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EPIKERATOPHAKIA: REFRACTIVE KERATOPLASTY FOR THE CORRECTION OF APHAKIA

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INTRODUCTION

Several hundred thousand cataract operations are performed annually in the United States [1, 2]. Many aphakic patients experience a poor quality of vision with aphakic spectacles despite good visual acuity because of inherent defects in aphakic spectacle lenses such as magnification, distortion, swim, and restricted visual field [2, 3]. Newer designs in lens manufacture have not eliminated these problems [4]. Because of size imbalance, spectacle correction is of no value in unilaterally aphakic patients, when the phakic eye has good vision [5].

Extended wear contact lenses seem to offer a simple alternative to spectacles; however, not all patients can tolerate these lenses. It has been estimated that only about 50 to 60% of unselected patients can be successfull fitted with these lenses for a prolonged period of time [1, 6]. Alternately, daily wear contact lenses could be utilized; however they often present a significant problem for the elderly cataract patient, who has difficulty with their manipulation [7]. Even with the successfull fitting and tolerance of contact lenses, these devices can cause severe, sometimes irreversible corneal damage, such as epithelial defects, neovascular invasion, and infections with either bacteria or fungi [6, 8, 9]. Finally, lens deposits, loss of lenses, and damage during manipulation make periodic replacement a necessity [10].

Approximately 80,000 intraocular lenses were implanted in 1979 in the United States [11]. Despite their widespread usage, the long term safety of these devices remains unproven. In addition, the technique of insertion is significantly more difficult than that required for routine cataract surgery, thus creating increased morbidity (persistent iritis, lens dislocation, and corneal decompensation) in the hands of many surgeons [11, 13, 14, 15]. Once an eye with an intraocular lens decompensates, the removal of the lens (often necessitating a simultaneous corneal transplant) does not in many cases restore good vision because of persistent cystoid edema [16].

Because of these problems with currently available forms of aphakic correction, we have attempted to develop a surgical procedure to meet the following criteria: 1) safety for the patient, including reversibility; 2) simplicity for the ophthalmic surgeon; 3) effective and long-lasting correction of the visual deficiency. Epikeratophakia, the "living contact lens" is a form of refractive keratoplasty, or surgical correction of vision, that may prove to meet these criteria.

EPIKERATOPHAKIA

The extensive theoretical and clinical work of Dr. Jose Barraquer [17, 18], has shown the feasibility of refractive keratoplasty for the correction of refractive error, and a few studies have been published confirming his results [19, 20]. However, the complexity of both keratophakia and keratomileusis, in terms of mathematical computations as well as cryolathing and surgical techniques and equipment, makes them essentially unavailable to the vast majority of ophthalmic surgeons.

Epikeratophakia is a simplified form of refractive keratoplasty in which a preserved, lathed, donor corneal lenticule is sutured on the de-epithelialized surface of the recipient cornea (Figure), avoiding the potentially hazardous procedure of lamellar keratectomy [1]. This tissue serves the function of a "living contact lens". Because only a small peripheral scar is created in the recipient cornea, the lenticule can be removed at a later time without effectively altering the recipient eye. Thus epikeratophakia embodies all of the desirable features of aphakic correction: safety, technical simplicity, good optical potential, general applicability, and reversibility.

In addition, many of the problems associated with computer tecnology and the cryolathing procedure may be eliminated with the use of preserved, pre-cut donor corneal tissue, which will allow the ophthalmic surgeon to

order lenticules in a fashion analogous to ordering a contact lens[21]. With the availability of pre-cut lenticules, the technique of epikeratophakia should become available to the majority of opthalmic surgeons as a reasonable and practical alternative for the visual rehabilitation of the aphakic patient.

APPLICABILITY OF EPIKERATOPHAKIA

There are several categories of patients for whom epikeratophakia may prove to be the only available safe procedure. Patients who have had unilateral cataract surgery, who cannot tolerate contact lenses, and who do not want to risk the secondary implantation of an intraocular lens now have no reasonable alternative for visual correction. A considerable number of monocular aphakic children cannot be managed effectively with contac lenses, and they are not candidates for intraocular lenses because of the question of long term stability of these implants[22]. Many children with either acquired or congenital cataracts are now destined to develop irreversible amblyopia because the necessary surgery is not done due to the problems of visual rehabilitation and the resultant poor visual outcome[23]. Epikeratophakia offers the possibility of early, permanent visual rehabitation of these patients and may dramatically affect their overall visual prognosis.

In addition to the correction of refractive problems of aphakia, this procedure could have much wider applicability. Theoretically, it would be possible to correct large astigmatic errors as well as refractive errors due to high myopia. Also, cosmetic problems from corneal scarring could possibly be treated with painted or tattooed epikeratophakia grafts.

