PENETRATING KERATOPLASTY

OBSERVATIONS BASED ON A SERIES OF 148 CASES WITH SPECIAL EMPHASIS ON TECHNIQUES OF GRAFT FIXATION

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INTRODUCTION

Transplantation of the cornea is undoubtedly one of the most fascinating subjects in modern ophthalmology. During the past nineteen years, I have had the opportunity of doing 148 of these grafts, principally at the Massachusetts Eye and Ear Infirmary and St. John's Hospital, Lowell. The statistical results of cases from the ward service of the Massachusetts Eye and Ear Infirmary before 1947 were included in the report on corneal transplantation sponsored that year by the American Academy of Ophthalmology and Otolaryngology. The Lowell cases, however, which include those from active ward services and all my private cases, have not been reported previously. Using this series with its extremely diverse results as a background, I would like to emphasize a few points on transplantation which experience indicates to be of more than ordinary interest or importance. A statistical analysis will also be included of 100 consecutive transplants done during the years 1944 to 1954.

Classification of transplants.—Transplants are classified in two ways, by surface area and by depth (Figure 1). According to area, they are total if the entire width of the cornea is used, and circumscribed, or partial, if only a window is taken from the cornea. According to depth, they are

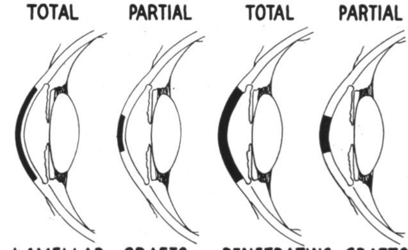


FIGURE 1. CLASSIFICATION OF GRAFTS

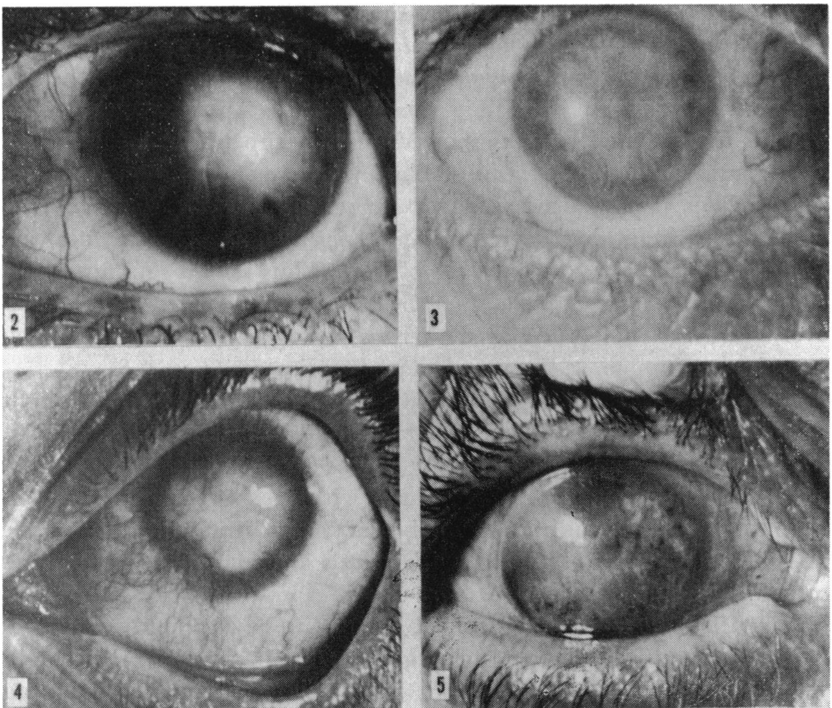
lamellar when only the top layers or lamellas are replaced, and penetrating when the full thickness of the cornea is transplanted. Thus one recognizes four types: total and partial lamellar, and total and partial penetrating keratoplasty. Until a few years ago only the partial penetrating was considered of value; but lamellar grafts are now widely used also.

Selection of cases.—The first key to success is the proper selection of cases. Favorable cases are those in which the eye is normal except for the cornea; the leucoma, or scar, is not dense or vascular; and there are areas of clear or slightly scarred cornea surrounding the graft to furnish it nutrition (Figures 2 and 3). Especially unfavorable cases are those with dense scarring of the entire cornea, vascularized pannus from old trachoma or severe chemical burns (Figure 4), and edema of the cornea as in Fuchs's dystrophy (Figure 5). In my experience the "most favorable cases" have been the following groups in the order listed: (1) small central scars from any cause, (2) keratoconus, (3) Groenouw's familial dystrophy, and lattice keratitis, (4) diffuse thin scarring as from old phlyctenular keratitis, and (5) old interstitial keratitis with irregular moderate scarring.

PREPARATORY TREATMENT AND CONSIDERATIONS

Corneal blood vessels.—Many eyes that are otherwise hopeless can be made suitable for grafting by preliminary surgery. One of the worst problems is getting rid of the blood vessels. Some of these vessels can be closed by means of cautery or diathermy applied to the vessels at the limbus for 2 mm. I have done a very large number of these, and, in general, my results are unsatisfactory. Nine out of ten of the vessels soon reopen. Corneal stripping (superficial keratectomy) is helpful when the vessels are large and superficial; but again, the results of stripping are disappointing. Radiation is the most effective method.

Since radiation works well only on small vessels and new capillaries, the larger trunks should still be treated by stripping or diathermy peritomy. Radiation may be given in many ways. Since 1948, I have been using a 23 mc. radium D applicator and consider this the most satisfactory method to date. These applicators are much more expensive than the other available beta ray applicators, costing several times as much as strontium 90. The radium D beta rays have less penetrating power than those of strontium 90, radium, and radon, and the rays are almost completely absorbed in the corneal tissue. Since less than a fourth as much radiation from radium D reaches the lens surface as from the other applicators, it is particularly safe and suitable for corneal



FIGURES 2-5. SCAR TYPES

2. Central; very favorable.
3. Old disciform; favorable.
4. Vascularized lime burn; unfavorable.
5. Fuchs's dystrophy; very unfavorable.

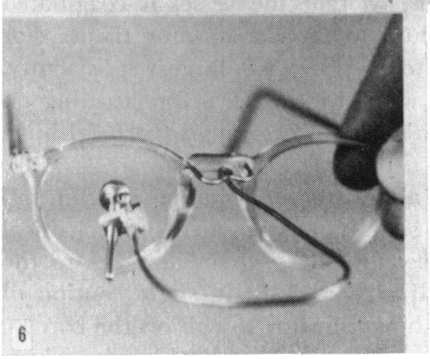


FIGURE 6. HOLDER FOR BETA-RAY APPLICATOR

treatment, and is unquestionably the method of choice for superficial corneal vessels.

Some ophthalmologists (1, 2) have reported radium D ineffective in treating corneal vascularization. My applicator has been used for a total of about two thousand treatments on approximately three hundred people for corneal vascularization of many types including a great many cases of rosacea keratitis, recurrent pterygium, and chemical burns. In practically all of these cases the radium D proved extremely effective even when there was deep vascularization. About one third of the cases with deep vascularization had some temporary irritation of the eye during the treatment, but ill effects were rare. Approximately 2 per cent of the radiated corneas showed delayed superficial ulceration of the cornea lasting several months. The few eyes so afflicted originally had full thickness dense leucomas with extremely extensive deep vascularization, and each also had a preliminary superficial keratectomy followed by more than the customary dose of beta. Thus far no cataract which can be attributed to radium D has been observed. Other authors, however, have recently reported numerous radiation cataracts following use of strontium 90, radium, and radon applicators (3, 4, 5, 6).

No one applicator can be best for all situations, and in the light of present knowledge the ideal therapy would be to use radium D on eyes with vascularization primarily in the anterior two thirds of the cornea. The more dangerous applicators with deeper penetration (strontium 90, radon, or radium) could be substituted for radium D in the relatively small group of cases with vessels abundant in the posterior cornea.

Immediately after the first beta treatment, a diathermy peritomy is done on any large vessels running across the limbus into the treated area. When doing the peritomy it is desirable to wear a magnifying loupe, and to regulate the current so that the vessel is coagulated without causing any measurable burn to the surrounding tissues. For peritomies done in the office a Britcher Hyfrecator is very satisfactory. The needle should be in contact with the cornea before turning on the current to avoid making a spark gap and causing superficial burn outside the vessel area.

Since with a 23-mc. radium D applicator each 5-mm. area of vascularization requires about five six-minute treatments, mechanical holders are desirable. The Stevenson holder, which attaches to the speculum, is rather difficult to adjust; and with it, slight motion of the speculum is enough to allow the applicator to rub on the cornea. A few years ago, I designed one consisting of a malleable wire which slides into holes in an eye glass frame or headband (Figure 6). The wire is set in place over the desired area of the cornea and the fine adjustment is made on an easily turning screw at the radium end of the wire.

Under the slit lamp, the radiated corneal vessels appear to undergo an obliterative endarteritis. They get smaller in caliber, darker in color, and frequently show little hemorrhages along their course. Later, short

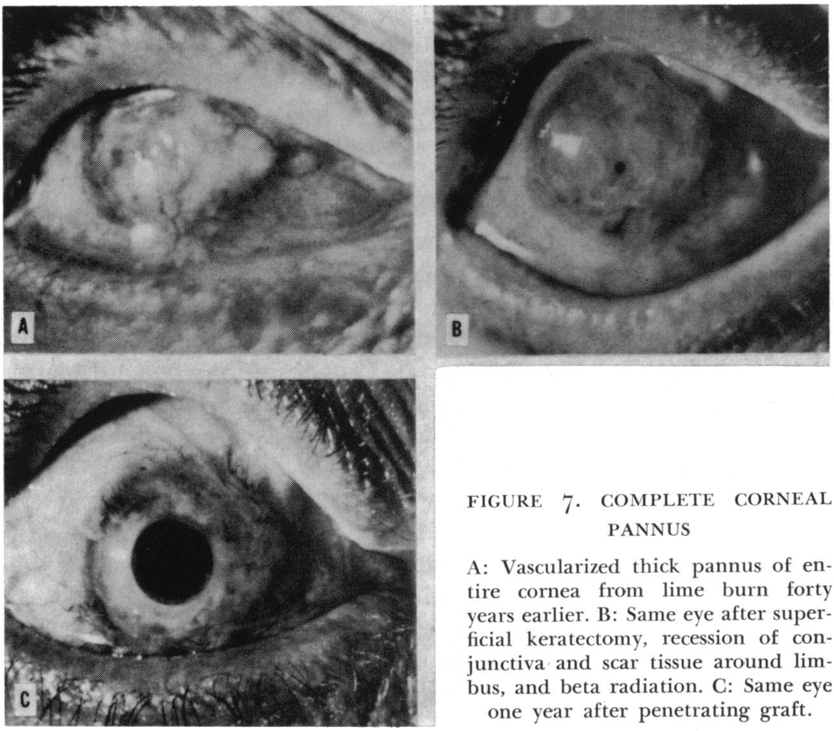


FIGURE 7. COMPLETE CORNEAL PANNUS

A: Vascularized thick pannus of entire cornea from lime burn forty years earlier. B: Same eye after superficial keratectomy, recession of conjunctiva and scar tissue around limbus, and beta radiation. C: Same eye one year after penetrating graft.

sections of the vessels disappear completely. The effect is usually not complete until three months after the last treatment.

Complete corneal pannus.—When there is extensive thick pannus of the cornea a superficial keratectomy is done, and the conjunctiva and scar tissue are resected for 4 mm. back of the limbus (Figures 7A, B, C). The sclera is scraped bare and free of vessels in much the same manner as when transplanting a pterygium. It was formerly thought that complete recession of the conjunctiva all around the limbus, leaving the sclera bare, would cause interference with corneal nutrition and possible serious corneal damage. In 1947, however, Lombardo (7) showed that this method was often helpful in removal of extensive pannus in trachoma and caused no damage to the cornea. I tried his method in a few cases, but did not find it effective until it was combined with radiation.

The cut edges of the conjunctiva are held in position by four silk sutures passed through episcleral tissue. Three days later, beta radiation is started before the vessels have time to grow in again. Incidentally, it is very difficult to do an extensive corneal stripping with a cataract knife or an ordinary surgical knife such as the Bard Parker No. 15. The process is greatly simplified by using the gently rounded blade of a sharp Demarres corneal splitter similar to that frequently used in lamellar keratoplasty. Where this is not available the round tipped Beaver No. 44 blade is moderately satisfactory.

Extreme keratoconus.—In some severe keratoconus cases there is rupture of Descemet's membrane and acute ectasia of the cornea. In two cases in this series this was extreme. The entire cornea in one case was edematous and white, and vision was reduced to light projection only. In both cases, elastic pressure bandages worn constantly for several weeks reduced the ectasia, and the edema gradually cleared completely. In the worse case there was no keratoconus three months later, but the entire cornea was semi-opaque and a number of small vessels had grown in due to the keratitis. Following beta radiation both of these eyes were suitable for grafting.

Some surgeons advocate reducing the marked keratoconus by cautery at the apex before grafting. This flattens the cone, but unfortunately it often causes marked vascularization of the cornea; in general, this therapy is not to be recommended.

Synechia.—Anterior and posterior synechias should be released when possible and the pupil made dilatable, as otherwise anterior synechias may form at the edges of the new graft. A preliminary iridectomy may be needed in some cases.

Location of graft.—The location for the new graft should be picked carefully. It should be in an area that leaves as much clear cornea for its border as possible. This is of great benefit to the nutrition of the graft; and, in fact, the amount of healthy corneal tissue at the graft margin is probably the most important single factor in determining the ultimate success of the graft.

The graft should also be located so that it will lie within the pupillary area or the opening formed by the pupil plus the preliminary iridectomy in order to lessen the chance of anterior synechias.

In keratoconus cases it is desirable that the entire thin part of the cone should be removed so that the edge of the graft will be in contact with host cornea of at least 60 percent normal thickness. This generally calls for a graft at least 6 mm. in diameter with the center often slightly down and to the nasal side.

Size of graft.—The size of graft preferred in ordinary cases varies with the surgeon and with the size and shape of the corneal scar, but most of mine have been from 4.5 to 6 mm., with the great majority being 5 mm. in width. The 5-mm. graft is also most widely used by other surgeons. The smaller the grafts, the less the chance of dislocation and anterior synechias, so before the advent of direct sutures a 4.5-mm. graft was desirable for patients whose postoperative behavior we distrusted, or for eyes in which the pupils could not be dilated.

There are two main disadvantages to small grafts. If additional direct sutures are desired, inserting these sutures in the graft is much more difficult than in a large graft, and the suture track also encroaches on a larger percentage of new cornea. In addition, when there is proliferation of tissue on the back of the graft, or edema of one edge due to slightly defective union, the pathologic process has a shorter distance to go to affect the center of the graft and visual acuity. Judging from my cases, another disadvantage, much less important, is that the average residual astigmatic error is greater in smaller grafts than in large ones, presumably because any irregularity becomes greater in relation to a smaller diameter and thus causes a greater change in curvature.

The disadvantages of the larger grafts are the need of direct sutures, increasing tendency for anterior synechias and their attendant complications, increasing tendency for poor coaptation in one area or for bulging of the entire graft, and, in very large grafts, increasing tendency for vascularization due to proximity of the graft margin to the limbus.

Miscellaneous factors.—If a cataract is present, the graft should be done first and the cataract removed about four months later, as the chance of a successful graft in aphakic cases is very slight. Following the transplant a cataract extraction is no more difficult than on a normal patient. Former glaucoma cases must be under complete control without miotics. Nystagmus is not necessarily a contraindication.

THE DONOR

Condition of the donor.—It is generally agreed that cadavers provide as satisfactory material as living subjects. Blood grouping and systemic diseases appear to make no difference. In the light of recent work on possible tissue sensitivity, it is probable that some incompatibilities will eventually be found. Randolph (1949) in experiments on rabbits decided that it is practically impossible to transmit syphilis in the graft (8). Despite this work, however, in the United States corneas are usually not accepted for transplantation unless the donor has had a negative blood test. The eyes are also considered unsuitable when death is from an acute infection or from blood dyscrasias such as leukemia.

The eye, of course, should be free from inflammatory changes and from any suggestion of corneal dystrophy. In earlier years I used several eyes enucleated for painful glaucoma. These corneas are apparently satisfactory if the edema has been of short duration and it is still possible to clear the cornea with glycerin or hypertonic saline. Arruga (9), Filatov (10), Wright (11), and Paton (12) also consider these glaucoma eyes satisfactory. Since the corneal nutrition is abnormal following several days of edema, however, and since corneal material is now more plentiful, I have used no glaucomatous eyes during the past ten years.

A similar situation exists in regard to malignant tumors in the posterior segment of the eye. I formerly used eyes with malignant melanoma of the choroid provided there were no aqueous or corneal changes by slit lamp. Many surgeons (12) consider this safe; and as yet there has been no case in the literature of a melanoma recurring in a recipient eye. Since a single cell on the back of the cornea might spread the malignancy, however, I feel it is unwise to use these eyes, and this opinion is shared by many other surgeons. Retinoblastomas are more malignant and spread more quickly, and since Hata (13) reported a case in which a retinoblastoma again occurred after keratoplasty, most surgeons reject all such eyes.

Recently, I successfully utilized the cornea of an electrocuted convict, an experience which has also been reported by other surgeons (14). These corneas appear satisfactory, provided there is no visible corneal opacity.

