FASCIA LATA: ITS NATURE AND FATE AFTER IMPLANTATION AND ITS USE IN OPHTHALMIC SURGERY

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THE PURPOSE OF THIS PAPER is to investigate the nature of fascia lata, to further explore and report on its fate after implantation, and to describe its uses in ophthalmic surgery.

HISTORY OF THE SURGICAL USE OF FASCIA

Transplantation of fascia was first done by McArthur in 1901.[1] He used strips of the aponeurosis of the external oblique muscle of the abdomen as living sutures in the repair of inguinal hernias. In an article published in 1912, Brun described surgery he did in Lucerne, Switzerland, in 1905. He applied a band of fascia lata for ligation during repair of a prolapsed rectum.[2]

Kirschner,[3] at the surgical clinic in Greifswald, Germany, worked under Professor A. Payr for a year and a half experimenting with fascia lata. He is said to have been the first to suggest its use to join tendons, and to repair defects in the dura mater. He concluded that fascia lata, as an autogenous graft, grew well in any new environment and had great strength (1909). At a meeting of the Medical Association of Greifswald, 4 December 1908, Payr[4] presented a patient on whom he had corrected a congenital ptosis of the upper eyelid by using a free autogenous transplant of fascia lata to sling the tarsus below to the frontalis muscle above, passing the fascia under the orbicularis muscle. The result was satisfactory a year and a half later from both a functional and a cosmetic viewpoint.

Gradually fascia lata was used in a greater variety of surgical procedures. Koenig (1909)[5,6] is said to have been the first to employ fascia to bridge defects in the walls of hollow organs. He used it on one case of recurrence of abdominal hernia, after four previous attempts at closure had failed, by placing a flap of fascia over the suture

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line. The wound healed with firm apposition. In 1910 a piece of fascia was placed between the vertebral border of the scapula and the supraspinous ligament to correct a dropped shoulder due to a paralysis of the trapezius muscle,[7] and in 1911 fascia was used for occlusion of the pylorus using free autogenous fascia in strips.[8] A year later its application to cover a defect caused by the removal of a tumor from the parietal bone including dura, to cover brain defects, to repair joints, to strengthen abdominal repair after ventral hernia, and to bridge urethral defects was described by Denk.[9,10] He stated that in an aseptic field, fascia always heals if it is in contact with a nourishing tissue. Up to this time, autogenous transplants were used almost exclusively, but in 1914 it was shown experimentally by Lexer[11] and Rehn[12] that homotransplants behaved similarly.

Autogenous fascia continued to be used to an increasing extent with good results in arthroplasty. It was used as a sling to elevate the angle of the mouth in several patients with permanent facial paralysis.[13–15] Gallie and LeMesurier (1921, 1922)[16,17] devised a special needle for inserting living fascial sutures and demonstrated their value in the treatment of hernia, injuries to tendons and ligaments, and paralytic deformities.

Kleinschmidt (1914),[18] recognizing the advantages of fascia, pointed out the practical value of having available an almost inexhaustible supply of this autoplastic aseptic material. It has great firmness and elasticity, permiting easy molding to all possible shapes. These characteristics led to the wide use of this living material in surgical procedures. The large number of publications concerned with such autoplastic material foreshadowed the advances that would be made in the use of free fascial transplantation.

The technique of treating facial paralysis by fascial slings was improved by Blair (1926, 1930).[19,20] He used a modified Reverdin needle to insert the fascia, making its placement much easier. To compensate for paralysis of the abdominal muscles due to poliomyelitis, Lowman[21] attached the slings to non-paralyzed muscle or the rib margin above and to the pubis or the ilium below. Shouldice (1939)[22] used fascia to correct fallen metatarsal arches. Passing a strip of fascia across the sole beneath the heads of the second, third, and fourth metatarsals, he anchored it to the first and fifth metatarsals. Fascial slings have also been used in the treatment of certain types of vesical and anal incontinence.

The technique of using free fascial transplants in arthroplasty has been refined. The most suitable joints for its use are the temporomandibular joint, the elbow, and the hip. It is rarely used now for the knee because results have been unsatisfactory.

Development of the use of fascia to correct congenital ptosis was slow. The first report by Payr was in 1908.[4] It was 1922 when Dr. W. W. Wright described a method of repairing congenital ptosis.[23] This work was done at the time that Gallie and LeMesurier were doing their experimental work with fascia lata. In 1928 Dr. G. S. Derby described "correction of ptosis by fascia lata hammock."[24] The operation was again advocated in 1956 by Crawford[25] with some modifications of the techniques of previous workers. Since that time there have been many variations of this operation described.

NATURE OF FASCIA

Fascia lata invests the whole of the limb. It is wrapped around the muscles, vessels, and nerves like a bandage, the fibers being chiefly circularly arranged. The deep fascia is thickened where muscles are attached to it, and the direction of its fibers takes the line of pull of the muscles, e.g., gluteus medius. The deep fascia sends intermuscular septa between various muscles and muscle groups and then blends with, or attaches to, periosteum. It is extremely strong laterally because in between two thin layers of circularly disposed fibers there runs a broad band of coarse vertical fibers called the iliotibial tract. This tract is the conjoint aponeurosis of the tensor fasciae latae and the gluteus maximus.

Fascia consists of (*a*) bundles of white or collagenous fibers which, by branching and uniting with other bundles, form an open webbing filled with tissue fluid, (*b*) a slender network of yellow elastic fibers, and (*c*) scattered connective tissue cells. Fascia as it lies in the body is composed of an inner subserous layer, a middle layer whose thicker fibers run longitudinally, and an outer subcutaneous layer whose fibers are more transverse. The inner and outer areolar layers allow for the slippage of muscles, the skin, and superficial tissues.

The connective tissue of the body develops from the middle layer of the embryo, the mesoderm. In particular, it develops from a subdivision of mesoderm called mesenchyme (middle infusion), a typically loose, soft tissue which infiltrates between the various structures of the body developing from sources other than mesenchyme. It consists of both cells and the intercellular substance in which they lie. Tiny fibrils, the forerunners of the fibrous types of intercellular substance, can be demonstrated by special methods at the tips of some of the cytoplasmic arms. The great bulk of the intercellular substance

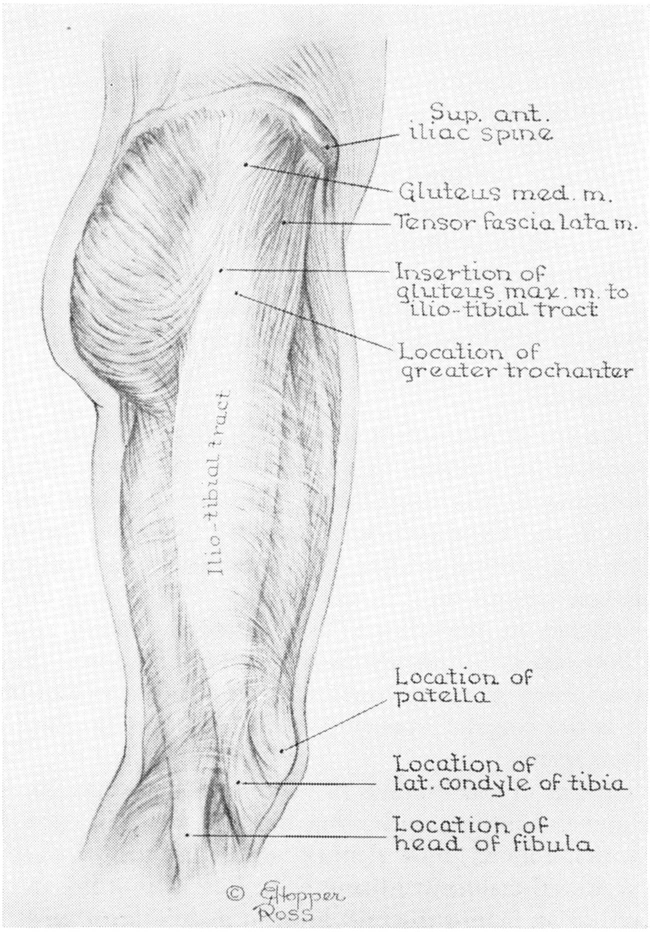


FIGURE 1
Diagram of muscles of leg, demonstrating position of fascia lata.

of mesenchyme is amorphous and has only a few fibers scattered through it. When the mesenchymal cells first develop in the embryo and are as yet undifferentiated, they are multi-potential (having capacity to differentiate along any one of several lines that lead to the formation of the many different kinds of cells in connective tissue). Once specialized, they lose this potential and the farther they differentiate the less they are able to form cells of any but the one type; finally, most of them become restricted to producing one type of cell within the connective-tissue family.

The term mesenchyme was introduced by Hertwig (1881)[26] to describe the non-epithelial cells with ameboid characteristics which come to lie between the epithelial and mesothelial layers of the embryo. They are predominantly of mesodermal origin but they can come from ectoderm, either directly or by way of the neural crest, and perhaps in lesser numbers from the endoderm. To some extent the differences between mesenchymal and epithelial cells are due to positional or environmental factors. Using tissue cultures, it has been demonstrated that under altered conditions epithelial cells may take on mesenchymal characteristics, and *vice versa.* There are intrinsic factors involved in determining tissue differentiation, and undoubtedly these factors act in association with environmental conditions, producing the change from an epithelial to a mesenchymal cell. Growth *in vitro* acts as a general leveler, for when tissues are grown *in vitro* the cells sooner or later revert to one of the three main morphological types. These types have been called mechanocytes, e.g., fibroblasts; amebocytes, e.g., certain blood cells; and epitheliocytes. Each type possesses well-defined physiological, biochemical, and pharmacological properties.

Primitive mesenchymal cells are stellate, or polymorphous, with a number of longer or shorter processes which come into intimate contact with those of adjacent cells to form a network. The meshes of the network are filled with a structureless, semi-fluid, jelly-like substance. Mesenchymal cells possess ameboid characteristics and in some regions, particularly in the early stages, may act in the transfer of food material to, and metabolic products from, the developing organs and tissues. They also possess phagocytic properties and may play a part in the removal of dead cells or atrophic organs.

The mesenchymal cell can differentiate in a number of ways. It may give origin to one or other of the varieties of fixed connective-tissue cell or mechanocyte (fibroblast, fibrocyte, osteoblast, osteocyte, chondroblast, and chondrocyte). Such mesenchymal cells are responsible for the elaboration and specialization of the intercellular jelly-like matrix. Thus, the fibroblasts are associated with the appearance of reticular, collagenous, or elastic fibrils in the matrix. These fixed connective-tissue cells, even when apparently completely differentiated, may become transformed into other types, for example, fibrocytes. In certain circumstances they may acquire osteogenic properties, and it is even possible for chondrocytes to become osteocytes.

Developmentally, fascia arises from the mesenchyme between and surrounding the various organ rudiments, for example, around the primordia of muscles, bones, vessels, and viscera. The mesenchymal regions may differentiate into one of the following:

1. dense fibroelastic tissue making up most of the more definite "named" fascias of the body, especially the fascia of muscles
2. areolar tissue which is the chief constituent of subcutaneous tissue (superficial fascia) and of fascial spaces where movement occurs between condensed fascias
3. reticular tissue which is an even more delicate fascial material found in the supporting framework of fat masses and of the tissues of most organs
4. adipose tissue.

Most of the fascias are associated with muscles or are found in "named" fascial layers. Tendons, which are composed of dense connective tissue, take their origins from the same mother mesenchyme which produces cartilage, bone, and many other tissues. If one removed the gelatinous matrix of hyaline cartilage and the calcified matrix of bone so that the collagenous fibers could be visualized, both tissues would resemble dense connective tissue. In a similar way, if the meibomian glands were absent in the tarsus, which is composed of a dense connective tissue, the tarsal plate would closely resemble fibrocartilage.

Connective tissue binds and retains tissues and organs in units. The connective tissue system also provides for separation. Cells and cell groups in each organ that are separated by connective tissue have developed specific capabilities in the kind of local environment best suited for the performance of special duties. The division of the body into special compartments by partitions of connective tissue is every bit as necessary for vital activities as the space arrangement in a manufacturing plant. Movement between one structure and another in the body is facilitated by the presence of very loose areolar tissue, the same modification of connective tissue seen in the formation of tendon sheaths which allow movement during contraction and relaxation of muscles.

Connective tissues differentiate into well-defined, "named" sheets, such as the fascia lata which forms a tight-fitting sleeve for the thigh muscles. With muscular activity, it promotes the circulation in venous channels and in the lymphatics. When the muscle contracts against the resistant fascial sheath, compression of the soft-walled veins and lymphatic vessels accelerates the flow of their contents in the direction determined by their valves.

There appears to be very little difference in the appearance of human (Figure 8) and rabbit fascia (Figure 2). Bovine fascia (Figure 14) shows a much more wavy pattern of the collagen fibers.

The fibroblasts, the parenchymal cells in fascia, are scattered rather sparsely among the dense bundles of collagenous fibers. Thus, the intercellular substance is the prominent feature of fascia and of tendon. Among the fibroblasts, which originate from mesenchymal cells, quantities of collagen have been laid down. This collagen aggregates into collagenous fibers which are arranged according to the forces of stress and strain. The fibroblasts in dense fascia are thin flat cells squeezed into their flattened shape by the dense collagenous fiber bundles surrounding them, so that in profile they appear spindle-shaped. The nucleus is large and oval and the cytoplasm is fairly clear except for fine fat droplets. Macrophages and undifferentiated connective-tissue cells which appear like fixed fibroblasts are scattered through the deep fascia. During infection and wound repair many or perhaps all of the flattened fibroblasts become plump and active. It is believed that the macrophages play the part of scavengers, removing cell debris from the connective-tissue spaces, while the fibroblasts act as builders, producing collagenous fibers.

The manner in which fibroblasts lay down collagenous fibers has been a source of controversy for years. Wolbach,[27] in wound-healing experiments on animals, demonstrated that collagen first appeared as a diffuse deposit about the fibroblasts, which he interpreted as a secretion. He concluded that collagen is secreted by the fibroblast, and that collagenous fibers and recticular fibers are the same material in different physical states. There are other theories as to how the collagen fibers are produced, but in any case the results are the same.

There is no direct evidence that the fibroblasts which produce collagenous fibers can also elaborate elastic fibers. Individual collagenous fibers do not anastomose with each other. They are arranged in bundles and run a characteristic undulating course. Electron microscopic examination reveals that the individual fibers are composed of fibrils with a segmented or striated appearance. In contrast to collagenous fibers, elastic fibers, which also form part of the fascia, run singly, branch frequently, and anastomose with each other. They consist of a very durable albuminoid called elastin, which is resistant to both acid and boiling. Under the electron microscope they appear as homogeneous structures which are not composed of smaller fibrils as are collagenous fibers.

PROPERTIES OF FASCIA

Collagen is perhaps the most abundant protein in the animal kingdom. It is the major fibrous constituent of skin, tendon, ligament, cartilage, and bone. In tendon it has its great tensile strength. In tests conducted by the New York Testing Laboratory on the standard tension machine, Gratz[28] found that the specific gravity for fascia lata is about 1.31 and the average tensile strength approximately 7000 pounds per square inch, whereas soft steel has a specific gravity of 7.83 and an ultimate strength of 45,000 pounds per square inch. Thus, weight for weight, fascia lata is nearly as strong as soft steel. These observations presuppose that sutures are used in such a way that the stress is placed longitudinally in the direction of the fibers, since fascia has very little strength in the transverse direction.

A comparison was made of the tensile strengths of fresh, frozen, and freeze-dried fascia lata, obtained from cadavers within twenty-four hours after death.[29] The upper ends of quarter-inch-wide strips of fascia were fixed to a frame and the lower ends, to a balance arm to which increasing weights were attached. The results showed that fresh fascia lata had an average strength of 10.73 pounds, frozen fascia, 10.33 pounds, and freeze-dried fascia, 10.70 pounds. The mean tensile strength of male fascia was 12.02 pounds and that of females, 6.92 pounds. In the series, however, the mean age of the females was much greater than that of the males casting some doubt on the relevance of these figures to sex differences. The mean tensile strength by age was (male and female):

Age 20–35, 14.4 pounds
Age 35–45, 10.9 pounds
Age 45–60, 10.9 pounds
Age 60–75, 9.2 pounds
Age 75 and over, 10.1 pounds

They concluded that there was no significant difference in the tensile strength of fresh, frozen, and freeze-dried fascia, although there were differences between individuals and between the groups studied attributable to age, cause of death, and sex.

Gross[30] states that the basic collagen molecule is made up of three polypeptide chains each composed of about 1000 amino-acid units linked together. In ordinary proteins the chains are assembled from the standard assortment of twenty-two amino acids, and once linked together end to end, the acids are not further altered. In the synthesis of collagen, however, two unusual amino acids, hydroxyproline and hydroxylysine, seem to be formed after the molecular chain has been assembled; the new amino acids are created by the addition of hydroxyl (OH) groups to some of the proline and lysine units in the chain. Proline and hydroxyproline, which together make up as much as 25 per cent of the links in the collagen molecule, prevent easy rotation of the regions in which they are located, thus imparting rigidity and stability to the collagen molecule. The higher the content of proline and hydroxyproline, the higher the resistance of the molecule to heat or chemical denaturation.

Collagen owes its properties not only to its chemical content but also to the physical arrangement of its individual molecules. The basic molecular chain is twisted into a left-handed helix, and three such helices are wrapped around each other to form a right-handed superhelix. The three chains appear to be held together by hydrogen bonds established between the oxygen atoms, located at the juncture of amino acids and peptide linkages in one chain, and the nitrogen atoms, located at peptide linkages in an adjacent chain. The collagen molecule seems to be about 700 Å long (700×10^{-7} meters). Recently, a new fibril with bands spaced at about 2800 Å has been designated as FLS (fibrous long spacing) to indicate that it is fibrous and had a long period. These threadlike units, about 2800 Å long and less than 50 Å wide, are the fundamental unit of collagen structure and are known as tropocollagen. The tropocollagen molecule is composed of three helical chains. In the native collagen fibril the molecules are lined up facing in the same direction and overlapping by about one-fourth of their length. It is this overlapping that creates the periodicity of about 700 Å.

The more rapidly the animal grows, the larger is the amount of collagen that can be extracted. Should growth cease as a result of starvation for a period as short as two days, this collagen fraction disappears from the tissues. This information, as well as the comparison of tensile strengths of fascias of different age groups, would indicate that when collecting fascia for preservation and later use we should obtain it, if there is a choice, from young, muscular adults.

STORAGE OF FASCIA

After fresh auto- and homografts were considered successful, attempts were made to store the fascia for use at another time. The cells in heat-treated and preserved homogenous fascial grafts are dead at the time of transfer and are replaced by infiltrating host fibroblasts, but the fate of the collagenous fibers in the graft is not definitely known. No investigator has commented on the fate of the sparse but durable elastic fibers in homogenous fascial grafts, either fresh or preserved.

Fascia has been preserved in a number of ways. Chandy,[31] using ox fascia, first placed it in 70 per cent alcohol and then transferred it to absolute alcohol for a total of two weeks. Robins *et al.*[32] preserved fascia taken from dogs by placing it in jars containing sterile saline, where it was kept from 12–14 days and then transferred to a solution of 0.88 per cent beta-propiolactone in buffered isotonic saline and 0.2 *M* sodium bicarbonate solution. After two hours the fascia was removed and stored in sterile saline solution. Other methods of preservation include ethylene oxide sterilization and freeze-drying.

