COMPLETENESS OF REGENERATION DURING HEALING OF SKIN WOUNDS IN BIRDS

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Healing of full-thickness skin defects in pigeons is characterized by marked contraction of the wound followed by an increase in the area of the epithelized surface of the regenerating skin. The regenerating skin differs from normal in the same part of the pigeon's body by the absence of complex folds and of feathers.

Few detailed studies have been made of the healing of skin wounds in birds [1, 2, 4, 5]. The workers cited consider that as a result of the healing of full-thickness skin wounds in birds a scar is formed, which subsequently becomes converted into skin which is typical of the skin found in that part of the animal's body.

In an investigation on hens [3], the writer showed that the young connective tissue produced at the site of the defect is converted into regenerating skin, in which skin folds typical of the normal skin of that area subsequently appear. In other words, in this case healing of full-thickness skin wounds takes place without a scar.

Because of the contradictory conclusions which have been reached concerning the completeness of regeneration of the skin in birds, it was decided to continue these investigations in order to study the healing of skin wounds in these warm-blooded animals. The objective of the present investigation was to study the healing of full-thickness skin wounds in pigeons.

EXPERIMENTAL METHOD

Experiments were carried out on 36 pigeons (Columba livia) weighing 260-290 g. Square flaps of skin of full thickness and measuring 1×1 cm were removed from all the birds beneath the right wing at its base. Before the operation, the feathers were plucked from the birds around the site of the future defect, and the skin was marked with ink to within 0.5-1 mm from the edge of the wound; the ink was introduced into the dermis by two soldered needles. The five control pigeons were labeled in the same way, but no skin defect was produced. The areas of the defects were measured at successive times during healing: 0, 5, 7, 11, 18, 24, 28, 40, and 90 days after the operation. Pieces of tissue were taken for histological analysis from the region of the defect and the adjacent areas of intact skin 7, 11, 18, 24, 40, and 90 days after the operation.

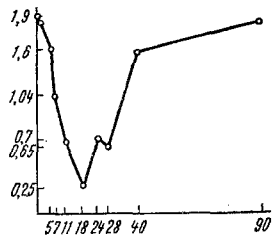

Fig. 1. Graph showing contraction of skin defect. Abscissa, area (in cm^2); ordinate, time after operation (days).

The material was fixed in 12% formalin solution, taken through celloidin, and embedded in paraffin wax; sections 7-9 μ in thickness were stained with hematoxylin-eosin and with orcein.

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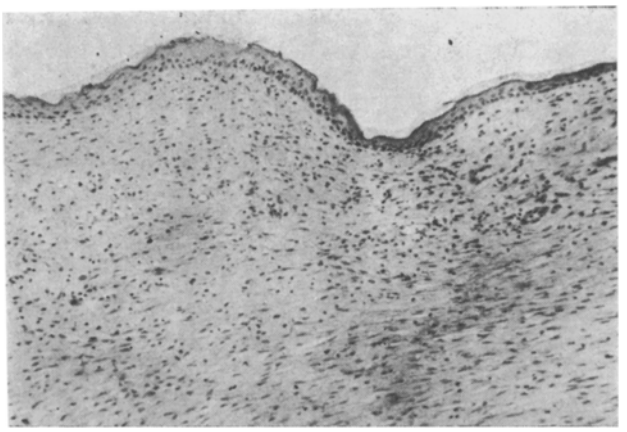

Fig. 2. Vertical section through pigeon's skin in region of wound defect 18 days after operation. Formalin. Hematoxylin-eosin, 160×.

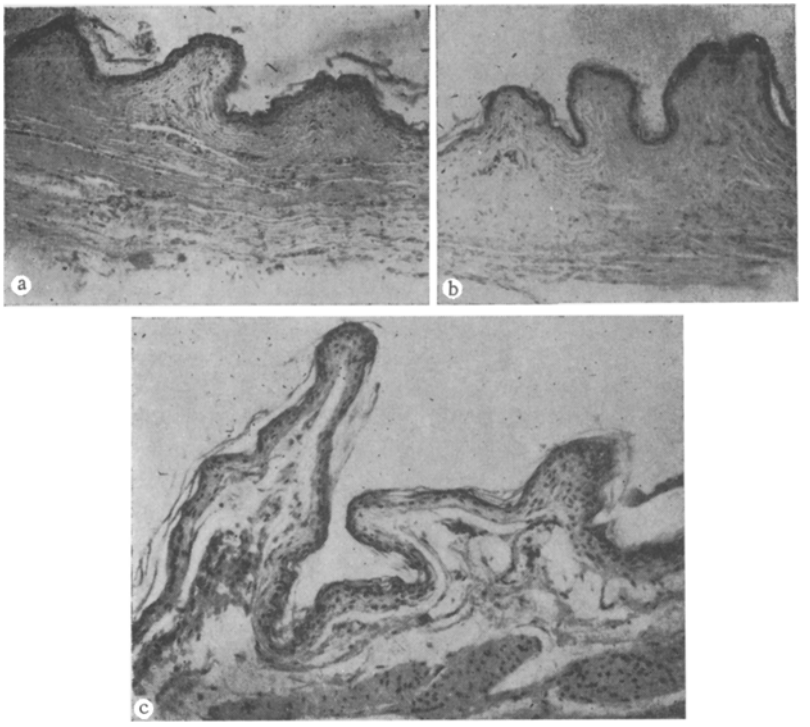

Fig. 3. Vertical section through regenerating and normal pigeon's skin: a) folds of regenerating skin; b, c) folds of normal skin. Formalin. Hematoxylin-eosin, 90×.

