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INSTRUMENTATION AND TECHNIQUES OF KERATOPLASTY

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THERE has been a plethora of literature on corneal transplantation since the last symposium on this subject held in Chicago twelve years ago at the Fifty-Second Annual Meeting of the American Academy of Ophthalmology and Otolaryngology.[21] In the short time allotted me I cannot possibly enumerate even a fraction of the many valuable contributions made to this phase of ocular surgery during this relatively short period of time. Fortunately, since 1947 several excellent books on keratoplasty have been published, all with very complete descriptions of the instruments and techniques. Among them I should like to mention, in chronological order, *Les Greffes de la Cornée* by Paufique, Sourdille and Offret,[22] *Keratoplasty* by Paton,[20] *The Cornea* by Thomas,[28] and *Corneal Grafts* by Rycroft.[25] In addition, several texts on general ophthalmic surgery contain comprehensive chapters on corneal transplantation. These include Arruga's *Ocular Surgery,*[1] Stallard's *Eye Surgery,*[26] and others. Those interested in a more detailed study of instrumentation and techniques are referred to these books. I shall deal only with a few highlights of the advances made since the last symposium.

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Presented at the Sixty-Fourth Annual Session of the American Academy of Ophthalmology and Otolaryngology, Oct. 11-16, 1959, Chicago.

In his presentation on techniques at the 1947 symposium, McLean[19] pointed out that a review of the literature showed the various surgical procedures which were being considered at that time were total keratoplasty, rotating autokeratoplasty, superficial lamellar keratoplasty and partial penetrating keratoplasty. He said that for general use the last was by far the most popular and had the widest application. He found that total keratoplasty had had sufficient trial in animal experiments and human cases to be discarded and that it was not successful in practical application nor feasible on theoretical grounds.

According to McLean's analysis in 1947:

> Rotating autokeratoplasty, while theoretically sound, does not work well in practice. . . .
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> Superficial lamellar keratoplasty is theoretically feasible but very little used in this country. Since it is a form of nonpenetrating keratoplasty there must be an area of wound union all the way across the base of the graft with some attendant scarring. For most surface scars keratectomy is simpler and just as effective. However, in certain cases of deeper scarring where any form of penetrating keratoplasty seems to introduce excess risk, it must be considered. An example of this would be a case of aphakia with bulging vitreous. Here the risk of vitreous loss and vitreous incarceration at the edges of the graft might outweigh the better visual prospects of an uneventful penerating graft and militate in favor of the safer, if visually poorer, nonpenetrating graft.

The partial penetrating corneal graft is the most successful method in ordinary cases.

In 1947 the small graft was favored, but a gradual swing toward larger and larger grafts with greater visual success was already under way. McLean pointed out, however, that the graft should not be so large as to interfere with the angle of the anterior chamber or to allow iris incarceration or prolapse at the edges.

An overlying suture was used for fixation of the graft. It was either continuous or consisted of two crossed sutures fixed in the cornea of the host near the graft. This method was preferred to direct suturing of the graft to the recipient cornea, which seemed to further unnecessary trauma to the graft. Therefore, direct suturing was avoided in ordinary cases and used only under special conditions. Omission of sutures and the use of other devices for fixation of the graft at that time had usually proved unsuccessful. Equivalent results were obtained with the two most popular shapes then in use, the round and the square graft. For preparation of the graft, the hand trephine was preferred to the high-speed trephine, which involved greater risk of injuring the lens. The pupil was dilated at the end of the operation to avoid synechias and incarceration of the iris. All donor material had to be corneal tissue. Attempts made to use buttons of glass, plastic and other tissues had all been unsuccessful. The donor material best suited to corneal transplantation was obtained from a freshly enucleated eye or one satisfactorily preserved. The New York Eye Bank, recently organized, facilitated the collection and distribution of donor material previously difficult for the individual surgeon and small hospitals to obtain.

The percentage of success depended on the suitability of the cases selected for keratoplasty. A fair number of successful grafts could be expected only in favorable and moderately favorable eyes. Many patients, classified as not suitable for successful corneal transplantation, were dismissed completely.