In general, autoplasty (from same individual) has no advantage over homoplasty (from same species). Blumenthal (15) reported a successful graft from a Negro to a white person. Because of the possibility that delayed edema of the graft may be due to tissue sensitivity, it is reasonable to expect, however, that autogenous grafts will ultimately be proven more successful. Heteroplasty (from one species to another as from cat to man), despite some temporary success, has never given a satisfactory result in animal or man.

Age of the donor.—Many years ago when beveled grafts were more widely used, the eyes of newborn babies were frequently utilized. I consider these very unsatisfactory for our present method with non-beveled implants, and this opinion is shared by most surgeons (12, 15, 17). Babies' corneas are thinner than those of adults. Because of their limpness, there is far more danger of poor union or postoperative bulging. Because of their short radius of curvature, they also tend to cause high myopia. Vannas (18) claims that a contact lens is often necessary to correct this resultant myopia.

The eyes of young children are satisfactory, but possess to a lesser degree the disadvantages of infants' corneas. From adolescence to the age of about seventy corneas appear to me to be especially suitable. In general, the cornea tends to be stiffer in the older person and therefore is easier to manipulate when a large size graft is used; it also is more apt to stay exactly in place. Elschnig (19), Thomas (20), Lohlein (21), and McLean (22) consider the age of the donor of little significance. Barraquer (23), Franceschetti and Bischler (24), Filatov (10), and Paton (12), however, believe corneas from old people are superior.

There is no evidence available as to the relative value of corneas from extremely old people. Since very elderly corneas transmit less light than those of younger people, and since senile corneal tissue in life is more prone to a number of degenerations, extremely old corneas should be considered less desirable until proven otherwise.

Methods of preservation.—The usual method of preservation in the United States is to refrigerate the eye at ordinary ice-box temperature (4° C.). It may be kept in normal saline if it is to be used within six to ten hours. If it is to be kept for a longer period, it should be in a sealed moist chamber with gauze and saline in the bottom. The cornea is upright and is not covered by the fluid.

In Europe, refrigeration in liquid paraffin is preferred by many surgeons (25, 26, 27, 28, 29, 30). Success has also been reported in preservation by partial dehydration (31) of the cornea and reconstitution with saline shortly before grafting, and by freezing (32).

Most surgeons, and probably all in the United States, preserve the entire eye. Vannas (18), Amsler (33), and a few others, however, take only the cornea. This considerably simplifies the procedure in acquiring donor grafts, as no enucleation is required when the cornea is taken from a cadaver.

Length of preservation.—Most surgeons (34, 35, 36) believe that for penetrating keratoplasty the graft should be utilized as soon as possible, and the earlier after death the eye is used the better. Fialho (37) found that in eyes preserved in liquid paraffin, opacification started on the posterior surface after twenty-four hours and was complete by the seventh or eighth day, but the process was more delayed the sooner after death the eyes were removed. Petrossian (38) reports that eyes preserved in saline and studied under a microscope show a similar course. They begin to degenerate very soon, but are transparent despite irregular epithelial lesions up to the eighth or tenth day. On the fifteenth, they are semitransparent and on the twentieth completely opaque.

In my own experience, the eyes tended to get soft in twelve to eighteen hours, and when examined with an ophthalmoscope and corneal microscope they showed progressive wrinkling of Descemet's membrane and irregular epithelial deterioration. When the intraocular pressure was increased by squeezing, most of the folds in Descemet's membrane disappeared. In some eyes the corneas remained semitransparent as long as twenty-five days.

In all the early cases of this series (those preceding the 100 cases tabulated), eyes enucleated from living people were employed and the transplants were done within one to three hours. When the Eye Bank was first started, I used corneas up to twenty-four hours old. After using one cornea with markedly wrinkled Descemet's membrane, however, similar folds remained permanently in the otherwise transparent graft; since then I have tried to use material less than twenty hours old. Most surgeons, however, use tissue up to twenty-four hours, and many up to forty-eight hours, after death. There are no satisfactory statistics to prove definitely the relationship of this time interval to graft success, but it is my impression that my results have been better when this period has been very short.

Filatov (39) in Russia takes a diametrically opposite viewpoint. He thinks aging of the graft in refrigeration for four days causes changes in the tissue which improve the biological qualities of the transplant and make it less able to react unfavorably to so-called "tissue sensitivity," thus resulting in fewer cases of delayed edema of graft. Some French surgeons, including Paufique and Sourdille (40), have followed his teaching in this matter but are not definitely convinced. They do, however, agree that preservation for several days appears definitely beneficial in the case of lamellar grafts.

TECHNIQUE

PRELIMINARY CONSIDERATIONS

I have tried many different techniques, but from 1937 to 1944, 90 percent of my cases were done with beveled edges by the square method of Castroviejo. About that time along with other American surgeons, I realized that the use of non-beveled grafts, as long advocated by Filatov, actually was a sound and practical surgical method. A switch to round grafts followed, and with these the operations have been in general much easier and more satisfactory. The advantages of a round graft are many:

1. When stained with fluorescein, the outline of the circle is always much more visible than the square marked by the knife. This is a great help when inserting sutures or finishing the cutting of the graft.

2. After the sutures are inserted, the trephine can be reapplied with

much less danger of a false incision than with the double knife. A double knife, incidentally, often spreads slightly during the incision, so the cuts are not strictly parallel.

3. With the round graft, no keratome incision is necessary. In cases with dense leucoma this keratome incision is a delicate procedure, as too shallow an incision will split the corneal lamellas, and too deep a one may injure the lens.

4. After the anterior chamber is opened, excision of the remainder of the graft by scissors is much easier with the round graft, as a trephine cut can be safely made much deeper than a knife cut.

5. Elimination of the corners of the graft reduces the danger of anterior synechias.

There are occasional cases, however, in which, due to the configuration of the scar, a square graft may provide more clear cornea at the graft margin, and in these the square method may still be desirable.

Preliminary medication.—An enema is routinely ordered. For sedation Sodium Amytal 100 mg. is given one and a half hours prior to surgery and Demerol 50 mg. one half hour before operation. The pupil is widely dilated with instillations of 1 percent atropine one and a half hours and one hour before operation, and two drops of 10 percent Neo-Synephrine fifteen minutes before operation.

With grafts over 6 mm. in diameter, it is difficult to keep the pupils dilated enough to prevent formation of anterior synechias. In these cases, instead of mydriasis, preliminary miosis is obtained with pilocarpine or eserine. Since the margin of the pupil adheres to the graft edges more readily than do other areas of the iris, it is safer to keep the pupil inside the graft area for the first twenty-four hours rather than near its border.

Anesthesia.—Three drops of 1 percent Pontocaine and three of 4 percent cocaine are instilled at one-minute intervals just before the operation. A Van Lint–type injection of 2 percent Novocain with adrenalin is given in the orbicularis fibers of the lid and under the skin for 3 cm. external to the outer canthus. If the patient has a small palpebral aperture or is nervous, the tissue of the outer canthus is crushed in the tip of a hemostat for about 5 mm. and a bloodless canthotomy is then done with Stevens tenotomy scissors. A small amount of Novocain-adrenalin solution is injected subconjunctivally over the insertions of the four rectus muscles. No hyaluronidase is used and no retrobulbar injection is given, as the soft eye so desirable for some other surgical procedures is a complication in keratoplasty until after trephining is completed.

In aphakic cases, however, retrobulbar injections and pressure on the eye for several minutes are advantageous. With the lens already out there is no danger of hurting it with a trephine, and with a soft eye there is less tendency for vitreous prolapse to occur. In non-aphakic patients, also, if the eye is moving too much, a retrobulbar injection may be given after penetration of the chamber by the trephine before excision of the disc is completed.

Speculum.—In earlier years I used a Guist speculum, but later I found the Arruga type much more satisfactory. Like the Guist model, this also has little foot plates which hold the lids off the eyeball, but the Arruga type allows more working room between the eyelids. I have modified the Arruga speculum with a third "foot plate," adjustable on the lower cheek, which can be slipped on for rare cases where the lower lid still shows undue pressure on the eyeball. Lid sutures or lid clamps are also satisfactory.

Choice of trephine.—Automatic trephines, which I have used in a number of cases, usually take the button out without need of scissors. There are certain disadvantages to these, however, and I continue to favor the more deliberate hand trephine. My two automatic trephines have blades fashioned by renowned instrument makers. Despite this, the majority of the blades when tested lightly against epithelium show a slight "shimmy," indicating a microscopic defect in the axis of rotation. In some cases this leaves a rather wide line of epithelial abrasion instead of the fine cut expected.

With the hand trephine, minute defects in the angling or centering of the trephine handle are immaterial. The trephine is being rotated back and forth in a groove instead of being spun around, and it remains in its own original track. Most surgeons prefer the hand trephine, but there are some dissenters, including Arato (41), whose instrument works in a guide supported from the limbus, Vannas (18), Boase (42), and Lohlein (21). The latter reports a considerably higher proportion of clear grafts from a mechanical than from a hand-driven trephine.

I prefer the old-style Castroviejo trephine with open sides and no central plunger. This allows full visibility of the corneal button, and, when working on a recipient eye, a central control suture from the corneal button can be pulled up and out through the window of the trephine.

All regular trephine handles have certain disadvantages, chief of which are lack of flexibility and slowness in rotation. For years I have put a one-inch piece of number 10 rubber catheter on the top of the trephine shaft, and I find this makes a perfect handle. It is satisfactorily flexible, and due to its very small diameter more rotation is obtained with less finger motion.

METHODS OF GRAFT FIXATION AND POSTOPERATIVE CARE

Of the numerous changes being continually made in techniques, by far the most important recent advances have been in the field of fixation of the new graft.

In general, presently advocated fixation methods may be divided into four types: (1) Overlying bridge sutures, (2) Overlying splints, (3) Direct sutures, and (4) Fibrin fixation.

Before considering actual methods, it should be emphasized that perfect fitting of the graft is one of the most important factors in obtaining good fixation. The success of any given suture method, therefore, varies widely with the accuracy of the cutting technique. It is generally recognized that the round graft is a more accurate fit than the square one, and it is technically easier to do; most routines at present call for a round non-beveled transplant.

If the graft is a good fit, the edges should be air tight immediately following operation. In these cases new endothelium and epithelium grow across the edges in twenty-four hours. If there is slightly defective apposition only in some areas, serum and fibrin usually fill the gaps and fibroblasts soon grow in leaving a broader scar than do perfectly apposed edges.

The margins are not united firmly for a month (34), but in the absence of unusual trauma or pressure, the graft should hold without further use of sutures after six days. Since the first few days are crucial, the essential point in fixation is to provide steady apposition of the margins for at least that period.

Overlying sutures.—Until recent years, all really successful techniques employed some variation of overlying sutures, and these bridge sutures are still widely favored for small grafts.

The original Von Hippel technique of 1887 (43), was a partial lamellar keratoplasty done with a mechanical trephine. No sutures were used, and the graft was kept in position by pressure of the eyelids only. In 1905 Zirm (44) did a full-thickness graft by Von Hippel technique, but the graft was held in position by two cross sutures inserted in the conjunctiva above and below. Since that time the trend has been toward an increasing number of sutures, and the sutures now are firmly anchored in the cornea about 1 mm. from the graft margin and are carried across the graft to hold it in place.

Thomas, in England, originally used only two vertical and horizontal cross sutures for fixation of his beveled graft. For many years, however, he has used multiple sutures so that the radial sutures cross the graft margin at eight different points to hold it firmly in place (Figure 8A). Incidentally, Thomas (20) still bevels his grafts, though nearly all other surgeons are now using the non-beveled graft. The Thomas suture and its numerous modifications, such as those of Castroviejo and Paton, are widely used throughout the world today.

Castroviejo (34) developed his modification of the Thomas suture about 1935 (Figure 8B). Paton (45) has a further slight variation, but there are still four radial sutures so the graft margin is crossed by the supporting sutures at eight places.

Paton recently designed a plastic plate (Figure 8C), overlying the center of the graft only, to prevent cutting in of sutures. I believe this is unnecessary, as sutures can be left in for fourteen days without any permanent marks. In addition, since the sutures are elevated where they cross the plate, apposition of the sutures to the graft margin is not perfect.

Bietti (46) uses two vertical and two horizontal sutures (Figure 8D). These are simple, but approximation is less satisfactory than with the eight radial sutures.

Filatov (39) for many years used sutures similar to the ones now used by Bietti; but recently (Figure 8E) he has switched to a reversed conjunctival flap anchored at the opposite limbus.

Incidentally, regular conjunctival flaps (not reversed) have been used by many surgeons, but have been universally discarded. Castroviejo (34) did his first 21 grafts using conjunctival flaps without sutures. He found this method unsatisfactory and gave it up when one of his transplants became detached. He then switched to a combination of overlying sutures and conjunctival flap with the flap actually completely covering the corneal sutures. This is the method I used in my first cases in 1937 and 1938. This method (Figure 8F) was fairly satisfactory, but it caused intense reaction in the eye. In addition, if any portion of the graft margin was not completely flush with the cornea, there was a tendency for the conjunctiva to unite to this graft margin and cause vascularization of the graft. This method was soon discarded.

Rycroft and Romanes (47) and others use similar overlying sutures, but insert a piece of egg membrane or thin rubber under them.

About 1940 Wiener (48) developed his punch technique (Figure 9A). An incision is made at the upper limbus. The flat blade of a punch is introduced into the anterior chamber, and the corneal button punched out. I tried two of these thirteen years ago, but consider both the punch

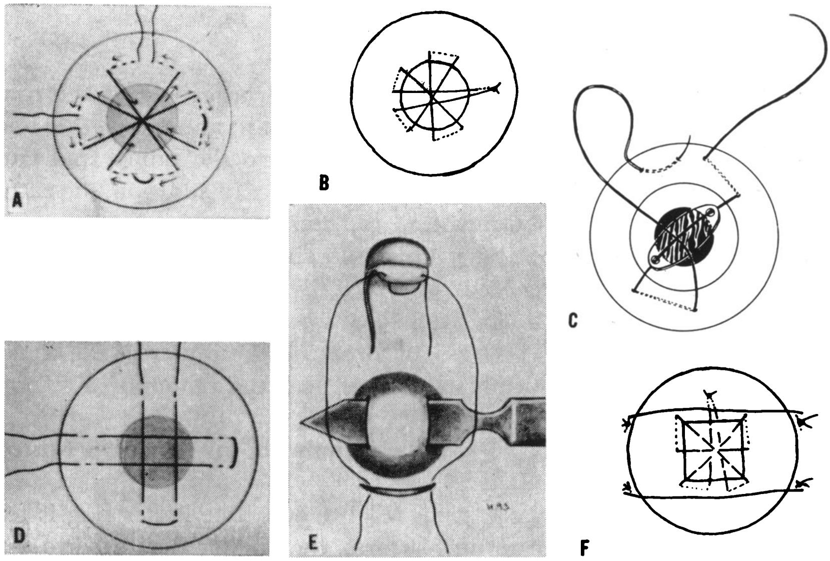


FIGURE 8. EARLY SUTURE METHODS

A: Thomas. B: Castroviejo. C: Paton. D: Bietti. E: Filatov. F: Sutures plus conjunctival flap (1937).

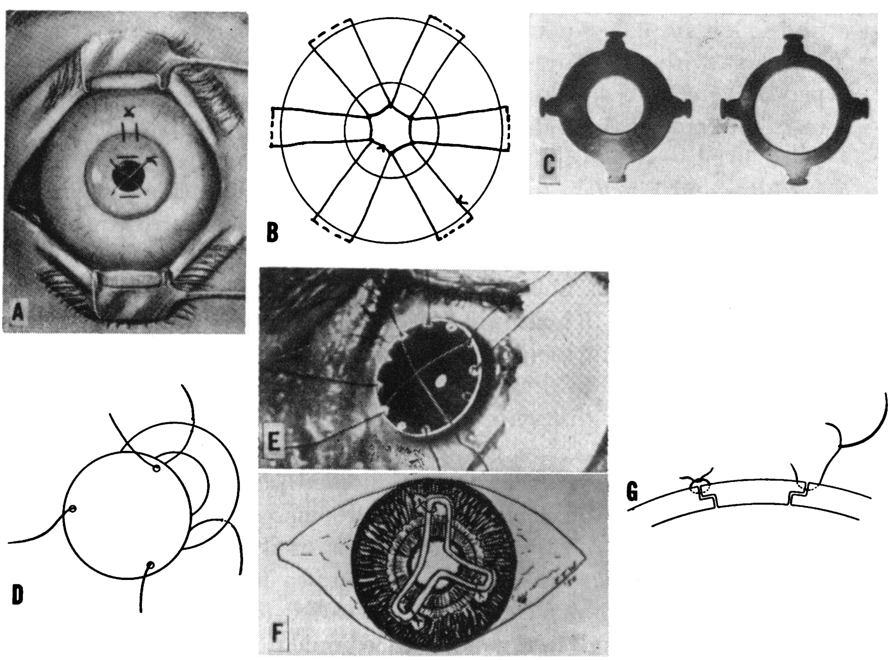


FIGURE 9. PRESENT SUTURE METHODS

A: Wiener. B: Lindeman. C: Pittar. D: Fritz. E: Philps and Fincham. F: Worcester. G: Ebeling and Carrel.

technique and the suturing unsatisfactory. The cornea is stretched considerably when the bullet shaped punch engages it; and in one case one of the sutures was inadvertently pulled up into the punch and cut, causing considerable inconvenience in resuturing. In addition, the extra peripheral corneal incision may lead to anterior synechia.