Davis in 1911[33] repaired ventral hernias in dogs with fascia that had been preserved in saline at zero degrees centrigrade for 56 days. Koontz in 1926[34] successfully used ox fascia preserved in alcohol for the same purpose. In 1927 he reported good early clinical results, repairing hernias with ox fascia in 17 patients.[35] In general, however, his overall results were disappointing.[36] Using sutures made of freeze-dried human fascia and also ox fascia for repairing hernias in humans, Usher *et al.* had good results.[37,38] Andresen *et al.*[39] showed that exposing the fascia to be used for transplant in rabbits to temperatures of below –20° C for twenty minutes or to temperatures of +56° C for twenty-seven minutes eliminated all factors responsible for characteristic autologous and homologous host-graft interactions. In their stead there is a new form of host-graft interaction, which is identical for autologous and homologous transplants. This is defined as a "null interaction." It is characterized by negligible proliferation of cells and retarded resorption of tissues of the graft, coupled with avascular encapsulation and indolent avascular penetration of the graft by stromal tissues of the host.

Sewell and Koth[40] used freeze-dried fascia to repair diaphragmatic and abdominal wall defects. Only the homologous fascia was replaced by host fibroblasts and could be expected to function satisfactorily for a long period. Homografts failed when used to repair defects in diaphragms of dogs. One complete surface of the graft should be in contact with living host tissue if replacement is to take place. It cannot occur if the host fibroblasts can grow in only from the graft edges. Koontz and Kimberly,[41] using ox fascia sterilized by the electron beam to repair defects in the abdominal wall in dogs, found that in all cases the fascia was completely absorbed and was not suitable for hernia repair or replacement of abdominal wall defects. The results obtained by Snyderman *et al.*,[42] using freeze-dried fascia from the tissue bank at the Memorial Sloan-Kettering Cancer Center in association with the tissue bank at the National Naval Medical Center, were reported in 183 cases, 15 of which were cases of facial paralysis. In two cases, after biopsy from the face six years later, it was presumed that the freeze-dried fascia had been absorbed and the fascia seen was composed of fibroblasts from the recipient. Their conclusion was that human freeze-dried fascia is just as satisfactory as fresh autogenous fascia. Gutman's method of preparing fascia was to double-package and treat with three million rads of cobalt radiation.[43] A later report by Falls *et al.*,[44] an extension of Gutman's work, showed satisfactory results in 17 operations on the eyelids.

Woodruff[45] has pointed out that in considering the fate of living fascial transplants there are four possibilities.

1. The transplant becomes established and survives permanently. Claims for permanent survival should be made only if the following criteria are fulfilled: (*a*) the transplant survives throughout the life of the recipient, (*b*) the recipient survives for a long time—preferably at least one year, and (*c*) histological examination of the transplant after death of the recipient gives no grounds for supposing that the transplant would have been destroyed had the recipient lived longer.
2. The transplant is systematically replaced by regenerating host tissue. Although, finally, none of the original transplant remains, the appearance of the growth may suggest that the transplant has survived. This "creeping replacement" occurs characteristically with orthotopic transplants of bone.
3. The transplant survives for a time but is subsequently destroyed, leaving either a trace or a mass of scar tissue, which may or may not contain necrotic remnants of the transplant.
4. The transplant is rapidly destroyed.

NON-LIVING TRANSPLANTS

With transplants of dead tissue there are three possibilities:

1. The dead material remains *in situ* for a long period, e.g., heterotransplants of preserved cartilage.
2. The dead material is systematically replaced by living host tissues, e.g., freeze-dried transplants of bones and arteries.
3. The dead material is rapidly absorbed or discharged.

Kirschner in 1909[3] had reported the successful use of autogenous fascial grafts and stated that the transplants retained their structure after transfer and remained in the host area as living tissue, but Von Saar[46] in 1910 questioned the permanent viability of fascial transplants. The conflicting opinions of these two investigators have been confirmed or repudiated by all later workers with fascial transplants. Davis,[33] Kleinschmidt,[47] and Greggio[48] on the basis of animal experiments concluded that autogenous fascial grafts survived as such after transplantation, with living fascial cells and normal intercellular structure. The later work of Gallie and LeMesurier[49] demonstrated that autogenous fascial transplants remain alive after transfer and heal in firmly with the surrounding host tissue. Their later experimental work confirmed their earlier observations that the cells in the graft can survive and retain their normal collagenous matrix.

At present, the preponderance of opinion favors the view that free autogenous fascial grafts in animals remain viable after transfer. Valentin[50,51] concluded that the cells in fresh homogenous fascial grafts survived after transfer. Rehn[12] preferred the use of autogenous grafts because he felt that fresh homografts were changed into host tissue and that the original cells were replaced by host fibroblasts. The majority of recent investigators support the view that the parenchymal fibroblasts in fresh homografts die and are replaced by host cells. The cells in heat-treated and preserved homogenous fascial grafts (other than frozen) are dead at the time of transfer. These dead cells are replaced by infiltrating fibroblasts from the host, but the fate of the collagenous fibers in the graft is not known.

The eventual fate of heterogenous fascial grafts in animals is not established. They give rise to more cellular reaction in host tissues and microscopic examination of the heterografts indicates that the foreign graft is replaced by host tissue. Some workers feel that the heterogenous graft structure is replaced by ordinary scar tissue, which lacks the tensile strength of true fascia.

Foshee,[52] in examining the process of regeneration of fascia lata at the site of removal for surgical purposes, found that a new layer of fascia will fill in the space, and not be any more adherent to the muscles beneath than was the original layer. The regenerated fascia, one-half to two-thirds as thick as the original, is composed of two layers instead of three and has the same tensile strength. This finding is significant because it indicates that fascia replaces itself with fascia not merely with scar tissue, an important point when assessing the value of living transplants as opposed to irradiated grafts.

EXPERIMENTS WITH FASCIA

TISSUE REACTIONS

New Zealand white rabbits were used in these experiments. Twelve rabbits received implants of autogenous fascia and twelve others received homogenous fascia (Figure 2). With the animal anesthetized by barbiturates, an incision was made into the cornea at its superior aspect, 1 mm below and parallel to the limbus. An iris spatula was used to separate the corneal stroma and to make a pocket extending down about two-thirds of the diameter of the cornea (Figures 3–5). The same procedure was carried out on both eyes, the second eye being used as a control. A piece of fascia measuring 5 × 5 mm was pushed down into the pocket of one cornea. A larger piece of fascia measuring 5 × 10 mm was placed under the conjunctiva (Figures 6 and 7) of the same eye in which the fascia was implanted in the cornea, and another piece was implanted under the skin of the flank. Irradiated fascia was prepared as follows: the fascia was removed from Hank's balanced salt solution containing 10,000 units of penicillin per 100 ml and 50 mg of streptomycin per 100 ml and then double-packaged in a manner similar to that used for surgical gut sutures. The package was then exposed to gamma radiation from cobalt 60 to between 2.4 and 3.2 megarads, given uniformly over the tissue for four hours. After irradiation, the cells appeared to be unchanged. In this dose range, the destruction of the enzymes in the cells themselves delays autolysis, and though the cells are dead they appear normal.

Observations were made over a four-month period using the operating microscope. The degree of reaction in the cornea was graded as follows:

0 (no visible reaction): in microscopic sections of grade 0 reactions, new vessels of capillary size were seen in the corneal stroma and the graft in four cases.

1: one vessel reached the graft or several vessels crossed the limbus but failed to reach the graft.

2: one or more vessels reached the graft, but did not surround it.

3: many vessels entered or surrounded the graft with no opacity and no perforation.

4: many vessels surrounded and entered the graft with opacity of the surrounding cornea with or without perforation.

With the auto- and homotransplants (all fresh) there was very little reaction either in the corneas or about the fascia in the subconjunctival

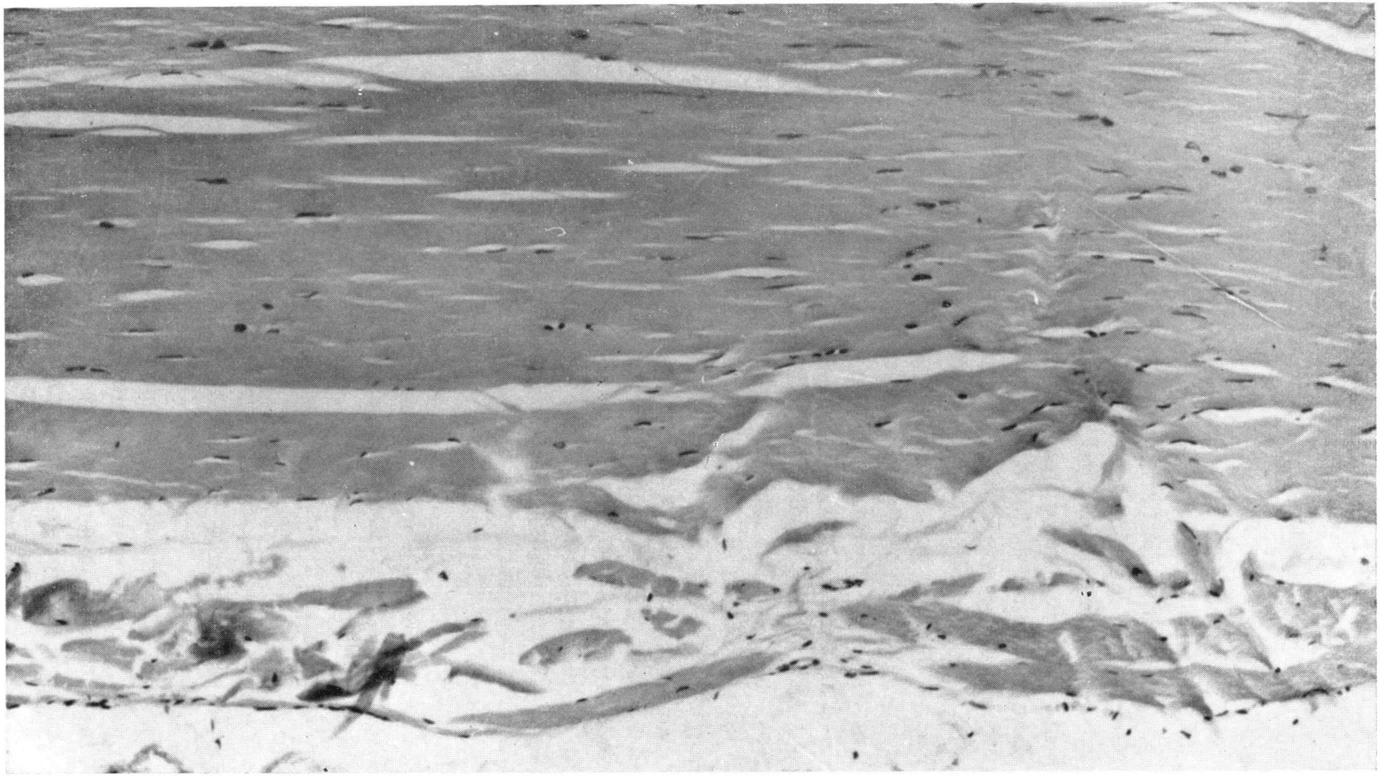


FIGURE 2

Fresh rabbit fascia. The appearance is very similar to human fascia (Figure 8).

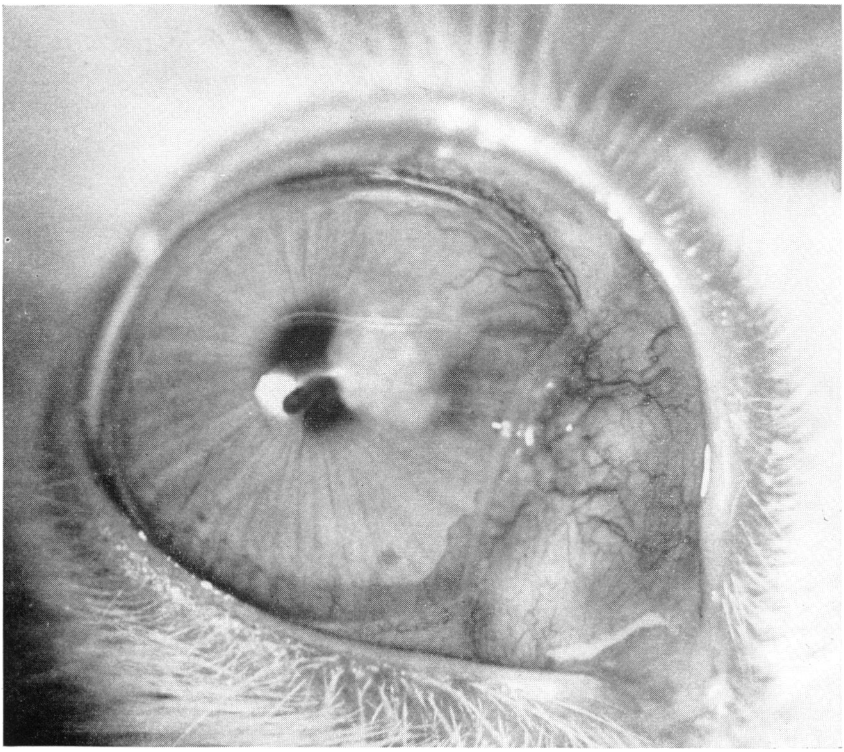


FIGURE 3
Rabbit fascia autograft in cornea at six weeks. Mild reaction (1+) beginning to subside.

pockets. There was no difference in the reaction between auto- and homotransplants. Vessels grew across the limbal incision in from one to three weeks and in 18 out of 24 cases they reached the graft (grades 1 and 2). In the remainder, the vessels grew down into the cornea a distance of from 2 to 3 mm and in some cases half way to the graft, and then after four to six weeks regressed (grade 0). In 12 out of 61 of the control eyes of the animals, vessels grew 2 or 3 mm across the incision and regressed after three weeks (grade 1). In the other 49 control corneas no vessels crossed the incision. In all but one of the 24 rabbits receiving auto- and homografts, the corneas remained clear and all of the vessels regressed. The cornea clouded and became opaque in the one exception (grade 4).

Using the opposite eye as a control, we implanted fresh human fascia (Figure 8) in one cornea of each of 10 animals, and irradiated

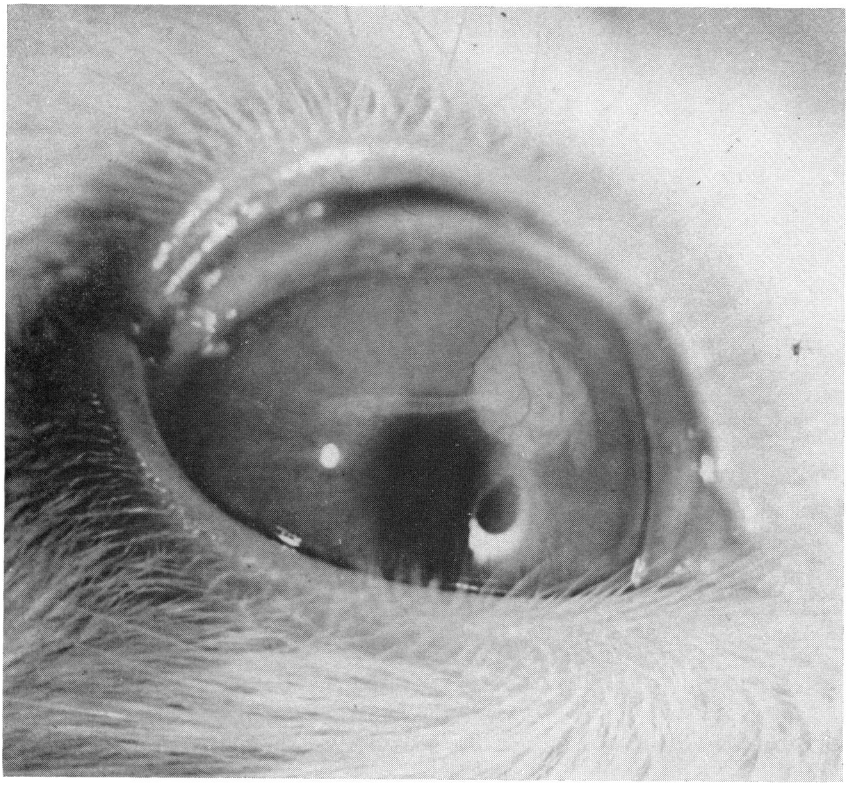


FIGURE 4
Rabbit fascia homograft in cornea at four weeks. Mild reaction at its peak.

human fascia in one cornea of each of 17 animals. In each animal fascia was also embedded under the conjunctiva and under the skin of the flank. We observed the eyes with the fresh fascial implants for up to 16 weeks (Figures 9 and 10), and those with irradiated fascial implants for up to 12 weeks (Figures 11–13). Reaction was graded at the time it was maximum, in most cases about three weeks. Where fresh and irradiated human fascia had been implanted, reaction was of grades 0, 1, or 2 in 23 instances, grade 3 in one, and grade 4 in three instances. In these three cases there was perforation and extrusion of the graft. By six weeks, reaction had begun to subside in 24 cases. There was no difference in the reactions to fresh or to irradiated human fascia.

Bovine fascia (Figure 14) was implanted in ten corneas (Figures

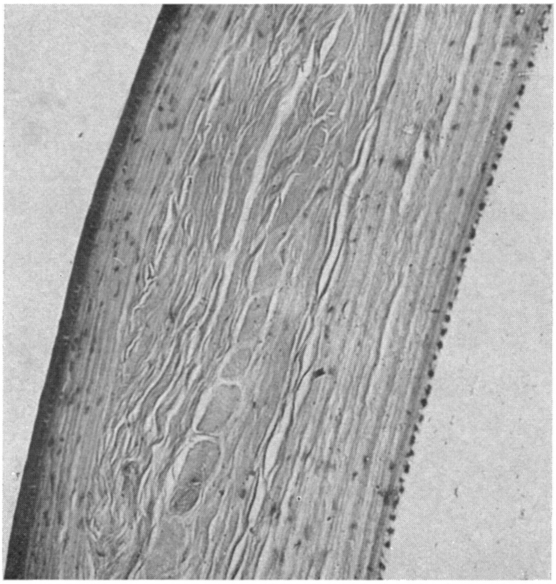


FIGURE 5
Rabbit autograft in cornea after twenty-six weeks, with minimal reaction.

15–17) with a pocket in the fellow eye being used as a control. Grafts were also made under the conjunctive and skin of the flank as before. In every one of the eyes with bovine implants there was a grade 3 or 4 reaction; also the reaction reached its maximum in one to two weeks in most instances compared with a time of two to four weeks with the auto, homo, and human fascial grafts which were maximal from two to four weeks. In six out of ten of these cases the cornea perforated anteriorly and the graft became partially extruded in from two to six weeks (grade 4). In the other four cases there was a grade 3 reaction, two of these showing some clearing later.

The reaction to the beef fascia in the flanks and under the conjunctivas of the rabbits on inspection seemed not very severe, but microscopically there was much more reaction than with human, auto-, or homotransplants.

In the grafts to the cornea (human, bovine, or rabbit) there was no evidence of absorption or replacement of the graft except in two bovine fascial grafts that showed some necrosis of the graft at four and six weeks, respectively. The above results are shown diagrammatically in Figures 18 and 19.

