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Dynamics of skin scar formation as a subject of forensic veterinary examination

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The study examines the morphological, histological, ultrasonographic, and luminescent characteristics of skin scars in dogs and cats caused by stabbing and cutting instruments, analyzed dynamically throughout the wound healing process. It is demonstrated that skin scars possess clearly defined features that vary depending on the duration of scar tissue formation and can be used for the approximate determination of the age of injury. It was established that the process of scar formation proceeds through sequential stages of inflammation, proliferation, and remodeling, which are characterized by specific histomorphological patterns, including changes in cellular composition, organization of collagen fibers, and restoration of skin appendages. Histological studies showed that already at the early stages (days 8–12), active regeneration of the dermis, epidermis, and skin appendages occurs within the scar area, accompanied by high fibroblast activity and the formation of a collagen matrix. However, at later stages (days 21–25), scar tissue acquires a microscopic structure that closely approximates that of intact skin. This enables an objective assessment of the stages and completion of the healing process and, consequently, the determination of the age of injury, which constitutes the subject of forensic veterinary examination. Examination of skin scars under ultraviolet radiation on day 14 allows the detection of weakly expressed or absent fluorescence of scar tissue, which is due to the insufficient accumulation of mature collagen, despite the already relatively ordered orientation of collagen bundles. Wound healing in dogs occurs more rapidly and intensively than in cats, which is manifested by a more pronounced inflammatory response, more active neoangiogenesis, higher fibroblastic activity, and faster remodeling of scar tissue. An author-developed classification of skin scars, comprising 17 criteria, was created and formed the basis for forensic veterinary analysis aimed at assessing their impact on exterior disfigurement and mutilation of animals, as well as influencing the formulation of an accurate and comprehensive forensic veterinary diagnosis. The practical significance of the study lies in substantiating the objectives of forensic veterinary examinations of animals injured by sharp objects, particularly in the possibility of using a complex of macroscopic, histological, ultrasonographic, and luminescent scar features to establish the mechanism of trauma, the approximate age of injury, and to assess the degree of trauma-induced morphological and functional disorders in the organism.

Keywords: forensic veterinary examination; trauma; injury; sharp objects; wounds; skin scars; age of formation.

Introduction

The developed democracies of the world place considerable emphasis on animal protection, aimed at preventing violence, cruelty, injury, and unjustified killing of animals (Fox, 2024). During the pre-trial investigation of criminal offenses involving animal cruelty, forensic veterinary examination plays a significant role as one of the means of evidence, while the expert opinion constitutes admissible evidence in court. Therefore, the Kharkiv scientific school of forensic expertise is actively developing the theory, methodology, and praxeology of this field (Yatsenko, 2024).

Accordingly, the subject of forensic veterinary research includes, inter alia, factual data and circumstances of criminal cases related to establishing causal relationships between injuries of various origins and their consequences for animal health or even death. One type of injury encountered in such cases is that caused by sharp objects (Yatsenko & Kozachok, 2024). Consequently, law enforcement agencies and courts are faced with the need to determine the age of injury infliction. This task can be addressed through specialized veterinary knowledge by analyzing the morphological features of injuries (Yatsenko et al., 2025), and at later stages of wound healing-by assessing the structural characteristics of skin scars (Neves et al., 2023).

As researchers rightly note, scarring represents the final stage of skin repair in mammals, during which the structure of normal skin is replaced by fibrous tissue with a predominance of type I collagen, a reduction in the number of skin glands, and decreased elasticity (Mascharak et al., 2025). At the same time, Ghosh et al. (2020) emphasize that scarring is the predominant outcome of wound healing in adult mammals, despite the fact that its formation is associated with partial loss of function. The authors described the structure of a normal full-thickness scar with dual biomechanical compartments using *in vivo* and *ex vivo* experiments, as well as structural mechanics modeling for computational simulation of deformation fields and stress distribution within the scar in response to external forces. Despite the loss of certain tissue components, the researchers found that scars possess stress-adaptive properties that protect underlying tissues from external mechanical influences. Thus, this discovery may stimulate further research aimed at understanding the biomechanical advantages of scar tissue in maintaining the primary function of the skin as a mechanical barrier, despite the persistent loss of some tissue elements and specialized functions.

To date, the problem of skin scarring in both humans and animals from clinical and forensic perspectives has been investigated by numerous researchers. In particular, Rayner et al. (2020) and Lux (2022) described the physiological and clinical features of wound healing; Jiang et al. (2020) demonstrated that trauma in mice initiates collective migration of fascial fibroblasts, leading to scar formation via N-cadherin; Kawakami et al. (2021), using a fetal mouse model, demonstrated histochemical and morphometric features of scarless wound healing; Jiang et al. (2021) and Jiang (2020) provided an updated review of fibroblast heterogeneity as fibroblast-centric mechanisms and determinants of the scarring–regeneration continuum, focusing on intercellular and cell–matrix adhesion and the role of fibroblasts in wound regeneration and scarring; Short et al. (2021) established that interleukin-10 produced by T lymphocytes attenuates skin scarring; Kuan et al. (2024) showed that delayed collagen production without myofibroblast formation contributes to reduced scarring of skin microwounds; Deng et al. (2024) emphasized that visible red and blue light accelerates skin wound healing and facilitates scar formation in mice; and Mistry et al. (2024) compared scarring models in animals and humans, noting that although sharp incisions were used to induce scar tissue, the rabbit ear model remains the most widely applied. The authors also demonstrated that porcine and human scar tissue are highly similar.

In addition, it should be emphasized that ongoing discussions in the scientific community focus on the mechanisms of scarring and the formation of physiological and pathological scars. In particular, Rippa et al. (2019), Supp (2019), Cao et al. (2022), Lin et al. (2022), Han et al. (2023), Kohlhauser et al. (2024), Nabai et al. (2024), Szlachcikowska et al. (2024), Kussie et al. (2024) argue that understanding the complex interplay between fibroblasts and other cellular and molecular components is crucial for elucidating the fundamental mechanisms underlying scar formation. The authors emphasize that hypertrophic, keloid, and atrophic scars arise from dysregulation of wound healing processes, accompanied by persistent inflammation, abnormal collagen accumulation, impaired extracellular matrix remodeling, and mechanotransduction, i.e., the conversion of mechanical stimuli into cellular responses. Fibroblasts play a central role in the development of these pathological scars by promoting aberrant extracellular matrix remodeling, resulting in elevated or depressed fibrotic structures.

The significance of local inflammation and hypoxia as determining factors in the formation of hypertrophic scars in animal models has been demonstrated by Nischwitz et al. (2023) and Wang et al. (2023). These authors concluded that keloid and hypertrophic scars are pathological entities arising from abnormal wound healing, particularly sustained inflammation and excessive collagen deposition.

