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REGENERATION OF THE PLANTAR SKIN IN MAMMALS

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Two posterior plantar pads together with the surrounding skin were removed from the hind limb in rats, and one plantar pad each without the surrounding skin was removed from the hind and fore limbs of hedgehogs. As a result of healing of the skin wounds in the rats and hedgehogs, areas of regeneration were formed with the typical stratum papillare of plantar skin. In hedgehogs the regenerating skin covered the restored plantar pad. In rats the plantar pads were not restored.

KEY WORDS: plantar pads; regenerating plantar skin; dermal papillae.

The stratum papillare of the dermis is well defined in the plantar skin of mammalian limbs, with the result that the stratum basale of the epithelium, which ultimately forms the thick stratum corneum, is greatly enlarged in area. This type of structure of the plantar skin is undoubtedly adaptive in character, for the thick stratum corneum gives the skin reliable protection against the mechanical action to which it is often exposed and enables it to cope with its increased load.

In many mammals plantar pads covered with skin with a characteristic stratum papillare are present on the sole of the foot. There are indications that these plantar pads in rats can regenerate completely [1]. The author cited removed all six plantar pads from the hind limb of rats together with the surrounding skin and observed regeneration of pads with the typical shape. Under different experimental conditions, when the pads were removed without the surrounding skin, they did not regenerate so well. However, this worker does not give an account of a histological analysis of regeneration of the pads in its successive stages and draws his conclusions mainly from visual observations.

So far in mammals regeneration of the skin with regular restoration of its specific structures (hair and sebaceous glands) has been observed only after full-thickness skin wounds on the concha auriculae in rabbits and on the horns of stags [2-5].

The object of this investigation was to discover whether regeneration of the skin with its characteristic features can take place on the sole in mammals and to determine the conditions under which regeneration of the plantar pads is possible.

EXPERIMENTAL METHOD

Experiments were carried out on 52 noninbred male albino rats weighing 120-150 g and on eight European hedgehogs (Erinaceus europaeus) weighing 550-720 g (two females and six males).

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Fig. 1. Vertical section through area of wound defect in rat 10 days after operation: 1) projections of young epithelium. Hematoxylin–eosin, 120×.

Two posterior plantar pads together with the surrounding skin were removed from the left hind limb of the rats. The edges of the wound defect were marked with ink. One plantar pad, without the surrounding skin, was removed from the left hind limb and one from the right forelimb of the hedgehogs. The areas of the wound defects in the rats were measured immediately after the operation and at successive times during healing (on the 5th, 10th, 24th, 30th, 60th, and 105th days), and in the hedgehogs on the 5th, 10th, and 30th days. Pieces of tissue were taken for histological analysis from the region of the defect and the adjacent areas of intact skin of the rats on the 5th, 10th, 24th, 30th, 60th, and 105th days after the operation, and in hedgehogs on the 10th and 30th days. The material was fixed in 12% formalin, taken through celloidin, and embedded in paraffin wax. Histological sections 7-9 μ thick were stained with hematoxylin–eosin.

EXPERIMENTAL RESULTS

In all the animals the wounds healed beneath a scab. Immediately after infliction the mean area of the wounds in the rats was 0.76 cm^2. Epithelization of the defect was complete on the 10th-12th day, by which time the area of the epithelized surface of the wound defect averaged 0.72 cm^2, i.e., it was virtually unchanged. By the 30th day after the operation the area of the epithelized surface of the defect was 0.59 cm^2, after which no further reduction took place. At this time the wound surface was nodular and projected above the surface of the surrounding skin. This projection resembled visually a plantar pad. On the 60th day after the operation the nodular appearance in the region of the defect disappeared and the epithelized surface of the wound defect no longer projected above the surface of the surrounding skin. Restoration of the plantar pads was not observed in this experiment.

In hedgehogs the mean area of the initial defect of the forelimb was 0.26 cm^2 and on the hind limb 0.35 cm^2. Complete epithelization of the wound defect occurred on the 10th day after the operation. No decrease in area of the wounds was observed. Regeneration of the plantar pads was found 30 days after the operation, and their original shape (rectangular, circular, etc.) was restored in every case. However, the regenerating pads differed from the intact in their lighter color, which was evidently due to the fact that the new pads contained fewer pigment cells.

Histological investigation showed that in rats 5 days after wounding about one third of the surface of the defect was already covered by young epithelium. It formed long projections into the underlying young connective tissue, which consisted mainly of cells and thin fibrils. The epithelial projections varied in shape and