ANIMAL STUDIES OF EPIKERATOPHAKIA

We have tested epikeratophakia on dogs and monkeys. Our initial experimental work, performed on four dogs, was carried out primarily to establish the operative procedure and suture technique. Autopsy donor cornea material was lathed prior to surgery and stored in liquid nitrogen until the day of surgery. At surgery the recipient epithelium was removed. For the first animal, the lathed lenticule was sutured on top of the recipient cornea with a single running 10-0 nylon suture. Three additional dogs had a 7.5 mm trephine mark extending 0.15 mm into corneal stroma performed before the lathed tissue was sutured in place.

One of these four grafts became infected, but the recipient cornea beneath remained clear. The three remaining animals had epithelial cover over the grafts by day 11; however, they all showed an intense vascular reaction at the periphery of the recipient cornea that necessitated removal of the 10-0 sutures. The single graft with no trephine mark dehisced at day 17, leaving a normal receipient cornea beneath. Despite removal of all suture material and tropical as well as systemic steroid therapy the animals continued to have an intense vascular reaction to the grafts.

Similar grafts were performed on three monkeys. One monkey had no peripheral trephine mark, one had a trephine mark with a 0.2 mm wedge resection of corneal tissue at the inner edge of the trephine mark, and the third had trephine mark, wedge resection, and peripheral undermining of the superficial stroma. None of the monkeys developed the vascular reaction seen in the dogs. The monkey with no trephine mark covered the graft with epithelium in one month (at which time the running 10-0 suture was removed) and the graft has remained clear until the present time. The remaining two animals had persistent epithelial problems. One of the grafts tore during suture removal. Later, the graft was removed, leaving a clear, normal-appearing recipient cornea beneath. The other monkey had its graft removed at one month for histologic examination. Again the cornea beneath returned to its original state in the course of a few weeks. The histologic study showed evidence of repopulation of the graft by host keratocytes.

EARLY TRIALS OF EPIKERATOPHAKIA IN HUMANS

Four unilateral aphakic patients with intolerance of soft contact lenses recieved epikeratophakia grafts. Three have successfully re-epithelialized. The first patient done had persistent epithelial problems and eventual dehiscence of the graft along the suture line, resulting in loss of the graft. The recipient cornea has re-epithelialized and the patient's vision is again correctable to 20/20.

The dioptric correction was within 2 diopters of the desired value in two of the three cases. One graft was done on an amblyopic 4-year-old child, and keratometry has not yet been completed. Two months postoperatively, the visual acuity in the second of the epikeratophakia patients is corrected to 20/60 with + 2.00 + 2.00 x 85° (20/80 uncorrected). The third epikeratophakia patient had optic nerve pathology prior to grafting and

visual acuity is difficult to assess. Visual acuity in the 4-year-old patient similarly can not yet be accurately assessed.

In summary, it appears that the major technical problem with this procedure is that of epithelialization. Only subjects that failed to epithelialize developed problems with wound dehiscence and tearing of the grafts. It must be stressed that, even after those grafts that did poorly were removed, the underlying corneas appeared quite normal and did well after re-epithelialization. The graft epithelialization problem in the last three human subjects was managed very effectively with bandage soft contact lenses or by suturing lids closed for several days.

METHODS OF PROCEDURE

Epikeratophakia grafts must adhere firmly to the host cornea. The donor stromal matrix must be repopulated by host keratocytes[24], and the anterior surface must be re-covered with host epithelium. To achieve this, the following procedure has been adopted for the long term, prospective study of epikeratophakia in non-human primates now underway at the LSU Eye Center.

Each graft (preserved in liquid nitrogen or at -70°C) is lathed to a plus fourteen diopter correction (measured at the corneal plane). After the monkeys have been intubated, the operative eye is prepared and draped and a canthotomy performed if exposure is inadequate. A single Flieringa ring is sutured to the globe with four nylon sutures, the epithelium is removed with absolute alcohol, and the eye is irrigated with saline.

A 7 mm trephine mark 0.15 mm deep is made on the recipient cornea and a 0.2 mm wedge is cut from the inner edge of this mark around the entire circumference. The edge (wing) of the lathed donod tissue graft is then sutured into the groove created by the wedge resection so that donor and recipient Bowman's membrane are in direct continuity. (Figure).

The grafts are sutured in place with a single running 16 micron suture after intitially placing four cardinal 10-0 sutures. The cardinals are removed after the 16 micron suture is tied. The 16 micron suture is removed only when and if a significant vascular reaction becomes apparent or the sutures become loose.

After the graft is sutured in place, the Flieringa ring is removed. 40 mg of subtenons Depo-Medrol (methylprednisolone acetate) and 10 mg of

subconjunctival gentamicin are injected. The canthotomy is closed with a single 4-0 gut suture.