Scientific periodicals also report studies addressing methods for visualizing skin scars. Thus, Meikle et al. (2024) detailed ultrasonographic measurement of traumatic scars; Ramesh et al. (2022) described visualization of scar development using SCAD analysis (*ex situ* skin scar analysis); and Ghosh et al. (2021) demonstrated the potential effectiveness of optical coherence tomography for quantitative assessment of skin wound healing and scar morphology.

Consequently, contemporary scientific evidence confirms that scarring in animals is a complex process characterized by species-specific differences and multiple pathomorphological variants (normotrophic, hypertrophic, and keloid-like scars). Therefore, to ensure effective clinical management and accurate forensic veterinary examination, a cross-species approach is required, including correct interpretation of wound healing stages and their histological verification. However, the lack of unified temporal scales for determining the age of skin scars across different animal species may lead to expert errors.

The aim of this study is to systematize and characterize the informative criteria for the forensic veterinary determination of the age of skin scar formation in dogs and cats following injuries caused by sharp objects.

Materials and methods

The study of morphological characteristics of skin scars formed as a result of injuries caused by stabbing and cutting instruments was conducted *in vivo* on dogs (n = 5) and cats (n = 5) that had sustained traumatic injuries and were undergoing treatment at veterinary clinics in the city of Kharkiv. All animals were under continuous clinical supervision, and all procedures were performed in compliance with generally accepted veterinary ethical standards and principles of humane animal treatment.

Macroscopic assessment of scars was carried out directly on live animals. The description included determination of scar localization with specification of the anatomical region, its shape, dimensions (length, width, height, or depth of retraction), orientation relative to the longitudinal body axis or clock-face reference, surface relief, color, consistency, and degree of mobility in relation to underlying tissues. The presence or absence of hair covering in the scar area, signs of deformation of surrounding tissues, adhesion to underlying structures, as well as changes in the adjacent skin (pigmentation, induration, atrophy) were recorded separately.

For histomorphological analysis, skin scar biopsies were obtained from live animals. The biopsy material included a fragment encompassing the scar area itself, the transitional zone between "scarred/normal" skin, and the surrounding intact skin, which allowed assessment of the nature of morphological changes and the gradual transition between tissues. The samples were immediately fixed in a 10% neutral buffered formalin solution.

After fixation, the material was processed according to standard histological protocols: dehydration was performed using graded alcohols, followed by paraffin embedding. Serial histological sections with a thickness not exceeding 5 μm were prepared from the paraffin blocks.

Histological sections were stained with hematoxylin and eosin according to conventional methods. Microscopic examination was performed using a light microscope at various magnifications, followed by photographic documentation for morphometric and comparative analyses. During histological evaluation, the condition of the epidermis, differentiation of its layers, dermal architecture, arrangement and density of collagen fibers, cellular composition, vascular status, and the presence and degree of regeneration of skin appendages were assessed.

Ultrasonographic evaluation of scars was performed to investigate their structure and depth during the dynamics of healing. Examinations were carried out using a Chison CBit 9 ultrasound system equipped with a linear Chison transducer (China). The thickness of scar tissue, its layered structure, echogenicity of superficial, middle, and deep scar zones, as well as the clarity of boundaries between the scar and adjacent tissues were evaluated.

The obtained macroscopic, histological, and ultrasonographic data were summarized and analyzed in an integrated manner, which allowed for an objective characterization of the morphological features of skin scars caused by stabbing and cutting instruments and for the assessment of their diagnostic and forensic veterinary relevance.

Results

Connective tissue skin scars in dogs and cats that form during the healing of traumatic wounds exhibit distinct characteristics that may be useful for determining the type of injuring instrument as well as the age of injury during forensic veterinary examination.

Macroscopically, skin scars appear as dense grayish-white formations. Their surface may be smooth or slightly irregular, and hair is absent within the scar area. Depending on the scar type, elevation above or depression below the surrounding skin level may be observed at the site of formation.

Scars that develop after the healing of puncture wounds are usually round, oval, or stellate in shape and are characterized by small size. In cases of incised wounds, a narrow, mobile, linear scar is formed after healing. In contrast, scars resulting from chopping wounds are also linear in shape but are poorly mobile and relatively massive. Large scars on the animal's body may cause significant disfigurement of the exterior.

The clinical and forensic veterinary significance of scars for the organism of dogs and cats was also determined. The presence of scar tissue may indicate previous surgical intervention and may cause locomotor dysfunctions, including contractures, ankyloses, deformities, and asymmetries. At the same time, scars serve as a direct visual indicator of wound healing and an important marker of the duration of the wound process. Based on our own observations, it is appropriate to distinguish several stages of scar formation, each characterized by specific histomorphological patterns during the transformation of scar tissue. Thus, within the first 72 hours after injury, edema, disintegration of the intercellular matrix, massive neutrophilic infiltration, vascular dilation with corresponding erythrocyte stasis, necrotic conglomerates consisting of fibrin and erythrocytes, and initial activation of fibroblasts at the periphery of the injury were observed.

During the subsequent proliferative stage (3–14 days), intense proliferation of myofibroblasts and formation of granulation tissue were recorded, including vertical "columns" of capillaries with a well-developed endothelial layer and pronounced neoangiogenesis, with a predominance of thin-walled blood vessels with wide lumina.

The remodeling stage (15–30 days) was characterized by transformation of fibroblasts into fibrocytes, reduction in the number of capillaries, contraction of myofibroblasts, and localized topographic orientation of collagen fibers in accordance with mechanical loading.

According to our data, a mature scar is characterized by a minimal number of cells, complete absence of immature myofibroblasts, presence of blood vessels with narrow lumina and mature walls, minimization of amorphous intercellular matrix, and a wavy topographic orientation of collagen fibers corresponding to mechanical stress.

Histological examination of skin scars at different stages of their formation demonstrated that by day 8, the scar already microscopically resembled the structure of intact skin (Fig. 1). At this stage, skin appendages were already detected in the dermis, including hair follicles with hair shafts, sebaceous glands, and sweat glands. However, whereas in normal skin the appendages are typically located within the reticular dermis at a considerable distance from the epidermis, in the scar on day 8 they were also found directly beneath the epidermis. In addition, the number of skin appendages was markedly increased, indicating extremely intensive regenerative activity.