Using the quoted conclusions reached at the last symposium on corneal transplantation held by the Academy in 1947 as a comparison, I shall now discuss briefly a few of the highlights of the present status of techniques and instrumentation to emphasize the tremendous changes that have taken place and the progress made in the short span of twelve years in this highly specialized field of ocular surgery.

FIXATION OF THE GRAFT

Direct suturing of the graft to the recipient cornea was recommended only in cases of aphakia to prevent dislocation of the graft by vitreous prolapse, or in infants and unruly adults when a stormy postoperative course was anticipated. Although it was obvious that marginal sutures constituted the ideal method of holding the graft in position, the systematic use of this technique was possible only with very sharp needles to minimize trauma to both the graft and the host cornea. Unfortunately such needles were not then available, so marginal fixation of the graft was limited to the special cases already mentioned.

In keratoplasty the needle should be considered one of the most delicate instruments, essential to a smooth performance of the operation with a minimum of trauma to both the graft and the host cornea. When needles with very fine points, highly polished and with sharp edges, became readily available (the Vogt-Barraquer[2] triangular cross section no. 81 and the Castroviejo[10] flat cross section no. 82 manufactured by

Greishaber, and similar needles made later by other firms), it was possible to fix the graft routinely to the host cornea by direct suturing, and this method of fixing the graft was almost universally accepted. Greishaber needles 81 and 82 are available in three sizes: 5, 7 and 10 mm. The 7 mm. size is most widely used for keratoplasty, although some surgeons prefer the smaller one (5 mm.) or even the new 4 mm. needle (no. 83) designed by José I. Barraquer and manufactured by Greishaber.

Until recently most surgeons used 6-0 silk, but the tendency today is toward finer suturing material and the use of 7-0 silk. In the search for still finer sutures less traumatic to the ocular tissue, Barraquer advocated the use of raw silk, which he gauged at 12-0 but which is 8-0 according to American standards. The great advantage of this fine silk is that it may be left in the eye for three weeks or longer, causing little irritation. Its tensile strength, however, is low and it bleaches shortly after application. A staining solution, such as fluorescein or methylene blue, must be used to visualize the stitches for removal.

During the past year Ethicon has developed a new atraumatic needle of 0.008-inch wire with 7-0 braided silk. This fine silk has practically all the advantages of raw silk but its tensile strength is greater. It is easier to handle, does not bleach and is well tolerated by the eye for three weeks or longer. Although the Ethicon needle is not as sharp as those manufactured by Greishaber, it is thinner, quite adequate, and the least traumatic of all the needles presently available. The point and cutting edges of this needle have been made in such a way that it will penetrate tough corneal tissue but will not cut out in any direction. It is to be hoped that when this needle becomes available for general use, it will have the same good qualities as those submitted to ophthalmic surgeons throughout the United States during its trial stage. Several ophthalmic surgeons have developed needle holders to be used with these delicate needles. Some prefer a needle holder without a catch; others prefer a catch to minimize finger tension.

In addition to the fine needles and the comparatively fine needle holders, delicate suturing forceps are necessary to hold fractions of the thickness of the corneal tissue. A number of surgeons have designed several models of these forceps in varying shapes and sizes to meet their personal requirements. The combination of a fine needle, a fine and smoothly working needle holder and a delicate fixation and suturing forceps has become essential for the performance of a keratoplasty, particularly for marginal suturing of the graft.

The operative field should be sufficiently magnified to ensure accurate performance of these precise surgical procedures. Some surgeons prefer fairly high magnification, using binocular microscopes similar to those used by otolaryngologists for fenestration operations. Others find this high degree of magnification not only nonessential for corneal surgery but even undesirable, as it hampers maneuverability. Binocular magnifying loupes, some self-illuminating, are now available with magnification up to five times. This is ample for corneal surgery and the loupes, attached either to ordinary frames or to a headband, allow more flexibility of movement than is possible with the microscopes. Good illumination of the operative field is essential in corneal surgery. This remark may seem unnecessary, as it is taken for granted that the ophthalmic surgeon always uses adequate lighting, but unfortunately this often is not the case. The light for corneal surgery must not be diffused; it must be concentrated, with fairly high intensity, within the

palpebral fissure and particularly on the cornea. A light that can be moved by the surgeon and directed to the desired area to give the right angle of illumination at all times is preferable.