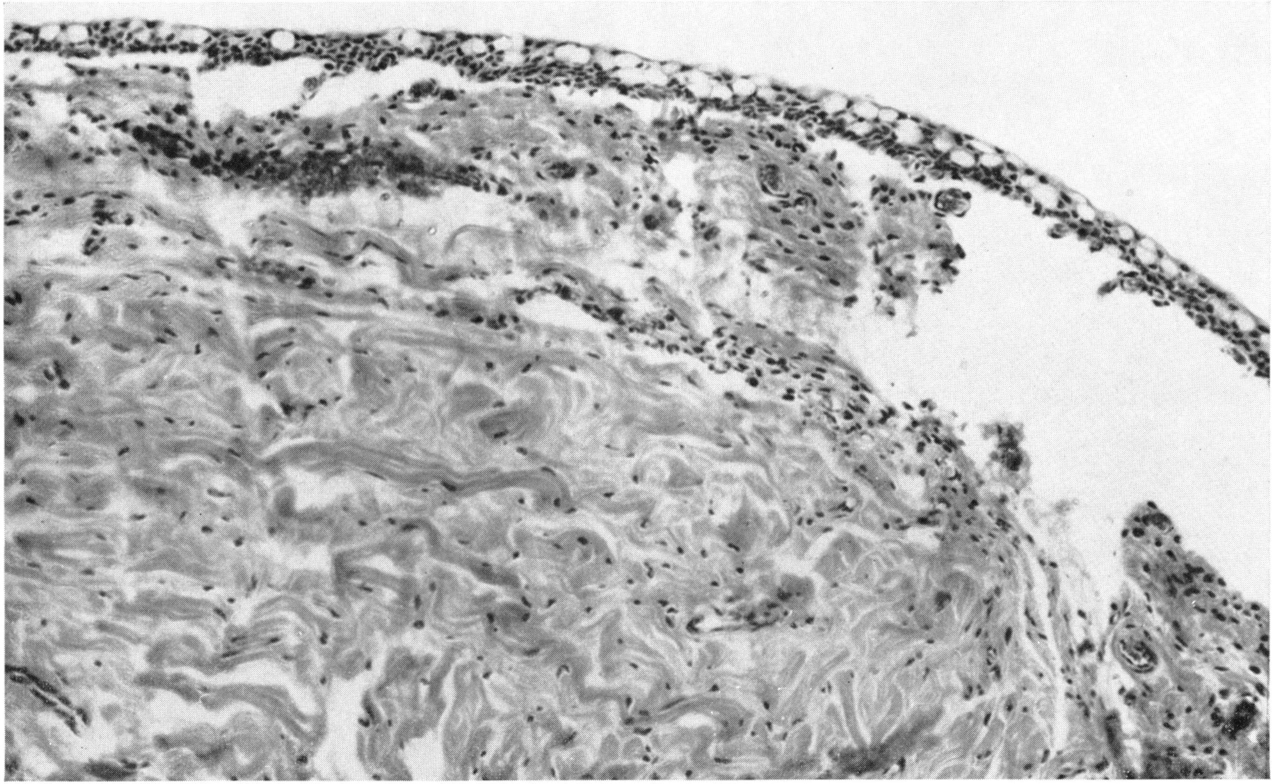


FIGURE 6

Rabbit fascia autograft in conjunctiva for three weeks. Graft shows little reaction with few blood vessels. There is proliferation of host and graft fibroblasts, with a few lymphocytes and macrophages penetrating the graft.

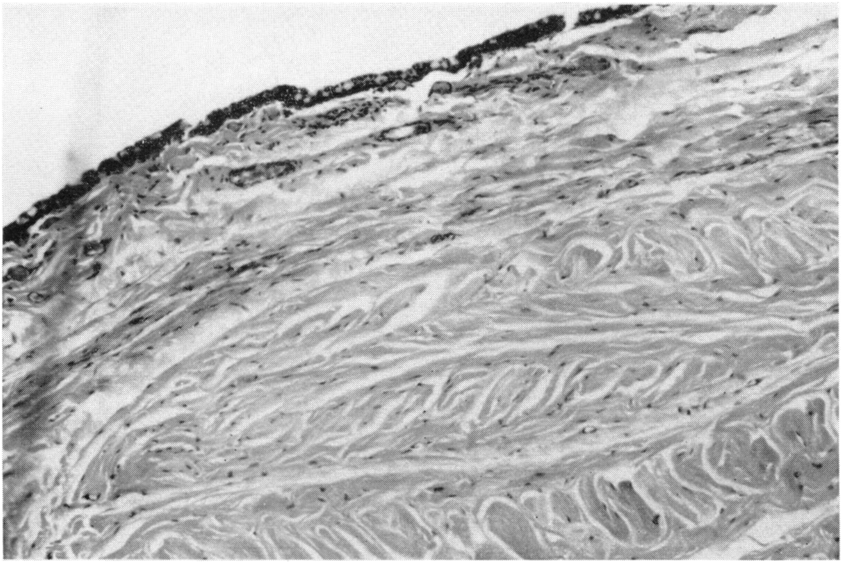


FIGURE 7
Rabbit fascia homograft in conjunctiva at twenty-six weeks. This graft shows a minimal reaction.

EFFECTS OF TENSION ON IRRADIATED FASCIAL GRAFTS (HUMAN AND BOVINE)

Springs

Springs were made from 1½-inch safety pins (Figure 20). The tension of each spring, measured before the fascia was attached, was between 100 and 200 grams. A strip of fascia 2 mm wide and 15 to 20 mm long was fastened between the arms of the spring and fixed on itself with silk sutures. The length was measured. Ten of these springs with fascia attached were implanted subcutaneously over the scapular area. We used human fascia for six preparations and bovine fascia for four. The results were observed over periods of two to twelve weeks.

In each case the diameter of the fascia decreased due to "rolling." When placed on a board and teased out from its rolled shape, the strip regained its original 2-mm width. There was no lengthening of the fascia in any case. The measurements were considered accurate to within half a millimeter. In all cases there was a mild chronic inflammatory reaction with proliferation of fibrous tissue around the metal of the spring. We found no difference between human and bovine fascia in the spring experiments. The fascial grafts became surrounded

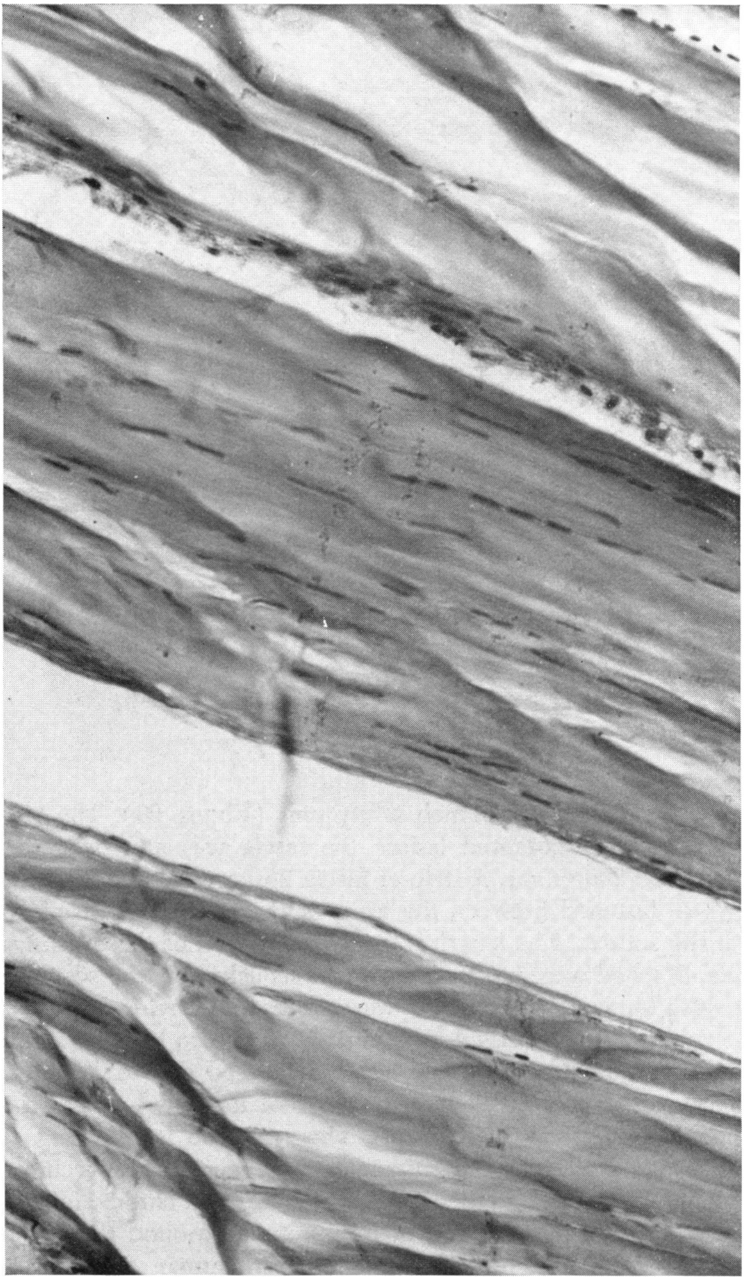


FIGURE 8

Fresh human fascia (low power) showing the parallel bands of collagen fibers. Fibroblasts are arranged in line with the collagen fibers.

FIGURE 9

Fresh human fascia in rabbits cornea at three weeks, with moderate cellular response. Surrounding the graft there are a large number of cells, most of which are lymphocytes and eosinophils. This represents a moderate reaction at its maximum.

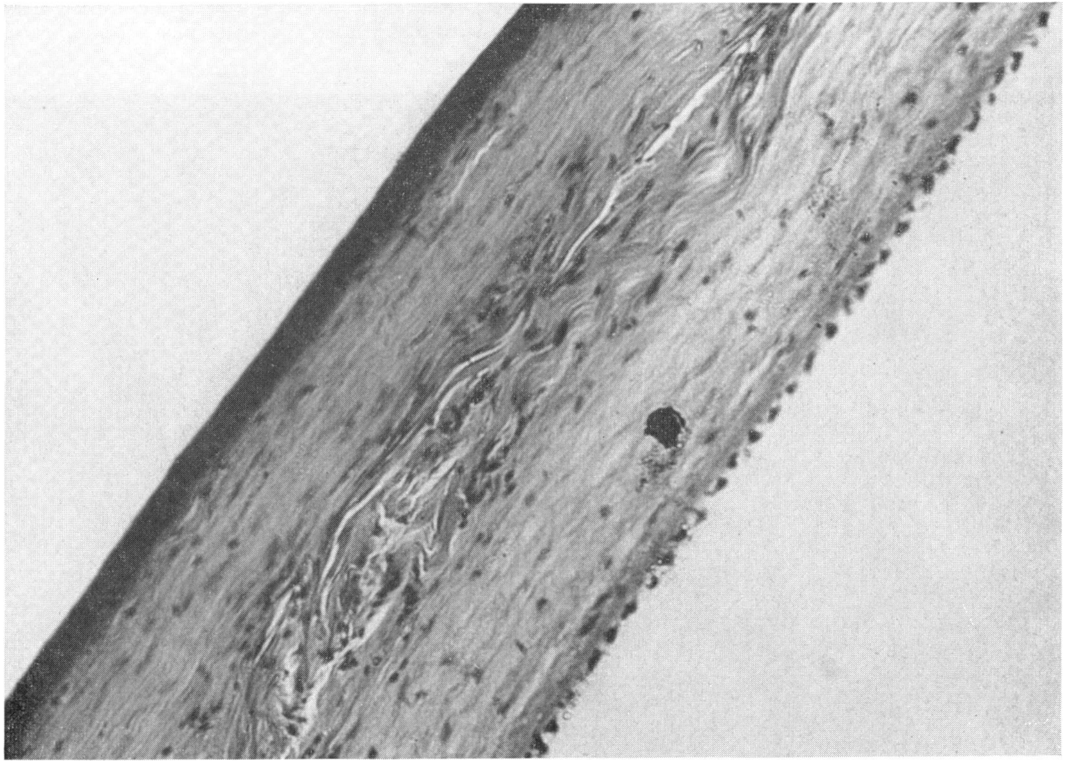


FIGURE 10

Human fascia in rabbits cornea at sixteen weeks. There is no attempt at encapsulation by the host in corneal grafts. There is a light cellular response, mostly of fibroblasts. This represents a quiet reaction to human tissue.

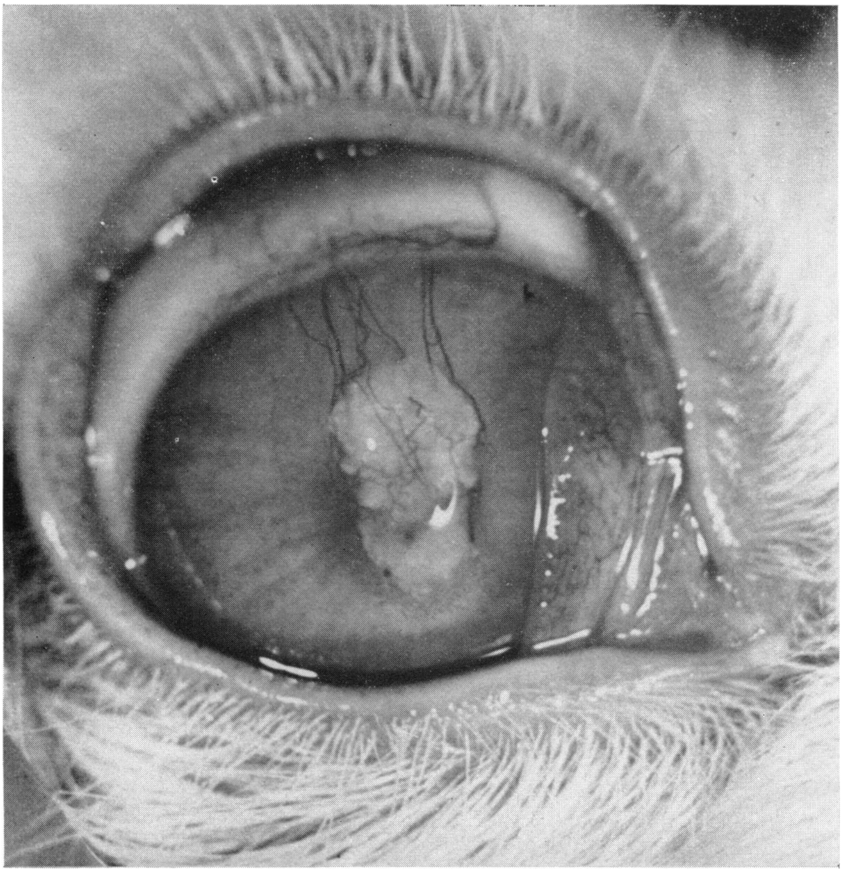


FIGURE 11
Human irradiated fascia graft in cornea at four weeks. Moderate reaction (at height of reaction).

by a thin sheath of host fibrous tissue containing fine blood vessels. Microscopic examination showed a loss of graft fibroblasts even after one week of implantation, and there was a parallel compact arrangement of the collagenous fibers. The wavy appearance characteristic of normal fascial fibers had almost disappeared (Figure 21).

Surgical Tension

This portion of the experiment was carried out using strips of fascia 2 mm wide placed subcutaneously. One end of the fascia was attached to the deep surface of the skin by running the end of the fascial strip

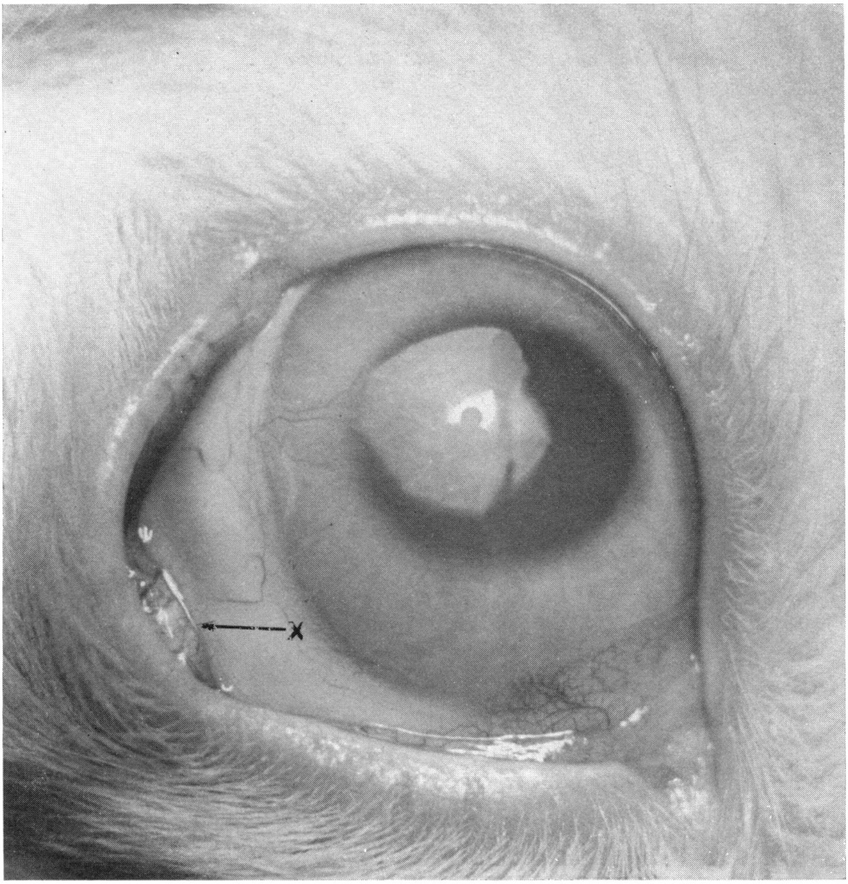


FIGURE 12
Human irradiated fascia graft in cornea at eight weeks with grade 2 reaction subsiding showing graft under conjunctiva (arrow).

through a 4- to 5-mm tunnel in the dense subcutaneous fibrous tissue, bending it back on itself, and suturing the end to the strip. The fascia was fastened to the skin on the left flank and led subcutaneously to the right flank, pulled as tight as possible, and attached to the skin of the right side, producing a large fold of skin. We made several such tension folds in each rabbit in different areas, longitudinally in either flank, or from shoulder to shoulder. In seven of ten rabbits we implanted human fascia in several areas and in three rabbits we similarly implanted bovine fascia.

