibustion consist of burning a small amount of dried mugwort (*Artemisia argyi*) on designated points of the body, generally the same points as those used in acupuncture. This medical practice can be traced back to the Warring States Period (475 BC to 221 BC) (Wolfgang 2005).

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During medieval England, Dame Juliana Berners published the renowned “The Boke of Seynt Albans” or “The Boke of Saint Albans” (Berners 1486). This was followed by “The Booke of Hauking, Huntyng and Fysshyng” by the same author (Berners 1559). These publications were revised by Gervase Markham and published under the title “The Gentlemans Academie or The Booke of S. Albans” (Markham 1595). In this treatise, Markham provides a treatment for the “podagre or podagree”. This was the term in medieval England used to describe pododermatitis in birds used for falconry. The proposed treatment for the “podagree” was, “When your hawkes feet are swollen shee hath the podagree, the cure is, take fresh Maie butter and as much oliue, and of allum, and chase them well together at the fire, and make thereof an ointment and anoint her feete foure daies together, and set her in the sunne, and give her the flesh of a catte, and if you see it auaille not, seeth the cutting of a vine, and wrappe it about the swelling and let her sit uppon a colde stone, and anoint her with butter till she be whole” (Markham 1595).

Gervase Markham also published a book entitled “Cheap and Good Husbandry for the well-Ordering of all the Beasts and Fowls, and for the general Cure of their Diseases” (Markham 1683), describing treatments for diseases affecting cows, horses, sheep, goats, pigs, poultry, falcons, bees, and fish. Markham describes the treatment for under the subheading “Of all swelling in Hawks feet, and of the pin in the foot” proposing “For the pin in the sole of the Hawks foot; or for any swelling upon the foot, whether it be soft or hard, there is not any thing more sovereign, than to bathe it in Patch-grease moulten, and applied to, exceeding hot; and then fold a fine Cambric rag dipt in the same grease about the sore” (Markham 1683). Cambric rag is a fine white linen or cotton fabric commonly used for bandaging in that epoch.

Gervase Markham published a book entitled “The Compleat Country Contentments: or, the Husbandmans Recreations.” In Chapter 35, denominated “Diseases in Hawkes”, under the subheading “To cure the pin in the foot. The broken pounce. Bones broken, Bones out of joynt,” Markham mentioned “First, you shall place the member right, if there be either breach or dislocation, then take of Galbanum, of White-Pitch, of turpentine, of each a like quantity, and melt them together on a soft Fire; then plaister-wise spread it upon a fine Linnen Cloth, and to fold it about the sore; then splint it if need require, otherwise only rowl it up with a fine Linnen rag, and the remedy will soon be effected, as hath been often by me and others

seen, and proved, by experience” (Markham 1654). Galbanum is an aromatic sticky tar-like resin and a product of some umbelliferous Persian plant species of the genus *Ferula*, mainly *Ferula gummosa* (synonym *F. galbaniflua*) and *Ferula rubricaulis*, (Chisholm 1911) widely used for making incense offerings and perfume making. White-pitch is a turpentine oleoresin obtained mainly from the Scotch pine (*Pinus sylvestris*) or the cluster pine (*Pinus pinaster*), purified by melting with water and straining (Chisholm 1911).

Symon Latham was a renowned falconer and author of the world famous “Latham’s Falconry Or, the Falcon’s Lure and Cure”. In Chapter 35 under the title “To cure the pinne,” Latham wrote “You must have your Hawke well and easily cast, and with a sharpe knife search and pare out the pinne, or core, or corne, for they are all one, the which is it have not planted it felte too deep amongst the sinews, whereby to annoy and hurt them, it will easily be amended, the which to effect and bring to an end, you must have from the Apothecaries a salve, which he will make you at an instant of these things, namely, Galbanon, white pitch, and venice Turpentine, the which you must vie in this sort. Take a little of the finest leather that may be got, and make your plasters of the same with your salve to vie at your need, as broad as the ball of her foot, and apply the same unto it, having provided of other soft leather, as a meanes to keepe it on that it may not remaine; and so dresse it thrife in a week, and withall let her sit very soft and warme, and this will cure her out of all doubt” (Latham 1633). As observed, the treatment as proposed by Latham use the same ingredients to those suggested by Markham for the treatment of pododermatitis.