Lindeman (49) developed a double "star ring" suture (Figure 9B). A continuous suture is anchored concentrically at several points on the corneal scleral margin. Loops are left between each point of sufficient length to allow them to be brought almost to the center of the transplant. These loops are firmly connected near the center by a second ring suture.

Splints.—During the past few years a number of surgeons have turned to splints to hold the graft in place.

Pittar (50) uses two plastic rings (Figure 9C). The larger ring is for marking the sites for the corneal sutures, the smaller is sutured to the cornea to cover and overlap the edge of the corneal graft.

Fritz (51) of Belgium uses a contact lens (Figure 9D) the exact size and shape of the cornea with three holes in the periphery. The lens is held by three sutures deeply placed in corneoscleral tissue at the limbus, and is left in place for twelve days. Walser (52) uses a perforated contact lens without sutures. Strampelli (53) uses sutures, but stitches a protective contact lens to the four rectus muscles. The corneal sutures may be removed through large perforations in the contact lens, which is left in place for several days after removing the sutures.

Philps and Fincham (54) use a 12-mm. contact lens (Figure 9E) with an inside curvature of 8.5 mm. radius. There are twelve tiny suture holes near the periphery. Four double arm sutures are placed in the cornea close to the limbus, and are passed through eight of the contact lens holes and tied to hold it in place. It is left undisturbed for fourteen days. The results in their series of cases were good when their grafts were photographed by the photo-keratoscope of Amsler. They felt there was less astigmatic distortion in the graft than was obtained without contact lenses.

Worcester (55) developed an open molded plastic cap held by three sutures near the limbus. He also reported some very interesting research on corneal caps done under the auspices of the Eye Bank for Sight Restoration. Plastic caps covering the cornea from limbus to limbus were sutured to rabbits' eyes, and after varied lengths of time the eyes were enucleated and sectioned. This complete corneal covering damaged the corneal nutrition. The cornea became opaque in a few days, and microscopic examination showed loss of the epithelium and considerable interstitial keratitis and iritis.

When only a partial cap was used (a 6-mm. circular solid disc) the reaction was much less, but the epithelium remained absent in areas where the cap touched the cornea. When this 6-mm. circular solid cap was sutured over a corneal graft, practically no union occurred at the trephine wound. Because of this Worcester decided a cap must fulfill the following requirements: (1) permit adequate respiration of both recipient and donor corneas, and (2) permit adequate support about the circumference of the wound to obtain a solid union and yet permit maximum exposure of the wound for atmospheric respiration.

Various caps were designed and tried. These varied from discs with various-sized perforations to permit respiration, to triangles with perforations. It was soon evident that another factor must be considered—namely, the circulation of fluid from the limbus to the center of the cornea. Any type of cap with a complete ring about its periphery was soon discarded and replaced by an open type. The final design—later modified for human cases—was somewhat triangular, in that it had three radiating arms, with a large central opening (Figure 9F). Worcester reports that on the three human cases done by this method results were good, and there was less reaction to the cap than to ordinary sutures. Because of this excellent bit of research, it would seem that the increasing use of solid contact lenses as transplantation splints should be discouraged.

Vannas (18) uses a cap of condom rubber or plastic material held by peripheral sutures.

One interesting innovation is the use by Brecher and Gunther (56) of a corneoconjunctival cap taken from a cadaver. This has also been used by other surgeons, including Vannas. The second cornea is sutured loosely in place, the graft is cut and inserted and the sutures in the corneal cap are tightened. Good results are reported, but I feel the presence of this dead tissue might predispose to infection. In addition, the work of Worcester in regard to the disadvantages of covering the graft with a solid corneal cap would presumably apply as much here as to a contact lens.

In general, I regard these plastic conformers as just a variation of overlying sutures and do not feel they possess any advantage over these sutures. These conformers are held in place by sutures to superficial tissue. Since the conformer is raised above the corneal surface, lateral push from motion of the eyeball could easily cause some of these sutures to slough out prematurely with serious consequences.

Direct sutures.—During the past six years, the most worth-while change in technique has been the increasing use of direct corneal sutures. As recently as 1941 Castroviejo (34) wrote: "If the sutures are placed through any part of the graft, partial or total opacification of the latter appears." Actually, however, direct sutures had been used with limited success by Ebeling and Carrel (57) in 1921 (Figure 9G). During the early forties French surgeons began to advocate them again, and at the present time direct sutures of 6-0 silk are very widely used.

Popularity of direct sutures has been increased by two factors: (1) the need of large grafts for certain types of corneal scars, and (2) the development of special needles which cut through the cornea more easily. With overlying sutures, large grafts have always been dangerous because of a tendency for portions of the graft margins to dislocate. This could lead to loss of the anterior chamber, edema, poor union of the graft, anterior synechias, and possibly secondary glaucoma. If the area of poor union did heal, it often resulted in overgrowth of scar tissue and proliferation of connective tissue on the back of the graft.

A boon to direct sutures was the Barraquer-Greishaber needle. This had a cutting edge on the convex undersurface and passed through cornea more easily than the needles on regular atraumatic 6-0 sutures. Recently a new flat 7 mm. Greishaber needle has become available with super sharp edges on each side. This goes through cornea very easily. Since it is flat, is less difficult to handle than the triangular needle, and it is ideal for direct corneal suturing.

Graft holders.—The major problem in direct suturing is inserting the first two sutures. In small grafts especially, if the free graft is held by a toothed forceps while attempting to insert the needle, it bobs around in the direction of the needle causing marked tissue distortion. Hence some means of holding the graft firmly while inserting the first suture is helpful. I designed and reported (58) several models of double fixation forceps one of which is illustrated in Figure 10. These are angled so that the operator's fingers do not get between his eyes and the forceps tips to obstruct his view. They have long bowed legs so that the surgeon can watch the top of the needle from above or from one side. The tips of these forceps are 1 mm. apart. One model is made with slightly projecting teeth for grasping the donor graft. For working on the recipient cornea lying against the lens the straight tooth model is safer. With a projecting rat-tooth forceps, of course, there is always a possibility of scratching the lens surface. These double forceps are also excellent for repairing corneal lacerations.

A few years ago I helped Dr. Fred Thorne develop a very handy little counter pressure instrument which we called a "corneal suturing aid" (Figure 11). The original model was designed for reinserting track sutures in cataract extraction, and it was modified later for the small needles used in grafting. This instrument immobilizes the graft at, above, and below its margin, and has a tiny slot through which the needle can be passed. It is easy to use, and it is very helpful where only one or two sutures are to be put in the graft. In general it can be handled with more facility than the angled double fixation forceps.

Arruga (59) developed box forceps (Figure 12) to hold the graft while the initial sutures are placed. This has been adopted with minor variations by a number of surgeons, including Bietti and Paton.

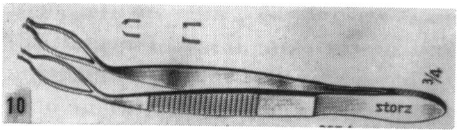
Castroviejo recently designed a spatula-type instrument with a round open metal box at one end with four slots in the sides. This helps to hold the larger grafts for preliminary suturing, and to lift the graft into place on the recipient eye.

In the past few years I have also designed various types of graft holders, my favorite of which is the one shown in Figure 13. Little turrets of varying size are interchangeable in this plastic base. The opening in the top of the turret is 1.5 mm. deep, and the little slots are .6 mm. in width. The floor of the turret (and the bottom of the slot) is elevated one quarter of an inch above the base plate to facilitate grasping the tip of the tiny needle as it is pushed through. The graft may be fixed even more firmly by stretching an ordinary rubber band over the center of the turret and around the back of the flat plexiglass base. The band is snipped with scissors when the sutures have been inserted. These graft holders are especially helpful when two or more direct sutures are used or when sutures in the graft button are being matched to tracks preplaced in the donor eye according to my method to be discussed later.

Unless a box type graft holder is used, it is good practice to leave the graft in site in the donor cornea. This aids in immobilizing the graft and also prevents trauma to its posterior surface. Katzin (60), however, prefers to pin the graft on a piece of cork to fix it while the first sutures are inserted.

Previous techniques.—Another method I originated in 1945, but later abandoned, for inserting the first two sutures in the graft is to cut almost through with a trephine, then finish cutting the button (Figure 14). This technique is satisfactory, but it is slightly more complex, and pulling on the sutures could conceivably cause more trauma to the graft margin.

Several years ago I tried passing preliminary track sutures in donor and recipient, as is done in a Verhoeff track suture cataract extraction. The idea was to cut through the preliminary sutures in both corneas,



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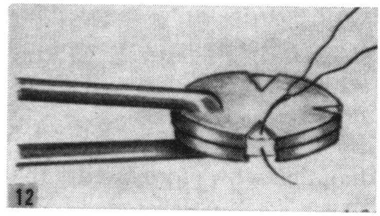

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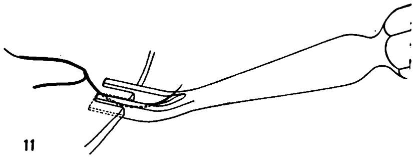

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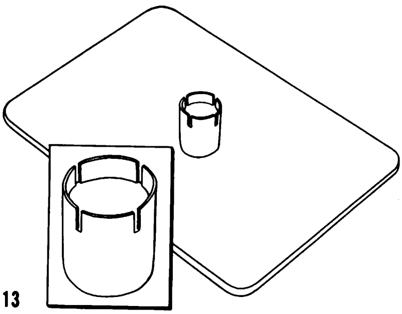

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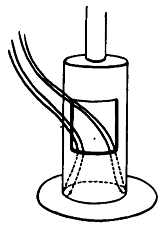

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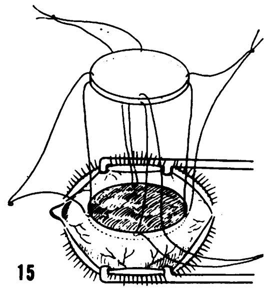

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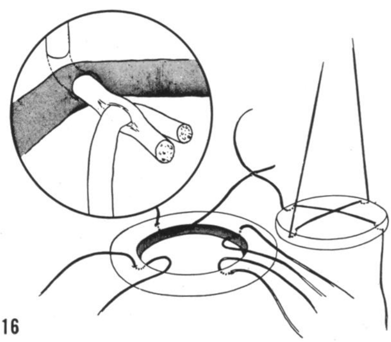

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FIGURE 10. DOUBLE FORCEPS FOR CORNEAL SUTURING

FIGURE 11. SUTURING AID (THORNE AND LEAHEY, 1950)

FIGURE 12. ARRUGA GRAFT HOLDER

FIGURE 13. TURRET-TYPE GRAFT HOLDER

FIGURE 14. PREPLACED SUTURES IN GRAFT (LEAHEY, 1944)

FIGURE 15. PREPLACED SUTURES IN GRAFT AND RECIPIENT (FRIEDE, 1938)

FIGURE 16. PREPLACED TRACK SUTURES; TRANSFIXION METHOD (1942)

but leave the ends in place until the permanent sutures were passed. This was unsatisfactory for two reasons. The trephine often did not cut cleanly, and during subsequent manipulation the suture ends often came out.

In 1938 Friede (61) announced a very interesting technique. After cutting almost through the recipient cornea he put in four preplaced direct sutures (Figure 15). These were run from the edge of the recipient cornea to corresponding positions in the edge of the graft. The cutting of the opaque cornea was then completed, the graft merely dropped into place and the sutures tied. This technique was developed for complete penetrating grafts, but it seems equally applicable to partial ones. I tried it experimentally on animal corneas, but found the preplaced sutures got in the way; it was difficult to complete the cutting without sometimes cutting a suture, and there was apt to be needless exposure and trauma to the new graft.

Anyone using Verhoeff track sutures for cataract extractions finds that the final 6-0 suture often actually transfixes the preliminary track suture.

As a matter of fact Verhoeff (62) had once suggested utilizing this ability to put one suture through the other for re-inserting cataract sutures. In 1942, it was suggested by Cogan and Sullivan (63) that this technique might be adapted for preplaced transplant sutures. Consequently, I experimented with a technique combining the Friede method, preliminary track sutures, and this Verhoeff idea.

Track sutures were inserted in the recipient cornea. After cutting through the sutures and almost through the cornea, new sutures were put through the tracks as in the Friede technique and the needles removed. Cutting of the opaque button was then completed but left in place temporarily. The donor graft was cut and four sutures inserted in it corresponding to those in the recipient (Figure 16).

The central end of each suture in the recipient cornea was laid on a small rubber mat, the needle from the equivalent graft suture speared through it, and the needle cut off. By pulling the transfixed thread in the recipient cornea it was possible to pull the graft suture through the track in the recipient also. Each graft suture was pulled through in this manner and tied to complete the operation.

This technique was rather complicated, slow, and difficult; and sometimes the transfixed suture pulled out. Because of this, and since direct sutures at that time were considered of dubious value, the method was abandoned without being tried on human eyes.

In 1954 Avello (64) revived Friede's preplaced sutures for partial

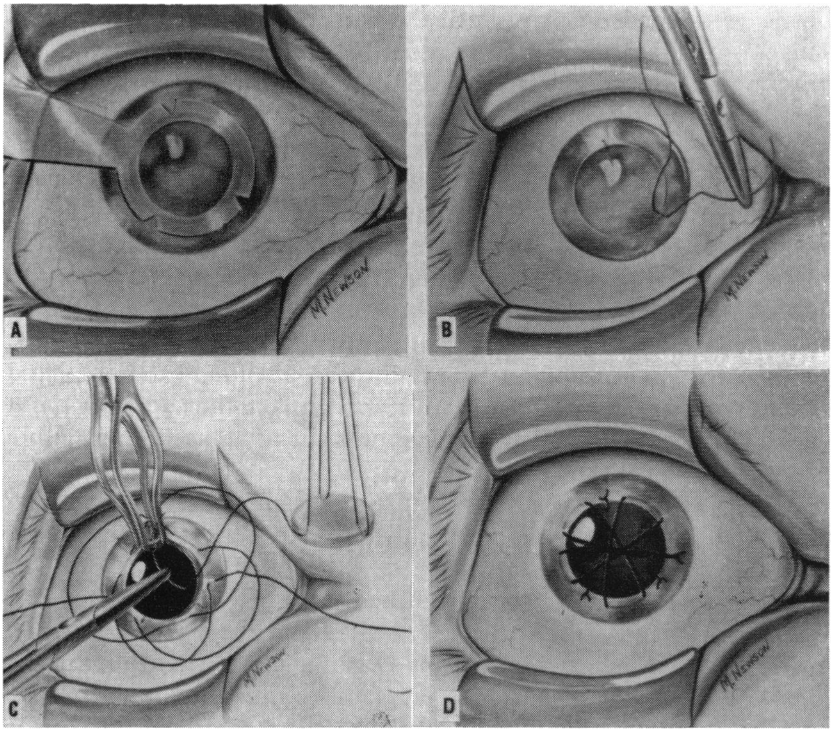


FIGURE 17. USE OF PRELIMINARY STAINED TRACK SUTURES (LEAHEY, 1948)
A: Plastic markers notched at desired points indicate identical suture sites on donor and recipient. B: Preliminary sutures stained with methylene blue are inserted at identical sites in donor and recipient and pulled through, leaving blue tracks. C: Overlying sutures have been inserted; cutting of opaque cornea is completed and new graft with sutures already inserted is swung into place; sutures in graft are passed through tracks in recipient. D: Direct sutures are tied first; overlying sutures are then pulled through and tied.

penetrating transplantation, but reported the method erroneously as an original technique.

In 1948, I reported the use of preliminary track sutures (65) stained with methylene blue. If more than one direct suture is desired, perfect apposition of sutures preplaced in both donor and host is possible only by using a marking device. For this purpose I designed markers made of transparent plastic notched at the suture sites (Figure 17A). The preliminary track sutures stained with methylene blue are inserted at the desired places on the recipient cornea after marking the graft area with the trephine (Figure 17B). The track runs 1 mm. on each side of the trephine cut. The sutures are pulled completely through, leaving blue tracks. This process is repeated on the donor cornea. The usual overlying sutures are also inserted in the recipient cornea.

After the donor graft is cut, new sutures are inserted in the blue tracks of the donor graft. For these sutures I utilize one of my three special instruments, the double fixation forceps, the corneal suturing aid, or the turret type graft holder. The graft is lifted into its new position and the same sutures are passed through the blue tracks of the recipient cornea with the aid of the special double forceps (Figure 17C). The direct corneal sutures are tied first. If overlying sutures are also being used, they are pulled through and tied (Figure 17D); otherwise additional direct sutures are inserted. These later direct sutures are much easier to insert as the graft has now been immobilized, markedly simplifying passage of the needles.

This effective but rather cumbersome technique was used extensively several years ago before corneal needles such as those of Greishaber were available. With these very sharp needles it is relatively simple to insert sutures in the recipient cornea without undue tissue manipulation and trauma. Another factor to be considered is that even with careful marking technique the tracks in the new graft and in the recipient cornea often do not match exactly.

Present technique.—Because of these factors, I now put only two preliminary stained track sutures in the recipient cornea. Because of the ease with which sutures may be inserted in the graft with the plastic turret graft holder, stained track sutures in the donor are omitted completely. With the graft held firmly in the holder, two to four sutures are easily inserted in the donor cornea without need of these tracks.

Regardless of how the initial sutures are inserted in the graft, I like to use a single double-arm suture for two opposing suture points. This eliminates many extra threads and loose ends. Where multiple sutures are desired, the same method is used.