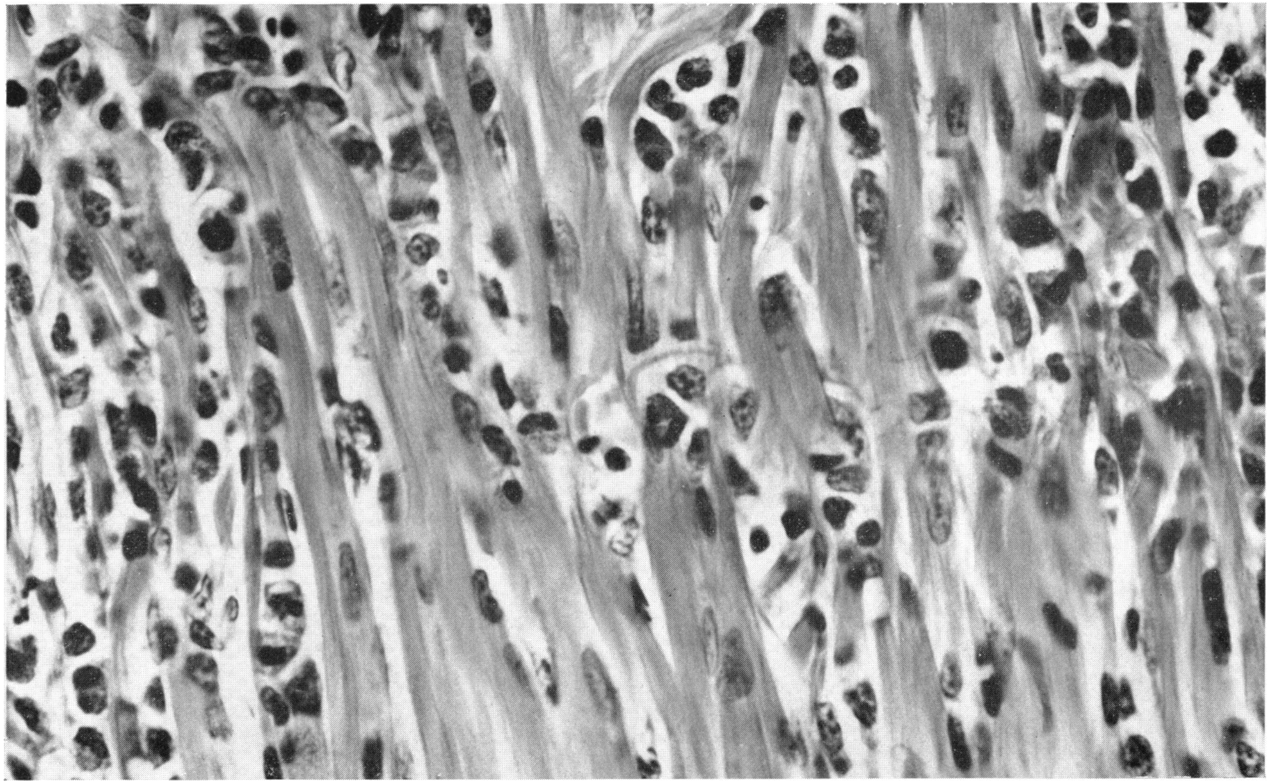


FIGURE 13

Human fascia after implantation under rabbit's conjunctiva at three weeks. There is moderate cellular graft reaction. Host lymphocytes predominate and are spreading into the graft. There are some eosinophils toward the periphery. This represents a moderate graft reaction at its height at this time.

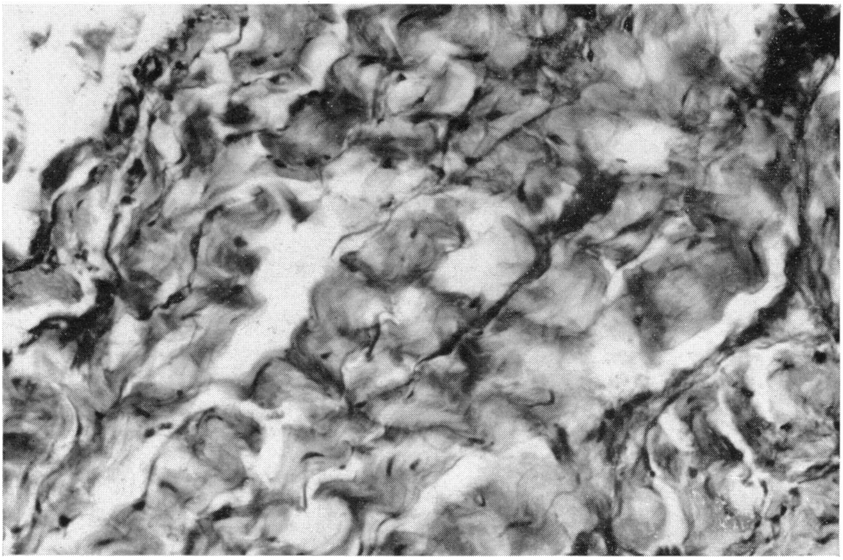


FIGURE 14
Fresh bovine fascia showing the wavy arrangement of the collagen fibers.

On examination of the rabbits two weeks after implant we found that in every case the tension had not been maintained. One or both of the attachments of the fascia had broken away. There was a stretching and proliferation of fibrous tissue of the host at the point of attachment of the fascia. Though there was only slight reaction microscopically in the surrounding tissues of the host, it was more marked about the bovine fascia. As in the cases where springs were used, the fascia had become encased in moderately vascular fibrous tissue. There was no stretching or lengthening of the fascia itself.

FATE OF KNOTS IN FASCIAL GRAFTS

This portion of the experiment was carried out to study what happens to pieces of irradiated fascia lata joined together by various means and implanted into the rabbit. We tried four different techniques. (1) Two pieces of fascia, 2 mm wide and 5 cm long, were embedded under the skin over the scapula of the animal, allowing 2 cm of each to overlap the other. (2) In one flank two pieces of fascia were placed in apposition to each other in the form of a cross and were implanted. (3) In the scapular area we implanted a 2 mm wide strip of fascia, bent into a large circle with the ends intertwined

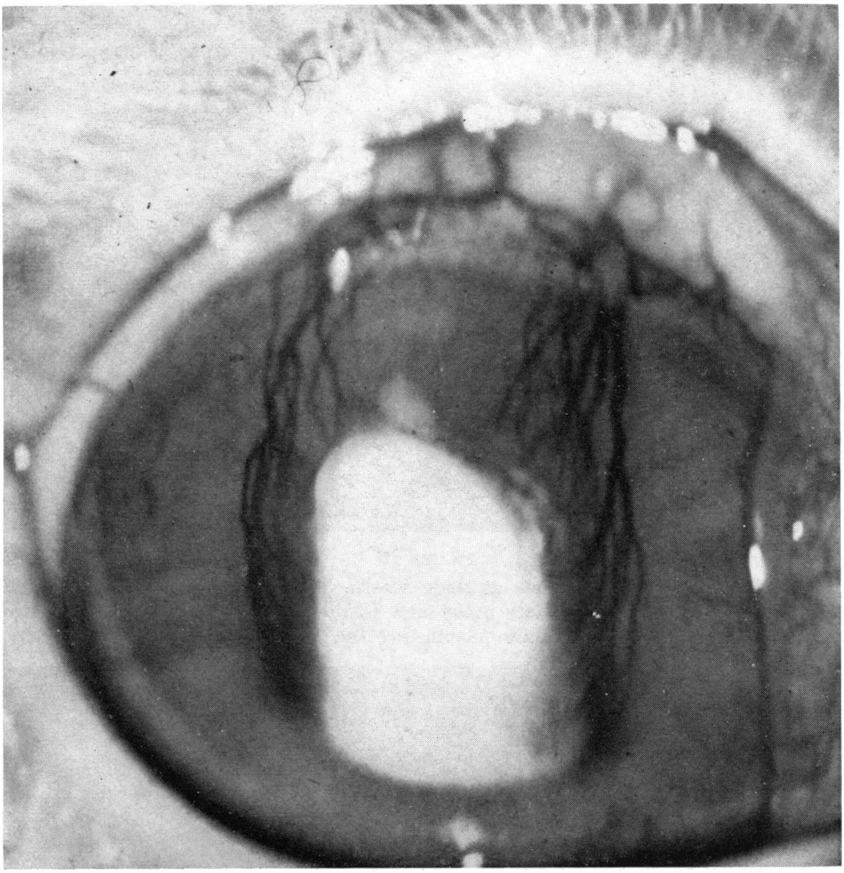


FIGURE 15
Bovine fascia graft in cornea at ten days. Severe reaction in its early stage before cornea becomes opaque.

as they would be in the first half of a surgical knot (Figure 22). (4) In the other flank the fascia was tied together in the form of a double knot. We used 12 rabbits (48 implants) in this experiment. At the end of nine weeks they were examined.

Strips of fascia that overlapped each other, strips of fascia placed to form a cross, and strips placed as in the first half of a knot were found to be only loosely joined together and could be easily pulled apart (Figure 22). They were held together by only a thin covering of fibrous tissue which ensheathed the whole piece of fascia. In the case of the fascial strips doubly tied, however, fibrous tissue ensheathed the

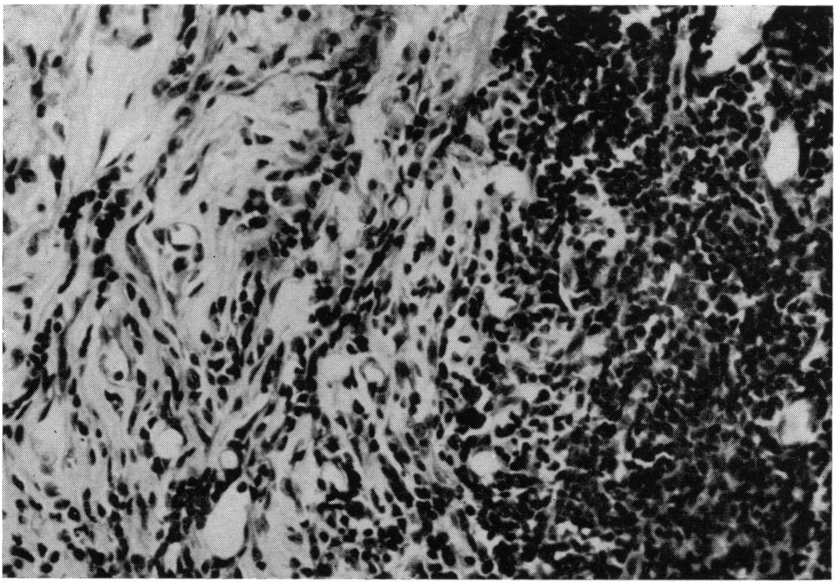


FIGURE 16

Bovine fascia in rabbit's cornea at three weeks. This shows an intense reaction surrounding the graft. There are many new blood vessels. Most of the cells are lymphocytes, but eosinophils are penetrating the graft behind the lymphocytes.

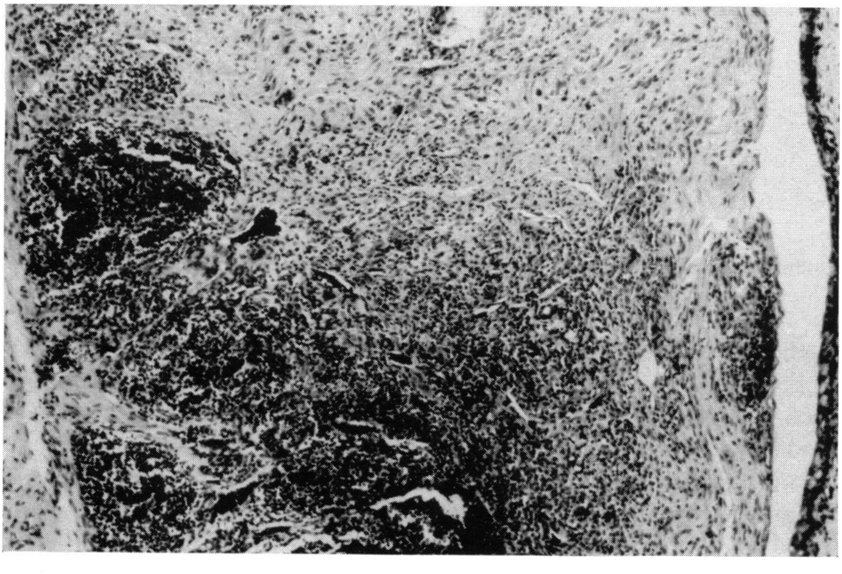


FIGURE 17

Bovine fascia in rabbit's conjunctiva at six weeks. This slide shows an intense graft reaction with a wall of newly formed fibrous tissue surrounding the graft, containing many blood vessels. There are areas of necrosis of the graft tissue with giant cells.

Numbers	4	5	3	0	0
Grade	0	1	2	3	4
Percent	33	42	25	0	0

RABBIT AUTO FASCIA GRAFTS

Numbers	2	6	3	0	1
Grade	0	1	2	3	4
Percent	17	50	25	0	8

RABBIT HOMO FASCIA GRAFTS

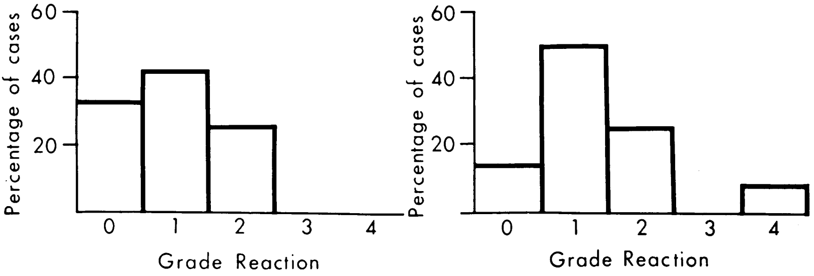


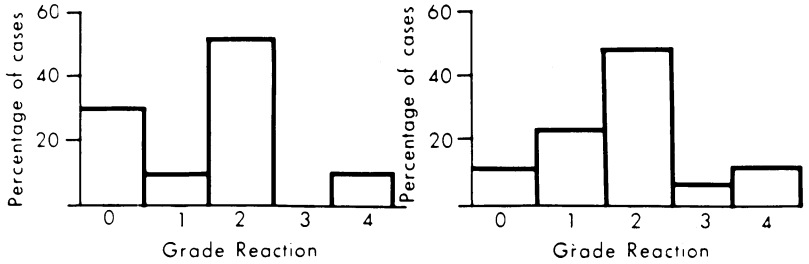
FIGURE 18
Percentage of cases against maximum grade of reaction.

Numbers	3	1	5	0	1
Grade	0	1	2	3	4
Percent	30	10	50	0	10

HUMAN FRESH
FASCIA GRAFTS

Numbers	2	4	8	1	2
Grade	0	1	2	3	4
Percent	12	23	47	6	12

HUMAN IRRADIATED
FASCIA GRAFTS



Numbers	0	0	0	4	6
Grade	0	1	2	3	4
Percent	0	0	0	40	60

BEEF IRRADIATED FASCIA GRAFTS

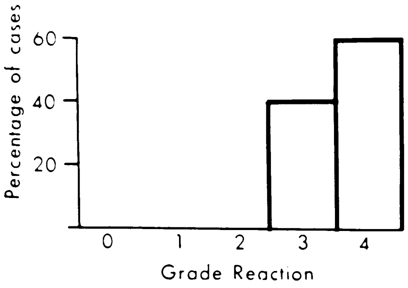


FIGURE 19
Percentage of cases against maximum grade of reaction.

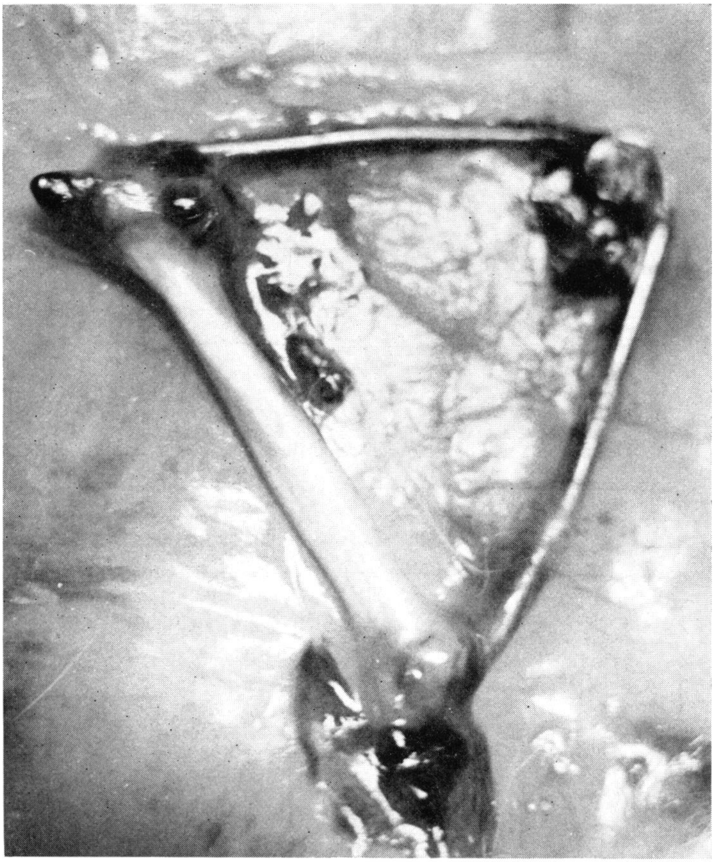


FIGURE 20
Human irradiated fascia on a spring after implantation in rabbits flank for eight weeks.

entire knot. The strips were strongly joined together and could not be separated.

EFFECTS OF VARIOUS PRESERVATIVE SOLUTIONS ON TISSUE REACTION TO IRRADIATED FASCIAL GRAFTS

This portion of the experiment was prompted by the observation that the reaction to fascia embedded into the corneas of rabbits varied from rabbit to rabbit. Since we considered that this might have been a reaction to the saline solution in which the fascia was soaking, we

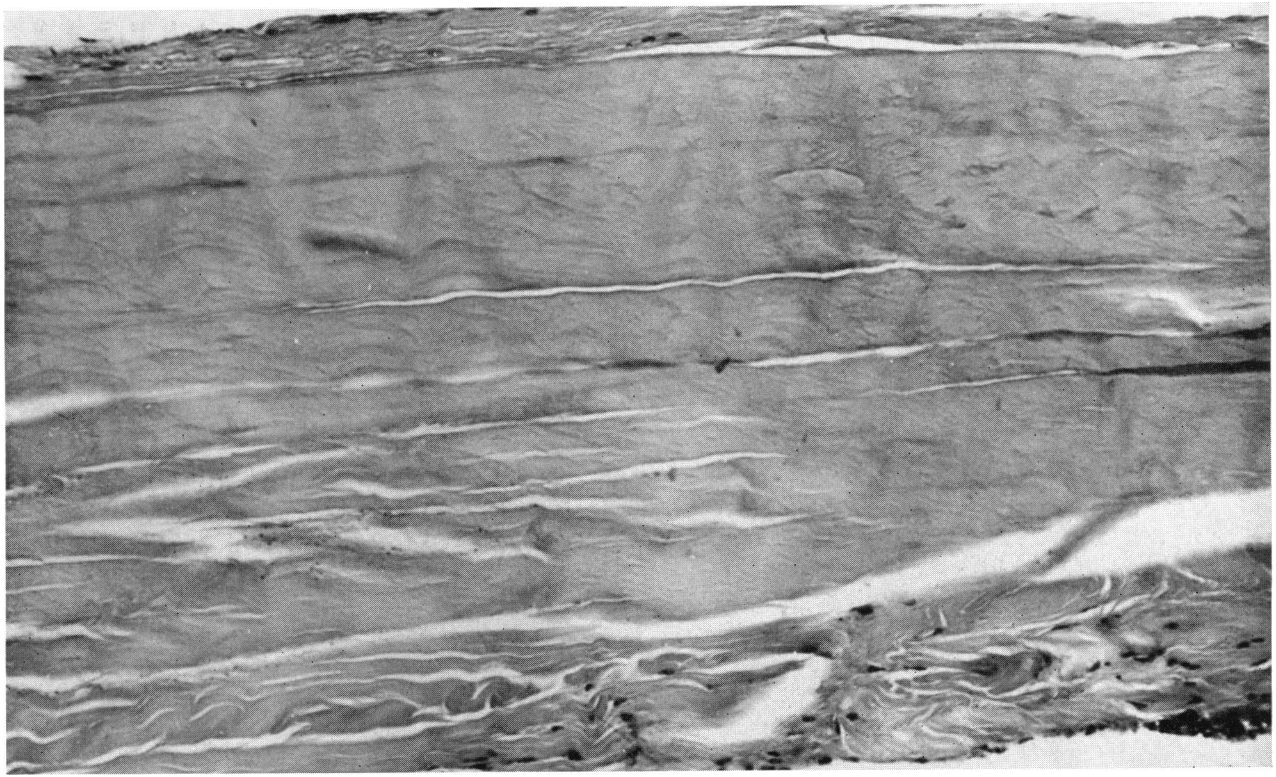


FIGURE 21

Human irradiated fascia after being on a spring for eight weeks, showing loss of fibroblasts and a parallel compact arrangement of the collagenous fibers.