Latham published another treatise on falconry entitled “THE GENTLEMANS EXERCISE’ OR, A Supplement to Mr. Latham’s Bookes of Faulconry” published in 1662. This book has a strong emphasis on falconry, and although there is a section on diseases denominated “Of the Cures of the Diseases, and Greifs incident to Hawks” it does not mention the treatment for pododermatitis (Latham 1662).

Juan de Canoua published a book entitled “Libro de Cetreria de Caça de Açor” in the city of Salamanca. Spain (Canoua 1565). The book includes the treatment of diseases of the Northern goshawk (*Accipiter gentilis*), a species widely used for falconry in mediaeval Spain. However, in Chapter 18, de Canoua mentioned the condition called “clavos,” the term used in Spanish to denominate pododermatitis. In this chapter, de Canoua mentions that gyr (*Falco rusticolus*) falcons are more susceptible to develop pododermatitis due to the

size and weight followed by the “alfaneque” the name in Spanish for lanner (*Falco biarmicus*) falcon. Lack of exercise is mentioned as one of the reasons for developing pododermatitis (Canoua 1565). For the treatment of pododermatitis de Canoua suggested first to purge the falcon with two or more pills made up from “zaragatona” (*Plantago psyllium*) or African plantain. After the bird has been purged, he suggested to cast the falcon and using a pair of pliers similar to those used by farriers, to trim all talons short to produce hemorrhage. A salve is then prepared using turpentine, French soap shavings and the ashes of vine shoots in quantity enough to thicken the mix. These ingredients are mixed in a cooking pot and made to boil mixing it constantly. The mixture is then applied to the affected foot using a dressing held in place by an interdigital bandage made from thin leather strap and left in place for three days (Canoua 1565). De Canoua also suggested a different salve made up with ground acorns of the holm oak (*Quercus ilex*), iron dust, shoots of myrtle (*Myrtus communis*), cypress galls (*Cupressus*), and peel of pomegranate (*Punica granatum*), mixed with red wine and boiling the mixture to reduce the volume until it has thickened. This salve is spread over three or four folds of fine linen and cover a stone or a perch with it and make the falcon stand on it for half day. The salve is added every day in order to maintain the linen wet all the time. De Canoua also suggested to feed the falcon with chicken chicks, heart of young sheep, washed with zaragatona, and to avoid giving pigeons or sparrow as these are considered too hot (Canoua 1565). It is interesting to note that de Canoua suggested to trim the talons short to make them bleed. The authors have not been able to determine the reason of such treatment, although “bloodletting” was a common medical and veterinary procedure widely used in medieval times (Seigworth 1980).

Pedro López de Ayala (1332 – 1407) was a poet, historian, and statesman of the Kingdom of Castille. López de Ayala wrote the book entitled “Libro de la caza de las aves” (Lopez de Ayala 1385) during the period he spent in jail in Óbidos (Portugal) after the defeat in Aljubarrota (Lapesa 1969). In Chapter 26 entitled “Del falcon que ha clavos en los pies,” or “Of the falcon with pododermatitis in the feet,” López de Ayala describes the same treatment as published by Juan de Canoua in “Libro de Cetreria de Caça de Açor” at an earlier date. Therefore, it is very likely that Juan de Canoua and other authors of the epoch including Iohan de Sant Fagún in the book “Delas aues que caçan” (Sant Fagún 1500) copied the information from Pedro López de Ayala and publish it in their treatise. During medieval times, it was common for authors to compile information

from manuscript written by different authors and publish it under a different title.

The book “Das Falken - und Hundebuch des Kalifen al-Mutawakkil: Ein arabischer Traktat aus dem 9. Jahrhundert (Wissenskultur und gesellschaftlicher Wandel, Band 11)” or “The Falcon and Dog Book of the Caliph Mutawakkil: an Arab Treatise from the 9th century (Culture of knowledge and Social Change, Volume 11)” was written by Muhammad ibn Abdallah al-Bazyar for the Caliph Mutawakkil (847 – 861). The work of al-Bazyar was translated into Latin under Frederick II (AD 1194-1250) and into Castilian under Alfonso the Wise (AD 1221-1284). More recently the book was translated from the original Arabic to the German language (Akasoy, Georges 2005). The book contains several citations on the treatment of gout, loss of claws, ulcers and pus on the soles of the feet, the treatment of fractures, swellings and fistulae on the feet of falcons is presented here-with by Chapters and their respective pages to ease referencing.