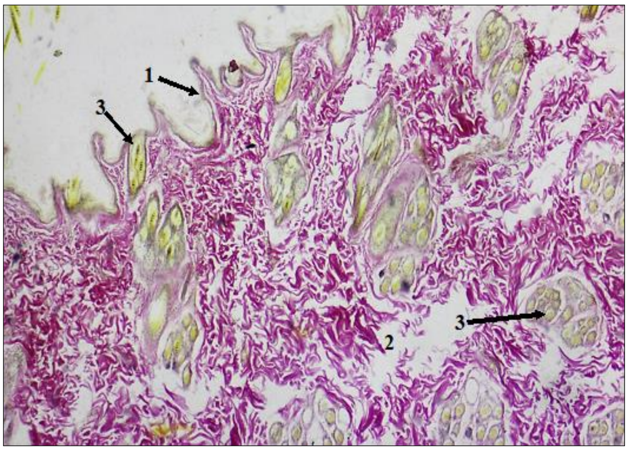

Fig. 1. Skin scar on day 8 of its formation in a dog: *1* – epidermis; *2* – dermis; *3* – skin appendages; hematoxylin and eosin, ×50

On day 9, all components of intact skin-the epidermis, dermis, and its appendages-were detected within the scar area. However, unlike the surface of intact skin, the surface of the scar at this stage was irregular. The epidermis was morphologically and functionally immature: it lacked clear stratification, and the superficially located epidermal cells did not yet produce a keratinized substance of typical composition, which in intact skin covers the surface and stains intensely eosinophilic. The dermis had also not yet fully acquired its typical structure. Its reticular layer was only beginning to differentiate, appearing as a narrow, uneven band of tissue located directly beneath the epidermis (Fig. 2).

On day 12 of observation, the papillary layer of the dermis was represented by markedly thinner bundles of collagen fibers compared to the reticular layer of the dermis, which were still loosely arranged and disorganized. A large number of fibroblasts was also observed in this layer (compared to the papillary layer of intact skin), indicating active formation of the dermal layer through intensive production of collagen fiber bundles (Fig. 3).

On day 13, the majority of the dermis at this stage of scar formation was represented by the reticular layer. However, this layer was still not fully developed. It consisted of loosely arranged, uneven, and disorganized thick bundles of collagen fibers, with relatively large interstitial spaces between them. The large number of fibroblasts (compared to the reticular layer of intact skin) also indicated active formation of this dermal layer (Fig. 4). On days 14–15 of observation, hair follicles showed the most intensive regeneration, with their number markedly increased. However, only a small portion of these follicles were fully developed and contained fully formed hair shafts (Fig. 5).

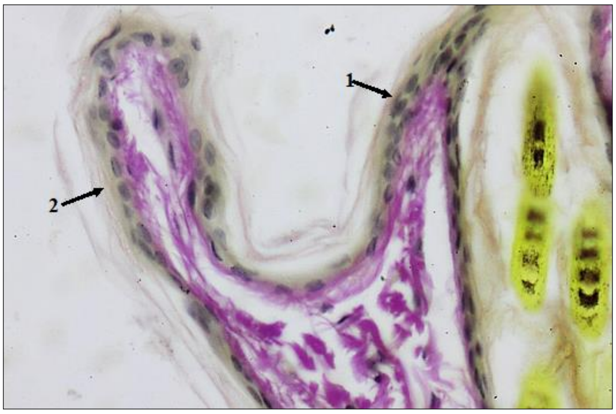

Fig. 2. Skin scar on day 9 of its formation in a dog: *1* – epidermis; *2* – keratinized material of a composition atypical for intact skin; hematoxylin and eosin, ×200

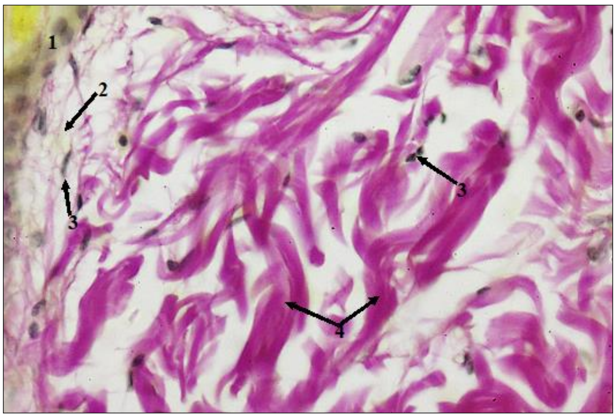

Fig. 3. Skin scar on day 12 of its formation: *1* – epidermis; *2* – thin bundles of collagen fibers in the papillary dermis; *3* – fibroblasts; *4* – thick, disorganized bundles of collagen fibers in the reticular dermis; hematoxylin and eosin, ×200

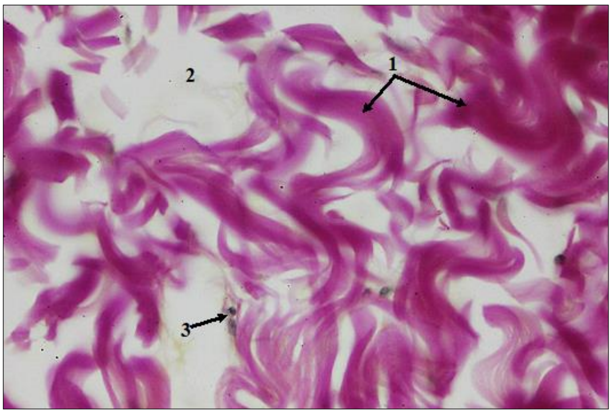

Fig. 4. Reticular layer of the dermis in a skin scar on day 13 of its formation: *1* – thick, disorganized bundles of collagen fibers; *2* – large interstitial spaces between collagen bundles; *3* – fibroblasts; hematoxylin and eosin, ×400

Fully developed hair follicles exhibited completely formed inner and outer root sheaths and hair bulbs, and the hair they produced contained medulla, cortex, and cuticle. However, the majority of hair follicles were still at various stages of development. Some consisted of clusters of proliferating cells of the follicle wall without any distinct layer differentiation. Even at this early stage of follicle formation, the follicular cells had already begun producing hair material in the form of an amorphous, shapeless, weakly eosinophilic substance.

By days 16–17 of scar formation, most hair follicles in the scar area, although not fully developed, were already producing hair. Nevertheless, the newly formed hair still differed significantly from intact hair (Fig. 6). By days 18–19 of observation, some of these newly formed hair shafts consisted of amorphous material, which stained fairly uniformly yellow. Newly formed sebaceous glands were also observed only adjacent to a few fully or partially developed hair follicles and were represented by small clusters of lipocytes without morphological signs of lipid secretion (Fig. 7).