The suture ends in the new graft are cut to approximately two-inch lengths. The turret graft holder with the graft still in place is held close to the recipient eye with the ends of the sutures lying on the turret base plate (Figure 18A). The two ends of one suture are bent back upon themselves and picked up with smooth forceps, so that the graft is suspended in the middle and the needles are locked on each end (Figure 18B). The assistant lifts off the scarred corneal button and the new cornea is dropped into place. After the two needles on the opposing ends of one suture have been carried through the blue tracks in the recipient cornea, a blunt iris hook is inserted under the center of the suture to bring it up in a loop 2 cm. long (Figure 18C). This central

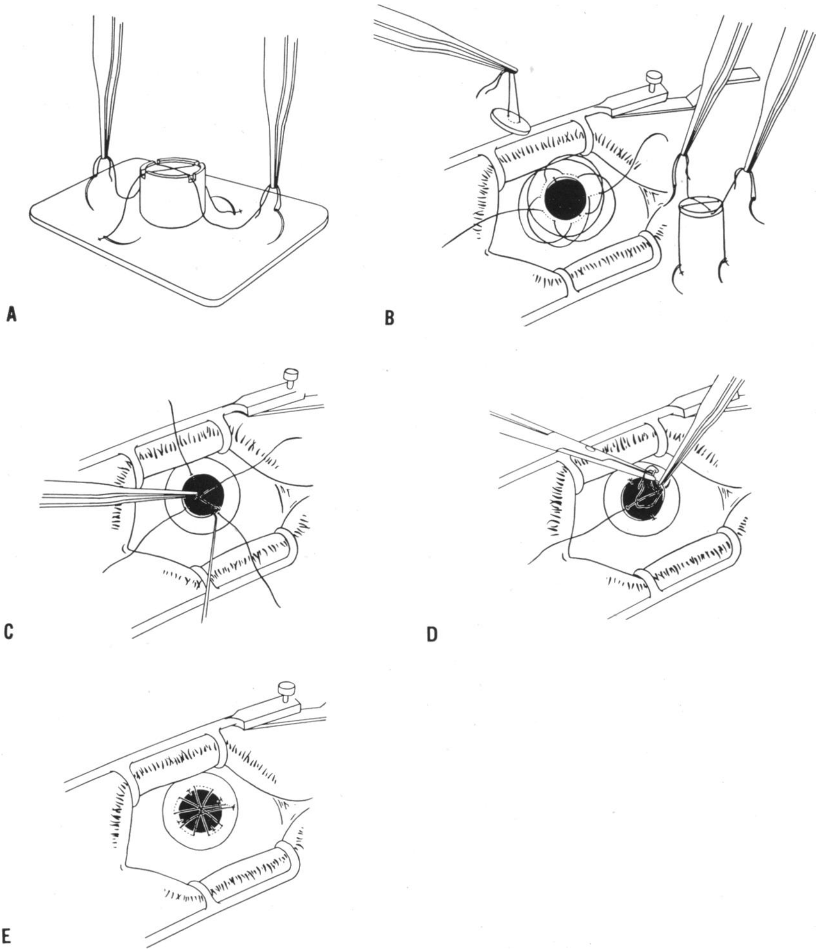


FIGURE 18. USE OF PREPLACED SUTURES IN GRAFT AND PREPLACED BLUE TRACKS IN RECIPIENT (LEAHEY, 1951)

A: Sutures inserted in graft held in turret holder; two ends of one suture doubled back on themselves so forceps will hold needles in place; ends of other sutures blocked with silver artery clips or knots. B: Assistant lifts out old cornea; with two smooth forceps graft is lifted into position by opposite ends of one suture. C: The two ends of one suture have been carried through blue preplaced tracks; before tying, center of this suture is pulled up in loop with aid of iris hook and cut. D: First two sutures have been tied; Greishaber needle on third is being passed through recipient with aid of sharp-toothed forceps. E: Four direct sutures have been tied.

loop is then cut, and the first two sutures are tied with the smooth forceps.

If four preliminary sutures are inserted with the turret holder, precautions must be taken to avoid dropping off the 7-mm. Greishaber needles the two sutures not held by forceps. The ends of the second two sutures should be blocked with tiny silver artery clips or knots before lifting the graft into place. After inserting the first two sutures through the preliminary stained tracks, the knot or artery clip is cut off the end of the third suture which is then passed through the recipient cornea with the aid of sharp-toothed forceps (Figure 18D). The corneal margin is everted slightly to increase visibility and reduce danger of trauma to the lens and the suture is readily inserted from the cut edge to the periphery. The fourth suture is then similarly inserted.

Handling of the fine sutures, pulling them through, and tying the knots are greatly facilitated by the use of two narrow smooth McCullough utility forceps with cross serrated jaws. With two forceps the knots can be tied more quickly and under more accurate control than by more customary methods. If overlying sutures are also being used they were, of course, preplaced before completing the trephining. These are now pulled through and tied (Figure 18C). Otherwise additional direct sutures are inserted.

As mentioned previously, I have preferred grafts 4.5 or 5 mm. in diameter, with the great majority in this series being 5 mm. Except for early conjunctival flap cases, all of the 4.5-mm. grafts and most of the early 5-mm. ones have been held in place only by the overlying sutures of Castroviejo. In about one third of the 5-mm. grafts (including *all* of my recent ones) one or two direct sutures have also been used. Since at least one or two direct sutures are now used in every transplant and since satisfactory suturing of a graft of only 4.5 mm. is difficult, I have discontinued use of 4.5-mm. grafts in recent years. In 5.5- to 6-mm. grafts, overlying stitches are combined with two to four direct sutures. In grafts 7 mm. or more, overlying sutures are omitted completely and the transplant is held in place by ten to twenty-two direct sutures.

There were no aphakic cases in this series, but, in general, grafts in aphakia are a poor risk and require special consideration. Numerous direct sutures are the rule, and before trephining most surgeons insert a wide spatula across the anterior chamber behind the graft area to prevent massive vitreous loss. Beside the danger of excessive vitreous loss during operation, there is a tendency for vitreous to get between the wound margins and delay healing. In one aphakic case done by another surgeon a few years ago the patient squeezed violently when the stitches were being removed on the twelfth day, and the apparently successful graft popped up in the air. This eye was later enucleated.

Total penetrating keratoplasty.—Recently there has been a revival of interest in total penetrating keratoplasty. Since 1913, when Filatov published his first attempt, this had been tried by a great many surgeons without success. The most interesting early contribution was the previously described technique of Friede (61) used between 1935 and 1938. All of his cases were failures, so he concluded along with the other authors that successful total transplantation could not be done.

Until 1950 the literature was almost as discouraging as earlier reports. DeJean (66) was so disappointed in the results of total grafts that he turned to subtotal grafts, meeting with more success. LeGrand (67), in one case out of eleven, was able to get useful vision following a secondary partial penetrating graft. Thomas, Cordier, and Algan (68) obtained 20/200 vision in one case. Sommer (69) included a fringe of conjunctiva in his grafts; all were soon opaque. Cavka (70) reported six cases which became totally opaque within three weeks. Castroviejo (71), however, reported twenty-one cases, in twelve of which there was considerable improvement in vision lasting up to ten months at the time of his report (1950).

His technique included removal of the lens when necessary, extensive removal of iris, fixation with about twenty-two direct sutures, and injection of air at the end of the operation. It is probable that the air injection was the greatest single reason for this radical and abrupt improvement in results.

Despite this encouraging report complete penetrating keratoplasty must still be regarded as a very speculative operation of poor prognosis, and should be considered only when there is complete degeneration of the entire cornea.

Fibrin fixation.—Recently fibrin has been suggested as a substitute for sutures. In 1946 Brown and Nantz (72) showed experimentally that fibrin increases the adhesive power of a corneal wound. In 1950 Tassman (73) advocated the use of fibrin to seal corneal grafts. He and other surgeons have done cataract extractions and also a number of grafts successfully by this method. In sections of dogs' eyes in which the fibrin coagulum was employed, not only did they find "no downgrowth of epithelium into the wound, but in all cases there was definite evidence of increased proliferation of fibroblasts in a shorter period of time than was found in the control eyes." Tassman reported three successful penetrating grafts kept in place by this technique without the aid of sutures. The technique is simple, and he considers it very effective.

Dunnington and Regan (74), however, have done a memorable piece of research on the effect of sutures and of thrombin upon ocular wound healing, and they are less encouraging about the fibrin fixation. They studied fibrin fixation of cataract incisions in monkeys. After adding the plasma, they held the edges of the wound together for about one minute. No sutures were employed.

> Histologic examination at the end of two days showed fibrin deposits beneath the conjunctiva in cases in which a flap was used. Irrespective of the use of a flap, fibrin was present between the wound edges, producing poor approximation. There was no evidence of fibroblastic proliferation, and in some instances epithelium was seen growing down between the tips of the wound. At the end of four days some fibroblasts were seen in the vicinity of the incision, there was little or no round cell infiltration, and the epithelium had proliferated still further along the wound. When a conjunctival flap was present, the fibrin and subepithelial tissues constituted a large anterior plug. At the end of one week fibroblasts had infiltrated this subepithelial tissue and invaded the fibrinous mesh work, making a broad scar which extended throughout the entire wound. When a corneal incision was used, the epithelial downgrowth sometimes lined both edges of the wound throughout its entire length. Fibroblasts were present beneath the epithelium. After two weeks, all incisions seemed well healed with dense broad fibrous cicatrices, the only exception being in these eyes in which the edges of the corneal wound were epithelized.
>
> From these studies we believe that in the presence of fibrin normal healing will occur without the round cell invasion of necrosis found in the vicinity of sutures. During the first few days of healing, fibrin tends to separate the edges of the wound. This may produce three undesirable effects:
>
> 1. The cohesive action of properly approximated wound edges is lacking.
> 2. A broad fibrous cicatrix will be created, which although usually satisfactory will lack the tensile strength of normal tissue.
> 3. As suggested by Brown and Nantz, the presence of a corneal incision epithelium may proliferate along the lips of the wound, producing a weakened area or possibly epithelization of the anterior chamber.

They conclude that since thrombin prevents apposition of the wound surfaces and is of very limited tensile strength, it is not the ideal material to insure accurate closure of ocular wounds.

We have had no experience with this method in the Boston area, but because of this research it is probable that the method will not become widely used until many more cases have been reported. Since penetrating grafts can be dislocated by lid squeezing, sutures appear to be a safer method on active patients. In the case of the lamellar grafts, however, adhesive quality is desired rather than tensile strength; there is little danger of dislocation by simple squeezing, as when vomiting, so in these grafts it is possible that fibrin fixation may become the method of choice. In such event the operation certainly would be much simplified.

At the present time Tassman (75) is still enthusiastic about this method. He reports that several men are using it for corneal lacerations and ulcerations, but to his knowledge no one else is using the technique for grafts. He now agrees, however, that sutures are also desirable to insure fixation.

Removal of sutures.—During the 1930s, overlying sutures were routinely removed in six days, as it was thought they would cut into the cornea, leaving permanent marks, or become infected. Removal of sutures at this early date is difficult, dangerous, and unnecessary. Overlying sutures are now removed in twelve days. If one edge of the graft has been partially dislocated, they have been left in up to eighteen days. After ten days these cross sutures usually leave a slight mark in the graft surface. Only the epithelium seems to be damaged, however, and two days later these marks have routinely disappeared on my cases. Direct sutures are left in eighteen days, and, if the patient is uncooperative, as much as a week longer, without apparent damage.

Direct sutures are considerably more difficult to remove. Some surgeons (12) use a sharp knife or discission needle. I prefer curved, sharp-tipped iris scissors. In most cases, the suture is cut before it is grasped by the forceps. When removing the direct sutures, it is important to pull from the recipient side and not from the graft side to prevent possible gaping of a poorly healed wound.

When stitches are removed on the twelfth day, one nurse holds the lids open and a second holds a focused flashlight. These small "pen lights" give adequate illumination and do not cause the photophobia or squeezing associated with regular operating room lights. When the direct sutures are taken out on the eighteenth day, such careful precautions are not necessary and an ordinary ophthalmic spot light is equally satisfactory. Rarely has it been necessary to bring an especially nervous patient to the operating room and use sodium pentothal anesthesia in order to remove the transplant sutures safely.

Use of air in anterior chamber.—Undoubtedly the greatest single improvement in my technique in recent years was the use of air injections in the anterior chamber postoperatively. I began to do this in 1945. After the sutures have been tied and the graft edges patted down into perfect position, the tip of a Randolph cyclodialysis cannula is gently inserted in the incision for about .5 mm. perpendicular to the lens surface, and a moderate sized air bubble is injected. This air bubble balloons the anterior chamber up, and remains there much better than saline solution. It takes three days to absorb and usually prevents what was formerly the most common complication, anterior synechia. To minimize further the danger of anterior synechia, adrenalin is injected subconjunctivly at the end of operation, and two drops of 4 percent atropine solution are instilled in the conjunctival sac.

In one recent case, the eye was so extremely soft that it was impossible to trephine safely. In this case a very oblique incision was made through cornea near the limbus with a Graefe knife after the manner described by Chandler (76). Air was then inserted with a 26-gauge, medium-bevel needle to make the eye firm. The obliquity of the corneal incision left a self-sealing wound, so the operation was easily completed. After the graft was in place and suturing was completed, another air bubble was easily inserted through this peripheral knife incision (much more easily than through the regular graft incision). This method is not to be recommended routinely, however, as in some cases the knife incision may not remain self-sealing when the cornea is pressed in by the trephine; in this case the operation might have to be temporarily abandoned.

COMPLICATIONS

Unfortunately, complications are frequently encountered.

Dislocation of the graft.—I have never seen a completely dislocated penetrating graft, but many have been reported and probably many more have been studiously forgotten. It was of course much more common in earlier days. Elschnig (77) reported expulsion of the graft in one sixth of his cases! This is a catastrophe, but rare cases have been saved by immediately replacing the graft or putting in a new one. In one such case in Philadelphia, several years ago, the new graft was found on the dressing the first time it was changed. No corneas were available through regular channels; but, because of the emergency, permission was secured to take a cornea from a corpse which had been dead for many hours in a local morgue. The second graft held satisfactorily and the eye was saved.

Loss of the graft into the anterior chamber is even more rare, since the graft rests at first upon the lens, and is elevated by the pressure of the aqueous only after the wound is sealed.

Slight elevation of one section of the graft is much more common. In earlier years, when square grafts with beveled edges were used without any direct sutures, this partial dislocation was more common and was treated by covering with a conjunctival flap. The five cases so treated in my series healed, but in each case the graft vascularized with little visual result.

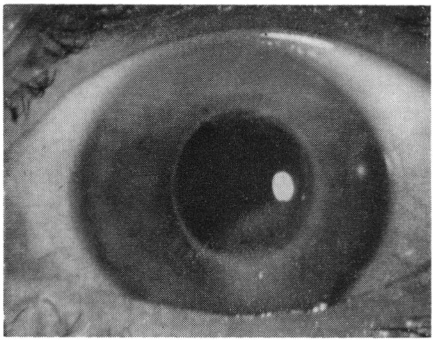


FIGURE 19. PERMANENTLY OPAQUE CORNEAL MARGIN FOLLOWING POOR APPROXIMATION OF SECTOR AND ELEVATION OF GRAFT EDGE

At the present time this bulging of the graft margin, either general or in one quadrant, is much less frequent due to improved techniques and suturing. If the graft is poorly united or protrudes above the rest of the cornea over any considerable area, moderate pressure with an Ace elastic bandage is applied as a complete head bandage amply supported with adhesive tape so that it will remain in place for seven to ten days. If the dressing is changed every day or two, and the eye is opened each time, this bulging or herniation can recur at each dressing with little ultimate improvement. With continued pressure, these elevated graft edges nearly always flatten out. When bulging is slight, a simple Elastoplast eye pressure dressing often suffices without the head bandage.

If there has been much elevation of the edges with or without gaping, the prognosis is poor for a clear graft, due to the tendency for connective tissue to proliferate from this area over the back of the graft (Figure 19). Since the cornea will usually heal solidly, however, a regraft can be done later if desired.

Anterior synechias.—Of all postoperative complications anterior synechias formerly were the most common. They are more apt to occur with very large grafts, or if the cornea is very thin with consequently less exact approximation. Delayed reformation of the anterior chamber or subsequent leaking of the wound is usually the causative factor.

The use of air injections in the anterior chamber at the end of operation has helped to reduce the incidence of anterior synechias in my own series to a fraction of its earlier frequency. Frequently the air bubble cannot be retained in the anterior chamber. In these cases, every two days wide dilation of the pupil is insured, at least temporarily, by two drops of 4 percent atropine and four drops of 10 percent Neo-Synephrine. To avoid dislodging the graft the patient is directed to look up, so the graft is covered and supported by the upper lid. The lower lid is gently pulled down and the drops instilled in the lower cul-de-sac.

Slight anterior synechias at the edge of a clear graft are almost certain to cause clouding of the graft in a few months. They may cause proliferation of connective tissue on the back of the graft, or they may cause haziness in the stroma or edema of the epithelium. They also may cause glaucoma. Occasional patients have shown synechias for many years without complications, but since it is impossible to know exactly which eyes will not be harmfully affected, an attempt should always be made to remove these adhesions. Lysis of the adhesions was necessary in 20 percent of the grafts done since 1944.