FIGURE 22
A 2-mm strip of human irradiated fascia placed in a large circle with the ends intertwined after embedding under the skin for eight weeks.

embedded in rabbit corneas pieces of human irradiated fascia previously soaked in one of five different solutions. Pieces of fascia were placed in the corneas in random fashion; for example one rabbit had a piece of fascia that was soaked in 5 *N* saline in one eye and in the other a piece of fascia that was soaked in Hank's balanced salt solution. Five tests were made with each solution and the reactions were watched over a period of six weeks. (1) Five normal saline, (2) *N* saline, (3) 0.9 or 1/5 *N* or physiological saline, (4) distilled water, and (5) Hank's balanced salt solution were used. The reactions differred somewhat from rabbit to rabbit, but not from solution to solution.

COMPARISON OF THE TENSILE STRENGTH AND ELASTICITY OF FRESH AND IRRADIATED HUMAN FASCIA LATA, HUMAN RECTUS SHEATH, AND BOVINE FASCIA LATA

To compare the tensile strength of fresh and irradiated human fascia (fascia lata and rectus abdominis sheath) and fresh and irradiated bovine fascia, the following tests were done. Twenty tests each were made on strips of fresh fascia lata 2 mm and 4 mm wide, respectively. Similar tests were made on irradiated fascia lata, fresh and irradiated sheath of human rectus abdominis, and on fresh and irradiated bovine fascia. The strips of human fascia (prepared from a cadaver within six hours of death) and bovine strips were cut from sheets of fascia spread out on cardboard and frozen by placing them in a deep freeze at –70° C for five minutes. Then the sheets were removed from the freezer, allowed to thaw for one minute, and sliced with a three-bladed knife with the blades 2 mm apart (Storz) (Figure 23). Freezing prevented slipping of the fascial layers on one another and simplified the cutting. We then placed the strips in Hank's balanced salt solution with added penicillin and streptomycin. Half of the 2-mm strips and half of the 4-mm strips were double-packaged with 1 to 2 cc of the solution and irradiated within twenty-four hours.

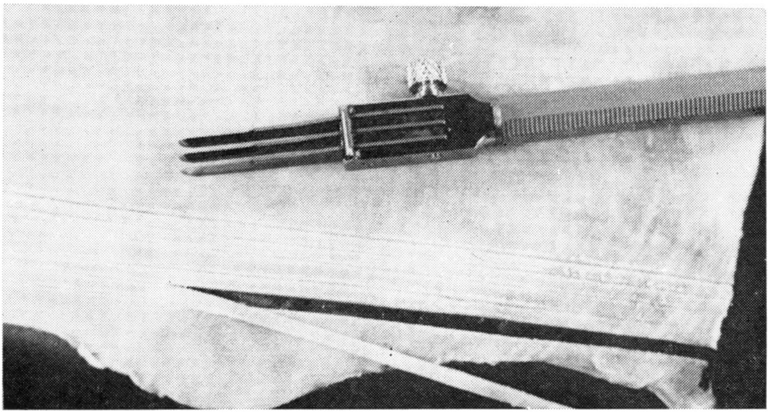


FIGURE 23

Three-bladed knife (Storz) used for cutting the fascia after freezing. Note the piece of fascia cut.

Fascial strips were attached to the arms of a Tensilgraph (Figure 24) and weights were gradually added until the fascia broke (Table 1). The rupture was always in the central part of the fascia and not at the point of attachment to the arms of the instrument. Variations in exact site of rupture were probably due to the limitations of the cutting technique and the angle of the fibers in the fascial layers to the lines of force.

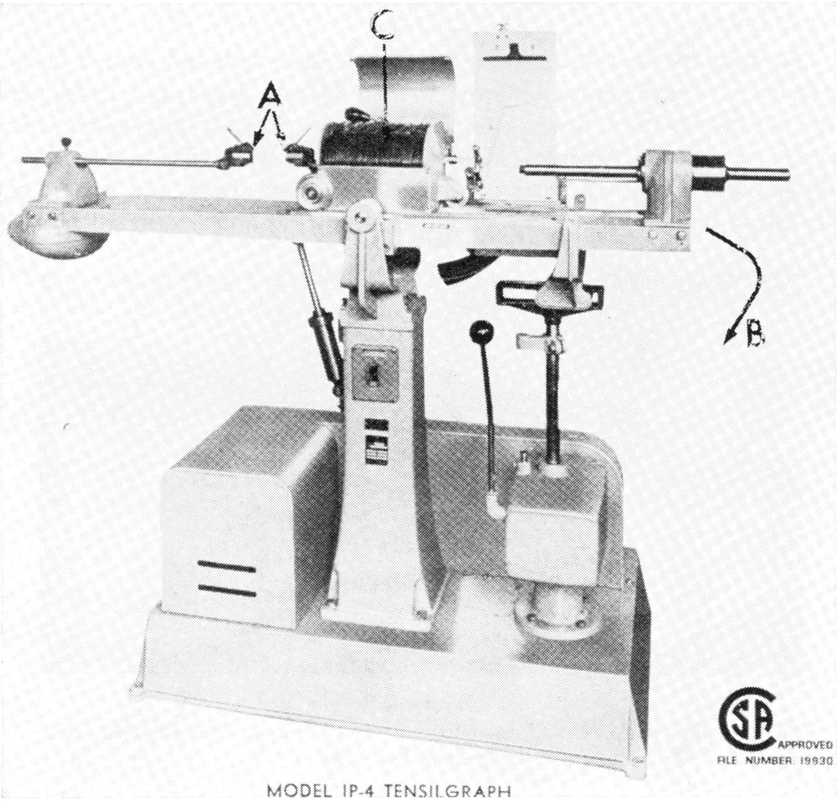


FIGURE 24

Tensilgraph—pieces of fascia are attached to the jaws at A. The arm of the instrument is moved in the direction B, and the force of the weights at C are gradually applied to the fascia.

There was no significant difference found between the strength of the fresh and irradiated specimens. Fascia lata was consistently stronger than the other two tissues tested. We preferred human fascia lata obtained from young males because we could obtain a large uni-

TABLE 1. TENSIL STRENGTH OF FASCIA

		Mean	Standard deviation
Fascia lata (human)	Fresh 2 mm strips	1.59 Kg	0.76
Fascia lata (human)	Irrad. 2 mm strips	1.52 Kg	0.93
Fascia lata (human)	Fresh 4 mm strips	3.52 Kg	1.79
Fascia lata (human)	Irrad. 4 mm strips	3.04 Kg	1.38
Rectus abdominis (human)	Fresh 2 mm strips	0.37	0.16
Rectus abdominis (human)	Irrad. 2 mm strips	0.28	0.16
Rectus abdominis (human)	Fresh 4 mm strips	1.16	0.55
Rectus abdominis (human)	Irrad. 4 mm strips	0.75	0.31
Bovine fascia	Fresh 2 mm strips	0.18	0.05
Bovine fascia	Irrad. 2 mm strips	0.29	0.14
Bovine fascia	Fresh 4 mm strips	1.02	0.55
Bovine fascia	Irrad. 4 mm strips	0.92	0.29

form sheet with the direction of the fibers clearly seen. In rectus abdominis sheath the fibers are not uniform in direction or thickness.

The maximum amount of stretching possible with human fascia was up to 15 per cent of the original length of the piece being tested, and was achieved just before the breaking strain was applied. In the case of beef fascia, stretching began as soon as the load was applied and reached a maximum of approximately 40 per cent of the original length before rupture.

FATE OF FRESH AUTO- AND HOMOGRAFTS AND OF PRESERVED IRRADIATED FASCIA LATA BY SEX-CHROMATIN STUDIES

A piece of irradiated human fascia was placed in a rabbit's cornea for three weeks. Tissue cultures made after this time in three instances showed no growth of human cells. The cells were dead at the time of transfer and appeared to be replaced by infiltrating fibroblasts from the host. The fate of the collagenous fibers in the graft could not be judged.

Fascia was taken from male rabbits and implanted into the corneas of female rabbits and fascia from female rabbits was implanted into the corneas of males. At the end of three weeks we removed the implants, being careful to take as little of the surrounding tissue as possible. Tissue cultures showed the fibroblasts (Figures 25–27) of the graft (identified by the presence or absence of sex chromatin, Barr bodies)[53] to be growing well and persistently. Macrophages and round cells appeared to be growing into the graft from the host, as shown by the sex chromatin.

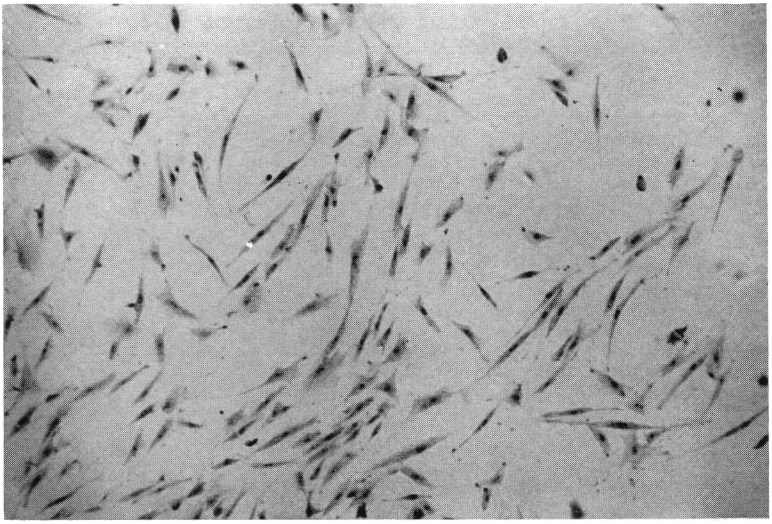


FIGURE 25
Outgrowth from human fascia showing fibroblasts after tissue culture.

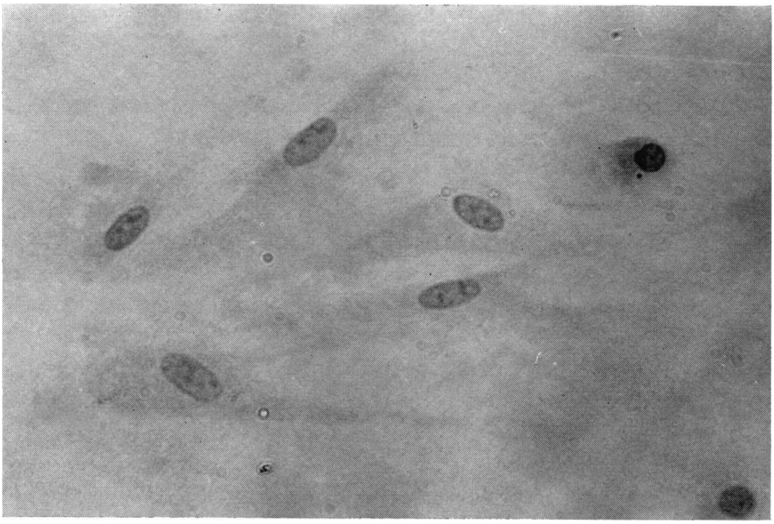


FIGURE 26
Male rabbit fibroblasts from fascia on tissue culture. This fascia had been transplanted in a female cornea for three weeks.

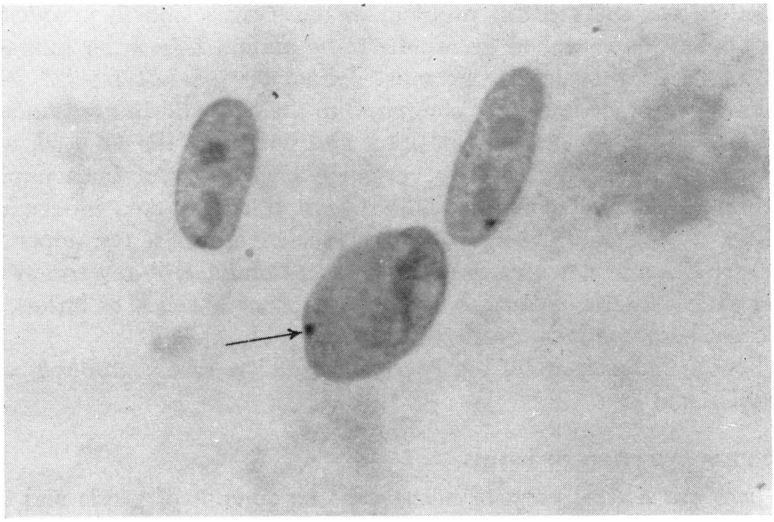


FIGURE 27

Rabbit fibroblast nuclei in tissue culture, grown from female fascia implanted in a male cornea after three weeks showing sex chromatin (Barr body).

THE USES OF FASCIA IN OPHTHALMIC SURGERY FOR BLEPHAROPTOSIS

There are many different types of ptosis of the upper lid and, depending on its nature, different types of surgery are employed for its correction.[54–58] Congenital ptosis, usually unilateral, shows great variation in the amount of levator function. Ptosis may be due to an injury or to general disease, to neurologic disorders such as myasthenia gravis, or to a myopathy such as a progressive ophthalmoplegia externa. Of the many different operations devised for the correction of ptosis the most suitable must be selected in each case. If adequate levator action is present, shortening of this muscle is the operation of choice and gives the best results. If levator function is poor, the lid can be elevated by fastening it to the frontalis muscle with fascia lata. The production of symmetry in the position of the lid and equality of the width of the palpebral fissure is the key to real success in surgery for ptosis. Attachment of the lid to the frontalis muscle at the brow has been achieved in various ways. Friedenwald and Guyton[59] developed a circular type of suture using silk, cotton, or braided tantalum. The sling extended across the lid, through the tarsus, and was brought up on each side to the frontalis muscle in a rhomboid fashion.

Infection was the greatest problem in these cases and in practically every case the suture had eventually to be removed. In order to assess the results of our surgery we must define the "perfect result." It is achievement of symmetry as compared to the other lid in position and contours of the lid margins, position and length of the lid fold, and width of the palpebral fissure; complete uncovering of both pupils; retention of normal winking without lagophthalmos, i.e., incomplete closure of the eyelid, with limitation of the excursion of the upper lid and restriction of downward movement; and absence of any complications such as notching of the lids, distortion or absence of lashes, or exposure keratopathy.

Though, unfortunately, the "perfect result" is rarely attained, one should aim at it.

PREOPERATIVE STUDY OF PTOSIS

There are several ways of measuring the amount of ptosis and the function of the levator muscle. The width of the palpebral fissure of each eye should be measured with a millimeter rule in the primary position. The position of the lower lid and the upper lid in relation to the cornea and pupil are noted and it is decided where the ptotic lid should be placed with respect to the upper limbus. To check the levator function, a millimeter rule is held before the eye while the thumb splints the frontalis muscle to prevent its action. The patient is instructed to look in the extreme down position of gaze and then look up, and the amount of excursion of the lid is measured. Should it be 6 mm or less, levator action is poor and fascial repair is indicated. In the unilateral cases especially, we should note the position of the lid folds so that they may be altered to make the ptotic lid as much as possible like the normal lid.

It is difficult to obtain fascia from a child under three years because his leg is too short to yield strips of sufficient length. Delaying the operation until the child is between three and five years of age is advisable provided the lid does not cover the pupil. If for any reason the lid is closed and we are anxious to get it open before this time, we are forced to resort to using either homogenous, irradiated, or freeze-dried fascia (Figures 28–31). By arranging for the operation on a younger child to follow immediately upon that of an older child, an excess of fascia can be taken from the older, kept in saline, and used for the younger. If this is not done, irradiated stored fascia may be used in the very young.

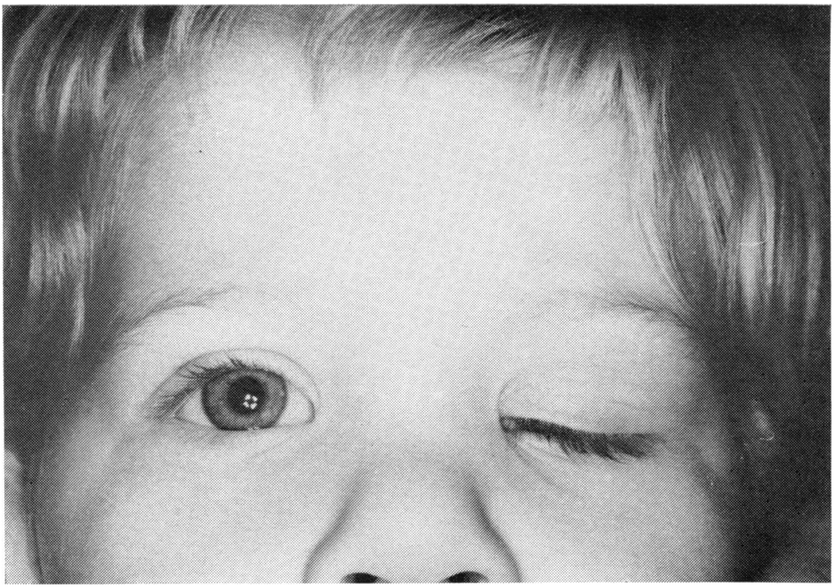


FIGURE 28
This one-year-old child shows a complete ptosis of the left upper lid present from birth.

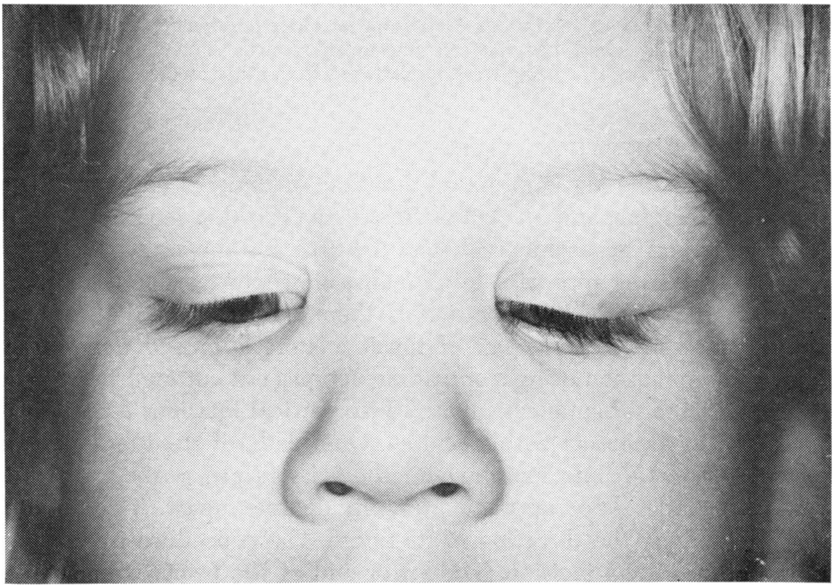


FIGURE 29
Same patient as in Figure 28, on looking down.

FIGURE 30

Same patient as in Figures 28 and 29. This picture was taken the morning after operation. Homogenous fascia was used from an older child who had just had a ptosis repair. The child has had an uneventful course. There have been no complications using fresh fascia taken from other children.