Muhammad ibn Abdallah al-Bazyar mentioned about the treatment of gout, loss of claws, ulcers and pus on the soles of the feet and treatment of fractures and swelling on the feet. (Al Bazyar 2005a). “When this occurs, take away bells and jesses from the birds, especially from the smaller ones, and let them walk freely in houses or spacious aviaries, which are outlaid with felt and they should be fed with meat, which is helpful in this kind of disease e.g., meat from swallows, sparrows or similar animals. Then take two dirhams of each, acacia (*Acacia penninervis*) and castor bean (*Ricinus communis*), 4-dirham autumn crocus (*Colchicum autumnale*), barley (*Hordeum vulgare*) flour and marsh-mallow (*Althaea officinalis*) and 8-dirham white bread which was soaked in cold water and break up this carefully, add each one part of vinegar and one part of egg white to it, knead it with it and put the mixture on the soles of the feet and bandage them for the duration of 3 days. The bandages should be replaced every day and every night. Give the birds pieces of meat with the medication that is used against mucus.”

“Take each one part of sieved chalk and egg white, mix both together and apply it on the soles of the feet. Then take pieces of linen and put them over it.”

“When the soles of their feet swell up by doing this, cut them open carefully with a new glass, so that blood and yellow fluid can disappear. Then take equal parts of aloe (*Aloe vera*), rosin gum (also called colophony or Greek pitch, is a solid form of resin obtained from pines and some other plants, but mostly conifers), varnish, saffron (*Crocus sativus*), green rust (crystalline chemical compounds

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containing iron cations, the hydroxide anion, and other anions such as carbonate, chloride, or sulfate, in a layered double hydroxide structure), and egg white, break them up, place them into a cooking pot and place it on the fire until the content gets hot. Mix the ingredients well and take them away from the fire. When the medication has cooled down enough, bandage the bird's feet with it and wrap leaves of the chicory around it. Then put cotton and then wrap cloths around the feet, because it is beneficial for them."

"Especially hawks suffer from swollen soles of the feet due to this disease. If the swelling is not clear yellow in color nor shows yellowness, take one part of new pottery and ant eggs, break it up, mix it with water, coat a cloth with it and put the cloth around the soles of the bird's feet. When the medication dried, spread water on it two times daily."

"Take an ointment made from burnt copper, large ants and egg white and bandage the lesions with it. If the swollen parts are clearly yellow in color, this indicates pus. In this case, heat a needle and open up the pus-filled parts, so that the pus inside can leave. Then take 14-dirham leaves of the beetroot (*Beta vulgaris*), from which the stalks have been put away, cook them in 15 ounces of undiluted wine and add the necessary amount of barley flour. Then, put the medication on a cloth and put the cloth on the part which has been cut open. Then bandage this part. Subject the birds to this treatment once every three days. Also give the birds their food with castor oil and apply it on the soles of their feet in the cold season. In the warm season, the birds should get donkey milk to drink, because this acts laxative, let them gain weight and heal and frees them of most diseases".

"Occasionally, the soles of their feet swell up due to another reason, because the birds rest too much and push themselves and move too little. One indication for this is that the birds are barely able to stand on the soles of their feet. If this occurs, take one daniq (a traditional Islamic silver coin weighing one sixth as much as a dinar) of benzoin (sap or gum resin that comes from cuts in the trunk of trees that belong to the *Styrax* family), break it up together with beef fat, apply it on the bird's feet soles, bandage them and let the birds wear the bandage one day and one night".

"Also take a cotton cloth, wrap it around the claws of the birds (and leave it) there for one hour. Then take a piece of sugar and rub gently above the swelling, until the top dermal layer is peeled off and carve the spot with a lancet carefully, so that the claws of the birds

will not be damaged. Then take the necessary amount of egg yolk, mix it with sesame seed (*Sesamum indicum*) oil and put it on the carved parts. By doing this prevent the claws from falling off."

"If the swelling is not severe, carve the lower part of the feet soles and the part underneath. There, there is located something like a millet seed, that has to be taken out with the needle, until the part is clean. Then, the area will be bandaged with green myrtle (*Myrtus communis*). Also take each one part of rosin gum and white lead (also known as hydrocerussite, is a complex salt, containing both carbonate and hydroxide ions, occurring naturally as a mineral), break them up carefully and apply it on the birds feet soles and the claws. Then bandage them and only take away the bandage until the bird's feet are healed. If there are signs of healing, moisten the bandage with old wine until it the scabs loosen and falls off."

