HISTOLOGICAL INVESTIGATION OF THE RESULTS OF TENDON REPAIR IN RABBITS USING VARIOUS PLASTIC MATERIALS

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The problem of the plastic repair of tendon defects is of great theoretical and practical interest. One of the main factors towards finding a successful solution of this problem is the choice of the most suitable raw material for the tendon graft. As yet there is no unanimity on this question. There are differences of opinion on the value of the simplest method of repair of a tendon defect, the alloplastic. There is no full agreement over comparison of the results of autoplastic repair of tendon defects with strips of fascia and tendon autografts, nor over the use of homografts for this purpose.

EXPERIMENTAL METHOD

Experiments were carried out on rabbits in which a defect in the tendo Achillis was repaired in four ways (see Table).

The tendo Achillis was exposed in the rabbits and from it was resected a piece about 2 cm long, after which the resulting defect was repaired with various plastic materials. In the first series of experiments silk thread was used for this purpose and was stretched between the ends of the tendon with known tension. In the 2nd series a defect of the same size was repaired with a homoplastic graft (2 cm long) from a rabbit. In the 3rd series the defect was repaired with strips of fascia lata from the thigh of the same animal, which was folded into a sleeve and sutured to the ends of the resected tendon. In the 4th series the defect was repaired with a tendon autograft taken from the other limb of the same rabbit. In all cases the grafts were sutured to the ends of the resected tendon by a Cuneo suture with fine (No. 0) silk. After suture of the tendon, the sheath was carefully sutured with fine continuous catgut. The skin was then sutured and the limb immobilized in a plaster of Paris cast for 14 days. Material taken for histological examination in all the experiments was fixed in 20% formalin (8% formaldehyde), cut on a freezing microtome and only partially embedded in paraffin wax. Sections were stained with hematoxylin-eosin.

EXPERIMENTAL RESULTS

From an analysis of the macro- and microscopic data from the experiments in which the tendon defect was repaired with silk thread, we observed that regeneration of connective tissue occurred along the course of the thread and on the 46th day it had reached 2 mm to become a thin band of scar tissue, adherent to the skin throughout its length; the same picture was observed at later periods — after 4-4½ months.

In our experiments we found degenerative changes in the region of the tendon ends joined by the silk thread. These changes took the form of obliteration of the structure of the collagen bundles and death of the tendon cells. Around the tendon stump and along the course of the silk thread there was new formation of dense fibrous connective tissue with very fine primary collagenous bundles arranged longitudinally and a large number of cells. The silk thread occupied an eccentric position in the regerating tissue and was infiltrated with leucocytes. In places in the dense connective tissue in the area of regeneration there were layers of loose connective tissue.

Number of Experiments and Periods of Observation

Series	Method of repair of defect	No. of experiments	Period of observation (number of days)
1	Silk thread	7	46-220
2	Tendon homograft	12	4-30
3	Fascial autograft	9	22-270
4	Tendon autograft	32	4-360
	Total	60	-

At later periods (after 4-6 months) the newly formed dense connective tissue situated along the course of the silk thread now resembled tendon tissue in its fine structure; on longitudinal and transverse sections the division of this tissue into primary and secondary bundles was clearly seen. Between the primary bundles were arranged cells with elongated nuclei, and between the secondary — layers of loose connective tissue containing blood vessels, nevertheless the structural resemblance found between this regenerating scar tissue and normal tendon (which agrees with the findings of G. M. Voronina and A. M. Gratsianskaya [2]) is still no argument in favor of the success of this method because the scar is unsatisfactory as an organ and it has extensive adhesions to the skin and surrounding tissues.

In cases where tendon homografts were used, at quite early stages rarefaction of the grafts was observed followed by complete degeneration and disintegration in the majority of cases. One third of our cases showed a relatively satisfactory preservation of the tendon graft. The degree of preservation of the homografts presumably depended on the biological nearness of the donor to the recipient. With a less pronounced immune reaction on the part of the recipient, degeneration in the homograft was also less pronounced and was confined to death of cells alone; the collagen fibers retained their structure. Later on the noncellular collagen tissue was observed to be in process of population by cells of fibroblastic type from the recipient. In these cases we can speak of the partial survival of the homografts. Subsequently these grafts underwent reorganization and partial replacement by dense fibrous connective tissue. However, in these cases an inflammatory reaction took place around the homografts in the form of an infiltration of cells leading to the formation of adhesions between the graft and surrounding tissues, considerably impeding the function of the limb.

Our results with tendon homografting thus do not lead to a favorable evaluation of this method.