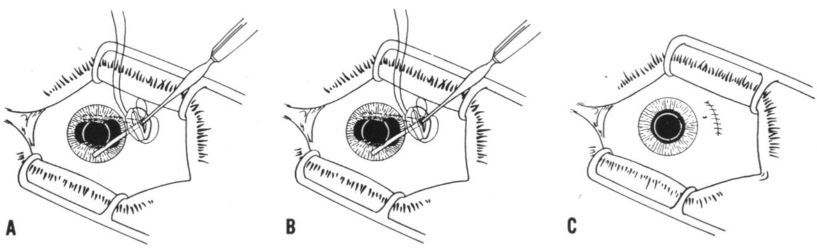


FIGURE 20. LYSIS OF ANTERIOR SYNECHIA

A: Cyclodialysis incision 4 mm. from limbus, one central scleral-conjunctival suture inserted. B: Sweeping away synechia with Elschnig spatula. C: Air bubble has been inserted and deep suture tied.

In 1941 (78) and again in 1947 (79) I reported methods of freeing these synechias through a cyclodialysis opening made 4 mm. outside the limbus (Figure 20A). The spatula is slid into the anterior chamber (Figure 20B), the synechia is swept away, and air is injected through a cyclodialysis cannula (Figure 20C). The air bubble usually prevents hemorrhage into the anterior chamber as well as a reformation of adhesions. The scleral incision is made closer to the limbus than for a regular cyclodialysis so the spatula can sweep far into the anterior chamber with less danger of pressure on the edge of the lens and also with less disturbance to the angle of the iris. Essentially similar methods have been developed independently by Castroviejo and by Barraquer (81), and recently Castroviejo (80) designed a hollow cyclodialysis spatula so that adhesions could be freed and air injected through the same instrument.

In some cases of extensive old anterior synechias, sweeping motion with a dull spatula will tear the iris off at the limbus rather than at the adhesion site. For these cases, cyclodialysis spatulas with blunt tips and sharp edges are effective.

Glaucoma.—This is one of the worst complications and, unfortunately, in my experience one of the most common. In this series, 33 percent of cases had increased tension at some time during convalescence. Glaucoma is much more frequent if the iris and ciliary body have participated in some fashion with the original corneal disease, mainly because the angle of the anterior chamber has been partially blocked by previous cellular debris or old peripheral anterior synechias. In this series glaucoma has been much more frequent in eyes with old chemical burns, disciform keratitis, and interstitial keratitis, and uncommon in the familial dystrophy and keratoconus patients (see Table 8).

Glaucoma is to be expected in cases with marked anterior synechias, but it also occurs in eyes with apparently perfect grafts and no visible adhesions. Many of the early glaucoma attacks are of mechanical origin due mainly to prolonged dilatation of the pupil with angle closure, and respond immediately to intensive treatment with miotics. Excellent results are obtained with 4 percent pilocarpine plus a solution of 1.5 percent Carcholine in 1/3,000 Zephiran. Because of the danger of this angle closure glaucoma, atropine is usually discontinued two weeks after operation even though ciliary injection and light sensitivity are usually present for several more weeks. Except in the few cases with high tension starting suddenly three to five weeks after transplantation, glaucoma is seldom of the acute type.

If the graft is reasonably clear, it is often possible to inspect the angle of the anterior chamber by gonioscopy and determine the type of surgery to be done. In most cases the angle will be found to be blocked either from previous iridocyclitis or from a prolonged flat anterior chamber. Cyclodialysis was for many years my most common remedial operation, but I used trephining with success in two early cases. For the past five years I have employed perforating cyclodiathermy almost exclusively. A 1.5-mm. needle is inserted through conjunctiva and sclera 5 to 8 mm. from the limbus, in eight to ten places. In most cases the patient was allowed to go home the same day; but the procedure frequently had to be repeated on one to three subsequent occasions.

Injury to the lens.—One traumatic cataract occurred in this series but was recognized only during convalescence. It was probably caused by the keratome tip during the excision of a square graft. Many such cases have been reported in the literature. If recognized at the time of operation it is considered wise to complete the capsulotomy and remove the nucleus before tying the graft sutures. In the case of large grafts there also have been reports of a number of cases of dislocation of the lens.

Vascularization.—Vascularization is far more common if the eye remains irritable for a considerable period or if there have previously been blood vessels in the recipient cornea. Interstitial keratitis cases are especially apt to show marked new vascularization. About ten days after operation three of my cases showed new typical interstitial keratitis involving the recipient cornea, with countless small vessels opening up and growing toward the graft. For a few days there may be a circle of vascularity surrounding the graft, and then the graft is also invaded by countless deep radial vessels. Soon both the new graft and the recipient cornea may resemble the vascularized "salmon patch" characteristic of the second stage of interstitial keratitis.

Vascularization of the graft may often be controlled by beta radiation but it is usually not practicable or safe to insert a speculum in the eye to administer beta rays for three to four weeks following transplantation.

In cases with a flare-up of old interstitial keratitis, the treatment of choice is steroids given orally. In two cases this was started when the condition was first recognized, between the tenth and fourteenth days, and improvement was dramatic. After the fourteenth day the steroids were also given locally. Three recent interstitial keratitis cases were given Meticorten beginning five days after operation. This apparently caused no interference in graft healing, and there was no flare-up of the keratitis.

Proliferation of tissue on posterior surface of graft.—Proliferation of connective tissue on the back of the graft is not uncommon. This is practically sure to occur in the presence of anterior synechias. In other cases it grows in from fibroblastic tissue at the margin of a perfect graft (Figure 21). There is no effective treatment for this, as radiation is apparently not of much use. Fortunately, in many cases proliferation occurs only 1 mm. or so on the posterior surface and then stops, but in other cases the fibroblasts grow entirely across the graft leaving a new layer of connective tissue behind Descemet's membrane.

About half of the cases with this posterior connective tissue proliferation showed slight edema of the corneal stroma and epithelium in the area immediately overlying the proliferation.

Approximately 26 percent of my cases in this series have at least a 1-mm. area of connective tissue proliferation posteriorly somewhere on the graft margin. In 10 percent of the series this was enough to lower the acuity of otherwise successful grafts to less than 20/70, with the final acuity of most of this impaired group varying from 8/200 to 20/200.

In another 8 percent with serious complications such as prolonged elevation of graft margins, extensive anterior synechia, or long continued inflammation, the connective tissue formed a complete or almost complete membrane over the posterior surface of the graft.

When the membrane is complete, Lohlein (82) has advocated making a keratome incision and pulling the membrane off with a blunt iris hook. This would be a difficult procedure when the anterior chamber is collapsed, with danger of injury to the lens. It is probable a new graft would be a lesser insult to the eye.

It is also possible to have proliferation of epithelium on the back of the graft as a result of a poorly approximated wound or the introduction of epithelial tissue at the time of trephination. The one probable case in my series is shown in Figure 22; long fingers of new cells reach well across the posterior surface of the graft.

Iris pigment can also proliferate on the back of the graft. Theoretically, donor pigment could be implanted with the graft, but in this series the 9 percent with visible pigment all acquired it from anterior synechias which were freed. In only two cases did the pigment proliferate. In these eyes (Figure 23) the pigmented areas grew for two to three years; but after four and six years, respectively, further growth has not been evident. Vision was not adversely affected.

Edema of the graft.—This is another complication which is both common and serious, and for which there is no really effective therapy, provided it is not the result of anterior synechia or glaucoma.

In some cases the customary edema found the first two weeks after operation may remain stationary or gradually increase (Figure 24). In others, the graft may appear quite clear after about three weeks and then suddenly develop slight edema. This gradually becomes worse and in a few weeks or months there may be actual bullous keratitis. When bullas are present there is usually an associated slight irritation and occasionally a tendency to eventual partial vascularization.

This edema of the graft occurring about three weeks after operation has been widely discussed. Klima (83) produced an allergic inflammatory reaction in rabbits' corneas by repeated injections of corneal extract into the stroma. He thinks the graft causes an allergic reaction in the host cornea owing to a group specific difference between them which leads to disease of the graft. In 1951 Maumenee (84) reported a series of rabbit experiments showing that donor-recipient sensitivity can be brought about and that it can cause opacification of the graft. He induced this sensitization by supplemental transplantation of skin from the same donor to the recipient's abdomen.

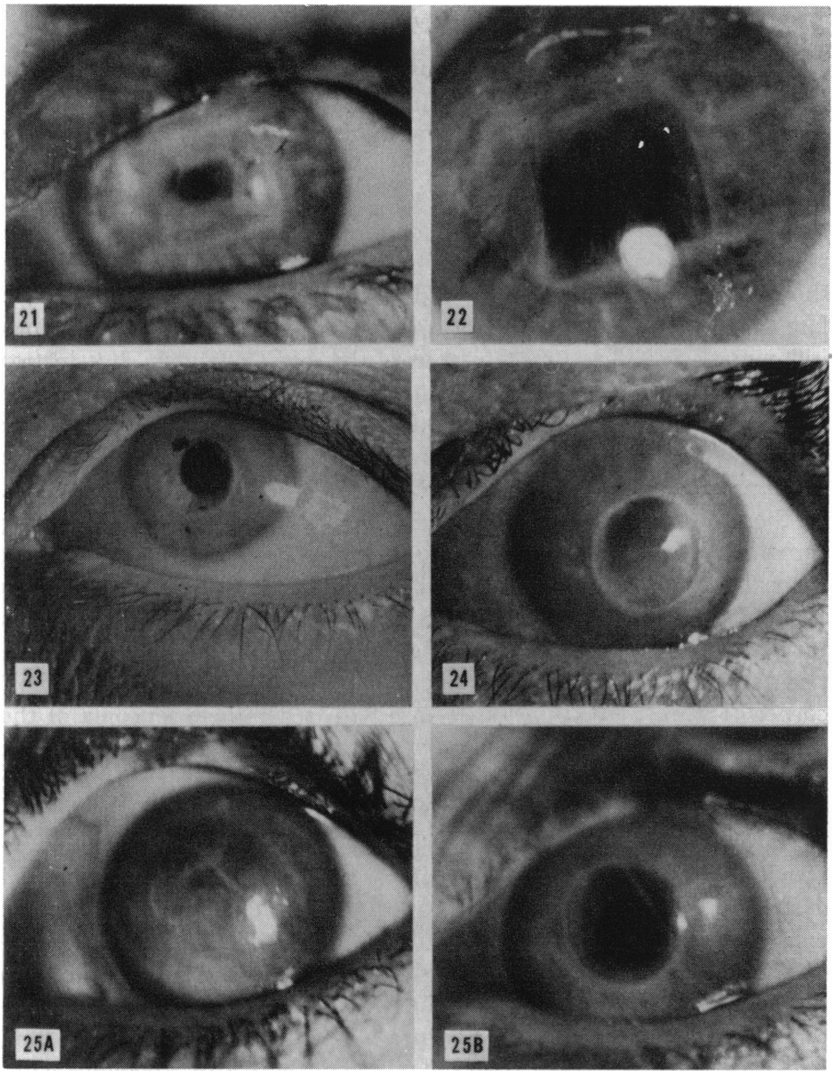


FIGURE 21. PROLIFERATION OF CONNECTIVE TISSUE OVER SQUARE GRAFT

Growth stopped within six months and graft has remained as pictured for eight years.

FIGURE 22. PROBABLE EPITHELIAL PROLIFERATION ON BACK OF GRAFT

Growth stopped within about six months and has remained as pictured for four years.

FIGURE 23. PIGMENT PROLIFERATION ON BACK OF CORNEA AFTER FREEING OF ANTERIOR SYNECHIA

Slight growth for three years, no change for past two years.

FIGURE 24. EDEMA OF CORNEA FOLLOWING APPARENT SUCCESS

Still present two years after graft.

FIGURE 25. LATE EDEMA OF CORNEA

A: Edema of cornea from injury; extensive rupture of Descemet's membrane. B: The same eye ten months after clear graft; permanent edema developed suddenly after thirteen months.

This tissue sensitivity is undoubtedly the cause for some opaque grafts, but in my own series this type of case occupies a relatively unimportant percentage (about 5 percent). In most of my cloudy grafts the slight edema present after surgery merely persisted and became worse.

In a few cases (4 percent) grafts were apparently perfectly clear with no complications for ten to fifteen months and then suddenly developed marked edema within a period of a few days. This very late edema should presumably not be regarded as of allergic origin. In all of these late cases grafts had been set in corneas severely damaged by previous inflammation. Severe lime burns were the worst offenders, but in two of these late cases the eyes had been severely damaged by very extensive former disciform keratitis. In another case there was almost complete edema and deterioration of the cornea due to a blow by a stone twelve years previously with rupture of Descemet's membrane (Figure 25A). At the time of transplant a shred of Descemet's membrane was running across the lens surface from 10:00 o'clock to 4:00 o'clock, indicating corneal damage well beyond the limits of the new graft. This graft was also sparkling clear for thirteen months with the shred of Descemet's membrane easily visible. The cornea then became edematous within a two-day period, assuming an appearance exactly like that of the host cornea (Figure 25B). In another case with a complete leucoma of the cornea from a lime burn, the graft was completely clear for six years, but during the next five years developed progressive faint edema of the graft stroma.

Since edema of both early and late type is much more common in previously damaged corneas than in cases with keratoconus or familial dystrophy, it is probable that the importance of the antigen factor, while considerable, is generally overestimated.

The thickness of the graft may also be a factor in edema. Welter (85) has stated that the thickness of the graft varies from .74 mm. to 1.03 mm., while that of the scarred cornea varies from .55 mm. to 2.67 mm. When the graft is thinner than the recipient there is relatively little disadvantage. When the graft is thicker it projects not posteriorly but anteriorly, probably because of pressure of the aqueous on the back of the graft as soon as the chamber is reformed. This forward bulging of the graft causes the corneal stroma at the margin to absorb tear fluid and swell further. This bulging also allows epithelium to grow over part of the cut section and thus oppose normal repair.

Infection.—Infection is fortunately an extremely rare occurrence. In many contemporary series there have been no infections. There was one panophthalmitis in this series nine years ago. The donor eye had been removed in a distant hospital by a person with no ophthalmic experience. It was not cultured or washed carefully, and it is probable infection was introduced directly with the graft. Since then all donor eyes have been washed in three successive cups of saline just before the graft was cut, and penicillin has been given for five days after operation as an extra precaution.

Recurrence of the original corneal pathology.—The consensus at present is that the graft preserves its own identity but is gradually partially replaced by the tissue of the host. It is reasonable, therefore, to expect that the graft would take on many of the qualities of the host cornea in the course of time. Recurrence of interstitial keratitis has already been discussed. Paufique describes recurrence of tuberculous keratitis in the graft, and I have observed cases with lipoid dystrophy develop similar fatty changes in the portion of the graft adjacent to the diseased host tissue. Corneal edema from any cause is notorious for its recurrences. Recently I observed recurrence of dendritic keratitis in two grafts which had been clear for two and four years respectively.

Authors vary widely in regard to recurrence of the hereditary dystrophies. My series indicates that if the dystrophy is of a progressive type such as Groenouw's nodular dystrophy or lattice keratitis the graft will ultimately again acquire this disease. The graft, however, will acquire the pathology probably at the same rate of speed as the original cornea developed it. My nineteen-year series includes twenty-five cases of nodular dystrophy and lattice keratitis and for nine years none of these showed any evidence of recurrence. After nine years, however, in one case, and eleven years in another, definite beginning recurrence of lattice keratitis was discovered. Recently a recurrence in seven years was also found. Nodular dystrophy recurrence has not yet been seen in this series, nor am I aware of its having been reported elsewhere.

There have been reports in the literature of a few cases of early to moderate Fuchs's dystrophy improved by grafting (86, 90). Since completing this series, I did an 8 mm. perforating graft in a Fuchs's dystrophy case, and followed it up five months later with an intracapsular cataract extraction via a deep scleral section. This cornea is still clear four months later. Since in the past, however, all types of edema of the cornea have been especially prone to recurrence, I believe that many of these apparently successful cases may again become cloudy in a relatively short time.

There has yet been no case in the literature of recurrence of keratoconus. This is probably because most keratoconus operations are on adults. It may be assumed the disease should take ten or fifteen years to again appear. The patient would by that time be outside of the age group of increasing keratoconus, so for this reason there actually might be no recurrence.

Refractive error.—A minor complication often found is a large refractive error. Myopia is frequent and often increases within the first four months after operation probably due to contraction of the scar tissue ring around the graft. Considerable astigmatism is also usually present, with the small grafts in general showing more astigmatism than large ones. In this series there were a number of cases in which there was nearly normal acuity with two to seven diopters of astigmatism. One woman with a transplant followed by a cataract extraction obtains 20/35 vision and reads Jaegar 1 print with a +4.50 sphere combined with a −12.00 cylinder. Undoubtedly, these patients could get 20/20 vision with contact lenses, but I have not yet ordered one for a transplant case.

In all types of corneal grafts the oral use of Meticorten starting eight to ten days after operation and the topical use of Hydrocortone solution starting two weeks after operation has proven of great value in preventing complications. Cortisone reduces inflammation and by so doing lessens the tendency for grafts to vascularize and for connective tissue to proliferate over the posterior surface. Both by decreasing iridocyclitis and by shortening actual atropinization time, cortisone also decreases the percentage of postoperative glaucoma. By decreasing allergic reaction it is probable that it also helps decrease the tendency toward edema in many cases.