Muhammad ibn Abdallah al-Bazyar mentioned about the treatment of gout, loss of claws, ulcers and pus on the soles of the feet and treatment of fractures and swelling on the feet (Al Bazyar 2005a), "Take the blood of a black chicken, immediately after it has been slaughtered, so that it is still warm, and add Arabic gum (This is a natural gum consisting of the hardened sap of two species of acacia tree, *Senegalia senegal* and *Vachellia seyal*), aloe, boxthorn (*Lycium ferocissimum*) juice, saffron and egg white. Break up the ingredients and apply the medication on the feet soles of the birds, if this is possible. If the birds recover it is fine. If not, carefully cauterize their feet soles with a branch of myrtle. Proceed in a similar manner as when branding, but take care not to burn the soles. After that, the soles of the feet should not be bandaged. Only cauterize, if all other treatments have failed. The birds will then recover".

Muhammad ibn Abdallah al-Bazyar wrote on the treatment of holes in the soles of their feet, that present as a fistula (Al Bazyar, 2005b). "To treat fistulae on the sole of the feet, take each one part of paste and one part of green rust, knead it together and cover the fistulae with it. Another dressing for the fistulae is prepared by taking equal parts of aloe, myrtle, red sandalwood (*Pterocarpus santalinus*), poppy (*Papaver somniferum*) and Indian betel nut (*Areca catechu*), break them up, sieve them and knead them with wine vinegar and apply it on the affected part. Especially beneficial for the treatment is to add camphor and the medications use for treatment of warts to these remedies. It is also beneficial to add poultices made from humid sand on the affected parts."

Kraenner (1925) advised against swollen feet, "Such a condition is caused by rough jesses or rough snow. To heal this condition: make a few straight scratches into the phalanges with a surgery knife or a sharp knife. Then, grind frankincense, lead monoxide, Alexandrian glass, an egg white and the sticky and fat of a slug, sprinkle the foot with it and bandage it and the bandage is not removed unless the falcon is healthy again. Then, the foot is moistened with warm wine and it will be fine again" (Kraenner 1925). Against swollen feet Kraenner suggested, "Mix 4 ounces of wax, 2 ounces of chicken fat and a sufficient amount of the juice of *Commiphora gileadensis*, make an ointment out of it and apply it" (Kraenner 1935). It was also mentioned that when the foot is swollen or inflamed, "Take equal parts of frankincense, Alexandrian glass and marble, grind it and add the bile of a ram and egg white. With this, cover the ankle of the falcon and bandage it" (Kraenner 1935). Against an inflammation (inflammation of a foot) of the falcon. "Take equal parts of oak apple, real myrtle and seed of acacia, grind it with a mortar and trickle wine vinegar on it. When the mixture is sticky, cover the feet with it." Against open wounds on the feet. "To heal the open parts completely by flushing them with continuously with cold water" (Kraenner 1935).

Gerdessen mentioned "Swollen feet will be treated primarily with frankincense, honey, milk, rose water, colophonium (a translucent brittle amber produced in the distillation of crude turpentine oleoresin) and different kind of fats" (Gerdessen 1956). "Pain of the talons and shrunken feet will be treated with egg white, dragon blood (red coloured resin obtained from the fruit of a tree *Daemonorops draco*) and colophonium" (Gerdessen 1956).

The statements made by Kraenner and Gerdessen were based on studies on the Codex Palatinum Germanicum 496 of the Middle Age.

MODERN PERSPECTIVE ON THE MANAGEMENT AND TREATMENT OF PODODERMATITIS IN FALCON MEDICINE

As illustrated in the previous section, pododermatitis (bumblefoot) has been recognised as a medical condition in falconry since the Middle Ages. Numerous predisposing factors have been discussed, numerous therapeutic approaches have been explored – still the pathophysiology of the disease syndrome is unchanged in the way that ischemic insult to the tissue develops into necrosis and inflammation affecting the plantar epithelium and/or deeper structures of the feet. Researching the pathophysiology of this syndrome helps understanding the relevance of predisposing factors and taking the appropriate measures. Micro epithelial damage (e.g., by overgrown

talons or penetrating trauma) or fragile skin due to suboptimal husbandry and skin hygiene allow the invasion of opportunistic pathogens and the development of localized ischemia with inflammation and necrosis. Increased pressure on the plantar aspect of the feet lead to reduced blood perfusion and the formation of micro-thrombosis in the capillary vessels. The devitalized tissue has a reduced immune response and healing capacity (Harcourt-Brown 2000, Cooper 2002). Depending on the severity of the inflammation and infection there might be irreparable tissue damage such as ruptured tendons and ligaments, septic arthritis or osteomyelitis.