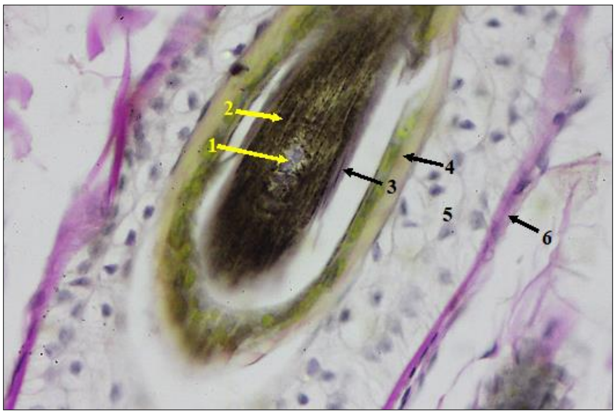

Fig. 5. Newly formed hair follicle in a skin scar on the 14th–15th day of its formation in a dog: *1* – medulla of the hair; *2* – cortex of the hair; *3* – cuticle of the hair; *4* – inner root sheath; *5* – outer root sheath; *6* – hair follicle sac; hematoxylin and eosin, ×400

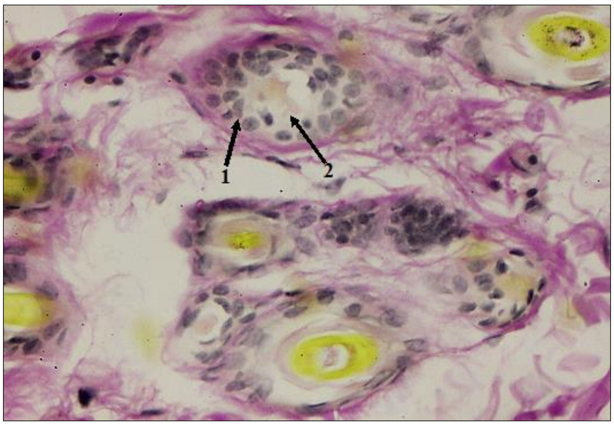

Fig. 6. Newly formed hair follicles in a skin scar on the 16th–17th day of its formation in a dog: *1* – formation of the hair follicle wall; *2* – onset of hair substance production; hematoxylin and eosin, ×200

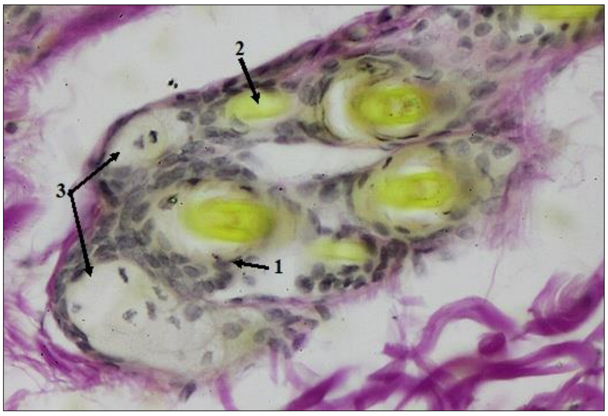

Fig. 7. Newly formed hair follicles in a skin scar on the 18th–19th day of its formation in a dog: *1* – formation of the hair follicle wall; *2* – onset of intensive hair substance production; *3* – formation of sebaceous glands; hematoxylin and eosin, ×200

By day 19, in some of these newly formed hair shafts, the cortical and medullary regions were already clearly differentiated, although they had not yet acquired the typical staining pattern characteristic of normal hair. Our studies also showed that regeneration of sweat and sebaceous glands on day 20 of skin scar formation lagged slightly behind the regeneration of hair follicles. Only in a few locations adjacent to some partially or fully developed hair follicles were partially formed sweat glands observed. These glands were covered by newly formed epithelium, which had not yet acquired the morphological structure typical of sweat gland epithelium in intact skin. This epithelium consisted of flat epithelial cells without morphological signs of secretory activity, and only in some newly formed sweat glands was the characteristic glandular lumen present (Fig. 8).

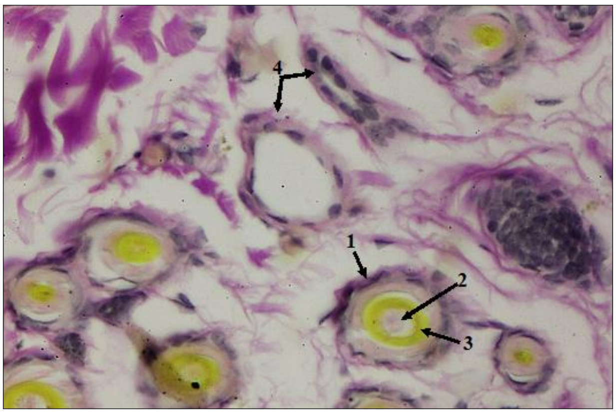

Fig. 8. Newly formed hair follicles in a skin scar on the 20th day of its formation: *1* – hair follicle wall in a dog; *2* – medulla of the hair; *3* – cortex of the hair; *4* – newly formed sweat glands; Hematoxylin and eosin, ×200

By day 21, the microscopic structure of the skin in the scar area was noticeably closer to that of intact skin. The skin surface no longer exhibited the long, sharp protrusions observed at earlier time points (Fig. 9).

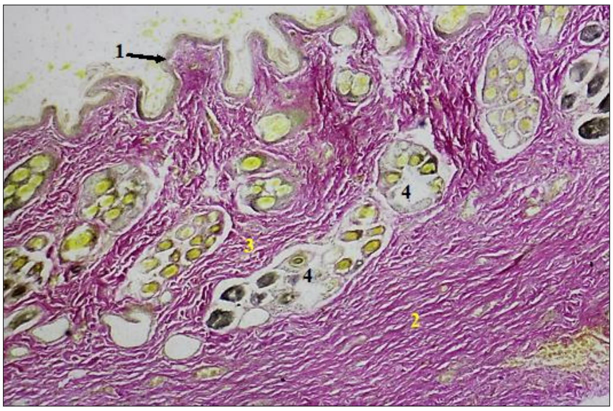

Fig. 9. Skin scar on the 21st day of its formation in a dog: *1* – epidermis; *2* – reticular layer of the dermis with orderly arranged collagen fiber bundles; *3* – reticular layer of the dermis with not fully orderly arranged collagen fiber bundles; *4* – skin appendages; hematoxylin and eosin, ×50

By day 22, the deeper region of the reticular dermis was already characterized by an ordered arrangement of thick collagen fiber bundles typical for this layer, although interstitial spaces were still present. A large number of fibroblasts was also observed in this region, indicating the continued formation of the dermal layer (Fig. 10).

By day 23 of observation, the papillary layer of the dermis was also microscopically closer to that of intact skin. It was represented by relatively thick bundles of collagen fibers, which were still not completely organized. The epidermis had also acquired a more mature microscopic structure. The basal, spinous, granular, and stratum corneum layers were already differentiated. However, the glossy layer of the epidermis was still present. The surface of the epidermis was covered with keratinized material, the composition of which was approaching that of intact skin, as the keratin had begun to stain red, although the intensity of this staining remained weak (Fig. 11).