Catgut has been used instead of silk so the stitches would not have to be removed, but it proved unsatisfactory as it tends to promote haziness of the graft, vascularization and even corneal abscesses. In addition, it occasionally remains unabsorbed for over three weeks and the stitches must then be removed to prevent the complications mentioned. Cotton and a variety of plastics have been found inferior to fine silk. Other methods of holding the graft in position, such as fibrin and splints, have not proved as effective as direct suturing and their use has been very limited.

Some surgeons advocate the use of razor-blade knives for the removal of the sutures, about twenty-one days after the operation in penetrating grafts and about two weeks in lamellar ones. I prefer sharp-pointed Wescott scissors and sharp-pointed jeweler's forceps for the removal of sutures, using akinesia of the orbicularis to prevent squinting in adults, and general anesthesia in children and unruly patients.

TECHNIQUES AND INDICATIONS

In this symposium I shall discuss only four techniques for keratoplasty: (1) lamellar: (a) partial central, (b) peripheral, and (c) total; (2) penetrating: (a) partial and (b) total; (3) combined lamellar and penetrating (the mushroom graft); and (4) keratoprosthesis. Because of their limited application, techniques other than those mentioned will not be discussed in this brief presentation, as a detailed description of these different types of procedures for keratoplasty may be found in books and articles on the subject.

Lamellar Keratoplasty

The French school of ophthalmology, through the pioneering work of Magitot and Morax, followed by Paufique, Sourdille and Offret, is responsible for the revival of this type of keratoplasty, a most valuable addition to this field of corneal surgery.

Indications for lamellar keratoplasty are many. The results obtained may be excellent when the indications are well established. The principal ones are restoration or improvement of vision; reconstruction as a preliminary operation to improve the cornea structurally and prepare it for a final keratoplasty for optical purposes; therapy and cosmetic purposes. The indication for lamellar keratoplasty for optical purposes is the treatment of opacities that do not involve the entire corneal thickness. It is most effective when the opacity is fairly superficial and may be completely removed by lamellar dissection.

In unruly patients and children, when a stormy postoperative recovery is to be expected, lamellar keratoplasty is preferable to the penetrating type unless the opacity involves the full thickness of the cornea. In aphakic eyes, a penetrating keratoplasty offers the risk of incarceration of the vitreous in the edge of the incision with subsequent cloudiness or opacification of the graft, and a lamellar transplant should be the operation of choice provided the corneal opacity does not involve all the corneal layers.

The lamellar graft should be used whenever possible, as it is less likely to cause severe complications in patients with only one useful eye. Some corneal dystrophies respond well to lamellar keratoplasty. In general, lamellar keratoplasties should be attempted for visual purposes whenever the opacity is likely to be completely removed by lamellar

dissection of the outer layers of the cornea. If at the time of the operation the opacity is found to be deeper than anticipated and the bed of the host cornea is still too cloudy to warrant a good visual result with a lamellar graft, a penetrating keratoplasty should be performed instead. A lamellar graft should be performed first in cases of dense superficial vascularization as observed after burns. In such cases, if the transplant remains fairly clear and there is sufficient improvement of vision, no further surgery will be required. However, if the transplant should become cloudy, the cornea (structurally improved but with no vascularization) should be in better condition for a final penetrating keratoplasty performed for visual purposes.