Based on the previously mentioned the classification following therapeutic principles are recommended: [1]

Classification I: antibiotics, and anti-inflammatory medication, husbandry adjustment

Classification II: antibiotics, and anti-inflammatory medication, bandages, husbandry adjustment

Classification III: antibiotics, and anti-inflammatory medication, bandages, surgery, husbandry adjustment – radiography recommended

Classification IV: antibiotics, and anti-inflammatory medication, bandages, surgery, husbandry adjustment, radiography essential, prognosis guarded

Classification V: antibiotics, and anti-inflammatory medication, bandages, surgery, husbandry adjustment – radiography crucial, prognosis poor, euthanasia a serious consideration.

Depending on the severity of the lesion different combinations of medical treatment, surgical debridement, bandaging and topical/conservative treatment are applied.

Antibacterial treatment should correspond to culture and sensitivity testing. Often antibiotics with good bone affinity and Gram-negative efficacy such as clindamycin, marbofloxacin or lincomycin are favoured. Due to necrosis and inflammatory tissue swelling there is reduced blood supply to the lesion resulting in abscess and granuloma formation. Antibiotic-impregnated beads, antibiotic containing hydrogels or suspensions designed for bovine intramammary treatment can be applied intra-lesional after surgical debridement to circumvent the lack of drug supply to the granulomatous lesion (Remple 2006). Systemic antibiotics, anti-inflammatory medication and analgesia, as well as antimycotic treatment – as indicated

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– should be continued as long as there is active inflammation in the feet. Further the application of blood circulation enhancer such as isoxsuprine or propentofylline can be advantageous.

Surgical debridement aims for the complete removal of all devitalised and necrotic tissue. Medical and bandage treatment can assist in the formation of a defined abscess facilitating removal. Often debridement is hindered by inflammation spreading into the surrounding tissue. Residual inflammation or abscess capsule support wound healing problems and recurrence. Any devitalised tissue needs removing, including affected ligaments and tendons, therefore in advanced cases the loss of digital function is a realistic complication that should be considered prior to surgery. Depending on the extend of the devitalised hyperkeratotic skin lesions surgical skin flaps or grafts may be performed. The need of multiple surgeries is not unusual.

Applying bandages in a way that the area around the lesion is weight bearing and the affected and debrided area is untroubled by pressure helps improving the blood flow to the affected area, by decreasing occlusion/compression of the local capillary network. Better vascularisation also promotes normal wound healing. Numerous bandages and foot castings have been designed using plastic casting material, thermoplastic tape with an opening over the lesion, bandage donuts or sleeping mat padding with corresponding openings. Bandages must be regularly changed and checked for constriction and appropriate bandage hygiene such as clean sand-free housing must be understood. Prior to surgical debridement bandages can help to hold ointment and dressing in place to assist softening the crusts, or drawing ointment to encourage encapsulation and abscess formation prior to surgery.

Identifying pododermatitis early in the disease process and not allowing it to progress further than classification I or at best II is the most effective treatment. These early lesions respond best to topical treatment, combined with systemic medication (antibiotics, anti-inflammatory drugs/analgesia and blood circulation enhancers) – only as long as there is active inflammation in the foot. The aim of topical/conservative treatment is to reduce inflammation, soften hyperkeratotic cores in the epithelium and to increase blood flow to the feet/lesion. To achieve this, bandages can be impregnated with e.g., DMSO (dimethylsulfoxide), chondroitin polysulfate ointment (to treat superficial phlebitis) or hyperaemic ointment/solutions e.g., containing camphor to reduce inflammation and increase blood circulation. Perfusion of the feet can also be increased by applying hot compresses.