In the next series of experiments strips of fascia lata from the thigh were used to repair the tendon defect. In all cases we observed survival of the fascial autografts. In this series of experiments the defect between the tendon stumps was also filled mainly with newly formed connective tissue. Side by side with the formation of a connective tissue scar, however, the partial survival of the transplanted material was observed; in this case the transplanted fascial tissue at first underwent degeneration to some extent, and later it became reorganized into tissue of the tendon type. We observed survival of the fascial autografts in all cases, but on account of the high plastic properties of fascia, extensive adhesions developed with the skin and surrounding tissues, which to a large extent impeded the function of the organ.

In a histological study of the transplanted fascia we were able to make out some degree of degeneration of the fascial tissue from 22 to 26 days after grafting in the form of partial death of the cells and reduction followed by total disappearance, of the transverse fibers. At the same time we observed an increase in the number of longitudinal fibers. The cells were preserved mainly in the peripheral portions of the fascial grafts. In the central portions of the grafts only the nuclei were left of most of the cells and these had disintegrated into clumps of chromatin. On the 40th day after grafting transverse fibers were left only in isolated areas of the transplanted fascia and the bulk of the fibers were longitudinal. Cells were distributed more thickly at the periphery of the layers of fascia. Between the layers of fascia there was marked new formation of dense fibrous connective tissue, often in greater volume than the material originally grafted. On the 70th day after grafting further reorganization

of the fascial autograft was observed, as shown by complete disappearance of the transverse fibers and a continuing increase in the number of longitudinal fibers. After 3 months it was already impossible to distinguish the grafted fascia among the mass of newly formed connective tissue based upon it.

In the opinion of several workers [5, 6], fascia is preserved intact after grafting. Our experimental results do not support this view but on the contrary agree with the findings of P. G. Kornev [4]. From our observation of the survival of a considerable portion of the fascial transplant and its subsequent reorganization, we believe that a fascial sleeve is a satisfactory conductor of regenerating tendon tissue, yet nevertheless the results of the experiments which we carried out must be regarded as unsatisfactory, since gross adhesions are formed under these circumstances with the surrounding tissues, impeding the function of the limb.

In the 4th and main series of our experiments we performed autoplastic tendon grafting. It must be pointed out in the first place that macroscopically the autografts developed a matte appearance after the first few days, losing their silver gloss, characteristic of the normal tendon. Accretion of the graft to the bed was observed only 16 days after transplantation. Until the 50th day the grafts preserved their initial length and diameter, and then a small increase was observed in the length of the grafts and some increase in their diameter. At 9 months the characteristic sheen began to appear on the grafts and one year after transplantation the tendon autograft shone like a normal tendon. In this respect the results of our experiments agree with those of N. Z. Tomilova [7], who observed the appearance of the characteristic silver sheen in a tendon autograft 9 months after transplantation. However, in contrast to our findings, this worker points out that the tendon autografts gradually became stretched and thinned so that their functional value diminished. This opinion of N. Z. Tomilova was challenged by Yu. Yu. Dzhanelidze [3], who considers that the grafts do not stretch and their function, on the contrary, improves in the course of time.

The histological investigations carried out in this series of experiments showed that the transplanted material mainly survives. Only its cells die, mainly those situated in the central areas of the graft. The collagen bundles do not die. In the course of time the collagen tissue becomes enriched with cells, first as a result of proliferation of the cells of the endo- and peritenon and later as a result of division (mainly amitotic) of the tendon cells themselves. During this process of population of the collagen bundles with cells, the bundles of the first order are reduced in diameter, as if by fission. Side by side with this reorganization of the old tendon tissue new formation of young connective tissue is taking place on account of cells of the peritenon of the grafts; the tendon stumps of the graft bed also take part in this process. In this case, then, besides survival of the already existing tendon material, new tendon tissue is formed as a result of regenerative processes. Both donor and recipient take part in these regenerative processes. The newly formed tissue may even exceed the volume of the graft. The reorganization of the grafted material and formation of young tendon tissue take place under identical conditions of stretching. This identity of functional conditions leads to identity of structure and as a result there is formed a tendon whose structure is homogeneous throughout its thickness. In the course of time the differentiation of the tissue of this tendon increases — the collagen bundles of the first order are increased in diameter, the number of tendon cells between them is reduced, these cells become elongated and flattened and their nuclei become rod-like in shape. The layers of endotenon become thinner. To sum up (at the end of one year after grafting) the tissue of the tendon autograft becomes indistinguishable in its structure from the tissue of a normal tendon.

SUMMARY

In replacing tendon of Achilles defects with silk thread and in tendon homoplasty the results were unsatisfactory. In facial autoplasty the transplant partially took and was reconstructed by the tendon type. However, the function of the extremity was disturbed as a result of extensive adhesions of the transplant to the surrounding tissues. The autoplastic transplantation of the tendon tissue resulted in complete restoration of the structure and reestablishment of the function of this organ.

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