EXPERIMENTAL RESULTS

The wounds healed beneath a scab. Immediately after formation of the defect the area of the wounds was on the average 1.9 cm^2. By the 7th day after the operation the wound had contracted and the mean area was 1.04 cm^2. By this time two-thirds of the surface of the defect had been epithelized. By the 11th day the mean area of the defect was 0.7 cm^2. At this time the whole surface of the defect was epithelized. By the 18th day the mean area of the defect was 0.25 cm^2. At the subsequent time the area of the epithelized surface of the defect gradually increased, so that by the 40th day it averaged 1.6 cm^2, and by the 90th day 1.8 cm^2 (Fig. 1), i.e., the area of the epithelized surface of the defect had practically reached the area of the original defect (the ink marks at these times were 1-1.5 mm away from the edge of the epithelized wound surface). However, in the control animals, which had not been wounded, the area included between the ink mark averaged 2.5 cm^2. The original area included between the ink marks was 1.2 cm^2. The increase in area was thus due to growth of the animal.

Histological examination showed that 7 days after the operation the epithelium covering the peripheral part of the defect was hypertrophied, and consisted of 7 or 8 layers of cells with progressive keratinization of the successive layers. The mean thickness of the epithelium was 62 μ. Beneath the epithelium was a layer of loose, young connective tissue, consisting mainly of cells and thin fibrils. Many thin-walled, dilated vessels, filled with red blood cells, were seen in the young connective tissue. The mean thickness of the young connective tissue was 810 μ.

After 11 days the epithelium covering the central part of the defect consisted of 8 or 9 layers of cells, with a mean thickness of 67 μ. The epithelium covering the peripheral part of the defect consisted of five or six layers of cells and its thickness was 52 μ. The thickness of the young connective tissue had increased to 1230 μ.

By the 18th day after the operation the epithelium covering the central part of the defect was hypertrophied still. It consisted of 7 or 8 layers of cells and its thickness was 65 μ, while in the peripheral parts the epithelium consisted of three or four layers of cells, with a thickness of 43 μ. The mean thickness of the young connective tissue was 1820 μ. In the central, upper part of the defect the connective tissue was still loose, but in the peripheral and deep parts of the dermis it was denser and consisted of thin fibrils and cells. Blood vessels, arranged mainly vertically relative to the surface of the defect, could be seen. They were fewer in number than at the preceding times.

The epithelium covering the peripheral part of the defect 24 days after the operation consisted of three or four layers of cells, and its mean thickness was 33 μ. The thickness of the young connective tissue was slightly smaller, averaging 1350 μ. Forty days after the operation, the epithelium was almost normal in appearance and consisted of three or four layers of cells, 20 μ in thickness. The mean thickness of the young connective tissue was 500 μ. It was densely fibrous in consistency. The fibers were arranged mainly parallel to the surface of the defect. Many cells could be seen between them. Small folds, averaging 180 μ in height, now appeared. They consisted of outgrowths of the newly formed dermis, covered by epithelium. In other words, regenerating skin had been formed at the site of the defect.

Three months after the operation the epithelium covering the regenerating skin was indistinguishable from normal epithelium; its mean thickness was 19 μ, and it consisted of three or four layers of cells. The cells were elongated, and their long axis was parallel to the surface of the defect. The mean thickness of the connective-tissue basis of the regenerating skin was 250 μ (the thickness of the connective-tissue basis of normal pigeon's skin was 310 μ). An elastic lamina had appeared. Over the whole extent of the regenerating skin, folds were now visible, varying from 90 to 220 μ in height. The structure of the regenerating skin was now beginning to resemble that of the normal skin of a pigeon of the same age. However, the normal pigeon's skin was more folded, and in vertical sections through it, besides the small and single folds, complex branching folds could also be seen, ranging in height from 80 to 450 μ (Figs. 2 and 3). Only a few small single, or sometimes double, folds were formed in the regenerating skin, and feathers never were observed.

Hence, regenerating of the skin in pigeons is similar in course to regeneration of the skin in hens [3]. The skin defect is closed mainly by contraction of the wound. At the time of complete epithelization of the defect, the wound is filled with young connective tissue, many times thicker than the normal corium. With time, the thickness of the young connective tissue, which becomes densely fibrous in appearance, is reduced, and it is gradually converted into regenerated skin, which increases in area throughout a long period of observation. The structure of the regenerating skin resembles that of the skin of normal animals of the same age, although it does not form the complex folds and no feathers are present. It can be postulated that these principles of healing of skin wounds in hens and pigeons also extend to other species of birds.

LITERATURE CITED

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