Recurrent herpetic keratitis offers a good indication for lamellar keratoplasty. Paufique, following the ideas first advocated by Filatov, found lamellar keratoplasty useful as a therapeutic measure to improve affected corneal tissue surrounding the graft. Lamellar peripheral keratoplasty has been advocated for the treatment of recurrent pterygium, but alone, without beta irradiation, it may not prevent recurrence. Keratectomy with beta irradiation is to be preferred for this purpose unless the cornea is very thin and the danger of perforation necessitates structural improvement of the cornea by a lamellar graft.

A total lamellar graft has proved useful in advanced cases of Fuchs' dystrophy with pronounced epithelial blister formation extending over the entire corneal surface, accompanied by great discomfort, not to improve the eye functionally but rather to arrest or diminish the epithelial edema and thus render the eye more comfortable.

Lamellar keratoplasty, in the shape of a ring of corneal tissue with a central opening, has been used to cover the ulcerated area in some cases of Mooren's ulcer, preserving the central portion of healthy corneal tissue of the host. However, this method is more complicated than a total lamellar graft, which yields similar, if not better, results.

Free-hand dissection, with scarifiers, special corneal dissectors or razor-blade knives, was first used for the dissection of lamellar grafts. This method was easily mastered by experienced surgeons but was not simple for the less experienced, particularly in the preparation of large grafts. The Franceschetti-Bock knife[4] made the dissection of small lamellar grafts easier. More recently, the Franceschetti-Doret apparatus[15] for the dissection of the mushroom graft has been modified to permit the semiautomatic dissection of lamellar grafts. The electrokeratotome, which I devised and reported in 1957,[13] made possible the fully automatic dissection of lamellar grafts of the correct thickness and any size, thus simplifying further the technique of dissecting lamellar grafts. Trephines with stops to regulate the depth of penetration of the trephine blade are necessary to dissect lamellar grafts. There are many different models of this type of trephine, and most of them perform well. The selection of the model to be used depends on the personal preference of the individual surgeon. The hand-operated trephine is more universally accepted than the motorized one.

Several instruments very similar in performance have been designed for the dissection of the opacity from the recipient eye. Again the selection of the instrument depends on the personal choice of the surgeon. I have found razor-blade knives, which are always sharp and easily obtainable, very useful for this purpose. Regarding shape, the circular corneal graft dissected with a trephine has become almost universally

accepted in preference to the square graft dissected with a double-bladed knife. Punches for corneal transplantation have not gained popularity.

Penetrating Keratoplasty

As already mentioned, unless lamellar grafts are clearly indicated, penetrating keratoplasty continues to be the operation of choice in a great majority of cases operated for visual improvement. Partial penetrating grafts, when successful, frequently render brilliant results with visions of 20/20 or better, which are seldom obtained with lamellar grafts. Therefore, unless the lamellar graft is clearly indicated for the reasons already set forth, the penetrating graft should be used to obtain optimum visual results. The use of direct sutures has increased the chances for success in keratoplasty in the same manner that the introduction of corneoscleral sutures improved the prognosis for an uneventful recovery after cataract surgery.

The prognosis was uncertain when overlying sutures were used to hold the graft. There was a high incidence of complications, such as synechias, incarceration of the iris in the incision, and even iris hernia. In children and other unruly patients, dislocation of the graft was occasionally observed. The incidence of this complication increased in direct proportion to the increase in the size of the graft. The use of direct suturing eliminated these complications in small and medium grafts. It has also tremendously improved the prognosis in cases of larger grafts. At present an 8 mm. or even larger graft, fixed by direct suturing, cicatrizes well with fewer complications than those previously observed with 5 or 6 mm. grafts when overlying sutures were used.

The size of the graft should correspond to the size of the lesion to be treated. If the corneal opacity in the pupillary area can be replaced with a 6.5 mm. graft, it is neither necessary nor desirable to use an 8 or 9 mm. graft. On the other hand, a dense opacity 8 mm. in diameter which involves the central cornea but is surrounded by a ring of healthy corneal tissue will require a large graft of 8.5 or 9 mm., with its borders in contact with the clear peripheral cornea of the host. This will cicatrize better and the graft is more apt to remain clear than would a small graft of 6 mm. placed in the center of a dense opacity entirely surrounded by scar tissue.