RESULTS

Results are meaningless without consideration of the type of cases. Complete statistics appear unfavorable since the operation is done on many nearly hopeless eyes and on eyes having many other defects. The gradual but steady improvement in results, however, has paralleled that of separated retina repair and has been truly gratifying. In Filatov's 1924 series 15 percent of the grafts remained clear (87). By 1933 his percentage of clear grafts had increased to 29 percent. Tudor Thomas (88) in 1936 reported 28 percent clear. In 1947 the American Academy symposium (89) reported 36.5 percent remained clear. In the "favorable groups," however, 68.3 percent of the grafts were clear. The 1948 report of the cases of Paufique, Sourdille, Offret, and Franceschetti (40) lists 36 percent clear and 48 percent with visual improvement. By 1950 Paton (90) had done 100 cases with 55 percent remaining clear. Of his 23 grafts in the "most favorable group," however, 82.7 percent were clear.

By his 1954 report (91), Paton's percentage of clear grafts (this series also includes many lamellar grafts) had climbed to 64.5 percent. As Paton himself mentioned, this figure is misleading on the high side for two reasons. Thirty-nine percent of all his grafts were in keratoconus eyes, and when multiple grafts were done on the same eye, only the clarity after the final operation was included in the statistics. This eliminated many unsatisfactory results. In 1955 Fine (92) reported 74 percent improved. His series also included 39 percent keratoconus cases.

The true present value of any operation should be based on statistics of the current technique rather than on those of previous inferior operations. At the present time, transplant results of practically all surgeons are very much better than those of a few years ago.

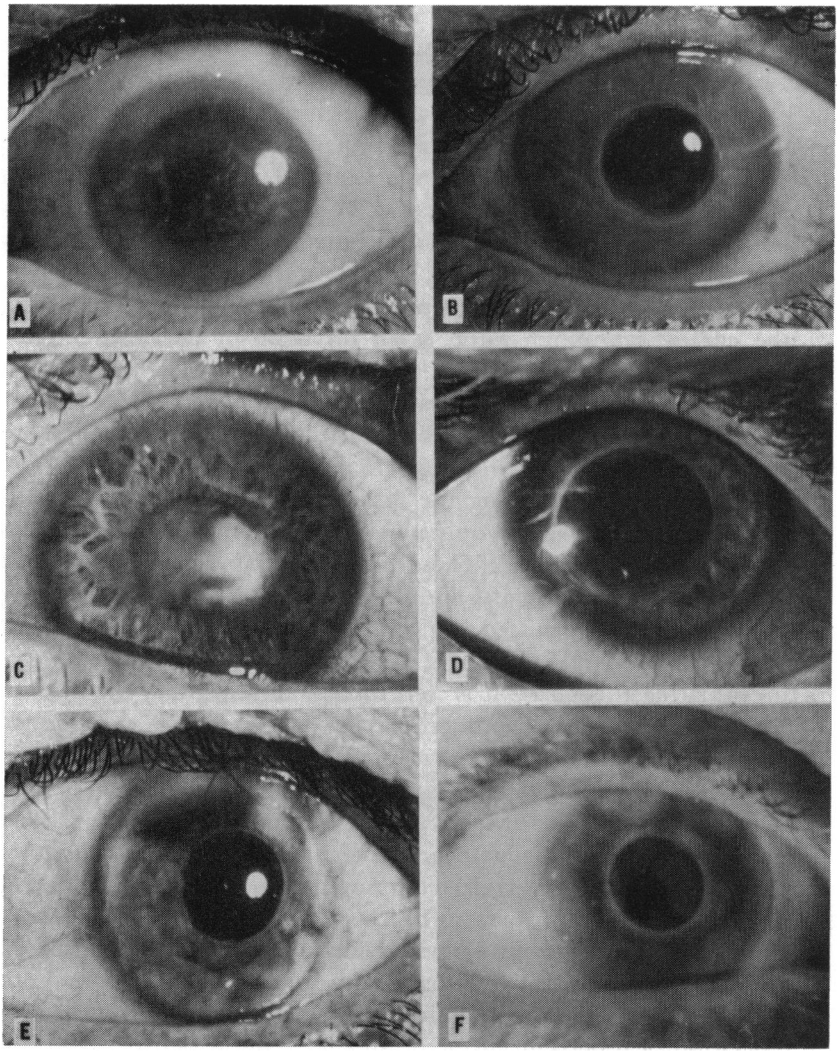
By discarding the results of earlier years, it is possible to get a more accurate appraisal of present value. In the following statistical summary, operations done during the first years of my series starting in 1937 have been omitted and only a more recent group of 100 consecutive cases has been included. These were done between 1944 and 1954 and include 91 primary grafts and nine regrafts. No case done during this period has been omitted, and all have been followed for at least one year.

In evaluating this series, it is well to bear in mind that the average original visual acuity was extraordinarily low due to the extreme pathology in cases selected for operation. In the 100 consecutive cases in the appendix, 57 eyes had preoperative vision of 2/200 or less (30 eyes, light projection only; 27 eyes, 1/200 or 2/200); 37 eyes had 3/200 to 10/200; 5 eyes had 11/200 to 18/200; 1 eye had 20/200. In other words 94 percent of all eyes selected for operation had original vision of 10/200 or less and only 1 percent had better than 18/200 acuity.

Standards for judging results vary widely. In this series "improved" means that the postoperative visual acuity is at least 10/200 and also is at least three times the preoperative acuity expressed in percent, i.e. an initial vision of 9 percent (18/200) must have improved to 27 percent (20/70).

As in Fine's series (92), an exception is made in cases with original vision of light projection only. For these unhappy people he felt vision of only 1/200 represented a distinct improvement, and these he listed as "improved." In my series, however, these are "improved" when acuities become 2/200 or better.

Any eye which loses 25 percent of its preoperative vision is "worse," and all eyes with results between three-fold improvement and 25 percent loss are "unchanged."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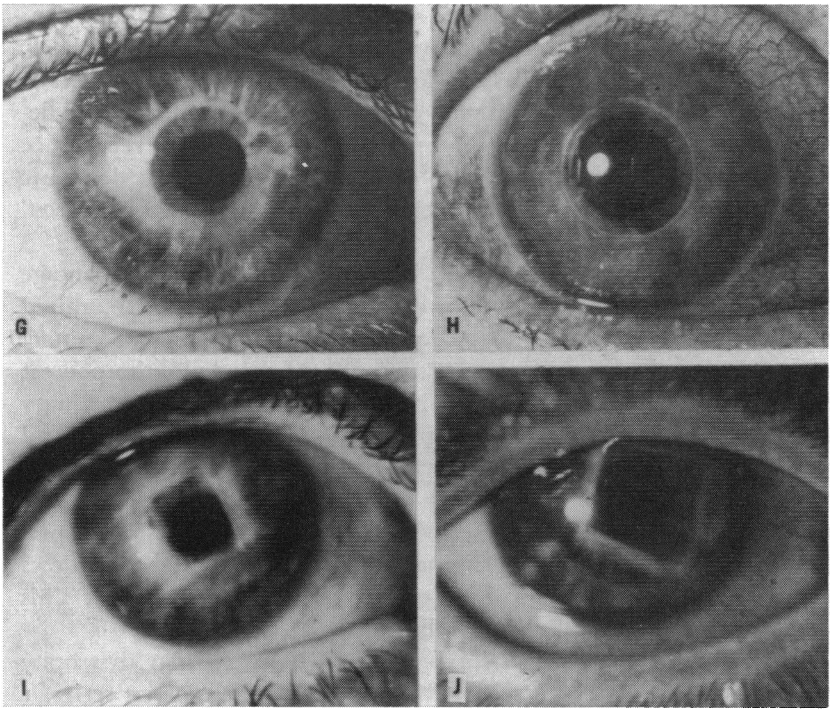

FIGURE 26. SUCCESSFUL PRIMARY GRAFTS

A: Nodular dystrophy. B: Same eye after graft. C: Keratoconus with cloudy apex. D: Same eye after graft. E: Old lime burn after beta radiation, graft, and cataract extraction. F: Severe phlyctenular disease forty years earlier. G: Graft for scars from old serpent ulcer. H: Chemical burn after superficial keratectomy, conjunctival recession, and graft. I: Old disciform keratitis with 4.7-mm. square graft. J: Square graft done for keratoconus ten years earlier.

Results in 100 consecutive cases.—In this series 73 percent had clear or fairly clear grafts and worth-while visual improvement one year later. When the cases were followed as long as possible, however (average follow-up in this series was six years), the percentage of clear grafts decreased because of late complications, including late edema, recurrence of the original pathology, or new corneal disease such as dendritic keratitis. With this long follow-up, the percentage of "improved cases" fell to 69 percent.

Keratoconus.—When considered by groups, the highest percentage of success has been in keratoconus eyes. Conical corneas were grafted only in extreme cases where the apex was very cloudy and contact lenses were not usable (Figures 26C, D). Of only 13 done, the poorest result had 20/70 acuity. Nine eyes had 20/30 or better with ordinary glasses. This was the only clinical group with 100 percent success and this figure will undoubtedly fall markedly as other eyes are done.

Incidentally, the 20/70 eye is the one with marked ectasia and the opacity of the entire cornea described earlier in the discussion of preliminary pressure bandaging. Original vision was perception of shadows only. The fellow eye has also been grafted and has 20/20 acuity. This gentleman is now doing full time clerical work.

Nodular dystrophy and lattice keratitis.—Of 25 nodular dystrophy (Figures 26A, B) and lattice keratitis cases (24 from 100-case series, 1 from early series), all but 5 had worth-while improvement (79 percent in this series, 80 percent in combined series). These familial dystrophy cases are particularly interesting, as there were several families each with several grafts in the family.

In one lattice keratitis family I did eight grafts, seven of them very successful, the eighth with partial improvement. Two of these patients (Cases 31, 35) had superficial keratectomies by Dr. Verhoeff with temporary improvement many years before he referred them for keratoplasty. This lattice keratitis family probably is unique in medical history and is being reported in detail in another paper.

Disciform and dendritic keratitis.—Eleven out of 16 cases of old disciform or dendritic keratitis were improved (69 percent). Since late edema in 2 cases and recurrence of dendritic in the graft in one resulted in some late decrease of acuity, early results were better than those reported.

Chemical burns.—Chemical burns proved more satisfactory than in some previous reports. Of 10 done, worthwhile improvement was obtained in 6 (60 percent).

In the earlier series, however (not reported here), chemical burn cases did not have a preparatory superficial keratectomy and beta radiation. Despite some temporary success, none of these early cases could be classified as "improved."

Interstitial keratitis.—The interstitial keratitis cases were a relatively unfavorable group compared to interstitial cases in general, as many of them had extreme corneal changes with some secondary lipoid dystrophy as well as other ocular pathology. Five out of 8 of these were improved (63 percent).

Leucomas from pyogenic ulcers.—This miscellaneous group with severe scarring included 2 with former perforated ulcers and one with an old serpent ulcer for which a Saemisch section had been done. Of 11 cases only 5 were improved (45 percent).

Edema of cornea.—Four cases of marked corneal edema secondary to corneal scarring and endothelial dystrophy were included, but none of these was a true Fuchs's dystrophy. One was a complete failure; 2 had excellent grafts, but immediately became edematous like the host cornea. The fourth had a crystal clear graft for thirteen months and then suddenly developed unexplained edema which resembled the original lesion (0 percent).

Regrafts.—The results of regrafts were encouraging, as 3 out of 9 (33 percent) were improved.

Photographs of successful primary grafts in a few other representative cases are reproduced in Figures 26E, F, G, H, I, J.

In the 100-case series, 12 eyes were ultimately worse than before operation. In 5 of these vision was reduced to nil; and in 3 of these unfortunate 5, enucleation was actually necessary, once for infection and twice for intractable secondary glaucoma. During the past seven years, however, only one eye has been reduced to no vision, and in no case has an enucleation been needed.

SUMMARY

During the nineteen years included in this 148-case series, corneal transplantation has grown from a speculative procedure to a successful and well established ophthalmic operation. Due to continuous improvements in technique and therapy, keratoplasty is a far more successful procedure at the present time than it was even five years ago.

Among recent improvements stressed are:

1. Pre-operative preparation for grafting by elimination of blood vessels by radiation, and in extreme cases by superficial keratectomy and conjunctival recession.

2. Improvements in fixation of the graft. Detailed descriptions are

given of two original track suture techniques and of several new instruments, including a plastic turret style graft holder to facilitate suturing of the graft.

3. Prevention of anterior synechias, principally by the use of air in the anterior chamber and, to a lesser extent, by improvements in graft suturing.

4. Use of steroids topically and orally for combating edema and inflammation with its attendant complications.

5. Prevention of vascularization in the new graft by reduction of inflammation and by use of beta radiation.

Technique.—In most cases the author uses a 5-mm. graft cut with a hand trephine and held in place by overlying sutures plus two direct sutures. In 5.5- to 6-mm. grafts overlying sutures are combined with two to four direct sutures. In grafts 7 mm. or larger overlying sutures are omitted completely and the cornea is held in place by ten to twenty-two direct ones.

Complications.—Of the complications encountered, glaucoma was one of the more frequent, being present at some time during convalescence in 33 percent of cases.

Anterior synechias were extremely common in the early cases, but in the more recent 100-case series they occurred in only 23 percent of cases. Edema of the cornea and proliferation of connective tissue on the back of the graft were also major complications. Infection and traumatic cataract each occurred once during the entire 148-case series.

Long postoperative follow-up (nineteen years in some cases) suggests that progressive dystrophies of the cornea eventually recur in the new cornea at the same rate as in the original cornea. Since time required for reappearance is usually many years, the probability of recurrence is not a contraindication to grafting.

Results.—Results of the entire nineteen-year series of 148 cases were 63.5 percent "improved." Recent results are much better than those of the 1930s; and, for the sake of current statistics, analysis is presented of 100 consecutive grafts (91 primary and 9 regrafts) done in recent years. In this series, running from 1944 to 1954, results were 69 percent "improved," 19 percent "unchanged," and 12 percent "worse."

In this latter series, results in "most favorable cases" (keratoconus, nodular dystrophy, and lattice keratitis) were excellent, with 32 out of 37 being improved (86.5 percent). By etiologic groups, results were as follows: keratoconus, 100 percent; nodular dystrophy and lattice keratitis, 79 percent; interstitial keratitis, 63 percent; disciform and dendritic keratitis, 69 percent; leucomas from pyogenic ulcers, 45 percent; chemical burns, 60 percent; edema of cornea (similar to but not true Fuchs's dystrophy), 0 percent; regrafts (miscellaneous), 33 percent.

Since the results in this 100-case series are better than those of the previous seven years, and since the results during the past few years have been better than those in the first part of the series, it is reasonable to expect that transplant statistics will continue to grow more favorable for many years to come.

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STATISTICAL TABLES

TABLE 1. SUMMARY OF PREOPERATIVE VISUAL ACUITIES OF 100 CONSECUTIVE TRANSPLANT PATIENTS

30 eyes	Light projection
27 eyes	1/200 to 2/200
37 eyes	3/200 to 10/200
5 eyes	11/200 to 18/20
1 eye	20/200

TABLE 2. VISUAL RESULTS IN 100 CONSECUTIVE CASES

		Percent
After 1-year follow-up		
	Improved	73
	Unchanged	15
	Worse	12
After full follow-up of 1 to 10 years (Average = 6 years)		
	Improved	69
	Unchanged	19
	Worse	12

TABLE 3. ANALYSIS OF RESULTS OF 100 CONSECUTIVE GRAFTS IN RELATION TO ETIOLOGY

Original pathology	*Total cases*	*Improved*	*Unchanged*	*Worse*	*Improved (percent)*	
Keratoconus	13	13			100	
Groenouw's dystrophy	13	9	3	1	69	Average for 24 dystrophy cases = 79%
Lattice keratitis	11	10		1	91	
Disciform or dendritic	16	11	3	2	69	
Interstitial keratitis	8	5	1	2	63	
Ulcers (pyogenic)	11	5	3	3	45	
Chemical burns	10	6	3	1	60	
Sclero-keratitis	4	3	1		75	
Trachoma	4	3	1		75	
Edema secondary to other corneal disease	4	0	3	1	0	
Lipoid dystrophy	1	1			100	
Salzmann's dystrophy	1	1			100	
Miscellaneous	4	2	1	1	50	

TABLE 4. ANALYSIS OF VISUAL ACUITY IN 69 IMPROVED CASES

Pathology	*Number improved*	*Vision 20/20 to 20/45*	*Vision 20/50 to 20/100*	*Vision 20/200 or less*
Keratoconus	13	12	1	
Groenouw's dystrophy and lattice keratitis	19	12	5	2
Disciform or dendritic	11	2	3	6
Interstitial keratitis	5	1	3	1
Chemical burns	6	0	4	2
Others	15	2	10	3
Total	69	29	26	14

TABLE 5. ANALYSIS OF 12 CASES WORSE AFTER KERATOPLASTY

Pathology	*Number worse*	*Case number*	*Preoperative vision*	*Postoperative vision*
Groenouw's dystrophy	1	25	3/200	L. proj.
Lattice keratitis	1	35	2/200	Nil
Disciform or dendritic	2	42	5/200	3/200
		46	3/200	Nil
Interstitial	2	59	2/200	L. proj.
		60	6/200	3/200
Ulcers	3	78	4/200	Nil
		79	3/200	Nil
		81	1/200	L. proj.
Chemical burn	1	68	18/200	7/200
Edema secondary to corneal disease	1	86	1/200	Nil
Keratitis with iridocyclitis (Type ?)	1	98	L. proj.	L. proj.

