COMPLETENESS OF REGENERATION OF THE SKIN

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Healing of full-thickness skin wounds was studied in carnivores: cats, foxes, and arctic foxes. Square wounds, initially measuring on average 2.2 cm^2, were inflicted on the back and head of the cats and on the thigh of the foxes and arctic foxes. Closure of the skin defect in all species of animals was found to take place mainly through contraction of the wound. The small focus of regeneration formed in the center of the initial defect closely resembled in many of its features the structure of normal skin: it contained hairs and sebaceous glands, and its connective-tissue basis resembled dermis in the arrangement of its fibers.
KEY WORDS: *healing of skin wounds; wound contraction; carnivores; skin structures.*

The view is widely held that the healing of full-thickness skin wounds in mammals ends with the formation of a connective-tissue scar. This view is evidently explained by the fact that the great majority of investigations of the completeness of skin regeneration have been carried out with the dorsal skin of rats, where a scar forms as a result of healing of full-thickness wounds [3-5].

It has recently been found that the healing of full-thickness skin wounds in mammals, including rats, does not always end with the formation of a scar. In some cases foci of regeneration, approximating intact skin in their structure, are formed at the site of a defect from the young tissues filling the wound. Completeness of restoration has been found to depend on the species of animal and the site of the defect [1-3, 6]. In rats, for instance, during healing of skin wounds on the sole and tail, foci of regeneration that differ from a scar in certain features are formed.

However, until recently the overwhelming majority of investigations into the completeness of skin regeneration had been carried out on rodents and virtually none on representatives of other orders of mammals. It was decided to study the completeness of regeneration of the skin in carnivores, namely cats, foxes, and artic foxes.

EXPERIMENTAL METHOD

Males were always used for the experiments. Full thickness square wounds, initially measuring on average 2.2 cm^2, down to the muscular fascia, were inflicted in 11 cats on the skin covering the vault of the skull, in 12 cats on the skin of the back, and in 5 arctic foxes and 6 ordinary foxes on the skin of the medial surface of the right thigh. To study the course of wound contraction and, in the later stages of healing, to determine the location of the defect, the edges of the wound defects were marked with ink. In the cats 12, 22, 42, and 90 days after the operation, and in the foxes and arctic foxes 12, 22, and 42 days after the operation, pieces of tissue were taken from the region of the wound and the adjacent areas of intact skin for histological analysis. Sections 7-9 μ thick were stained with hematoxylin-eosin.

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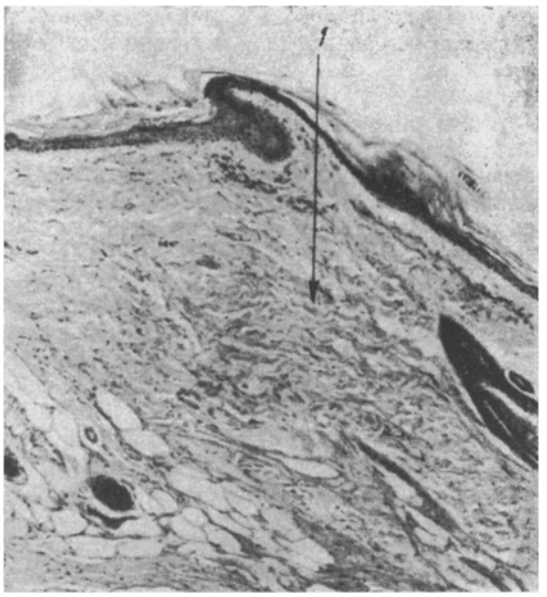

Fig. 1. Vertical section through regenerating skin on thigh of an artic fox 42 days after operation: 1) connective-tissue basis of focus of regeneration. Here and in Figs. 2 and 3: hematoxylin-eosin, 70×.

EXPERIMENTAL RESULTS

Wound healing in the cats, foxes, and arctic foxes took place under a thick scab. Complete epithelization of the wound defects in all three species of animals occurred on the 10th-12th day after the operation. The area of the epithelized surface of the defect was on average 46% of the area of the initial wound on the cats' head and 39% on their back, 32% on the thigh of the arctic foxes, and 29% on the thigh of the ordinary foxes. Later the area of the epithelized surface decreased in size so that by the 45th day after the operation it was equal to 9% of the initial area of the wound on the cats' head, 12% on their back, 12% on the thigh of the arctic foxes, and 8% on the thigh of the ordinary foxes.

Consequently, in all species of animals studied the area of the wound defect decreased sharply after its complete epithelization. Several pigmented hairs were found 45 days after the operation on the cats' back in the peripheral part of the epithelized surface of the defect, and over the whole surface of the defect on the cats' head and on the thigh of the foxes and arctic foxes.