In the same manner a Fuchs' dystrophy involving 7.5 mm. of the central cornea will require at least an 8 mm. corneal graft or the borders will not be surrounded by healthy tissue. If a smaller 6.5 or 7 mm. graft is used in these cases, it will almost certainly result in a recurrence of the dystrophy in the graft.

The treatment of advanced keratoconus also requires the excision of all, or practically all, of the conus, which is replaced by a graft seldom less than 7 mm. in diameter. In these cases a smaller graft of 6 to 7 mm., even when it remains transparent, if set in the protruding area of a not completely excised conus, will result in a refractive error, myopia or high astigmatism severe enough to defeat the purpose of the operation performed for visual purposes. Thus a larger graft, 8 or more millimeters in diameter, should improve the cornea structurally, restoring the curvature to normal or near normal, thereby ensuring better vision. Only keratoconus in the very early stages will benefit, as far as visual improvement is concerned, by grafts of 6 to 6.5 mm. The average small graft used nowadays is seldom less than 6 mm. in diameter. When a small graft is used, the slightest cloudiness within its borders tends to limit its useful visual area.

When overlying sutures were used, a patient had to remain in bed for ten to fourteen days with both eyes bandaged to ensure an uneventful recovery. In spite of this precaution, the incidence of postoperative complications, such as synechias, incarceration of the iris, and even iris hernia, was high. At the present time, for a patient undergoing keratoplasty with a graft of any size fixed with marginal sutures, it is required only that the operated eye be bandaged, and from the time he leaves the operating room he may be ambulatory. In addition, no special diet is necessary. Thus patients have a much more comfortable postoperative course and the complications are fewer than when overlying sutures were used.

Mydriatics to minimize the incidence of synechias in penetrating grafts are no longer needed with the use of direct suturing. If the sutures are applied every 2 or 2.5 mm., the incision thus accurately closed remains watertight and airtight. At the completion of the operation, an air bubble is injected into the anterior chamber to separate the iris from the corneal incision and to minimize the incidence of anterior synechias. If anterior synechias should develop, they should be treated during the fourth postoperative week before they have become firmly established, before they have affected the clarity of the graft, and before ocular tension increases, as it frequently does in these cases. In cases of large 9 to 9.5 mm. penetrating grafts, the iris is closer to the incision than it is with smaller grafts and the incidence of anterior synechias may be higher. This may be minimized by performing peripheral iridectomies in two, three, or even four quadrants, as advocated by Stocker[27] in 1953. A detailed description of the operations for the treatment of anterior synechias is not within the scope of this limited discussion.

Total Penetrating Keratoplasty

Total penetrating keratoplasty, considered a surgical impossibility at the time of the last symposium, may now be carried out successfully. The percentage of successes with visual improvement is low and the percentage of perfectly clear transplants obtained is still lower, but this operation offers the only possibility of functional improvement in very unfavorable eyes with densely opaque corneas, with or without anterior synechias. In these eyes, if they are not glaucomatous and if vision is at least good light perception and projection, a total penetrating keratoplasty is indicated. In order to minimize the incidence of postoperative glaucoma whenever a total or subtotal penetrating keratoplasty is performed in an eye with a normal anterior chamber, the lens should be removed, whether or not it is cataractous, and a large iridectomy performed. A total penetrating graft may remain perfectly clear, even in an eye with total anterior synechia. I operated on such an eye more than ten years ago. The operation consisted in the excision of the whole cornea, atrophic iris completely adherent to the posterior surface of the cornea and cataractous remnants. The vitreous was also found to be adherent to these structures, and vitreous loss took place which necessitated an injection of saline solution at completion of the operation to normalize the ocular tension. In spite of this complicated procedure, the homograft remained perfectly clear and at the end of ten years permitted a good ophthalmoscopic examination of the fundus, which showed macular changes with visual improvement from light perception and projection to 20/100. During this ten year period I performed other total penetrating homokeratoplasties, some of which have remained transparent, and have resulted in pronounced visual improvement. Others have remained only partially transparent, but

functionally the vision is improved. I have reported some of these cases of total penetrating homokeratoplasties during the past ten years.[6-9,11,12]