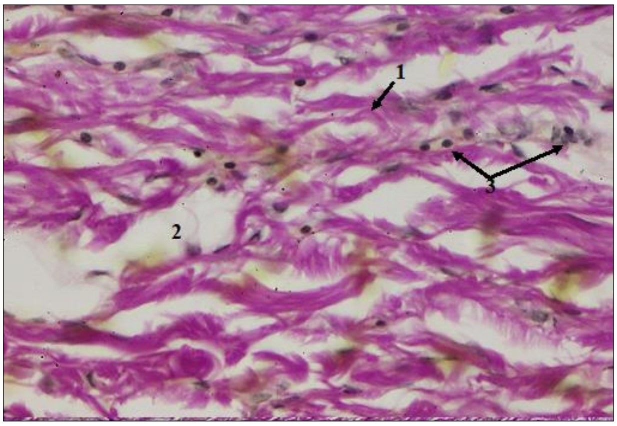

Fig. 10. A deeper area of the reticular layer of the skin scar on the 22nd day of its formation in a dog: *1* – thick, orderly arranged bundles of collagen fibers; *2* – spaces between collagen bundles; *3* – fibroblasts. Hematoxylin and eosin, ×400

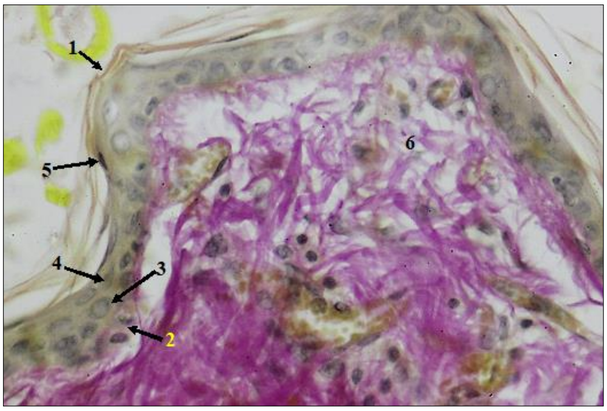

Fig. 11. Skin scar on the 23rd day of its formation in a dog: *1* – more mature stratum corneum; *2* – basal layer of the epidermis; *3* – spinous layer of the epidermis; *4* – granular layer of the epidermis; *5* – stratum corneum of the epidermis; *6* – reticular layer of the dermis; hematoxylin and eosin, ×200

By day 24 of scar tissue observation, approximately 50% of hair follicles had acquired their typical microscopic structure and were producing hair of typical microscopic appearance. Additionally, sweat glands with typical microscopic structure were formed in the scar area, producing the characteristic secretion of these glands (Fig. 12).

By day 25 of the study, sebaceous glands with fully developed, typical microscopic structure were observed in the scar (Fig. 13).

Thus, while on day 8 of observation, active formation of all skin layers and its appendages was observed in the scar, by day 25, the final stages of dermal and epidermal formation were recorded, with sweat and sebaceous glands fully formed and approximately 50% of hair follicles developed. A similar pattern of scar formation was observed in cats, although species-specific features of this process are determined by the timing of the inflammatory response, the formation of granulation tissue, and subsequent remodeling of injured tissues.

During ultrasonographic examination of dog scars to assess the diagnostic value of this method for wound healing dynamics, the following was established: on day 15 after injury, the superficial layer of the scar exhibited areas predominantly hypoechoic. In the middle layer of the scar, areas with hyperechoic structure were visualized (scar formation zone 8 mm). In the deeper layers of the scar, a nearly dynamic relationship of the examined regions in terms of echogenicity was observed, with a predominance of hypoechoic inclusions (Fig. 14).

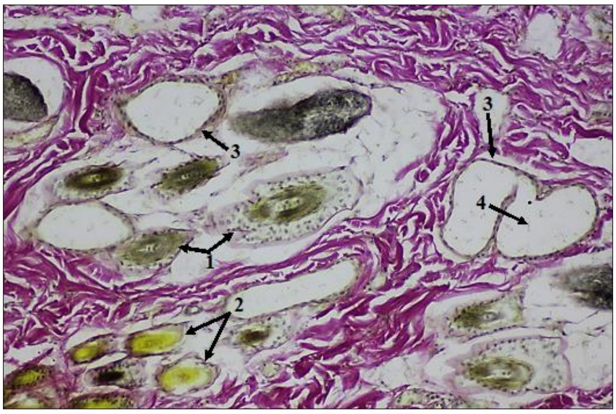

Fig. 12. Newly formed hair follicles in the skin scar on the 24th day of its formation in a dog: *1* – mature hair follicles; *2* – immature hair follicles; *3* – sweat gland; *4* – proteinaceous secretion in the lumen of the sweat gland; hematoxylin and eosin, ×400

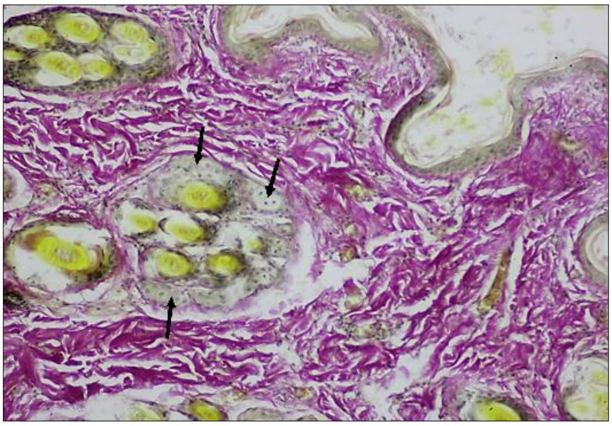

Fig. 13. Immature newly formed hair follicles in the skin scar on the 25th day of its formation in a dog; fully formed sebaceous glands; hematoxylin and eosin, ×200

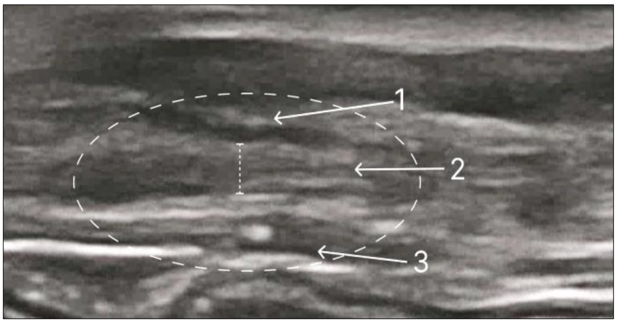

Fig. 14. Schematic representation of scar layers in the mesogastrium on the 15th day in a dog: *1* – superficial, *2* – middle, *3* – deep layers; ultrasound examination using Chison CBit 9 with a linear Chison probe (China)

By day 30 after the wound injury, the superficial layer of the scar predominantly exhibited hyperechoic areas. In the middle layer of the scar, regions with predominantly hypoechoic structure were visualized (scar formation zone 5.5 mm). In the deep layers of the scar, an almost dynamic distribution of the examined regions in terms of echogenicity was observed, with a predominance of hypoechoic inclusions (Fig. 15).

By day 45 after the wound injury, the superficial layer of the scar predominantly exhibited hyperechoic areas. In the middle zone, regions with predominantly hyperechoic structure were visualized (scar formation zone 3.5 mm). In the deep layers of the scar, an almost dynamic distribution of the examined regions in terms of echogenicity was observed, with a predominance of hypoechoic inclusions (Fig. 16).