Daily bathing of the affected foot in mild disinfectant or soap for 15 minutes proved very effective in softening hyperkeratotic cores and allowing tissue healing from the deeper layers to the surface. Often creativity is needed to perform this daily bathing with raptors; such as feeding the bird slowly bit by bit by hand while standing in the bath; such as using soaked foam flooring in transport boxes or soaked towels wrapped around the glove while carrying the bird. Conversely, a foot bath made up of a round plastic tray used for potted plants, lined with artificial turf, can be used fixed onto a falconry block and allow the falcon to stand for 20 to 30 min twice a day. The use of a salt water solution or simply sea water has been used for the same purpose in combination with antiseptic baths.

Increasing exercise, as long as the birds are in an appropriate condition to exercise, is most effective in fighting pododermatitis. Exercising with bandages might be more cumbersome but not impossible. Falconry birds can be taking back into training or so-called high jumps from a perch or the floor to the fist can be performed. Spacious aviaries can be provided with various measures to motivate flight, such as rotating feeding places, should be established.

The fact is that topical conservative treatment is very time consuming and effort intense, taking up to weeks or even months. However, this approach proves very rewarding with ample owner compliance. Recurrence after resolution of initial lesions is not uncommon. However, often there are less relapses with the conservative approach than with surgical debridement – even in less progressed pododermatitis lesions of the classification I or II. This observation might be biased due to the fact that owners with the dedication to undergo topical treatment will become more sensitive towards pododermatitis and react more quickly in light of epithelium damage, and might also be more open minded and effective in respect to husbandry adjustment. Conservative treatment will only be successful in combination with prevention of predisposing factors and husbandry adjustment.

The fact that pododermatitis has been recognised in falconry since the Middle Age and that therapy and surgery still remain challenging, draws the attention to the predisposing factors.

The following predisposing factors are found as relevant:

1. Excessive load bearing due to obesity or simply body size
2. Asymmetric weight distribution between legs due to trauma, pain, bone or joint deformity
3. Insufficient perch and aviary hygiene
4. Unsuitable perches resulting in pressure sores

Citation: J. SAMOUR, M. B. WERNICK and P. ZSIVANOVITS. (2021). "Therapeutic Management of Pododermatitis in Falcon Medicine: Historical and Modern Perspective". *Archives of Veterinary and Animal Sciences* 3(1).

5. General inactivity or abrupt cessation of flying post-season resulting in reduced blood supply to the feet

Husbandry adjustment is the most powerful, but also the most cumbersome and laborious tool in the management and prevention of pododermatitis, and often forces the angle of view away from falconry traditions.

- 1) Taking for example the tradition to keep eagle on blocks or bow perches, representing heavy sized raptors, that due to everyday life circumstances, are often not flown in any comparison to what these birds do in the wild. It is no surprise that being based on the highest point of an up-bend perch for an extensive time predisposes to pressure sores. When keeping heavy sized birds such as eagles or gyrfalcons, particular attention to perching needs to be paid. The vicious circle formed by heavy weight load combined with inactivity is well known and can only be disrupted by awareness and proactive action. Aviary birds, in particular, should not be allowed to gain too much weight. Check weight and feet on a regular basis also in aviary birds, and disregard the little disturbance caused by this. Try minimising stress and disturbance by such health checks via regular contentious handling and interaction with the birds, even throughout moulting times.
- 2) Similar, in the case of known leg trauma or bone deformities with resulting asymmetric weight bearing increased caution needs to be taken to avoid predisposing factors.
- 3) Thorough hygiene for all perches/surfaces and the aviary as well as a balanced vitamin rich nutrition should be a matter of course. That is the only way to effectively minimise pathogen contamination of the perches, including the uneven surface of the AstroTurf® or the effect of water retention with neoprene. Poor skin hygiene and malnutrition facilitate fragile skin and the development of microtrauma and pathogen invasion.
- 4) Correct perching is crucial in the prevention of predisposing factors. The perches must not be too big or too small for the bird's feet. Very flat and wide perches may encourage excessive weight bearing on the toe pads, while too small perches increase the pressure on the metatarsal pads.
- 5) AstroTurf® can be used to counterbalance the effect of hard surfaces. The spikes are considered to massage the plantar surface of the feet and assist in spreading the weight more equally. However, in some grades of AstroTurf® there are shorter, very hard spikes that need removing to avoid military pressure overload. Alternatively, neoprene surfaces proved useful.
- 6) Pododermatitis is no a disease syndrome exclusively found in raptors, but also a frequent problem in captive waterfowl, Galliformes, Passeriformes or psittacines. The principles from e.g., psittacines husbandry can well be transferred to raptors. There is a great advantage in providing different perch surfaces (under consideration of a rough and structured surface such as AstroTurf®) as well as differing perch sizes and diameters. Attention needs to be paid to the bird's behaviour, e.g., the bird's favoured sitting spot. The best distributed differing perches in an aviary would not help, if the bird is only sitting in the same spot. In that case the perches literally need to be moved around in the aviary, forcing the bird to use different perches. Another example are birds that tend to sit on the beams of the aviary fencing or the beams of the roof construction. If that is the case those beams need to be covered with e.g., AstroTurf® as well, not only the actual block or perch. A further often overlooked problem is that the perch size is correct, however the bird tends to sit mainly on the edge of the block. In those cases, AstroTurf® as an inlay in the centre of the block is not sufficient but needs to be extended and bend of the wooden edge of the block. As obvious these examples may appear, the practical veterinary daily routine proves differently.
- 7) Another very useful husbandry tool are swing perches, regularly used in psittacines. With swing perches the impact of landing is reduced and the birds are forced to balance, shifting the weight of their feet marginally but efficiently. With a little bit of creativity swing perches and blocks can be designed and used for raptors. A well-used counter-argument is that in nature raptors are often seen sitting on rocks etc. - still the fact remains that we see this disease syndrome in captivity and only rarely in nature and that living circumstances differ in captivity and are not one to one transferable.
- 8) Studies validate the importance of exercise for an appropriate blood supply to the feet by demonstrating the increased blood flow and temperature rise with exercise (Müller, Wernery, Kösters 2000). Lack of exercise due to insufficient flying opportunities is one problem. The other is the abrupt cessation of flying postseason in falconry birds – often in combination with a sudden excessive high energy and protein rich diet. There is a threefold likelihood to develop pododermatitis with an abrupt cessation compared to a gradually slowing down of the training over 3 to 4 weeks (Lierz 2003).