The results of the histological investigations showed that 12 days after the operation young epithelium covering the defect in all species of animals was hypertrophied and did not form invaginations into the underlying young granulation tissue. Epithelium covering the wound defect on the cats' head was particularly hypertrophied. In some places it was twice as thick as the intact epithelium. At this time the young connective tissue consisted of thin fibrils and cells. The fibrous structures were interwoven, but on the whole they were oriented mainly parallel to the surface of the defect. The young connective tissue of all the animals 22 days after the operation consisted mainly of fibrous structures. The young epithelium on the thigh of the foxes and on the cats' head over the whole surface of the defect, and in the peripheral part of the defect on the thigh of the arctic foxes and on the cats' back formed invaginations into the underlying young connective tissue. It is considered that later hairs and sebaceous glands were formed in the focus of regeneration from some of these invaginations.

The process of repair on the thigh of the foxes and arctic foxes and on the cats' back was virtually complete 42 days after the operation. The thickness of the young epithelium covering the focus of regeneration was not more than the thickness of normal epithelium. The regenerating epithelium did not form any more invaginations into the underlying young connective tissue. The connective-tissue basis of the extremely small focus of regeneration resembled normal dermis in the arrangement of its fibrous structures. The newly formed focus of regeneration differed from normal dermis in the arrangement and number of the hair follicles or in their absence (Fig. 1). As a rule single hair follicles were found in the focus of regeneration, in conjunction with sebaceous glands, although these were not formed into skin complexes.

As this period, the process of repair in skin defects on the cats' head was not yet complete. The young epithelium was still hypertrophied and formed invaginations into the young connective tissue of the focus of regeneration over the whole surface of the defect. Hairs and sebaceous glands were formed from these invaginations in the peripheral part of the focus of regeneration (Fig. 2). Cells were still very numerous in the connective-tissue basis of the focus of regeneration compared with the intact dermis.

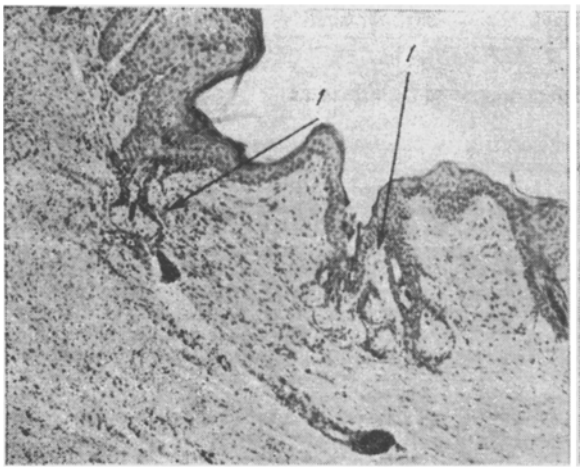

Fig. 2

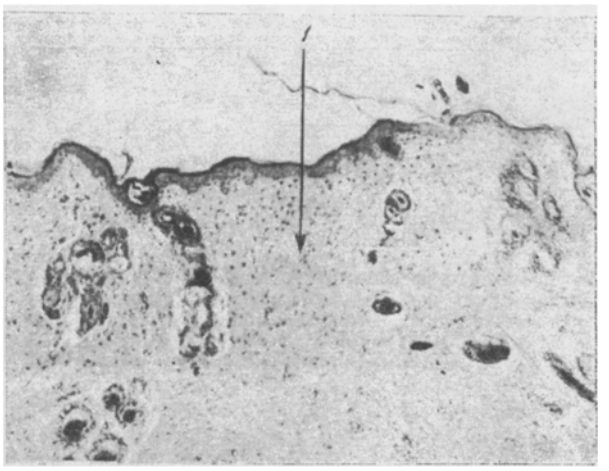

Fig. 3

Fig. 2. Vertical section through regenerating skin on cat's head 42 days after operation: 1) hair follicles.

Fig. 3. Vertical section through regenerating skin on cat's head 90 days after operation: 1) connective-tissue basis of regenerating skin.

Not until 90 days after the operation was the process of repair of skin wounds on the cats' head complete. The thickness of the young epithelium was similar to that of intact epithelium. The young epithelium did not form invaginations into the underlying connective tissue. The connective-tissue basis of the focus of regeneration resembled intact dermis in the arrangement of its fibrous structures (Fig. 3). In one of the four cats over the whole extent of the focus of regeneration, and in three cats in its peripheral part only, hair follicles were found.

Hence in carnivores — cats, arctic foxes, and ordinary foxes — closure of a full-thickness skin wound takes place mainly through contraction of the wound. The area of the focus of regeneration resembles that of normal skin: Hairs and sebaceous glands are found in it and the connective-tissue basis of the focus of regeneration resembles intact dermis in the arrangement of its fibrous structures.

It must be pointed out that the hair follicles found in the focus of regeneration were evidently of different origin. They could have been follicles arising from remnants of "old" follicles destroyed at the operation, or follicles formed from the regenerating epithelium and underlying young connective tissue. An area of intact dermis with "old" follicles could be incorporated into the upper layers of the focus of regeneration as the result of wound contraction.

These results confirm the hypothesis expressed above regarding the considerable variation in the process of healing of full-thickness skin wounds depending on the species of the animal. Variations in the completeness of regeneration are particularly clearly seen. Foci of regeneration formed at the site of full-thickness skin defects can vary very widely in structure depending on the species of animal and the site of the defect: from a focus of regeneration consisting of a connective-tissue scar, covered by epithelium above, to a focus similar in many features to intact skin.

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