In 1957, Barraquer[3] reported a case of successful total penetrating autokeratoplasty, and more recently Maumenee[18] reported five more cases of successful total penetrating corneal autotransplants. Maumenee feels that a total penetrating autokeratoplasty has a better chance of remaining transparent than the homograft, as there is no donor-recipient sensitization which may render the transplant cloudy or opaque. Unfortunately, this represents an ideal situation, and instances are not frequent in which the clear cornea of a blind eye of a patient may be used as an autotransplant to restore vision in the fellow eye blinded by a corneal opacity. Thus homokeratoplasty is the only available method in the majority of cases. The cases reported in the literature prove that total penetrating keratoplasty is no longer a surgical impossibility, as frequently stated. The successful transplantation of an entire cornea has been not only a great surgical achievement but also a most interesting biological phenomenon regarding the fate of corneal grafts and whether the graft is replaced by the tissue of the host or whether it preserves its individuality and survives in the midst of the host tissue.

COMBINED LAMELLAR AND PENETRATING GRAFT

The Mushroom Graft

In 1950 Franceschetti and Doret[16] reported a technique using a combined lamellar and penetrating corneal transplant called "mushroom graft." They advocated its use in unfavorable cases similar to those in which a total penetrating graft is indicated. This mushroom graft consisted of a large lamellar transplant (10 or 11 mm.) with a central circular area of 5, 6 or 7 mm. of full-thickness graft. It is prepared semiautomatically with a special instrument designed by the authors. This type of graft is supposed to have the advantage over the total penetrating graft of not altering the angle of the anterior chamber, when present. However, this operation cannot be judged on its merits, as no follow-up report on results obtained has been made available.

In 1953 Stocker[27] reported one case of mushroom graft that remained clear after three months. He did not use the Franceschetti-Doret apparatus to dissect the graft, but rather an ordinary dissector for the preparation of the lamellar graft and a trephine for the preparation of the full-thickness portion of the graft.

Keratoprosthesis

The first attempt to restore vision to patients affected with corneal opacities was by use of an artificial cornea, but it was never considered of practical value. The artificial cornea invariably extruded, leading to loss of the eye. In recent years several investigators have carried out promising animal experimentation and clinical trials with this procedure. In September 1959, I saw two patients who had been operated upon by Joaquin Barraquer. A small plastic button had been placed in the center of the eye and had remained clear for about two years, allowing the patients sufficient vision to carry on varied visual tasks, including the reading of large print. Keratoprosthesis is indicated only in very unfavorable cases in which the prognosis for any type of corneal transplantation is practically nil. Although many of these keratoprostheses are extruded, patients already benefitted by this type of operation prove that it is not completely use-

less in obtaining visual improvement, even though it may be of a temporary nature. Further research and clinical trials may increase the percentage of successful results in these extremely unfavorable cases and make keratoprosthesis a valuable addition to corneal surgery.

Corneal Transplantation in Other Unfavorable Cases

In addition to the cases already mentioned in which a total penetrating keratoplasty, mushroom graft or keratoprosthesis could be used, there are others with severe corneal scarring, often associated with extensive symblepharons, in which no type of corneal transplantation offers any possibility of success. Some of these eyes, formerly considered unfavorable for keratoplasty, may be rehabilitated by procedures of plastic conjunctival repair with or without buccal mucous transplantations, keratectomies and reconstructive keratoplasties as preliminary treatment to improve the eye structurally and render it more favorable for a final keratoplasty for optical purposes. Occasionally in these very unfavorable eyes with dense scarring, the scars may not be too deep and the underlying cornea and sclera may be preserved and in fairly good condition. When the scarred, contracted conjunctiva and the dense opacities over the cornea have been treated, the symblepharon corrected by plastic repair with or without buccal mucous grafts, and the cornea improved structurally by a keratectomy or a lamellar graft, the eye is rendered much more favorable for a final keratoplasty for optical purposes.