In addition to the long term study of epikeratophakia on non-human primates, we are conducting a long term, double blind, prospective study comparing keratomileusis and epikeratophakia in humans. All patients in this study are aphakic (most are unilaterally aphakic) with a history of contact lens intolerance. All have known, stable visual acuities. Extensive preoperative evaluations are performed on each patient, including visual fields, endothelial cell counts, and fluorescein angiography (where indicated). The surgical technique to be employed is similar to that described for non-human primates, above. The keratomileusis technique is that described by Barraquer, except that preserved, pre-cut corneal tissue is used exclusively. All patients are randomized to either keratomileusis or epikeratophakia. The only exceptions to this randomization are patients requiring more than 15 diopters of correction; these are placed in the epikeratophakia group because this procedure is more compatible with the larger optical correction. Patients with a history of controlled glaucoma are placed in the keratomileusis group because the overall resultant corneal thickness is closer to the normal corneal thickness and postoperative intraocular pressure measurements made with rountinely available instrumentation will probably be more accurate.

All postoperative determination of visual acuity will be made by an observer not involved in any of the surgical procedures. This observer will have no knowledge of the surgical techniques used in any given patient. It is hoped that about 40 patients will be enrolled in this study, to be followed postoperatively for as much as 5 years.

The data accumulated in this study will represent the first randomized, prospective comparison of these surgical techniques in patients with visual potentials clearly defined prior to refractive keratoplasty surgery.

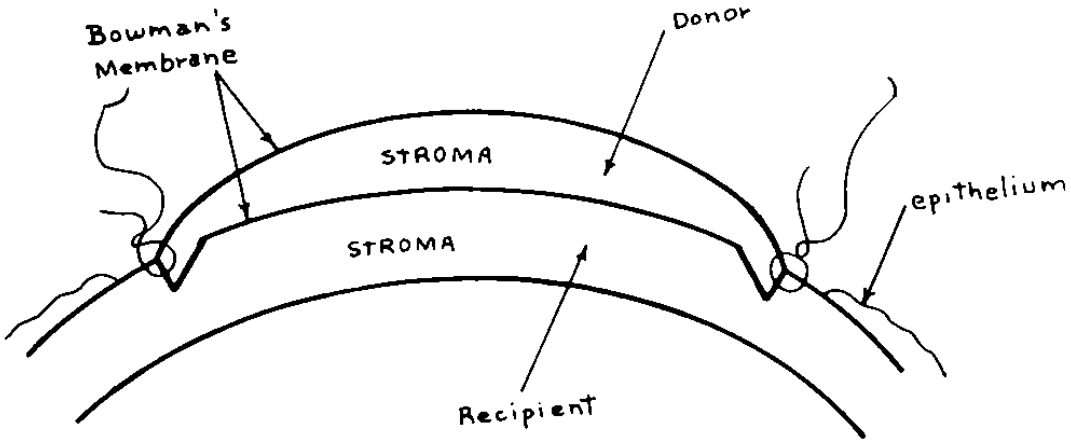
SUMMARY

We present a new, simplified surgical technique to change the refractive properties of the cornea. This procedure, called epikeratophakia, is a safe, relatively simple, and effective means for correction of aphakic vision, and possibly for other problems such as large amounts of astigmatism and myopia.

Although several modalities, such as spectacles, contact lenses, and intraocular lenses, exist for the correction of aphakia, each has specific risks and disadvantages. Keratophakia and keratomileusis are effective in this respec, but involve the mastery of extremely complex mathematical calculations and cryolathing techniques. In addition, the lamellar dissection of the host cornea essential to these procedures could be potentially damaging and is not reversible.

Epikeratophakia involves the suturing of a lathed donor corneal lenticule on the de-epithelialized anterior surface of the recipient cornea. The only alteration of the visual axis of the host cornea is the removal of the epithelium. With the use of preserved corneal tissue, the ophthalmic surgeon need not be concerned with the complexities of cryolathing. If for some reason the lathed disc of donor cornea has to be removed, the recipient cornea would, after re-epithelialization, be returned virtually to its original state. The only permanent alteration of the recipient cornea is a small peripheral scar from the trephine cut to which the disc is sutured.

The optical correction of epikeratophakia should be similar in quality to that obtained from a contact lens, but requires no maintenance or manipulation on the part of the recipient, and should be relatively permanent. In addition, the procedure can be reversed, i.e., the disc can be removed without compromising the visual axis, and further corrective measures can be attempted, including a second epikeratophakia graft.