TECHNIQUE OF OPERATION

The side of the leg is prepared (without shaving in children) with green soap, iodine, and alcohol or Betadene. The skin incision is made in line between the lateral condyle of the tibia and the anterior superior iliac spine, starting approximately 2 inches above the knee and extending upwards for 1 inch. The incision is then deepened until the fascia comes into view. A long pair of tonsil scissors is passed upwards in line with the incision using a spreading action (not cutting) to free the fascia from the subcutaneous tissue. Two vertical incisions 8 mm apart are made in the fascia with a scalpel. One blade of the tonsil scissors is passed through one incision and the scissors are pushed upwards with the blades kept approximately 15 degrees apart. This divides the fascia along the direction of its fibers. The procedure is repeated in the other fascial incision. The lower end of the fascia is cut across and the scissors are then passed upwards freeing the strip thus formed from the underlying muscles. The lower end of the strip is passed through the end of the fascia stripper (Figures 32 and 33)

FIGURE 31
Same patient as in Figures 28–30. On looking down there is a fold of skin which pushes the lashes downward. This skin was removed later and should have been removed at the time of the fascia repair.

and held with forceps. The fascia stripper is passed upwards until a strip of fascia 10 cm long is obtained. It is then cut. The piece of fascia so obtained should be sufficient to make four strips 2 mm wide, enough material to repair a bilateral ptosis. The fascia is fastened to a board with straight pins and cut down its center with a scalpel. Each half is again cut in half longitudinally.

Three skin incisions are made in the upper lid as close as possible to the margin but avoiding the lash follicles. The first incision is made in the center point of the margin and the other two are made halfway between this point and the canthi.

Two other incisions are made in the forehead 7 mm above the brow and parallel to it, the outer incision being made 6 mm lateral to, and the inner one 6 mm medial to, the corresponding lid incision. A third incision is made in the brow 6 mm above the midpoint of a line joining the other two incisions and parallel to them. A lid plate is placed under the upper lid in order to protect the globe. The Wright fascia needle is passed down through the lateral incision in the brow emerging from the lateral incision in the lid margin (Figure 34). The fascia is

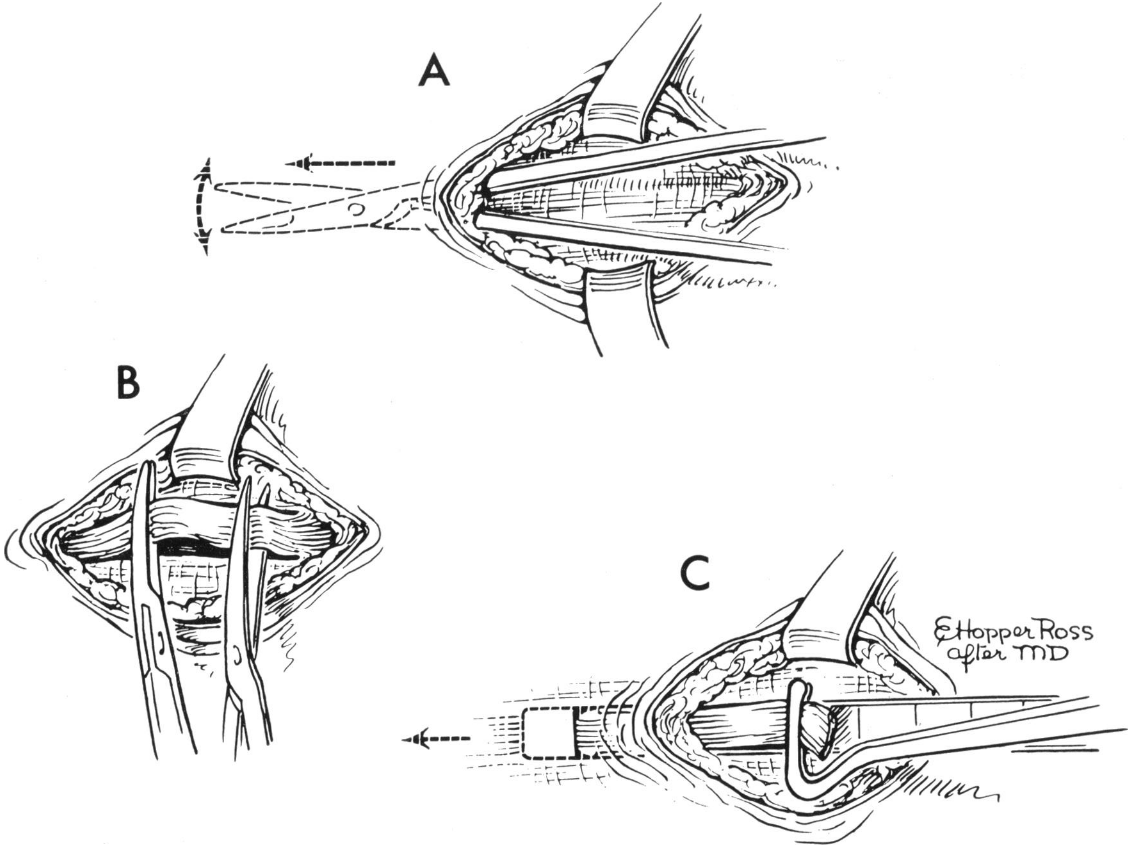


FIGURE 32

Method of obtaining fascia. A, overlying tissue is freed from the fascia. B, fascia is cut and posterior surface is dissected free with tonsil scissors. C, fascia stripper is pushed upward removing a 10-cm strip, 10 mm wide.

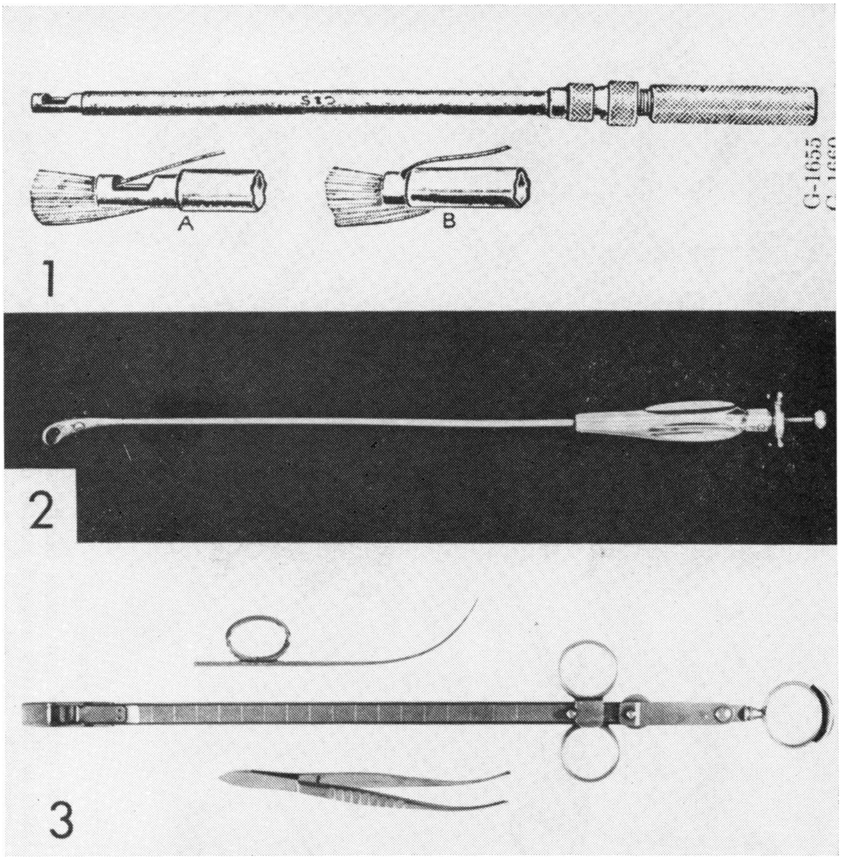


FIGURE 33
Different types of fascia strippers. 1. The Masson stripper, cylindrical in shape, with a blunt leading edge. Great difficulty was encountered in passing this stripper up to separate the fascia. 2. The Wilson stripper has a curved end with a blade that slides across the central opening to later cut off the fascia. This instrument also was blunt and very difficult to pass up the leg. 3. The Crawford stripper has cutting blades on both sides of the instrument which cut the fascia as the instrument is passed up the leg, and at the desired level a blade is moved forward to cut off the fascia.

threaded through the hole in the needle and drawn upwards pulling one end of the fascia out through the brow incision. The needle is then passed into the central incision in the lid margin, through the superficial substance in the tarsus to ensure a firm attachment of the fascia to it, and emerges through the lateral incision in the lid. The other end of the fascia is threaded through the needle and pulled medially

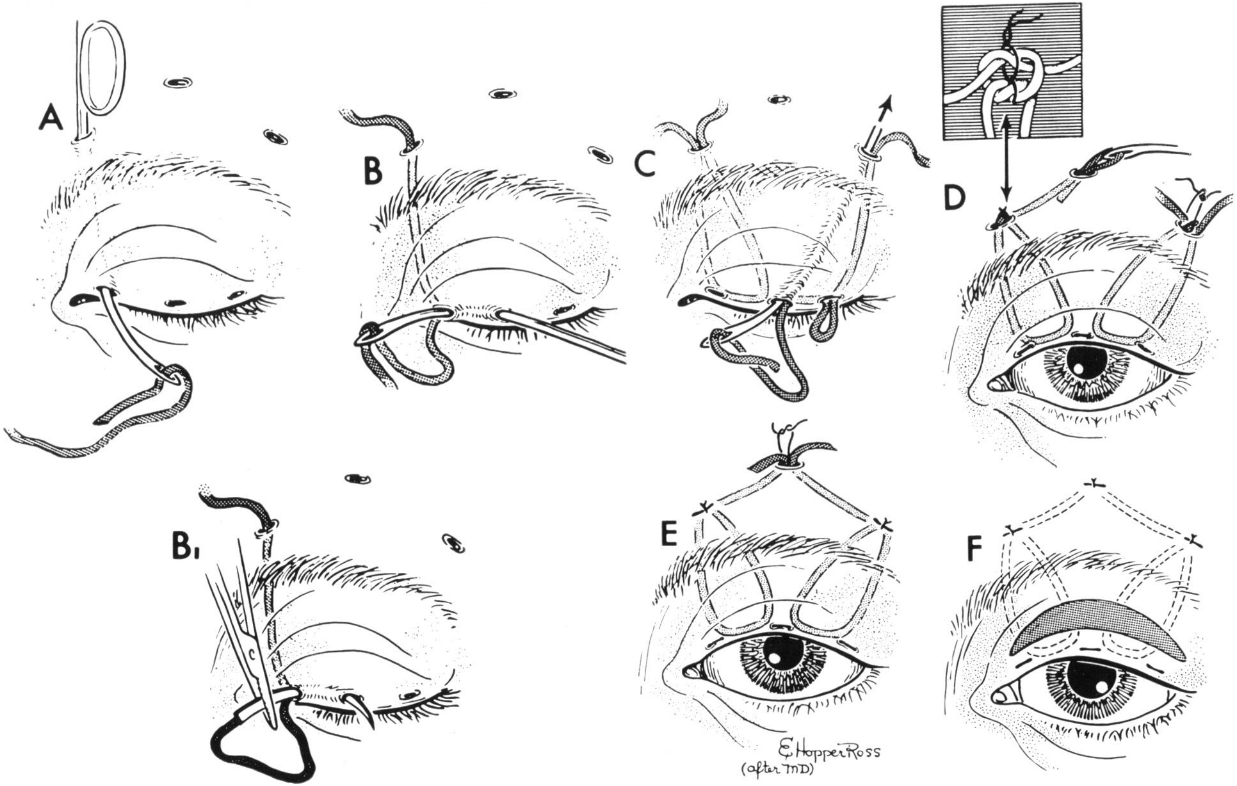


FIGURE 34

Strip of fascia lata looped through the lid with Wright fascia needle showing the method of tying the knot. B_1 is a new method of placing the fascia in the tarsus using a needle developed by the author and the Storz Company. This needle is shown in Figure 33B. The end may be opened and the fascia placed in the end (temporarily swaged) and so drawn singly through the tarsus. The Wright needle pulls the fascia, double thickness, and frequently does not get a secure bite in the tarsus.

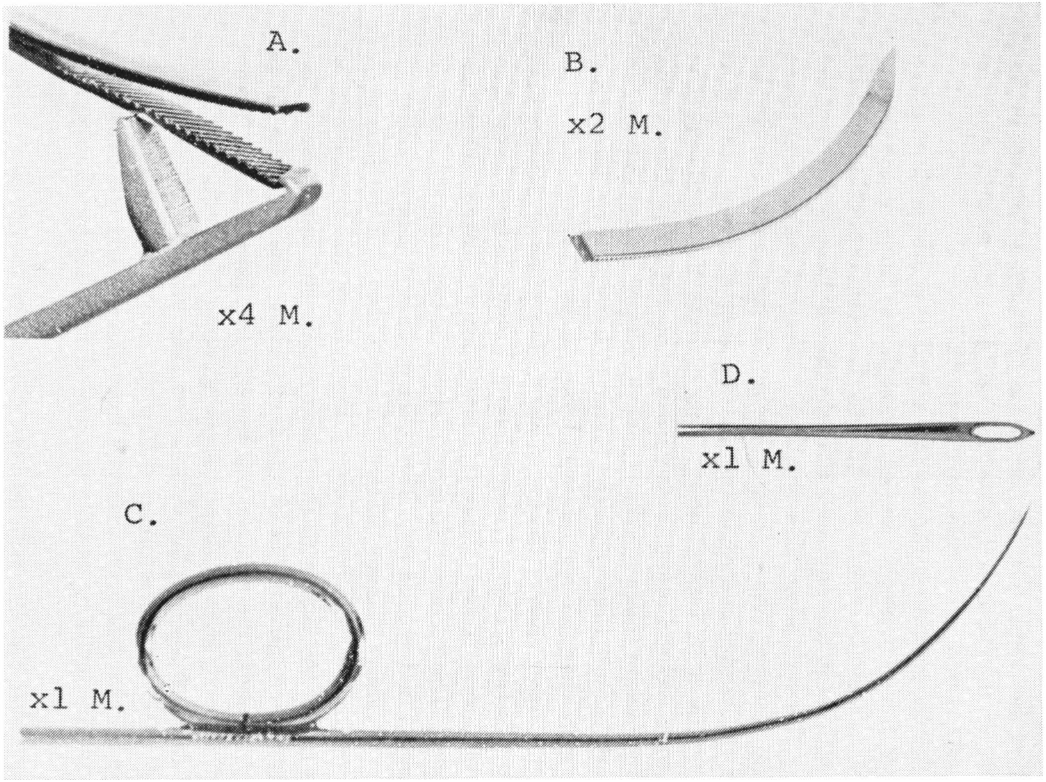


FIGURE 35
Fascia needles. B. Photograph (2×) of a new needle developed by the author and the Storz Company. The end may be opened to allow the end of the fascia to be held by the milled surfaces as shown in A. This needle is used to place the fascia in the tarsus and permits a secure bite without tearing the tarsus, as frequently happens with the Wright needle which pulls a double thickness of fascia through the tarsus. C. The Wright needle is used to place the fascia in the lid as shown in Figure 32.

and out through the central lid incision. The needle is then passed down from the lateral brow incision to come out through the central lid incision. There the end of the fascia is threaded on the needle and drawn up and out through the lateral brow incision, beside the other end of the strip. The second piece of fascia is placed in the medial side of the lid in a similar fashion. (A new needle, and the Wright fascia needle are shown in Figure 35.)

Before the upper ends of the fascia are tied, it is advisable to grasp the ends of the two pieces coming through the brow incisions and gently pull on them to elevate the lid into the desired position. Should it be obvious that in this position a fold of skin will hang down over the lid margin, this redundant skin should be removed before the fascia is tied. Skin is excised by making a horizontal incision across the lid parallel to the border and removing an ellipse of skin measuring 5 to 8 mm in width at its central point. This corrects the overhang. The skin edges are sutured together using 6–0 plain catgut in interrupted stitches. The greater the ptosis the bigger the ellipse of skin that should be removed. In unilateral cases the lid must be pulled up between 2 and 3 mm more than the desired result (Figures 36–43).

Before the upper ends of the fascia are tied, a piece of 3–0 chromic suture is laid between them. The first loop in the fascia is tied and then the chromic suture is tied about this half knot to prevent the fascia from slipping. The second loop in the fascia is tied and the chromic suture is again tied around this. The other piece of fascia is pulled up and tied in a similar manner. With both knots tied and the four ends dangling, one end of the fascia above the knot on the lateral side is pulled up under the skin with the fascia needle and out through the central brow incision. An end of the fascia above the medial knot is also pulled up under the skin and out through the same incision. These ends are then tied, with chromic catgut securing the knot. This prevents the fascia from slipping down. The skin incisions in the brow are closed with two interrupted 6–0 plain catgut sutures for each incision. If no skin has been removed from the lid it is not necessary to suture the lid incisions as they are pulled together by elevation of the lid.

To ensure that the eye will be kept closed for twenty-four hours, two modified Frost[60] sutures of black silk are placed through the lower lid, brought out through the skin of the brow, and tied over a button. The lid plate is removed, antibiotic ointment is instilled into the conjunctival sac, and the Frost sutures are pulled up and tied. In bilateral cases these sutures are removed the next morning. In unilateral cases, since the patient does have one eye open, it is not

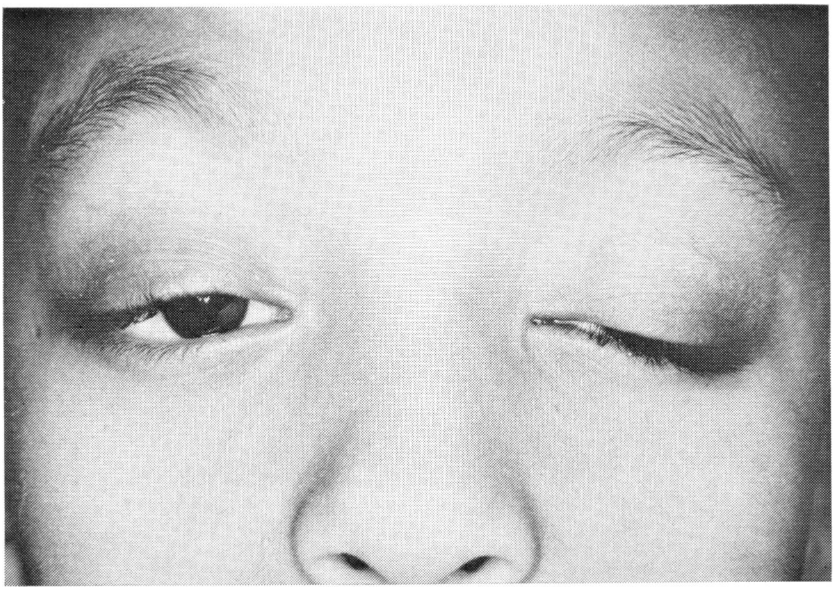


FIGURE 36
This five-year-old boy had a levator resection on the left eye, in Europe, with a poor result.

FIGURE 37
Same patient as in Figure 36. There was practically no movement of the left upper lid on looking up. There was 6 mm of elevation of the right upper lid on looking up.

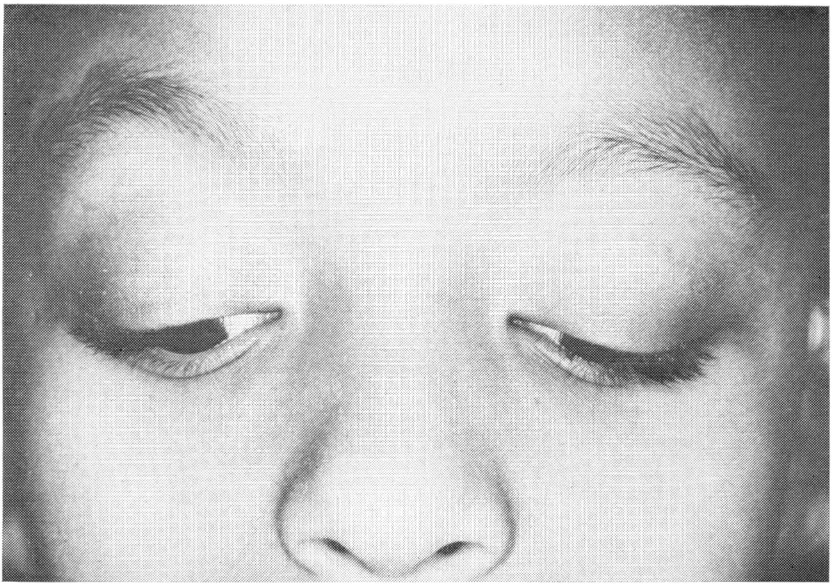


FIGURE 38

Same patient as in Figures 36 and 37, on looking down.