TABLE 6. ANALYSIS OF 9 GRAFTS SUCCESSFUL AFTER ONE YEAR BUT WITH DECREASE OF ACUITY IN SUBSEQUENT YEARS

Original pathology	*Case number*	*Cause of decreasing acuity*
Lattice keratitis	Case 28	Recurrence of lattice keratitis
Dendritic	Case 39	Recurrence of dendritic 2 yrs. later
Serpent ulcer with Saemisch section	Case 74	Dendritic in graft 6½ yrs. later
Chemical burn	Case 62	Gradual edema starting 5 yrs. later
Chemical burn	Case 68	Late edema
Edema (like Fuchs)	Case 83	Late edema
Disciform keratitis	Case 45	Late edema
Groenouw's dystrophy	Case 19	Late edema
Groenouw's dystrophy	Case 20	Late edema

TABLE 7. ANALYSIS OF RESULTS OF 9 REGRAFTS

Original pathology	*Case number*	*Results**	*Preoperative vision*	*Postoperative vision*
Lattice keratitis	29	+	2/200	20/30
Disciform	44	+	L. proj.	2/200
Disciform	46	−	3/200	Nil.
Disciform	51	0	L. proj.	L. proj.
Chemical burns	69	+	7/200	20/200
Groenouw's dystrophy	20	0	7/200	20/40 for 16 mos. (7/200 later)
Groenouw's dystrophy	26	0	L. proj.	L. proj.
Edema and leucoma	85	0	1/200	2/200
Vascularized keratitis and iridocyclitis (Type ?)	98	−	L. proj.	Poor L. proj.

*+ = improved; 0 = unchanged; − = worse.

TABLE 8. INCIDENCE OF POSTOPERATIVE GLAUCOMA IN 100 CONSECUTIVE CASES

Original pathology	*Number of cases*	*Number with glaucoma*	*Percent*
Keratoconus	13	1	7
Groenouw's dystrophy and lattice keratitis	24	6	25
Disciform and dendritic	16	7	44
Interstitial keratitis	8	5	63
Old ulcers	11	5	46
Chemical burns	10	5	50
Edema, secondary to previous inflammation or disease	4	1	25
Trachoma	4	2	50
Sclero-keratitis	4	1	25
Lipoid and Salzmann's dystrophy	2	0	0
Miscellaneous	4	0	0
Total	100	33	33

TABLE 9. ANALYSIS OF 100 CONSECUTIVE CASES OF PENETRATING KERATOPLASTY, 1944 TO 1954

Case	Length of follow-up	Age, sex, eye	Diagnosis and description	Preoperative vision	Acuity after graft	Result	Condition of graft	Complications and comment
1	3 yrs.	24 F R	KERATOCONUS. Marked conus with apical opacity. Has many allergies and was unable to wear any of several contact lenses.	1/200	20/30 −8.00 −7.00 X10	+	Clear	
2	2 yrs.	55 F L	KERATOCONUS. Mature cataract. Large apical opacities.	L. Proj.	20/35 +2.00 +5.50 X125	+	Clear	Had cataract extracted 5 mos. after graft with no complications.
3	6 yrs.	34 M L	KERATOCONUS. Extreme conus. Large tear in Descemets with wide opacity. Chronic irritation.	6/200 with contact 20/200	20/20 −2.25 −5.00 X115	+	Clear	
4	2½ yrs.	42 F L	KERATOCONUS. Vascularized scar from old cautery.	5/200 with contact 20/200, but not wearable.	20/25 −2.25 −5.00 X133	+	Clear	
5	11 yrs.	35 M L	KERATOCONUS. Extreme conus with marked central scarring.	1/200 20/100 with contact but not wearable.	20/25 −12.00 −7.00 X145	+	Clear	One year after 6-mm. square graft refractive error was −8.50 = −5.00 cyl. Myopia increased later, but no return of keratoconus.
6	5 yrs.	46 M L	KERATOCONUS. Former acute ectasia of cornea corrected by pressure bandage. Vascularized leucoma of entire cornea.	Shadows.	20/70 −3.50 −2.00 X60	+	Clear	Beta radiation before grafting. One anterior synechia released by miotics. Glaucoma controlled by iridectomy plus pilocarpine.
7	3½ yrs.	48 M R	KERATOCONUS. Marked conus with 3 mm. central opacity.	8/200 −4.00 cyl X165 with contact 20/50	20/20 −1.50 −4.50 X152	+	Clear	Other eye reported as Case 6.
8	1 yr.	22 M L	KERATOCONUS. Marked conus with 4 mm. apical opacity.	10/200 −10.00 −2.00 X135 with contact 20/60 (wearable only 4 hrs.)	20/25 −6.00 sph.	+	Clear	Patient has started in State Teachers College.
9	8 yrs.	20 F R	KERATOCONUS. Marked conus with 3 mm. opacity.	1/200 contact 20/60	20/20 −1.25 −50 X115	+	Clear	

10	2 yrs.	26 F L	KERATOCONUS. Marked conus with small central opacity.	16/200 −13.00 sph. contact 20/50	20/20 +50 −2.75 ×45	+	Clear	Cases 9 and 10 are same patient. Since the second eye was grafted, patient has passed eye test and does fine work in a large electronic plant.
11	2½ yrs.	32 M R	KERATOCONUS. Extreme vascularized leucoma of cornea due to previous cautery. Preliminary beta radiation needed.	1/200	20/40 −9.00 −2.00 ×50	+	Clear	Myopia increased about 4 diopters during first year.
12	7 yrs.	17 M L	KERATOCONUS. Extreme conus with 4 mm. opacity.	10/200 −23.00 contact 20/70 unwearable	20/25 −5.00 −2.75 ×45	+	Clear	
13	1 yr.	28 F R	KERATOCONUS. Moderate with only 1.5 mm. opacity. Had several prs. contacts but tolerates them only ½ hour!	3/200 −15.00 sph. contact 20/100 not wearable	20/35 −3.00 −3.00 ×170	+	Clear	Myopia changed from +2.00 to −3.00 in first few months.
14	7½ yrs.	50 M L	GROENOUW'S NODULAR DYSTROPHY. Numerous typical nodules with moderate gray opacity between dense spots.	5/200	20/45 −7.25 −4.00 ×170	+	Clear	Proliferation of connective tissue on back of upper third of graft following bulging margin in that area. (Pressure dressing used, graft flattened out.)
15	6 yrs.	35 M R	GROENOUW'S DYSTROPHY.	12/200	20/45 −2.00 −6.50 ×85	+	Clear	Pressure bandage used from 15th to 30th day.
16	7½ yrs.	28 M L	GROENOUW'S DYSTROPHY.	10/200	20/17 −4.50 −3.50 ×98	+	Clear	Lysis of tiny anterior synechia one month later.
17	4 yrs.	23 M L	GROENOUW'S DYSTROPHY.	1/200	20/200 −5.00 −2.50 ×25	+	Clear	Has incipient posterior cataract accounting for low vision (not due to graft).
18	7¼ yrs.	42 F L	GROENOUW'S DYSTROPHY.	4/200	20/30 −3.00 −4.00 ×140	+	Clear	
19	2½ yrs. (to regraft)	44 F R	GROENOUW'S DYSTROPHY.	3/200	7/200	0	Faint edema	Spastic entropion corrected 1 mo. later. Mild glaucoma controlled by drops.
20	2½ yrs.	47 F R	GROENOUW'S DYSTROPHY with edema of the graft. (This is a regraft.)	7/200	20/40 For 16 mos. / Late Edema 7/200	0	Variable edema	Same eye as Case 19. Preliminary iridectomy done. Perfectly clear for 16 mos., then developed edema in a single day! Vision now variable from 2/200 to 10/200. Tension normal.

TABLE 9 (*continued*)

Case	Length of follow-up	Age, sex, eye	Diagnosis and description	Preoperative vision	Acuity after graft	Result	Condition of graft	Complications and comment
21	8 yrs.	40 F R	GROENOUW'S DYSTROPHY. Fine white dots with irregular clouding. Cornea 2/3 normal thickness as "stripping" of cornea done 9 yrs. earlier.	2/200 −8.50 −4.00 X170	20/45 −12.00 −4.00 X170	+	Clear	Acute glaucoma on 19th day. Controlled by miotics. Lysis of small anterior synechia after one month.
22	4½ yrs.	42 F L	GROENOUW'S DYSTROPHY.	2/200 −8.00 −4.00 X145	20/100 −22.00 −4.00 X30	+	Clear	Donor cornea from 1½ yr. old baby. Also has incipient cataract and debris on lens surface from post-operative cyclitis.
23	5½ yrs.	45 F R	GROENOUW'S DYSTROPHY.	10/200	20/20+ +1.00 +5.00 X105	+	Clear	One quadrant of margin bulged for 3 mos., causing opacity of that area and marked astigmatism. Cylinder was 12 diopters at one time! See Figure 19.
24	8 yrs.	29 F R	GROENOUW'S DYSTROPHY.	4/200	20/30 −2 −14.00 −4.50 X110	+	Clear	Sister of Case 25.
25	4 yrs. (to regraft)	33 M L	GROENOUW'S DYSTROPHY.	3/200	L. Proj.	−	Opaque	Graft perfect, but following lysis of anterior synechia had hemorrhage in anterior chamber and organized clot on back of graft.
26	3½ yrs.	37 M L	GROENOUW'S DYSTROPHY with opaque graft. (This is a regraft.)	L. Proj.	L. Proj.	0	Opaque	Has more synechia and again had bleeding at time of lysis. Glaucoma controlled by several cyclodiathermy operations.
27	1 yr.	42 M R	LATTICE KERATITIS. Diffuse lattice changes with opacities between lines. Involvement of external 2/3 of cornea.	5/200	20/20 −50 −3.25 X150	+	Clear	Has a few wrinkles on back of graft. Reads J-1.
28	11 yrs.	56 F R	LATTICE KERATITIS. Extreme.	1/200	20/70 −9.00 −2.00 X70	+	Clear	Beginning reappearance of lattice keratitis in graft 9 years later.
29	3½ yrs.	64 F L	LATTICE KERATITIS. Successful graft done 12 yrs. earlier with recent recurrence of lattice in graft.	2/200 −11.00	20/30 +5.00 +2.50 X165	+	Clear	Had dense immature cataract, regraft done first, and cataract extracted 5 mos. later. This is other eye of Case 28.
30	9½ yrs.	57 F R	LATTICE KERATITIS, IMMATURE CATARACT.	3/200	20/35 +4.50 −12.00 X160	+	Clear	Cataract extraction 5 mos. after graft. Beginning recurrence of lattice keratitis in graft 7 years later.

31	7 yrs.	59 F L	LATTICE KERATITIS, MATURE CATARACT. Cornea ½ normal thickness as corneal stripping done 8 years earlier.	L. Proj.	20/40 +8.25 −2.25 X35	+	Clear	Temporary elevation of graft margin controlled by pressure bandage. Acute glaucoma required posterior sclerotomy, cyclodialysis, and lysis of synechia. Cataract removed 6 mos. after grafting. No recurrence of lattice dystrophy yet.
32	6 yrs.	60 M R	LATTICE KERATITIS. Dense generalized dystrophy of cornea. Deep "wrinkles" and diffuse clouding.	4/200	20/200 −3.00 −4.00 X15	+	Semi-clear	Anterior synechia and acute glaucoma. Cyclodialysis and lysis of adhesions and iridectomy later. Still had chronic glaucoma, controlled by drops.
33	9 yrs.	51 M R	LATTICE KERATITIS. Had "stripping" by Dr. Verhoeff 7 years earlier with temporary improvement.	3/200	20/70 −3.00 −4.00 X170	+	Clear	A few permanent folds in Descemet's membrane.
34	4 yrs.	56 M L	LATTICE KERATITIS.	18/200	20/70 −1.00 −75 X160	+	Clear	This and the previous 6 lattice keratitis eyes are all in same family. The 8th graft was done on Case 29 15½ yrs. ago and was clear for many years.
35	8 yrs.	44 M R	LATTICE KERATITIS. Superficial keratectomy done 7 years earlier.	2/200	Nil	−	Opaque	Square graft perfect at 1 month with tiny anterior synechia at three corners. Refused to have lysis! Not seen for 2 yrs., at which time eye was blind from glaucoma. Should have been a successful graft!
36	5 yrs.	65 F L	LATTICE KERATITIS.	5/200	20/70 −12.00 −2.00 X180	+	Clear	Extreme anterior synechia. Lysis 3 mos. later. One tiny synechia left, but has never caused trouble.
37	5 yrs.	41 F R	LATTICE KERATITIS.	7/200	20/25 −11.00 −2.00 X80	+	Clear	Case 37 is niece of Case 36.
38	3½ yrs.	45 F L	Recurrent DENDRITIC. Immature cataract. Dense irregular glaucoma.	4/200	5/200 −8.00 −4.00 X80	+ See comment	Clear	Graft crystal clear and poor vision is due to cataract. Classed as successful graft. Had glaucoma controlled by drops.
39	2 yrs.	32 M L	DENDRITIC. Dense leucoma with many vessels. Beta radiation used before operation.	18/200	20/25 −4.00 −2.00 X50 See comment	+	Clear	Temporary glaucoma controlled by drops. At the end of 2 years patient had new attack of dendritic in recipient cornea which soon involved graft. Present vision 9/200 but improving.
40	7 yrs.	42 F R	DENDRITIC. Dense irregular scar. Post. synechia and cyclitic membrane on lens. Incipient cataract.	2/200	20/70 +9.00 +3.50 X105	+	Clear	Had preliminary iridectomy. Cataract removed 6 yrs. later.

TABLE 9 (*continued*)

Case	Length of follow-up	Age, sex, eye	Diagnosis and description	Preoperative vision	Acuity after graft	Result	Condition of graft	Complications and comment
41	2 yrs.	53 M L	DISCIFORM. Dense disciform opacity 8 mm. wide with a few vessels.	2/200	20/70 +5.00 −10.00 ×45	+	Clear (except in lower third)	Had glaucoma before grafting controlled by cyclodiathermy. Glaucoma again after grafting controlled by one cyclodiathermy and drops. Bulging lower graft margin accounted for astigmatic error.
42	10 yrs.	47 F L	DISCIFORM. Dense wide leucoma with a few superficial and deep vessels.	5/200	3/200 +9.50 +2.00 ×150	−	Semi-clear	Traumatic cataract noticed during convalescence (from keratome incision in square graft?) Most of cataract absorbed but further surgery never done.
43	2 yrs. (to regraft) (see 46)	46 F R	DISCIFORM. Bullous keratitis, chronic glaucoma. Cataract, complete posterior synechia. Former chronic uveitis.	L. Proj.	L. Proj.	0	Marked edema	Iridectomy and two cyclodialyses for glaucoma and adhesions done first. Glaucoma recurred after graft. One cyclodialysis and two cyclodiathermies done with control of tension.
44	1½ yrs.	48 F R	DISCIFORM. Edema of cornea and graft. This is regraft of Case 43.	L. Proj.	2/200 +10.00	+	Faint edema of epithelium	Graft clear for 6 mos. and tension normal. Cataract removed. Faint edema of graft since then. One new cyclodiathermy was needed.
45	2½ yrs. (to regraft) (see 48)	56 F L	DISCIFORM. Very thick scar 10 mm. wide with a few deep vessels.	L. Proj.	20/25 +3.00 −7.00 ×160 1 yr. later 3/200 2 yrs. later	+	Clear for 1 year. Edema later	Graft crystal clear for 12 months then within 2-day period showed marked edema.
46	9 yrs.	58 F L	DISCIFORM. Edema of old graft. This is regraft of Case 45.	3/200	Nil	−	Opaque	Violent nausea first day postop. Nonunion of lower margin of square graft. Conjunctival flap later. Extensive anterior synechia and glaucoma.
47	8½ yrs.	23 M L	DENDRITIC. Irregular central scar 8 mm. in diameter.	7/200	20/200	+	Clear centrally	Proliferation of connective tissue on posterior graft surface except for 2 mm. centrally. Much aberration.
48	2½ yrs.	52 F R	Recurrent HERPES(?). One ulcer cauterized 5 yrs. earlier. About 30 irreg. punctate scars and 2 larger ones. Extreme aberration.	1/200	20/25 −9.00 −2.00 ×180	+	Clear	Other eye also has corneal scarring, but patient has been able to resume school teaching (which she had given up years ago).
49	4 yrs.	60 F L	DISCIFORM with secondary fatty dystrophy and calcification. Immature cataract.	L. Proj.	8/200	+	Clear	

50	2 yrs. (to regraft) (see Case 51)	60 F R	DISCIFORM. Large dense full thickness corneal leucoma. Immature cataract.	L. Proj.	L. Proj.	o	Edema	Marked psychosis. Up and about first night, bandages pulled off! Discharged without eye pad on third day! Extensive anterior synechia but graft healed firmly. Lysis of synechia done later.
51	3½ yrs.	62 F R	DISCIFORM. Edema of old graft. Immature cataract. (This is regraft of Case 50.)	L. Proj.	L. Proj.	o	Edema	Because of previous psychosis, direct sutures used, and patient uncovered in two days. Graft perfect with no synechia, but faint edema present early became marked in 6 months.
52	8 yrs.	64 M L	DISCIFORM. Dense leucoma 7 mm. wide centered temporally. Immature cataract.	L. Proj.	6/200 −7.50 sph.	+	Clear	Has myopic retinitis. Poor vision principally from cataract, however. Counted as "improved" as graft is perfect and tension is normal.
53	6 yrs.	63 M R	DISCIFORM. Deep opacities 8 mm. wide. Many vessels before use of beta.	2/200	20/50 −2.50 −6.00 ×10	+	Clear	Old debris on lens surface reduces vision.
54	6½ yrs.	63 F R	INTERSTITIAL KERATITIS. Diffuse opacity of entire cornea. Faint vessels.	8/200	20/60 −6.00 cyl. ×130	+	90% clear	Recurrence of typical interstitial keratitis in host and graft with eventual almost complete clearing of graft. Glaucoma later, controlled by drops.
55	4 yrs.	15 F R	INTERSTITIAL KERATITIS. Diffuse irregular scarring. Many old "ghost" vessels. Old debris on lens surface.	1/200	20/70 −14.00 −2.00 ×166	+	Clear	Recurrence of interstitial in graft—controlled by systemic cortisone. Chronic glaucoma controlled by pilocarpine and Floropryl.
56	1 yr.	18 F L	INTERSTITIAL KERATITIS. (Other eye of Case 55.) Extensive dense opacity with tiny old vessels—a few still patent.	1/200	20/40 −4.50 cyl. ×75	+	Clear	Was given systemic cortisone starting on 5th day. No recurrence of interstitial.
57	7 yrs.	30 F R	INTERSTITIAL KERATITIS. Wide dense gray scar with some secondary lipoid dystrophy.	2/200	20/70 −2.00 ×80	+	80% Clear	Done before cortisone was available. No unusual inflammation. Poor vision due to old cyclitic debris on lens surface and slight lens opacities.
58	11 yrs.	32 F R	INTERSTITIAL KERATITIS. Almost total opacity of cornea. Previous chronic glaucoma of each eye.	2/200	15/200	+	Clear in 1 mm. area only	Proliferation of connective tissue over back of entire graft except for area 1 mm. square. Glaucoma controlled by drops. Can read newsprint with +4.00 lens!
59	11 yrs.	63 M R	INTERSTITIAL KERATITIS. Also probable disciform keratitis. Dense 7 mm. leucoma centrally. Faint scarring in periphery.	2/200	L. Proj.	−	Opaque	Very uncooperative during and after operation. Extensive anterior synechia and a 1 mm. iris prolapse. Conjunctival flap. Cyclodialysis later. Glaucoma controlled by drops.