The epikeratophakia graft is sutured atop the de-epithelialized recipient cornea. A small, wedge-shaped groove is made at the inner aspect of a superficial trephine mark in the recipient cornea. For non-human primates, a 7 mm, trephine is used; for humans, an 8 mm, trephine is used. The edge of the donor disc is sutured into the groove, so that there is direct continuity between the Bowman's membrane of the donor tissue and the Bowman's membrane of the recipient cornea.

Thus, the surgical technique of epikeratophakia is safe, reasonably simple, and makes the correction of aphakia by refractive keratoplasty available to the general opthalmic community as a practical alternative to other, perhaps less satisfactory means of optical correction.

REFERENCES

1. KAUFMAN, H. E.: **The correction of aphakia.** Am. J. Ophthalmol., 89: 1-10, 1980.
2. DABEZIES, O. H.: **Defects of vision through aphakic spectacle lenses.** Ophthalmology, 86: 325-379, 1979.
3. GASSET, A. R., LOBO, L. HOUDE, W.: **Permanent wear of soft contact lenses in aphakic eyes.** Am. J. Ophthalmol., 83: 115-120, 1977.
4. WELSH, R. C.: **Newer designs of aphakic spectacle eyeglasses.** Ophthalmology 86: 380-388, 1979.
5. ENOCH, J. M.: **Physiology of monocular aphakia.** Ophthalmology, 86: 391-398, 1979.
6. HALBERG, G. P.: **Symposium: Contact Lens and Spectacle Lens Correction of Aphakia.** Discussion of contact lens papers. Ophthalmology, 86, 418-419, 1979.
7. BOYD, B. F.: **Extended wear contact lenses in 525 aphakic eyes.** Am. J. Ophthalmol., 88: 351-353, 1979.
8. WEINBERG, R. J.: **Deep corneal vascularization caused by aphakic soft contact lens wear.** Am. J. Ophthalmol., 83: 121-122, 1977.
9. COOPER, R. L.: **Soft contact lenses and infection.** Arch. Ophthalmol., 96: 1700, 1978.
10. KAUFMAN, H. E.: **Problems associated with prolonged wear soft contact lenses.** Ophthalmology, 86: 411-417, 1979.
11. JAFFE, N. S.: **The intraccular implant lens reflections on the current state of the art.** Ophthalmology, 86: 195-196, 1979.
12. JAFFE, N. S.: **The changing scene of intraocular lens surgery.** Am. J. Ophthalmol., 88: 819-828, 1979.
13. STARK, W. J., KRACHER, G. P., COWAN, C. L., et. al.: **Extended wear contact lenses and intraocular lenses for aphakic correction.** Am. J. Ophthalmol., 88: 535-542, 1979.
14. JAFFE, N. S., EICHENBAUM, D. M., CLAYMAN, H. M.: **A comparison of 500 Binkhorst implants with 500 routine intracapsular cataract extractions.** Am J. Ophthalmol., 85: 24-27, 1978.
15. STARK, W. J., HIRST, L. W., SNIP, R. C. et. al.: **A two-year trial of intraocular lenses at Wilmer Institute.** Am. J. Ophthalmol., 84: 769-774, 1977.
16. NORDAN, L. T., PETTIT, T. H.: **Hazards of bilateral intraocular lens implantation.** Am. J. Ophthalmol., 87: 322-329, 1979.

17. BARRAQUER, J. I.: **Keratomileusis and keratophakia, in Corneoplastic Surgery, Proceedings of the 2nd International Corneo-Plastic Conference**, PV Rycroft (ed). New York, Pergamon Press, 409-443, 1969.

18. TUCKER, D. N., BARRAQUER, J. I.: **Refractive keratoplasty: clinical results in 67 cases.** Ann. Ophthalmol., 5: 335-352, 1973.

19. AINSLIE, D.: **The surgical correction of refractive errors by keratomileusis and keratophakia.** Ann. Ophthalmol., 8: 349-367, 1976.

20. TROUTMAN, R. C., SWINGER, C. A., KELLY, R. J.: **Keratophakia: a preliminary evaluation.** Ophthalmology, 86: 523-530, 1979.

21. FRIEDLANDER, M. H., RICH, L. F., WERBLIN, T. P., et. al.: **Keratophakia using preserved lenticules.** Ophthalmology, in press.

22. MAIDA, J. W., SHEETS, J. H.: **Pseudophakia in children: A review of results of eighteen implant surgeons.** Ophthalmic. Surg. 10: 61-66, 1979.

23. HILER, D. A.: **The intraocular lens in the pediatric patient.** In Surgery of the Infant Eye. ML Kwitko (ed), New York, Appleton-Century-Crofts, 1979, Chapt 116, 265-289.

24. RICH, L. F., FRIEDLANDER, M. H., KAUFMAN, H. E., et. al.: **Keratocyte survival in keratophakia lenticules.** Submitted to Am. J. Ophthalmol.