FIGURE 39

Same patient as in Figures 36–38. In the interest of symmetry, a bilateral fascia lata repair of the ptosis was carried out. A large ellipse of skin was removed from the right upper lid. The position of the lashes on the left eye is much better than on the right, as the fold of skin on the right side causes the lashes to turn downward.

FIGURE 40

Same patient as in Figures 36–39. This shows the lagophthalmos on looking down. As patients grow older they learn to avoid this position of gaze by turning their heads down.

necessary to remove the Frost sutures so quickly but there is no reason why it should not be done.

INDICATIONS FOR THE USE OF FASCIA FOR PTOSIS

The advantages of using fascia for the repair of ptosis are many. The technique is simple and the operation is easily repeated if the results are not satisfactory. It may be used after levator resection has failed. There is less lid swelling than with other procedures, fascia is well tolerated and permanent, and there are no delayed infections. The disadvantage is imperfect mobility of the lid; lagophthalmos on looking down, or in sleep, may be deemed a less than perfect result.

Some types of ptosis seem especially suitable for repair with fascia. In children with bilateral congenital ptosis there is very little levator action and bilateral repair will give good symmetry; these are ideal cases for this type of operation. In unilateral congenital ptosis, levator resection should be tried if there is any reasonable hope of elevating the lid, but if there is 6 mm or less of levator function as measured by the excursion of the lid, then some type of frontalis procedure must be

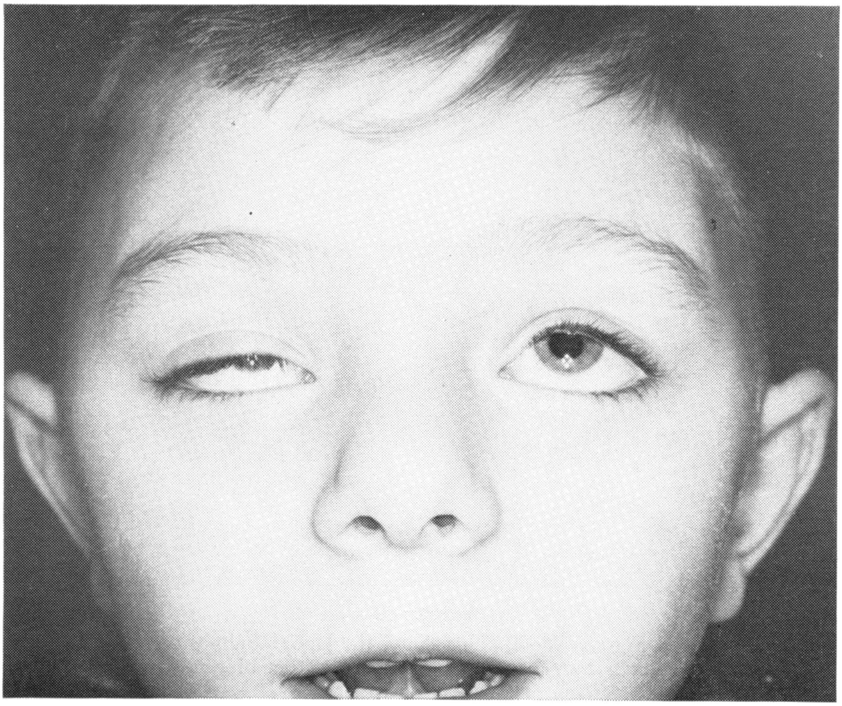


FIGURE 41
This four-year-old boy had a right ptosis with very little action of the levator muscle.

used. These cases should be overcorrected by 2 to 3 mm at the time of surgery. Beard[61] advocated cutting the levator muscle and removing 5 to 6 mm of the tendon on the normal side and then doing a bilateral fascial repair in unilateral cases.

Blepharophimosis associated with ptosis is always bilateral and occurs in about 3 per cent of congenital cases. The results of surgery in these cases are always disappointing because of the narrow lids and the difficulty of elevating them sufficiently. Johnson[62] advocated a lateral canthoplasty in order to widen the lids. Fascia lata is the method of choice in raising these lids but, though their appearance can be improved, the operative results are rather disappointing (Figures 44 and 45).

Children with congenital fibrosis syndrome (general fibrosis syndrome) have a bilateral strabismus fixus with ptosis. The eyes are usually fixed in the downward position and the child must tilt his head back in order to see straight ahead. To elevate the eyes before repairing the lids, we recess the inferior rectus and resect the superior rectus. Occasionally the inferior recti are so tight and fibrous that they must be cut free from the globe. A catgut suture through the inferior rectus stump and brought out through the lower lid will hold the globe up in the primary position. After the eye has been elevated we do a bilateral fascial repair of the ptosis (Figures 46 and 47).

About 6 per cent of all cases of congenital ptosis demonstrate the jaw-winking phenomenon (Marcus-Gunn syndrome) which is always unilateral. Since the affected lid moves upwards when the mandible either is depressed or moves to the opposite side, it clearly shows in the sucking infant. The syndrome may be associated with other muscle weaknesses, the commonest being paralysis of the superior rectus muscle. Presumably the syndrome is due to the levator being connected to both the third nucleus and the external pterygoid portion of the fifth nucleus. The degree of ptosis varies. If it is not severe and the lid movement is not too noticeable, treatment may be unnecessary. Levator resection will suffice if ptosis is associated with only slight jaw-winking. If the jaw-winking is unsightly, we treat it by removing at least 5 mm of the entire width of the levator tendon to produce a complete ptosis. A month later the lid is raised with fascia, elevating it 2 to 3 mm more than on the normal side. This procedure stops the jaw-winking quite satisfactorily (Figures 48 and 49).

Traumatic ptosis is usually caused by an injury cutting the levator muscle. In most cases, when there has been an injury to the lid and the levator muscle has been cut, an attempt should be made at the time of injury to find the ends of the levator muscle and suture them together again. Occasionally there is severe damage to the levator muscle and one must resort to the use of fascia.

Ptosis may be a complication of enucleation. The severe trauma necessitating enucleation may also have severed the levator muscle. The lids of three such patients with very little levator action were elevated with fascia. A slight undercorrection may be an advantage as it helps to hide the deformity of a prosthesis.

Ptosis may follow the removal of lid tumors, such as hemangioma (Figures 50–52) or neurofibroma (Figures 53 and 54). In cases of large hemangiomas or of neurofibromas invading the whole lid, the levator muscle may be damaged or removed during plastic surgery, leaving little choice of method of repair. Fascia lata slings can be used. The results, though far from perfect, improve cosmetically as the children grow older.

FIGURE 42
Same patient as in Figure 41, the day after his operation. Autogenous fascia was used.

FIGURE 43

Same patient as in Figures 41 and 42, one month later.

FIGURE 44

This little girl had blepharophimosis with ptosis. She had had a V-Y operation to widen the medial canthi.

FIGURE 45

Same patient as in Figure 44. Shows results after fascia lata repair of ptosis. The results are never good at best, but there is a definite improvement.

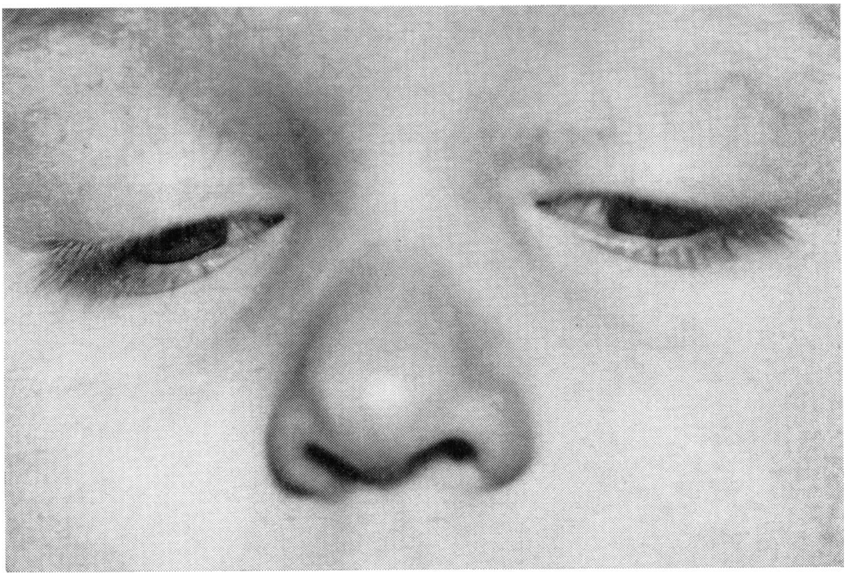


FIGURE 46

Strabismus fixus with ptosis (congenital fibrosis syndrome). In order to see straight ahead, this child had to tip his head back. In this figure the child's head is held straight and it is seen that the eyes are directed downward and the lids are practically closed.

FIGURE 47

Same patient as in Figure 46. Bilateral recession of the inferior rectus muscles with resection of the superior rectus muscles was carried out followed by a bilateral repair of the ptosis with fascia. The right eye has been elevated into a better position than the left. However, there was no binocular vision. Later, surgery elevated the left eye to match the right.

FIGURE 48

Marcus-Gunn Syndrome. A child with ptosis associated with the jaw-winking syndrome. The lid is shown in the positions affected by moving the jaw to one or the other side and also opening the mouth.

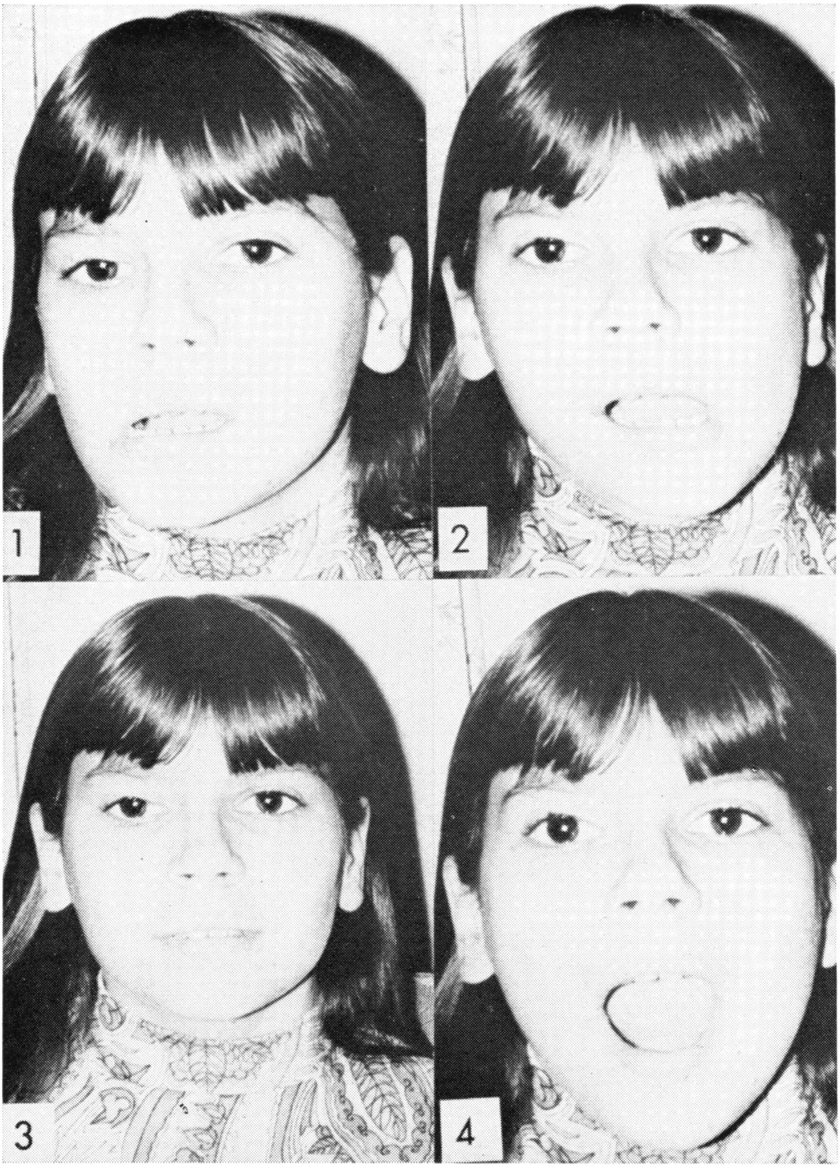


FIGURE 49
The same child as in Figure 48 two years later. A piece of the levator muscle was excised giving a complete ptosis and then after one month the lid was suspended with fascia to the frontalis muscle. The jaw-winking has been eliminated and the ptosis corrected. There still was some lagophthalmos on looking down.

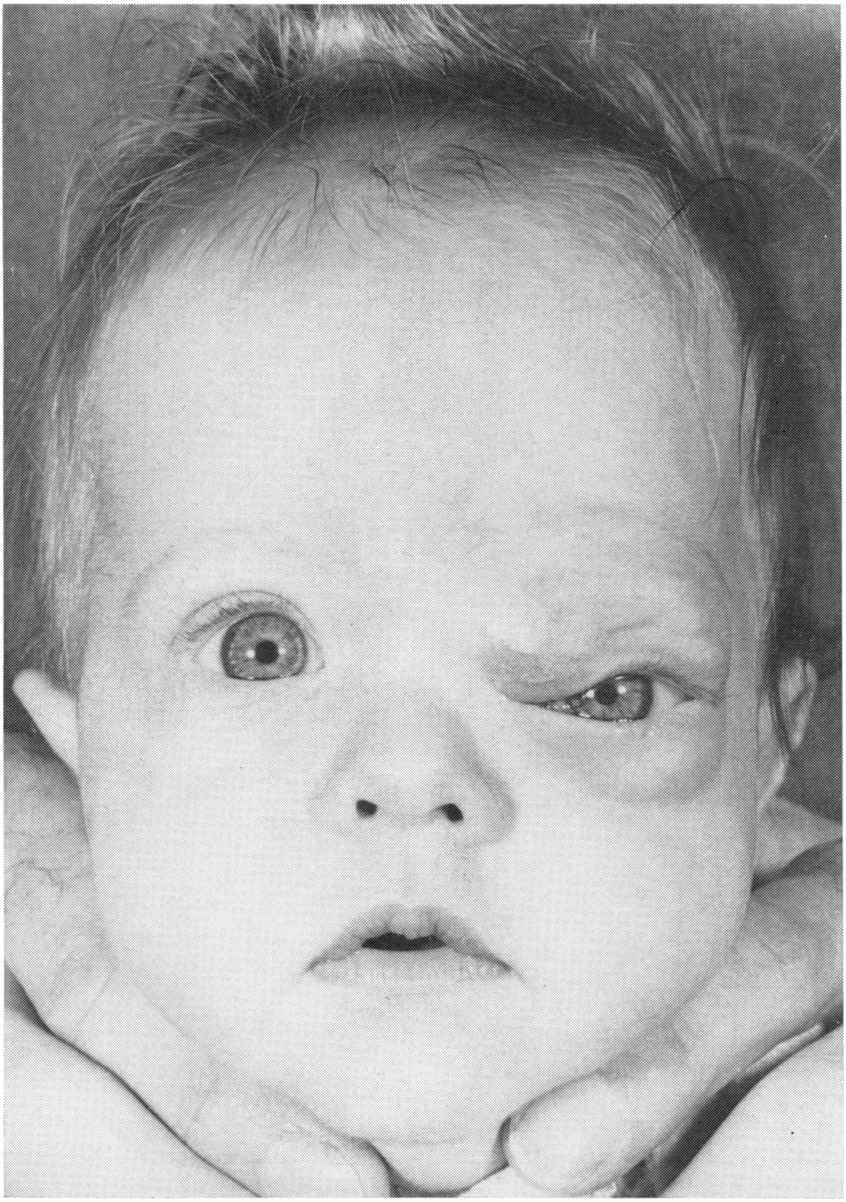


FIGURE 50

This nine-month-old infant had a large hemangioma of the left upper lid. Several operations had been done to remove the tumor, resulting in damage to the levator muscle and ptosis.

FIGURE 51
The same child as in Figure 50, at four years of age with ptosis of the left upper lid and no levator action.

REVIEW OF CASES OF PTOSIS

One hundred and eighty-six cases of ptosis repaired with fascia were studied (Table 2). Cases treated with fresh fascia were assessed at a minimum of one year postoperatively, and those treated with irradiated fascia, six months postoperatively. Since there was no obvious difference in the two groups we have combined them for evaluation.

BILATERAL CONGENITAL PTOSIS (41 CASES). In 37 of these patients the results were satisfactory with good symmetry of the two lids. In three cases one lid was noticeably lower than the other, but the discrepancy was not sufficient to warrant reoperation. One patient, aged 39, developed an exposure keratitis so the fascial strips were cut, returning her to her former ptosis.

UNILATERAL CONGENITAL PTOSIS (110 CASES). Assessment is difficult

FIGURE 52

Same patient as in Figures 50 and 51. Fascia lata repair of ptosis was carried out shortly after the picture in Figure 51 was taken. This picture of the child at age 7 shows how inconspicuous the lid condition is now.

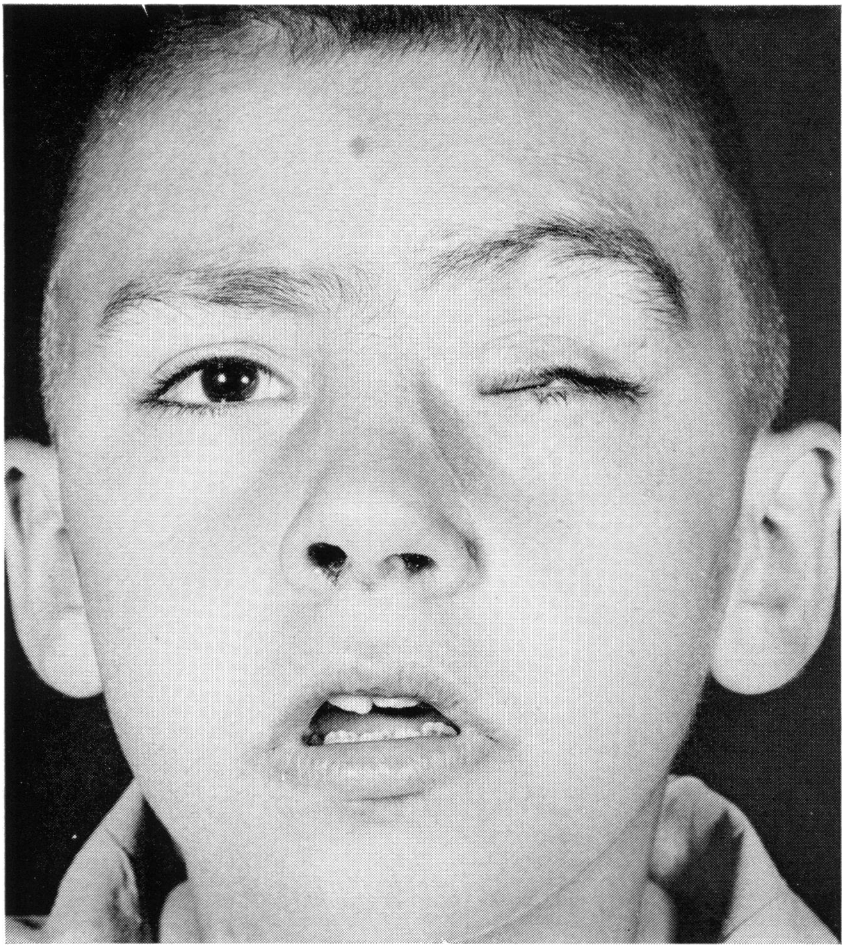


FIGURE 53

This boy had a neurofibromatosis involving the left upper lid. Several operations were performed to remove the tumor from the lid, resulting in complete ptosis.

in unilateral ptosis because of the difference between the lids on looking up and looking down. In 68 patients there was less than 2 mm difference in the level of the upper lids in the primary position, in 32 patients there was approximately 2 mm difference, and in 10 patients there was more than 3 mm difference.