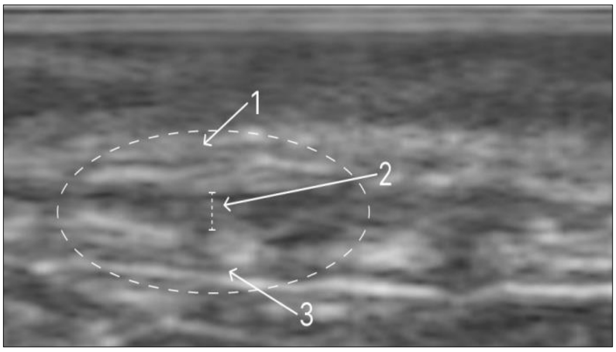

Fig. 15. Schematic representation of scar layers in the mesogastrium on the 30th day in a dog: *1* – superficial, *2* – middle, *3* – deep layers; ultrasound examination using Chison CBit 9 with a linear Chison probe (China)

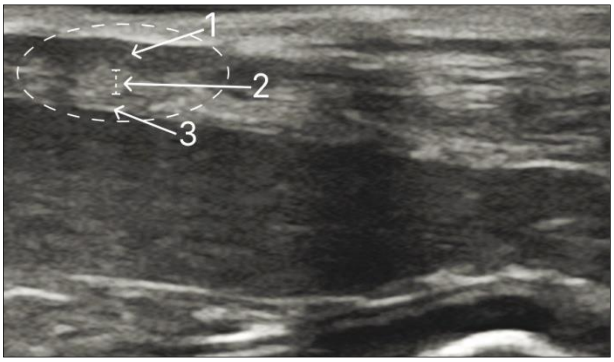

Fig. 16. Schematic representation of scar layers in the mesogastrium on the 45th day in a dog: *1* – superficial, *2* – middle, *3* – deep layers; ultrasound examination using Chison CBit 9 with a linear Chison probe (China)

By day 60 after the wound injury, the superficial layer of the scar predominantly exhibited hyperechoic areas. In the middle layer of the scar (scar formation zone), regions with predominantly hypoechoic structure were visualized (scar formation zone 2 mm). In the deep layers of the scar, the examined regions showed an almost equal distribution in terms of echogenicity, with a predominance of hypoechoic inclusions (Fig. 17).

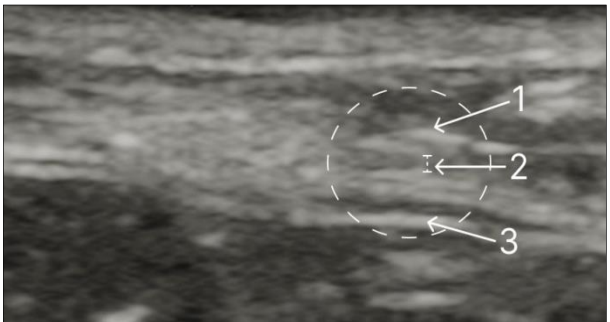

Fig. 17. Schematic representation of scar layers in the mesogastrium on the 60th day in a dog: *1* – superficial, *2* – middle, *3* – deep layers; ultrasound examination using Chison CBit 9 with a linear Chison probe (China)

Thus, ultrasonographic analysis demonstrated that the depth of scar formation decreases depending on the duration of the observation period. Wound healing in dogs and cats exhibits several interspecies differences related to the course of the inflammatory response, granulation tissue formation, and subsequent remodeling of injured tissues, as confirmed experimentally. In dogs, the inflammatory response is usually moderate and characterized by rapid neutrophil infiltration into the wound site, promoting effective wound cleansing and early transition to the proliferative phase. In cats, however, the inflammatory response is often less pronounced, and the onset of cellular infiltration occurs more slowly, which may delay subsequent stages of repair.

Granulation tissue formation in dogs proceeds relatively quickly and is accompanied by well-developed vascularization, ensuring adequate oxygen and nutrient supply. In cats, this process is slower, and neoangiogenesis is less intense, negatively affecting the rate of healing. Fibroblast activity in dogs is higher, contributing to rapid collagen synthesis and formation of the connective tissue matrix. In cats, fibroblast activity is reduced, and collagen fiber formation occurs more slowly.

Epithelialization of the wound surface proceeds relatively rapidly in dogs, whereas in cats it is significantly slower. During the remodeling phase, the skin scar in dogs forms and consolidates faster, shortening the overall wound healing time. In cats, however, the remodeling process is longer, and maturation of scar tissue occurs more slowly. Additionally, cats are more prone to purulent complications, likely due to poorer tissue vascularization and less effective local immune responses, whereas the risk of such complications in dogs is lower.

When examining dog and cat skin scars (Fig. 19) under ultraviolet light on day 14 of wound healing, we observed a phase of active scar remodeling with pronounced features of mature connective tissue, as evidenced by the moderate and dense organization of collagen fibers. It was shown that under ultraviolet irradiation, scar tissue generally does not exhibit pronounced fluorescence, likely due to the still relatively low collagen fiber content.

In Ukraine, as in other countries worldwide, the issue of protecting animals from cruelty and ensuring their welfare is highly relevant, as evidenced by both enacted legislation and numerous scientific publications (Patterson-Kane et al., 2022; Smith et al., 2022).

For the objective and unbiased clarification of facts and circumstances related to injuries of a violent nature, as well as in cases where injuries occur due to deficient veterinary care, law enforcement agencies and courts currently rely on specialized veterinary expertise in the form of forensic veterinary examination (Parry & Stoll, 2020; Piegari et al., 2024; Sinmez et al., 2024).

The most common manifestation of violent acts against animals is wound injuries of various origins, as confirmed by de Siqueira et al. (2016). Over the time following an animal injury, an important subject of forensic veterinary investigation is skin scars, which form during wound healing and have diagnostic value for determining the age of the injury (Mistry et al., 2022).

A variety of methods have been proposed for the assessment of skin scars, both for clinical purposes and for addressing forensic tasks (Kussie et al., 2024). However, these methods primarily concern laboratory animals used in experimental studies to clarify the characteristics of wound healing. Regarding the study of skin scars in productive and non-productive animals, such data are currently lacking in the scientific literature.

In the present study, the authors investigated the dynamics of skin scar formation in dogs and cats to address tasks in forensic veterinary examination, particularly for determining the age of inflicted wounds. During forensic veterinary examination of skin scars, we propose that their size should be assessed taking into account both area and volume. This includes specifying length, width at the middle of the scar, width at the ends, height above the skin surface or depth of indentation, as well as the thickness of the scar tissue.

It is also advisable to indicate the presence or absence of parallel scars in a given anatomical region (isolated injuries) and to describe the orientation of the longest dimension of the scar relative to the longitudinal axis of the body or using a clock-face orientation, distinguishing longitudinal, transverse, and oblique directions.