An interesting study from 2020 showed that significant trilateral interaction effect between perching surface (hard wood, neoprene and AstroTurf®), bandage type (none, interdigital and silicone show with central excavation), and compression force (body weight) (Barboza, Beaufrère, Moens 2020) It was demonstrated that not bandaged feet on hard wooden surfaces are impaired by statistically significant highest metatarsal pressure forces. For not bandaged feet, the second-best surface proved to be neoprene followed by artificial turf. With body weights of 250g and 500g the different bandage/surface combinations did not yielded major differences in metatarsal pressure forces. However, in the 1000g compression force group the differences increased significantly, with the silicon shoe option resulting in the lowest metatarsal pressure force, disregarding of the used surface (Barboza, Beaufrère, Moens 2020).

The use of Thrombocytes Leucocytes Rich Plasma (TLRP) offers a new possibility for the therapeutic management of ulcerative pododermatitis in birds of prey (Samour, 2019) The TLRP can be applied to the site using a saturated thin gauze swab covered with a sheet of plastic to stop leakage to the bandage. Conversely, TLRP can also be used in gel form ensuring longer contact with the ulcer or wound under treatment. The TLRP in gel form is obtained by adding calcium gluconate and the use commercially-available kits containing a solution of sodium diatrizoate polysucrose density 1.077 g/ml. This technique has been used successfully to promote tissue repair in chelonias (Di Ianni, Merli, Burtini and others 2015). A similar technique using Platelet Rich Plasma (PRP) is widely used for the treatment of tendonitis, osteoarthritis, and oral and cosmetic surgery in human medicine (Xu, Chen, Cheng 2019; Mishara, Woodall, Vieira 2009; Andia, Sanchez, Maffulli 2021; Esposito, Grusovin, Rees and others 2010; Por, Shi, Samuel and others 2009).

Pododermatitis is primarily seen in Falconiformes, but less in accipiters. However, the question is, if there is bias in the percentage of Falconiformes compared to accipiters that are used in falconry as well as differences in husbandry and hunting? In the past few years, Harris's hawks (*Parabuteo unicinctus*) have become increasingly popular in falconry and accordingly pododermatitis is increasingly more often seen in this species. Interestingly, pododermatitis is normally found in birds in captivity but not in free-ranging raptors. If there are reports of pododermatitis in wild raptors it is normally secondary to a trauma and injury to the feet. Therefore, it is fair to say that pododermatitis is a disease syndrome in relation

to husbandry and captivity. The key words in the management of pododermatitis are prevention and prophylaxis.

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