In all cases (bilateral and unilateral) the children slept with their operated lids open. After one year, approximately one-third of the

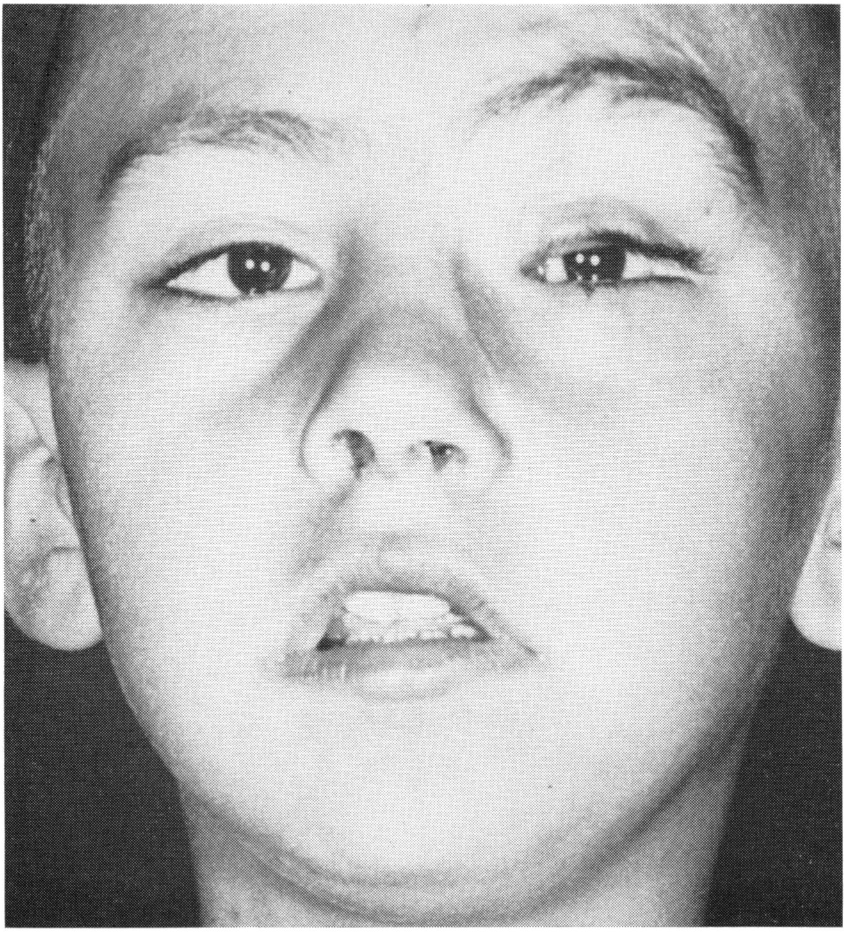


FIGURE 54
Same patient as in Figure 53, after repair of ptosis with fascia lata. It was difficult to raise this lid high enough because of the deep scarring following removal of the tumor. In this Figure the patient could use his eye.

parents of these children stated that the eyes were practically closed during sleep with just a small "open slit" remaining. Three patients developed exposure keratitis and the fascial strips were cut. Of these three patients, one patient (aged 39) had had a bilateral repair of congenital ptosis, the other two (aged 21 and 26) were unilateral cases. An improper lid fold did not seem to be a problem with bilateral cases, as the results were symmetrical. If large lid folds were produced

TABLE 2. CASES STUDIED

	Total	Unilateral	Bilateral
Autogenous fascia	173	117	56
Stored fascia	7	4	3
Homogenous	6	5	1
	186	126 68.27%	60 31/73%
Bilateral congenital ptosis	41		
Unilateral congenital ptosis	110		
Blepharophimosis	9		
Congenital fibrosis syndrome	10		
Marcus-Gunn	4	(3 of the 7 cases treated had levator resection only)	
Traumatic ptosis	4		
Ptosis after enucleation	3		
Ptosis following lid tumors	5		
	186		

and the lid caused a turning down of the lashes, it was necessary to remove an ellipse of skin from both lids. In patients with unilateral ptosis, an ellipse of skin should be removed in most cases. In our last 27 unilateral cases an ellipse of skin was removed. In the earlier monocular cases, approximately one-third later had skin removed from the lid. Care must be taken not to place the fascia too deeply in the lid or else entropion will result. Figure 55 shows a patient who had the fascial strips placed too deeply in the lid causing an entropion and lashes rubbing on the cornea. The fascia was cut and later replaced in the proper position with good results.

BLEPHAROPHIMOSIS (9 CASES, ALL BILATERAL). Since this condition usually represents only about 3 per cent of cases of congenital ptosis, in order to collect enough cases for consideration, we report those seen in a ten-year period, while other conditions are reported for a seven-year period. In all nine patients there was improvement in appearance; although results were not perfect by any standard, patients and their parents were pleased.

CONGENITAL FIBROSIS SYNDROME (10 CASES, ALL BILATERAL). We operated on seven patients to elevate the eyes by recession of the inferior rectus and resection of the superior rectus, before fascial repair of ptosis. Three had lid surgery only. All cases showed improvement in appearance. Appearance was not completely satisfactory in two of the children who had had surgery to elevate the eyes, because the eyes were not at the same level. The patients were pleased that they

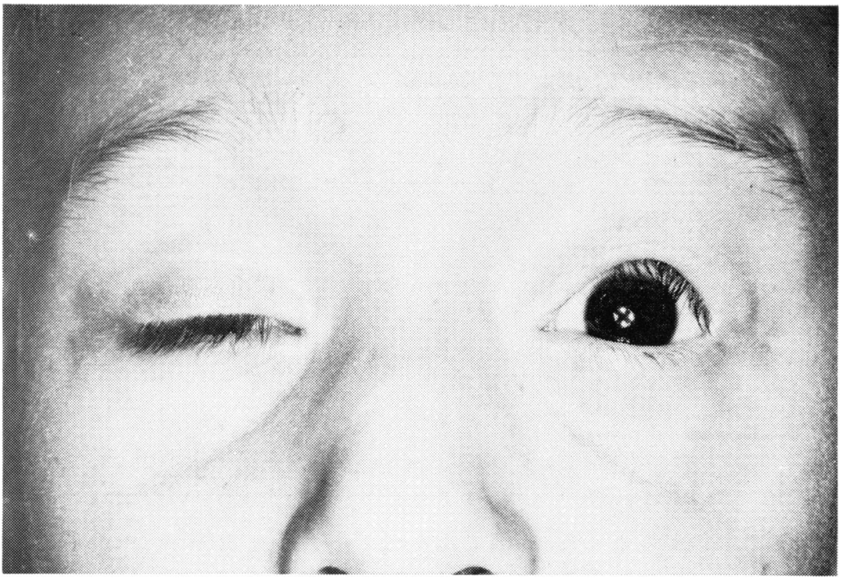


FIGURE 55

This boy has had a fascia lata repair of ptosis of his left upper lid and the fascia was placed too deeply, causing an entropion of the upper lid and lashes rubbed on the cornea. Correction of this condition was affected by cutting the fascia strips and pulling the lid down and then later replacing the fascia in the lid.

did not have to posture their head backward in order to see. The remaining cases were definitely improved. These patients do not have a positive Bell's phenomenon, since their eyes cannot roll upwards. All tolerated elevation of the lids with fascia without corneal exposure problems. Eight of the ten cases were under five years of age and two were older (25 and 45 years).

MARCUS-GUNN SYNDROME (7 CASES, ALL UNILATERAL). Four of these cases were repaired by first cutting the levator tendon and then excising between 5 and 6 mm of the tendon. One month later we suspended the lid with fascia from the frontalis muscle. Two had good results with good position of the lid in the primary position. One had a satisfactory result with good lid position, but the winking continues. Elimination of the winking was achieved in another child but the lid level is low and another operation is necessary. We resected the levator in three instances.

TRAUMATIC PTOSIS (4 CASES, ALL UNILATERAL). The levator muscle was severely damaged in all cases. It was impossible to find the levator tendon, and all were repaired with fascia. All patients were improved cosmetically.

PTOSIS AFTER ENUCLEATION (3 CASES, ALL UNILATERAL). Severe trauma to the orbit, damaging the globe and the levator muscle, led to enucleation. Fascial repair of the ptosis improved all cases.

PTOSIS FOLLOWING THE REMOVAL OF LID TUMORS. The appearance of three patients after removal of large neurofibromas and two after removal of hemangiomas was improved by fascial repair of ptosis. In one there was much lid scarring so that it was difficult to elevate the lid to the same height as its fellow, but there was a definite improvement from the preoperative appearance.

OTHER USES OF FASCIA

RETINAL DETACHMENT

Varieties of synthetic materials have been successfully used to create a permanent encircling indentation of the sclera in treatment of certain types of retinal detachment. Although completely inert, these foreign substances may slowly erode through the tissues and be extruded either externally or internally into the eye. Delayed infection may also occur. The problems of erosion and late infection can be eliminated by the use of human fascia lata strips in encircling procedures.

Havener and Olson (1962)[63] advocated the use of preserved human fascia lata strips. They placed the fascia from cadavers in test tubes with four drops of a solution,* each milliliter containing polymyxin B sulfate, 10,000 units, and neomycin sulphate, 5 mg. They stoppered the tube and sealed it with a plastic material,† assuring a waterproof and sterile seal over the whole end of the tube; it was then frozen in the freezer compartment of an ordinary refrigerator. Bacteriologic cultures of every new batch of fascia insured sterility. Prepared in this manner the fascia could be stored indefinitely. The fascia was placed around the eye in exactly the same manner as any other encircling substance and was tied by looping the ends over and under in a simple knot (as the first half of a square knot). The ends were grasped with forceps and the knot pulled tight. The fascia was secured by passing a 4–0 silk suture around the fascial knot and when it was at the proper tension the assistant tied a single over and under knot in the silk.

*Neosporin, Burroughs Wellcome & Co.

†Vi-drape, Burroughs Wellcome & Co.

They found that preserved human fascia lata was particularly valuable in circling eyes with very thin or weak scleras. Incorporated into the walls of the eye and invaded by connective tissue, it was gradually transformed into part of the living structure. They claimed that the postoperative reaction was no greater than anticipated from the trauma of surgery. In 1964 Havener and Wachtel[64] reported their experiences with the use of fascia lata in 136 patients. They found that the fascia did not cause a necrosis of underlying sclera as did polyethylene, and they also found that there was no late allergic response or delayed infection. Once healing had occurred, fascia did not migrate or slide anteriorly or posteriorly. In 1966 Smolin and Havener[65] further reported that they had treated 408 cases between 1961 and 1964 with no erosion, extrusion, migration, or late infection. Scott,[66] and Boniuk and Okun[67] have used plantaris tendon with success. There seems to be considerable agreement that autogenous and homogenous fascia are very desirable for retinal detachment surgery. Preserved fascia lata, since it can be stored, is probably the easiest to use.

SUPPORT OF POSTERIOR SCLERA

Curtin[68] advocated the use of fascia for the surgical treatment of sclerectatic myopia, a constant accompaniment of the enlargement of the posterior segment of the globe. The exact nature of the process is unknown. To reinforce the posterior sclera, fascia was placed around the back of the eye in the form of a periscleral ring; this ring was then anchored anteriorly. In the first part of his report, Curtin dealt with animal experiments showing that both autologous and homologous grafts were well tolerated by the globe, relatively harmless, equally effective, and capable of supporting the posterior sclera in a range beyond physiologic stress. In 1961 Curtin[69] used fascia lata exclusively in seven cases. He found that the unoperated control eyes increased in myopia from 0.00 D to −2.75 D while the operated eyes decreased in myopia in a range from 0.00 D to +2.5 D with an average of +1.07 D.

SURGICAL TREATMENT OF SCLEROMALACIA PERFORANS

Bick[70] in 1958 reported a 60-year-old male with severe progressive arthritis who had developed a small reddish nodule on the inferior nasal aspect of the left eye. The lesion grew until it involved the entire nasal quadrant of the eye. The conjunctiva was dissected off the lesion which was then cauterized to shrink it. A piece of fascia lata was laid to cover the lesion, with good success. Taffet and Carter

(1961)[71] described the clinical picture of the disease, stating that it usually occurred in women between fifty and sixty years of age with a history of long-standing rheumatoid arthritis. The ocular lesions were yellow nodules located in the sclera between the limbus and the equator. The nodules went on to abscesses with rupture of the uvea. They felt that the treatment of choice was to cover the lesion with a piece of autogenous fascia lata.

RETROTARSAL ATROPHY OF THE UPPER LID

A sinking of the orbital contents posterior to the septum orbitale in the upper lid developed in 30 per cent of all patients who had had enucleation, according to Cutler.[72] Material placed behind the septum orbitale has a tendency to disappear into the orbit. Therefore, in 134 patients he placed two strips of fascia across the lid under the orbicularis muscle, with good cosmetic results.

Fascia lata may be used as a filler or packing tissue in depressed fractures of the supraorbital margins and roof of the orbit.[73] In severe cases where the fragments of bone have lacerated the dura mater and the cerebrospinal fluid is leaking out, it is necessary to patch the defect with a graft of either fascia lata or temporalis fascia, cut to overlay the dural defect by 1 cm. Fascia lata may be used as a filler or packing tissue when a facial deformity results from a latent depressed fracture of the zygomatic bone and orbital margin. We have found that fascia lata is very useful in Tenon's capsule to fill up the space where an orbital implant has been extruded. In a four-year-old girl (Figures 56 and 57) who had lost her eye as a result of a perforating injury, infection followed the enucleation, and within two weeks the plastic sphere had been extruded. The child was left until the reaction in the socket had subsided. Then a small incision was made in the center of the orbit and Tenon's space was opened and the area packed with fascia lata (stored). Because the hole in the conjunctiva was very small, the wound healed quickly and the child was able to wear the prosthesis immediately after the operation. With packaged fascia one might consider using this material at the time of original enucleation.

ECTROPION AND ENTROPION

In ectropion of the lower lid Brenizer (1940)[74] reported on the use of fascia lata as a band for support. Blair (1930)[20] used a strip of fascia lata to hold up the lower lid in facial paralysis (Figure 58). A piece of fascia 3 mm × 10 cm was used by Elliott to correct senile ectropion.[75] The fascia was attached medially to the medial palpebral

FIGURE 56

A five-year-old child who had previously had her left eye removed. The ball implant was later extruded. There was a "sunken appearance" to the artificial eye.

FIGURE 57

Same patient as in Figure 56. A small incision was made into the central area of conjunctiva and Tenon's space was opened. Fascia lata was packed into the orbit and the wound was closed with chromic catgut. The prosthesis was immediately replaced and the child's appearance has remained satisfactory.

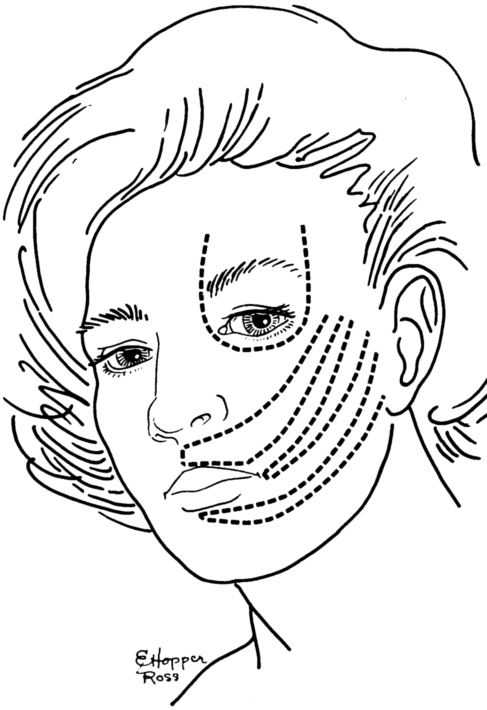


FIGURE 58
Blair's method[20] of placing fascia in the face to hold up the lower lid in facial paralysis.

ligament and laterally to a vertical strip of periosteum at the level of the lateral canthus. He used this technique in six successive cases of senile ectropion, with follow-up periods ranging from six months to two years, and achieved a lasting correction in every case.

SUMMARY AND CONCLUSIONS

Since the turn of the century, fascia has been used in an increasing number of operative procedures for repair of hernias, muscles, and tendons, for anthroplasty, and lately in a number of ophthalmological operations.

The factors making it suitable for these uses are inherent in the nature of the tissue itself: its wide distribution in sheet-like layers, its great tensile strength, and its survival after fresh transplant. Arising from the mesoderm it is made up of fibroblasts and bundles of collagen, a material laid down by the fascial fibroblasts. It is made strong by the arrangement of its chemical bonds.

To assure instant availability of fascia, many methods of preparation and storage have been developed. Fresh fascia from the patient himself can be used but the convenience of "a package deal" which eliminates an additional operation must be weighed against the effectiveness of the transplant. If autogenous human grafts are demonstrably better than the other types of fascia for a particular procedure, then the choice is clear.

To assess the relative merits of fresh and stored human fascia as a surgical tool and to explore the possibilities of using animal fascia in humans, we investigated the fate of fascial transplant in animals. We concluded that fresh auto or homo fascial transplants are "living sutures," and irradiated fascia merely provides a bridge for host fibroblasts. There is no significant difference in the strength of these tissues.

Fresh, auto or homo fascia, and irradiated fascia are equally useful materials for the repair of blepharoptosis when there is poor function of the levator muscle. Most satisfactory results are obtained in bilateral congenital ptosis, but we also get considerable improvement in the bilateral ptosis occurring in blepharophimosis and the congenital fibrosis syndrome, in unilateral ptosis occurring congenitally with poor levator action, in the Marcus-Gunn syndrome, after injury with severe damage to the levator muscle, or after the removal of lid tumors.

Fresh fascia lata is a very desirable material for use in these conditions because there is no tissue reaction or rejection, it withstands tension and is very strong, and it is easily stored.

More work needs to be done to see if there are other types of heterogenous fascia which would be tolerated by humans. There was very little reaction to human fascia implanted in rabbits, but marked reaction to bovine fascia. While beef fascia causes reaction in humans, the fascia of other animals may be tolerated, making other sources available for surgical repair.

By further studies, labeling the cells as host or graft in the manner described, it should be possible to determine if there is an advantage of fresh over irradiated fascia conferred by the two-way growth of fibroblasts from host to graft and from graft to host. If there is an advantage either of increased strength of repair or decreased time for maximum incorporation of the graft into the host, then fresh fascia would obviously be superior.

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