TABLE 9 (*continued*)

Case	Length of follow-up	Age, sex, eye	Diagnosis and description	Preoperative vision	Acuity after graft	Result	Condition of graft	Complications and comment
60		M R	INTERSTITIAL KERATITIS with extensive anterior synechia! Dense scarring of most of cornea.	6/200	3/200	—	Semi-Clear	Had lysis of anterior synechia before graft. Glaucoma later controlled by one cyclodiathermy and drops.
61	10 yrs.	35 M R	INTERSTITIAL KERATITIS. Bluish white opacity of entire cornea. Some fatty degeneration. Pupil not visible.	L. Proj.	L. Proj.	0	Opaque	Graft healed well. Obstinate glaucoma. Cyclodialysis and trephine operation done. Glaucoma now moderately well controlled with drops.
62	11 yrs.	55 M L	CHEMICAL BURN (Lime) 40 yrs. earlier. Complete leucoma. A few vessels.	L. Proj.	20/70 +5.00 sph. for 4 years. 3/200 after 11 yrs.	+	Clear for 4 years. Faint edema since then	Dense yellow leucoma with fatty degeneration. Graft very clear 4 yrs., then faint edema in stroma and epithelium. Gradually worse. Mild glaucoma controlled by drops.
63	5 yrs.	61 M R	LIME BURN. (46 yrs. ago). Dense thick heavily vascularized pannus of entire cornea. Had superficial keratectomy, resection of limbal scar tissue and beta.	L. Proj.	20/60 +4.00 −6.00 × 180	+	Clear	Glaucoma controlled by drops. This is other eye of Case 62. Is beginning to show stromal changes suggesting eventual trouble as in left eye.
64	3 yrs.	24 M L	LIME BURN. Complete pannus and dense leucoma of entire cornea.	L. Proj.	20/60 + +1.50 +4.00 × 145	+	70% Clear	Superficial keratectomy, recession of scar tissue and conjunctiva from limbus, and beta radiation before grafting.
65	2 1/3 yrs.	25 M L	AMMONIA BURN (from explosion). Complete dense white heavily vascularized leucoma.	L. Proj.	2/200	+	25% Clear	Superficial keratectomy and beta first. Patient's body jerks constantly, so operation done under general. Graft vascularized and was given beta later. Glaucoma controlled by drops.
66	2 yrs.	40 M R	CHEMICAL BURN (Caustic Soda). Dense white leucoma of entire cornea with many vessels.	L. Proj.	1/200	0	Central 2 mm. translucent	Superficial keratectomy and beta first. Bulging of graft and poor union inferiorly required pressure bandage, with eventual well healed margin.
67	2½ yrs.	27 M R	LIME BURN. Deep vascularized leucoma of 50% of cornea and superficial scarring of remainder.	3/200	20/60 −8.00 −4.00 × 180	+	Clear	Superficial keratectomy followed by beta radiation.

68	3½ yrs. (to regraft)	32 M R	AMMONIA BURN. Irregular scarring of most of cornea with many deep and superficial vessels.	18/200	20/70 −7.00 −4.00 × 180 1 yr. later 7/200 3 yrs. later	−	Clear for 15 mos. Faint edema later	Much beta before grafting. Also cautery to larger vessels at limbus. After late edema appeared to be permanent, regraft advised.
69	1¼ yrs.	36 M R	AMMONIA BURN with edema of graft. This is regraft of Case 68.	7/200	20/200 −3.00 −3.00 × 150	+	70% Clear	Considerable proliferation of connective tissue on back of graft with irregular astigmatism.
70	6½ yrs.	48 M L	1918 explosion and CHEMICAL BURN, type unknown. Complete vascularized leucoma.	Shadows See comment.	5/200 −6.00 −4.00 × 165	0 See comment	Semi-Clear (Faint edema)	Iridectomy and beta before grafting. Glaucoma controlled by drops after grafting. Vision improved to 4/200 after iridectomy and beta before graft, so graft result classed as 0.
71	11 yrs.	55 M L	LIME BURN. Diffuse deep opacities and degenerative changes. A few old vessels.	L. Proj.	1/200	0	Slightly Cloudy	Diathermy peritomies to occlude vessels before operation and preliminary iridectomy. Glaucoma controlled by drops.
72	11 yrs.	15 M L	CORNEAL ULCERS in infancy. Diffuse irregular scarring. A few small vessels. Nystagmus. Amblyopia.	Shadows	Shadows	0	Cloudy	Had peritomy with diathermy beforehand to reduce vascularization. One posterior synechia at corner of square graft.
73	7 yrs.	60 F L	ULCERS in childhood. Dense irregular scarring. No vessels. High myopia. Incip. cataract.	2/200	"Can see well." Data not available.	+	Clear	Tiny incarcerated iris prolapse. Excision with conjunctival flap 6 wks. later. Lysis of synechia twice. Cataract extraction 8 mos. after graft. Follow-up by letter from California, "can see well." No data given.
74	7 yrs.	51 M L	SERPENT ULCER with hypopyon. Saemisch section done. Dense vascularized leucoma.	1/200	20/35 +12.50 +2.50 × 40	+	Clear for 6½ yrs. Cloudy now due to recent dendritic.	Peritomies and beta first to remove vessels. Cataract extraction later. Clear graft for 6½ yrs. Dendritic keratitis in 1955 affected host cornea and graft. Present vision 4/200 but improving. Permanent scarring of graft!
75	8 yrs.	36 M L	ULCER in infancy. Dense leucoma over nearly entire cornea. Nystagmus. Amblyopia.	3/200	15/200	+	Faint edema	Temporary glaucoma controlled by drops.
76	9 yrs.	39 F L	Perforated CORNEAL ULCER. Dense leucoma of most of cornea with anterior synechia. 3 small vessels.	L. Proj.	L. Proj.	0	Very Opaque	Diathermy peritomy first. Almost complete anterior synechia after graft. Lysis done twice, and 1 iridectomy. Chronic glaucoma not well controlled.
77		56 F R	Recurrent CORNEAL ULCER since childhood. Dense irregular scarring. Immat. cat. High myopia.	3/200 −11.00	6/200 +8.00	0	70% Clear	Glaucoma controlled by pilocarpine. Cataract extraction 1 yr. later. Ectasia of cataract scar with repair 6 mos. later.

TABLE 9 *(continued)*

Case	Length of follow-up	Age, sex, eye	Diagnosis and description	Preoperative vision	Acuity after graft	Result	Condition of graft	Complications and comment
78	9 yrs. (?)	30? M ?	CORNEAL ULCER in childhood. Dense irregular scarring.	4/200	Nil	−	Enucleation	Severe iridocyclitis, pain, and secondary glaucoma. Cortisone or cyclodiathermy not available at that period. Enucleation several weeks later. Details from memory as record not available.
79	8½ yrs.	50 M L	Recurrent ULCERS. Dense irregular scar 7 mm. wide. A few tiny vessels.	3/200	Nil	−	Enucleation	Panophthalmitis on 3rd day. Donor eye from a distant small hospital, and not removed by ophthalmologist. Infection probably introduced with graft. This is only infection in 148 cases. Since then all donor eyes washed in three basins of saline at time of operation.
80	6 yrs. (till death 2 yrs. ago)	61 F L	Recurrent ULCERS in childhood. Diffuse dense scarring. No vessels. Immature cataract.	1/200	20/60 +7.00 +6.00 × 125	+	Clear	Cataract extraction done 5 mos. later.
81	5½ yrs.	56 M R	Recurrent CORNEAL ULCERS. Dense scarring of most of cornea. Many vessels. Immature cataract.	1/200	L. Proj.	−	Cloudy	Vessels removed by beta radiation before operation. Lower border of graft elevated with nonunion. Healed well with pressure bandage. Extensive anterior synechia inferiorly. Tension normal. Lysis and regraft advised but patient has not consented.
82	5 yrs.	75 M R	Recurrent ULCERS with secondary lipoid dystrophy. Mature cataract.	L. Proj.	L. Proj.	+ See comment	Clear	Intestinal obstruction after graft with abdominal operation on 10th day. Mature cataract found. Discharged to convalescent home with clear graft. In 1951 (5 yrs. later) patient still alive, with clear graft, but cataract never removed.
83	8 yrs.	39 F R	EDEMA of cornea—severe—secondary to blow from stone 12 yrs. before. Tear in Descemets across entire cornea. Eye constantly irritated.	1/200	20/60 +5.00 +4.50 × 170 (for 13 mos.) 3/200 (after 8 yrs.)	0 See comment	Clear 13 mos. Marked edema now	Crystal clear for 2 years; then sudden edema coming on in 2 days! Graft now resembles remainder of cornea but slightly less edematous.
84	6 yrs. (to regraft)	F L	Faint EDEMA of cornea. Large dense leucoma. Anterior and post. synechia. Old iridocyclitis. Immature cataract.	2/200	1/200	0	Faint edema	Lysis of synechia before grafting. Glaucoma after grafting controlled by drops. Graft perfect, but showed faint persistent edema.
85	2½ yrs.	F L	EDEMA of cornea and graft. This is regraft of Case 84.	1/200	2/200	0	Very faint edema	Excellent graft, but again shows persistent very faint edema, so cataract extraction not attempted.

86	8½ yrs.	76 F R	Marked EDEMA and dystrophy of entire cornea, resembling Fuchs' dystrophy. Old scar. Immature cataract.	1/200	Nil	–	Edema	Spastic entropion immediately after graft. Flat chamber. Anterior synechia. Glaucoma. Patient did not return for follow-up surgery. Enucleation elsewhere 3 yrs. later because of painful glaucoma.
87	5 yrs.	51 M R	Old TRACHOMA. Diffuse scarring of entire cornea with dense leucoma over pupil. Many small vessels.	20/200 −7.00 sph.	20/200 −6.00 −5.00 ×90	0	80% Clear	Beta radiation before and after operation. Severe postoperative inflammation. Pressure bandage for bulging graft. Clear graft, but irregular areas of connective tissue proliferation on posterior surface cause aberration.
88	4 yrs.	50 F R	Old TRACHOMA. Irregular diffuse scarring with numerous superficial vessels.	5/200	20/150 −4.00 −2.00 ×45	+	Clear	Beta radiation first. Graft clear but vision reduced by postcortical cataract. Postoperative glaucoma controlled by pilocarpine and one cyclodiathermy.
89	4½ yrs.	49 F R	Old TRACHOMA. Irregular dense scarring. A few vessels. Slight microphthalmos. Incipient cataract. Hypertension (220/140).	L. Proj.	20/100 0 correction (Reads V-2)	+	Clear	Glaucoma controlled by one iridectomy, one cyclodiathermy, and drops.
90	7 yrs.	60 M R	Old TRACHOMA. Dense opacity of entire cornea. Some secondary lipoid dystrophy. A few vessels. Immature cataract.	Shadows	20/60 +6.25 +4.00 ×18	+	Clear	Cataract extraction 6 mos. later. Media clear but has old chorioretinitis scar involving part of macula area. Other eye has no vision, but patient now working as barber!
91	10½ yrs.	55 F R	SCLERO-KERATITIS with secondary fatty dystrophy. Dense white scarring. No vessels. Chorioretinitis (found later).	Shadows	4/200	0	70% Clear	Uneventful convalescence. Irregular astigmatism in graft. Large patch of chorioretinal degeneration prevents better acuity. Graft clear enough to give 20/200 vision.
92	8½ yrs.	50 M L	SCLERO-KERATITIS. Also recurrent ulcers (phlyctenular keratitis?) in childhood. Diffuse irregular dense scars, no vessels.	4/200	20/100 −5.00 cyl. ×15	+	Clear	Fundus seen clearly so poor vision due to amblyopia exanopsia. Had tiny area of dendritic keratitis on graft 8 yrs. later with no permanent visual effect.
93	1½ yrs.	39 F R	SCLERO-KERATITIS. Many recurrent attacks (as was true of other cases also). Former Tbc. iridocyclitis. Diffuse deep scarring with moderate deep vascularization.	2/200	20/200 −3.00 −1.50 ×90	+	70% Clear	Had desensitization with old Tbc. several years before. Beta radiation to remove vessels. No marked inflammation after graft. Several tiny deep infiltrates in graft prevent better vision.
94	4 yrs.	34 F L	SCLERO-KERATITIS. Dense white scar covering upper 70% of cornea. A few deep vessels.	3/200	20/70 −9.00 −2.00 ×75	+	Clear	Graft crystal clear, but eye has had intermittent glaucoma attacks. Gonioscopy shows extensive peripheral anterior synechia. Tension controlled by four cyclodiathermies plus drops.

TABLE 9 (*continued*)

Case	Length of follow-up	Age, sex, eye	Diagnosis and description	Preoperative vision	Acuity after graft	Result	Condition of graft	Complications and comment
95	10½ yrs.	57 F L	LIPOID DYSTROPHY. Full thickness yellow-white fatty degeneration of 70% of cornea including pupillary area.	5/200 10/200 (dilated)	20/40 +1.25 −1.50×100	+	Clear	Anterior synechia at 2 corners of square graft freed by lysis later. Graft clear with slight lipoid changes in one corner only after several years. Lipoid dystrophy in remainder of cornea has improved since grafting!
96	3 yrs.	46 F L	SALZMANN'S DYSTROPHY. Childhood phlyctenular keratitis. Ridge like lesions, vascularized slightly. Diffuse opacities of rest of cornea.	7/200 −12.00	20/70 −17 −4.00×150	+	Clear	Crystal clear graft. Poor vision due to myopic type fundus degeneration with involvement of paramacula area.
97	2 yrs. (to regraft)	64 F L	Recurrent KERATITIS and IRIDOCYCLITIS, type unknown. Dense extremely vascularized leucoma. Mature cataract. Complete posterior synechia.	L. Proj.	L. Proj.	0	Opaque	Superficial keratectomy and beta radiation before grafting. Graft excellent, but chamber lost when sutures removed, and anterior synechia formed. Graft vascularized later.
98	1½ yrs.	66 F L	VASCULARIZED LEUCOMA and opaque corneal graft. Mat. cat. Anterior and posterior synechia. Regraft of case 97.	L. Proj.	L. Proj. (Slightly defective)	−	Opaque Vascularized	Had more beta after first graft in preparation for this. Graft technically perfect, but recurrence of iridocyclitis for 2 mos. Eye now white but tension is abnormally low.
99	1¼ yrs.	26 M R	METAPLASIA of epithelium of cornea and conjunctiva. Complete vascularized opacity of entire cornea with dry scaly appearance as in pemphigus. Extreme vascularization, deep and superficial.	L. Proj.	20/60 0 correction	+	Clear	Superficial keratectomy, recession of scar tissue from limbus and beta radiation. Diagnosed in Greece as "Malignant vernal catarrh," but diagnosis not confirmed here. Patient kept on topical hydro-cortisone and vitamins. No evidence of recurrence.
100	1½ yrs.	26 M L	METAPLASIA of epithelium of cornea and conjunctiva. Other eye of Case 99. Similar picture but much less extreme.	1/200	20/80 0 correction	+	Clear	Superficial keratectomy, recession of scar tissue for 4 mm. from limbus, and beta radiation. One anterior synechia, with lysis one month later. Some connective tissue proliferation on back of graft.