The condition of surrounding tissues should be described considering the presence or absence of edema, induration, hyperemia, atrophy, deformation, inflammatory changes, or pigmentation. Additionally, the state of tissues located deeper than the scar should be assessed separately. Tenderness of the scar should be evaluated while the animal is calm using palpation, noting its absence or intensity (mild, moderate, or pronounced).

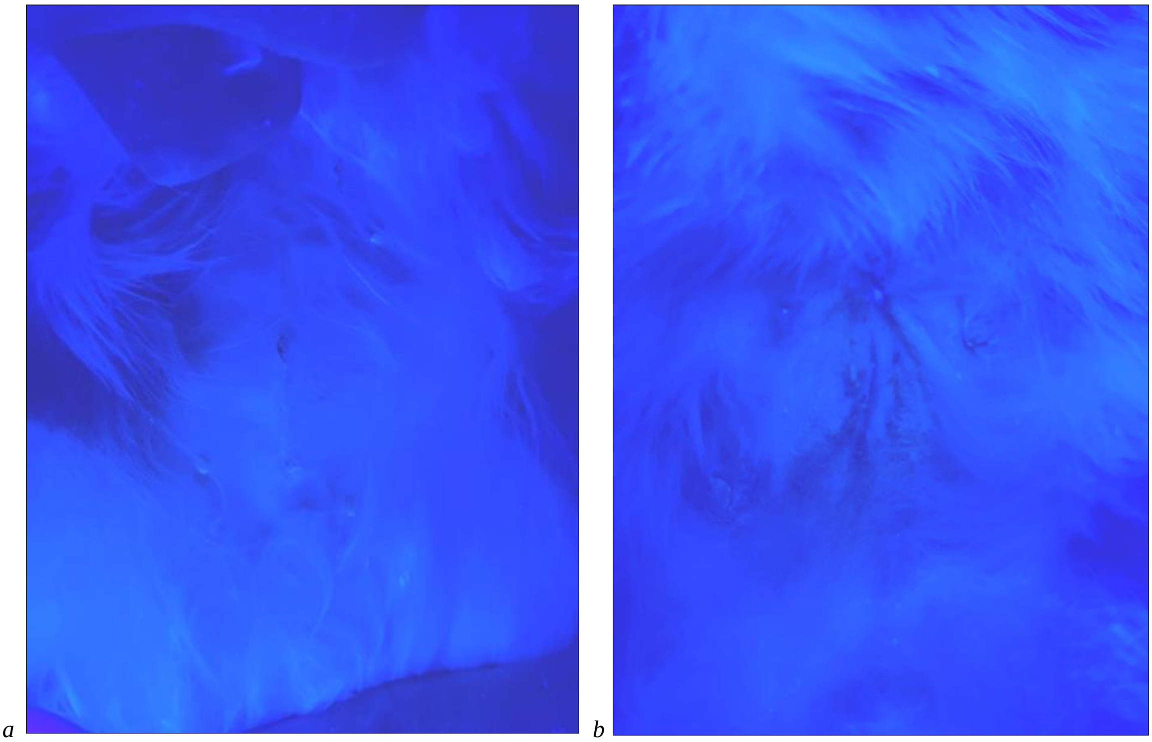

Fig. 18. Skin scar under ultraviolet light on the 14th day of observation: *a* – dog, *b* – cat

An important indicator for determining the post-traumatic period based on the condition of the skin scar is its vascular pattern. Therefore, it should be described in the superficial layers of the scar tissue, including the number of visible blood vessels, their location, distribution pattern, and degree of blood filling. Finally, changes in the projection of the scar should be characterized, including skin surface deformation, indentations, protrusions, displacement of anatomical landmarks, or alterations in the contours of adjacent areas.

The condition of tissues surrounding and located deeper than the skin scar should be assessed considering possible secondary changes, such as fibrosis, atrophy, sclerosis, or scar contractures. When multiple scars are present, their location and spatial relationships should be indicated (parallel, intersecting, non-intersecting, chaotically arranged, etc.).

Post-traumatic changes in deep tissues in the projection of the scar must be described, including damage to muscles, tendons, skeletal ligaments, and bones, with specification of the nature and degree of these changes. Based on these findings, the extent of morphological and functional impairments can be determined, including restriction of movement, reduction in contraction strength, and the severity of deformation or contracture.

Based on the results of instrumental and technical examinations, it is appropriate to determine the ultrasonographic characteristics of the scar, describing its thickness, structure, echogenicity, clarity of boundaries, and interaction with underlying tissue structures. The condition of the scar under ultraviolet radiation should be characterized, taking into account luminescence patterns or their absence. Capillaroscopy data of the skin scar should also be considered to evaluate the capillary network, its density, tortuosity, and level of microcirculation, which additionally helps determine the age of the scar. The authors have summarized and systematized the data regarding skin scar formation in dogs in Table 1. Thus, on the 8th day of observation, active processes of formation of all skin layers and its appendages were occurring in the scar; however, by the 25th day, the formation of the dermis and epidermis was completed. At this time, the sweat and sebaceous glands were fully formed, and approximately 50% of hair follicles were already developed.

We assert that skin scars in animals should be classified and described taking into account their localization, morphological, and functional characteristics as outlined above. Therefore, we present the authors' classification of skin scars based on the proposed 17 criteria.

Table 1
Dynamics of skin scar formation in dogs

Stage	Morphological characteristics of the scar
8 day	Microscopically, the scar is virtually indistinguishable from intact skin. In the dermal layer, directly beneath the epidermis, hair follicles with hair shafts, as well as sebaceous and sweat glands, are actively forming.
9 day	All elements of intact skin are preserved within the scar tissue, including the epidermis, dermis, and its appendages. The surface remains uneven. The epidermis is immature, lacking clear stratification and without formation of the stratum corneum. The reticular layer is only beginning to differentiate.
12 day	The collagen fibers of the papillary layer of the scar dermis are characterized by a loose and disorganized structure. A significant number of fibroblasts are observed in this layer.
13 day	The main portion of the dermis consists of a poorly developed reticular layer, in which loosely arranged, unevenly distributed, and disorganized thick bundles of collagen fibers with large inter-fiber spaces can be observed.
14–15 day	The restoration and increase in the number of hair follicles occur gradually. Some of them have already reached complete maturation, including fully formed hairs with hair follicles, inner and outer root sheaths, and the hair bulb. The hair shaft itself consists of the medulla, cortex, and cuticle. Most hair follicles are at various stages of development, while some appear as clusters of proliferating cells of the follicular wall without a distinct layer differentiation. Follicular cells begin to synthesize hair substance.
16–17 day	Most hair follicles within the scar area do not undergo complete development; however, they do produce hair that differs significantly from normal (healthy) hair.
18–19 day	Some hairs within the scar area appeared as amorphous, structureless masses. Newly formed sebaceous glands were observed adjacent to hair follicles in the form of clusters of lipocytes that did not exhibit morphological signs of lipid secretion. In certain hairs, the cortical and medullary layers could already be clearly distinguished; however, they lacked the characteristic pigmentation typical of healthy hair.
20 day	Regeneration of sweat and sebaceous glands was observed without evident morphological signs of secretory activity; in some cases, newly formed sweat glands exhibited a characteristic lumen. Regeneration of hair follicles was also noted.
21 day	The microscopic structure of the skin in the scar area is similar to that of intact skin. The skin surface remains smooth.
22 day	In the reticular layer of the dermis, thick bundles of collagen fibers are arranged in an orderly manner; however, interbundle spaces are still present.