DONOR MATERIAL

With the exception of the keratoprosthesis already mentioned, donor material must be corneal tissue. The graft may be either an autograft or a homograft. In the first case, the clear cornea from the blind eye is used to supply the transplant for the fellow eye affected with a corneal opacity. This fortunate circumstance occurs very infrequently; therefore, the only remaining possibility is a homograft. The homograft may be obtained from eyes enucleated because of noncorneal ocular disease and, since the availability of such eyes is very limited, from cadaver eyes which, when properly preserved by refrigeration at 2 or 3° C., may be used even two or three days after death.

In the United States the supply of eyes is still insufficient to meet the demand. Patients must be kept on a waiting list until donor material for the operation is available. During the past few years the establishment of other eye banks, in addition to the New York Eye Bank for Sight Restoration already functioning at the time of the last symposium, has increased the supply and improved the distribution of eyes available for corneal transplantation. These eye banks have enlisted the aid of individuals and organizations, the members of which are asked to will their eyes for this purpose. However, as an increasing number of ophthalmologists become proficient in the techniques of keratoplasty, the demand for donor material will not be met unless legislation, similar to that enacted in other countries, is passed to permit the removal of eyes from cadavers for corneal transplantation.

In an effort to prolong the short period for which the eye can now be preserved, other methods of preservation have been suggested. In 1948 Bürki[5] advocated the use of liquid paraffin, the tissue-storage method formerly used by Carrel. Bürki presented evidence that the corneas of eyes preserved in this way remained viable for several weeks. Rycroft,[24] in 1954, reported successful corneal transplantation using donor ma-

terial stored in liquid paraffin up to three weeks after enucleation. Eastcott and his associates[14] have reported successful lamellar grafts using corneal tissue several weeks after it was frozen at – 79° C.

King[17] has also reported successful lamellar corneal grafts using donor corneas dehydrated in 95 per cent sterile glycerin sealed in a vacuum and stored indefinitely at room temperature. Although this material has not proved as effective for penetrating keratoplasties, the fact that it may be stored indefinitely at room temperature makes it the most promising of all the new methods of preservation, particularly if it is improved to the point that it will render equally good results in penetrating keratoplasty.

Another method of indefinite storage of donor material has been reported by Payrau, Bonel and Guyard,[23] who used lyophilized corneas and obtained good results in lamellar keratoplasties.

IRRADIATION

Beta irradiation before corneal transplantation, or during the postoperative course, properly used for the treatment of corneal vascularization is an invaluable aid in procuring favorable results. Adequate training in the handling of beta rays is essential for successful corneal surgery. Irradiation of the eye must be kept to a minimum because overdosage of beta rays will later deprive the cornea of nutrition, interfering with fibroblastic proliferation and adequate cicatrization of the graft.

COMMENTS

In addition to the many improvements in techniques, instrumentation and irradiation, credit for the increased percentage of success in keratoplasty must be given to the use of such medical innovations as antibiotics to diminish infections both in the patient and the donor material; corticosteroids, both topical and systemic, to control inflammation and vascularization; the carbonic anhydrase inhibitors to keep the ocular tension within normal limits (especially useful in the postoperative treatment of total penetrating grafts); and the antihistaminics, which limit the allergic reaction in the eye, whether caused by a donor-recipient sensitization or by bacterial allergens.

The advancement in techniques and instrumentation outlined in this article, the application of beta rays and the use of antibiotics, corticosteroids, carbonic anhydrase inhibitors and antihistaminics, and other general supportive measures have greatly expanded the indications for keratoplasty and increased the number of patients who may be benefited by this type of surgery. Corneal transplantation is no longer an uncertain procedure. When the indications are well established, it is possible to predict fairly accurately the degree of success to be obtained in an individual case.

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Reprinted from the Transactions

American Academy of Ophthalmology and Otolaryngology

NOVEMBER - DECEMBER, 1960

PRINTED IN U.S.A.