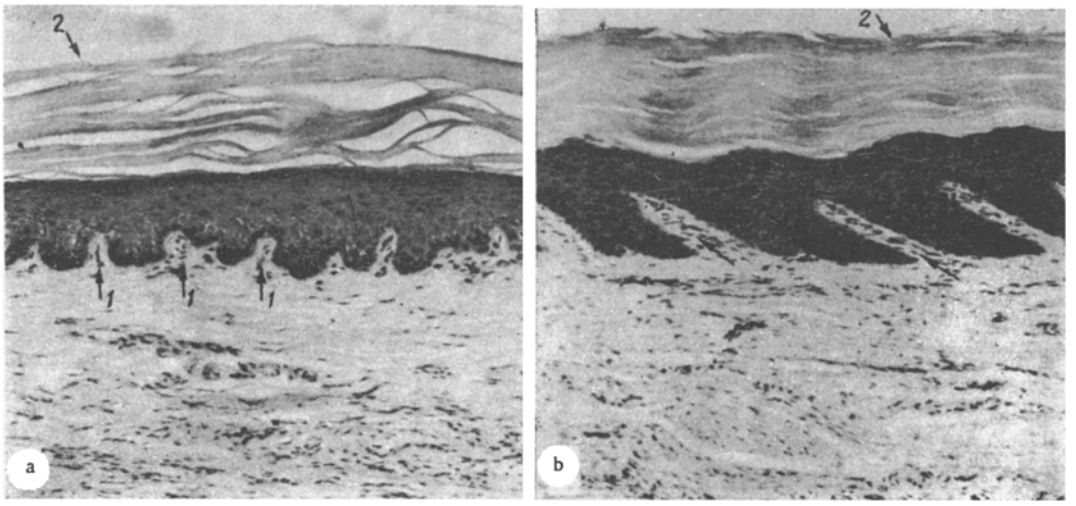

Fig. 2. Vertical section through region of intact skin (a) and through area of regenerating skin of rat 105 days after operation (b): 1) connective-tissue papilla; 2) stratum corneum of epithelium. Hematoxylin–eosin, 120×.

size and they grew larger as the distance increased from the wedge of growth of the epithelium. A large part of the epithelial layer was covered by stratum corneum. In most animals epithelization of the defect was complete 10 days after the operation. Young epithelium formed projections into the underlying young connective tissue. The epithelial projections attained a length of 660 μ and most of them lay at a certain angle to the surface of the defect (Fig. 1). At the site of the wound defect an area of regeneration in which a stratum papillare was observed had formed 24 h after the operation. The mean length of the connective-tissue papillae was 32 μ and the thickness of the epithelium between the connective-tissue papillae was 103 μ. In the intact epithelium at this time the mean length of the connective-tissue papillae was 36 μ and the thickness of the epithelium between the papillae was 82 μ. The connective-tissue basis of the regenerating epithelium consisted mainly of fibers arranged chiefly parallel to the surface of the defect, and of fibroblasts. The thickness of the connective-tissue basis of the regenerating epithelium was 36% greater than the thickness of the intact dermis. No significant changes in the structure of the regenerating tissues were observed 30 and 60 days after the operation. However, after 60 days the thickness of the connective-tissue basis of the regenerating skin was already close to the thickness of the intact dermis.

The stratum papillare was well defined in the regenerating skin 105 days after the operation, just as previously. The mean length of the connective-tissue papillae was 77 μ and the thickness of the epithelium between the papillae was 168 μ. The length of the connective-tissue papillae in the intact plantar skin was 35 μ and the thickness of the epithelium between the papillae was 138 μ. The mean thickness of the epithelium in the experimental series was 118 μ and in the intact skin 88 μ; just as at the previous times of the investigation the epithelium was covered by a thick stratum corneum. The connective-tissue papillae of the regenerating skin lay at an angle to its surface, whereas in the intact skin they lay mainly perpendicularly to the skin surface. The connective-tissue basis of the regenerating skin resembled the connective-tissue basis of the intact skin in its structure: The fibrous structures in both the control and the experimental series lay chiefly parallel to the skin surface, but they were interwoven. However, the fibers in the regenerating zone were more crowded than in the intact dermis (Fig. 2).

In the hedgehogs epithelization of the wound was complete after 10 days. The epithelium covering the wound defect formed projections into the young connective tissue. The length of the projections in the regenerating area of the forelimbs reached 670 μ and on the hind limbs 820 μ.

The structure of the regenerating tissue 30 days after the operation resembled that of the intact skin covering the plantar pad. A stratum papillare was present in the regenerating zone. The length of the connective-tissue papilla in the regenerating zone of the forelimbs was 280 μ and on the hind limbs 390 μ; in the intact skin on the forelimbs the mean length of the papillae was 210 μ and on the hind limbs 270 μ. The thickness of the epithelium in the regenerating zones on the forelimbs was 340 μ and on the hind limbs 460 μ; in the intact skin on the forelimbs the thickness of the epithelium on the plantar pads was 270 μ and on the hind limbs 410 μ. In the stratum basale of the epithelium pigmented cells were found both normally and in the experimental

Fig. 3. Vertical section through area of regenerating skin of a hedgehog 30 days after operation: 1) connective-tissue papilla; 2) duct of tubular gland. Homatoxylin–eosin, 75×.

series. Both in the experimental and control series the epithelium was covered by a well-developed stratum corneum, the thickness of which in the regenerating zones of the forelimbs was 124 μ and of the hind limbs 250 μ; in the skin of the intact pads the thickness of the stratum corneum on the forelimbs was 92 and on the hind limbs 189. Ducts of tubular glands were found in the connective-tissue basis of the regenerating zone. In the central part of the connective-tissue basis of the regenerating zone small condensations of connective tissue were observed in which the fibers were arranged parallel to the regenerating surface (Fig. 3).

At the site of the skin defect on the sole of the foot in rats a regenerating zone similar in structure to the intact skin of the same region is thus formed: The specific epithelium is restored with a thick stratum corneum and a characteristic stratum papillare. However, no plantar pads appear in the zone of injury.

In hedgehogs, as in rats, a zone of regeneration is formed at the site of a skin wound with a typical layer of epithelium, covered by a well-developed stratum corneum, and with the characteristic stratum papillare for this region of the skin. In this experiment regenerating skin covered a regenerating plantar pad.

It should be noted that the regenerating epithelium in animals of both species was thicker than the intact epithelium for a long time.

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