Stage	Morphological characteristics of the scar
23 day	The papillary layer of the dermis in scars resembles that of intact skin in its microscopic structure and is composed of dense bundles of collagen fibers. The epidermis has formed the basal, spinous, granular, and cornified layers, although the lucidum layer is still present. The surface of the mature epidermis is covered with a stratum corneum, the composition of which is similar to that of intact skin.
24 day	Approximately 50% of hair follicles within the scar have already developed a typical structure and have begun producing hair. The formation of sweat glands with a characteristic morphology was also observed, and they were actively secreting.
25 day	The section revealed fully developed sweat and sebaceous glands with typical microscopic structure, as well as hair follicles.

Authors' classification of skin scars based on 17 criteria:

I. By localization (depending on the anatomical region of the body): skin scars of the head, muzzle, neck, trunk (anterior, posterior, lateral surfaces), thoracic and pelvic limbs with specification of surface (anterior, posterior, medial, lateral).

II. By the number of scars: single and multiple; isolated (limited to one anatomical area) and combined (located in different anatomical areas).

III. By the mutual arrangement of multiple scars: parallel; non-intersecting; intersecting.

IV. By relief: flat or raised scars.

V. By shape: round, oval, star-shaped, linear, or of undefined shape.

VI. By configuration: scars of regular or irregular configuration.

VII. By symmetry: symmetrical or asymmetrical (in the case of multiple scars).

VIII. By the nature of edges: scars with even or uneven, smooth or jagged, sharply defined or blurred edges.

IX. By the nature of ends: scars with pointed, rounded, widened, doubled ends, or gradually blending into surrounding skin.

X. By surface characteristics (relief): smooth, uneven, nodular, ridged, wavy, or folded.

XI. By surface transparency: shiny or matte scars.

XII. By elevation relative to surrounding skin:

– hypotrophic (below the skin level),

– normotrophic (at skin level),

– hypertrophic (above skin level),

– keloid scars (prominently raised above the skin and extending beyond the original wound). The degree of elevation or depression should be measured in millimeters.

XIII. By color: pink; red with bluish hue; red with violet hue; violet; red; pale pink with brown shades of varying intensity; pale with isolated brown areas.

XIV. By consistency: soft; uniformly dense; moderately dense; heterogeneous density; slightly dense; or loose.

XV. By mobility relative to underlying tissues: immobile, slightly mobile, moderately mobile, highly mobile.

XVI. By adhesion to underlying tissues: non-adherent, moderately adherent, tightly adherent. This affects scar mobility and functional properties.

XVII. By the prominence of vascular pattern: faint, moderate, or sharply defined vascularization.

Thus, applying the authors' classification of skin scars, the scar observed on the examined animal (Fig. 19) is characterized by the following features: isolated, localized on the right side of the thoracic wall, flat, linear, with regular configuration; with even, smooth, sharply defined edges; pointed ends; smooth and matte surface; normotrophic; pale pink in color; moderately dense consistency; without depressions; moderately mobile; moderately adherent to underlying tissues; with a faintly expressed vascular pattern.

Based on the results of this study, we propose supplementing the methodologies currently applied in forensic veterinary examination in Ukraine, specifically: "Methodology for forensic veterinary examination of animals to determine their mutilation", "Methodology for forensic veterinary examination of animal cadavers in various conditions and types of death", and "Methodology for forensic veterinary examination of a living examined animal" with the provisions described in this article.

Fig. 19. Skin scar in a dog

In summary, these scientific developments are expected to enhance the efficiency and effectiveness of forensic veterinary examinations. They will enable forensic experts to provide well-substantiated and objective conclusions, thereby strengthening the evidentiary value of such assessments in judicial proceedings.

Conclusions

Skin scars in dogs and cats are the result of a complex, multicomponent reparative regeneration process, which proceeds through clearly defined stages: inflammatory, proliferative, and remodeling. Each stage exhibits characteristic macroscopic, histological, and functional features, allowing scar tissue to serve as a reliable morphological indicator of the age and nature of traumatic injury in forensic veterinary practice.

A detailed macroscopic description of scars, taking into account their localization, shape, relief, color, size, consistency, mobility, and degree of adhesion to underlying tissues, has high diagnostic and expert value. Such assessment enables correlation of the morphological characteristics of a scar with the type of injuring instrument and the mechanism of injury.

Histological studies have demonstrated that, in the early post-injury period (days 8–12), intensive restoration of the dermis, epidermis, and skin appendages occurs in the scar area, with high fibroblast activity and formation of the collagen matrix. In the later stages (days 21–25), scar tissue acquires a microscopic structure closely resembling intact skin, allowing an objective evaluation of the stage and completion of the healing process.

Ultrasonographic examination of scars in dynamics is an effective non-invasive method for monitoring reparative processes, as it clearly reflects changes in scar tissue thickness, the spatial organization of its layers, and variations in echogenicity, which correlate with the degree of collagenization and scar remodeling at different stages of its formation.

Examination of skin scars under ultraviolet light, particularly on day 14 of healing, demonstrates that scar tissue is in the phase of active remodeling: despite the absence or weak fluorescence caused by still insufficient collagen accumulation, a dense and relatively organized arrangement of collagen bundles is already observed. This serves as an important additional criterion for assessing scar maturity and determining the timing of wound formation in dogs and cats.

The proposed authorial classification of skin scars based on 17 criteria (including localization, number, relative position of multiple scars, relief, shape, configuration, symmetry, character of edges and ends, surface topography, surface transparency, elevation of the scar surface above the skin, color, consistency, degree of scar retraction, mobility relative to underlying tissues, degree of adhesion to underlying tissues, and the expression of vascular pattern) forms the basis for forensic veterinary examination of skin scars in both live animals and animal cadavers. It enables the assessment of their impact on animal conformation and injury, as well as the formulation of a forensic veterinary diagnosis.

The proposed classification of skin scars is reasonably considered a foundation for the development of information technologies in forensic veterinary expertise. This applies both to live animals and cadavers with wound injuries caused by sharp instruments. The classification aims to automate the data processing workflow, thereby increasing the speed and efficiency of such examinations.

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