EXTRACAPSULAR CATARACT EXTRACTION AND PSEUDOPHAKOS IMPLANTATION IN PRIMATES: A CLINICO-PATHOLOGIC STUDY*

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INTRODUCTION

THE HISTORY OF INTRAOCULAR LENS IMPLANTATION IS ONE OF CLINICAL TRIAL and error. Those lenses commonly referred to as the "first generation" were enthusiastically placed in patients without prior animal experimentation. They were abandoned after the high incidence of late complications became evident clinically and histologically.[1,2] The "new generation" of lens implants alleges to have made modifications to prevent the problems seen earlier. The first histologic report supporting this contention was that of Manschot[3] in 1974 describing a series of eight autopsy eyes with Binkhorst iris-plane lenses.

Following Manschot's paper and the initial clinical reports on the new generation of intraocular lens implants, it was thought that human lens implantation at this institution should be supplemented by studies in primates. It was hoped that histologic study of primate eyes with implants might manifest problems before they become clinically apparent as "late complications."[4] The study was begun with Binkhorst style iris-plane lenses, but as the Choyce anterior chamber and later the Shearing posterior chamber lenses each in turn became popular clinically, they were incorporated into the study.[5-7] This experimental primate model has provided an opportunity for histologic study of modern extracapsular cataract extraction as well as a comparison of these three major lens types.

MATERIAL AND METHODS

Rhesus monkeys were anesthetized with intramuscular ketamine hydrochloride and Xylazine. Their lenses were extracted and pseudophakei were implanted under microscopic visualization, utilizing the instruments and

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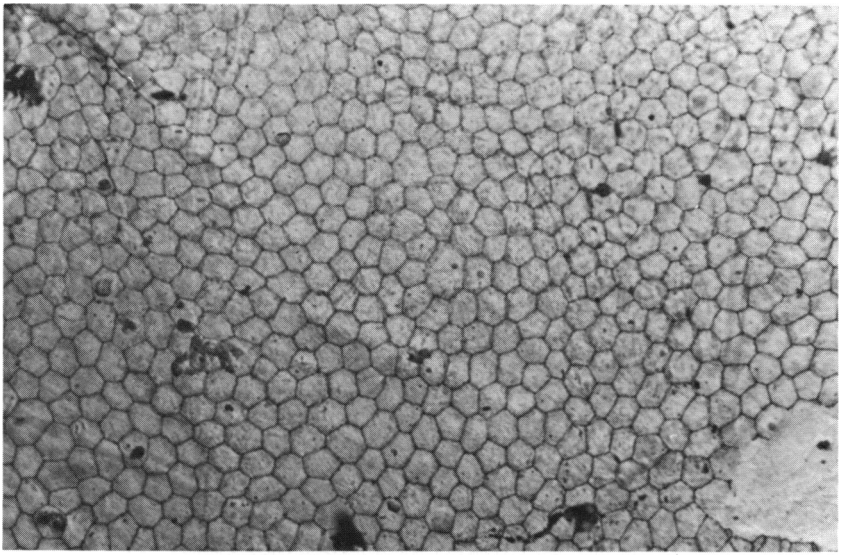


FIGURE 1
Flat preparation of monkey corneal endothelium six months postoperatively (×64).

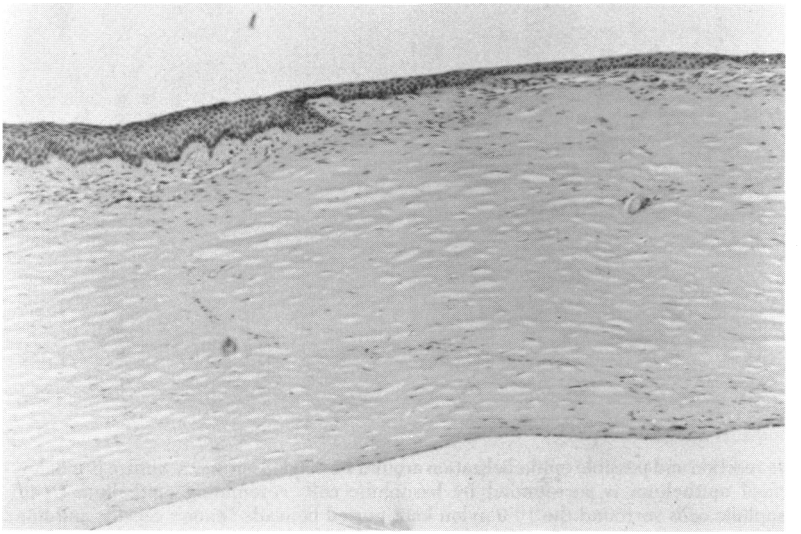


FIGURE 2
Well healed corneal wound six months postoperative (×22).

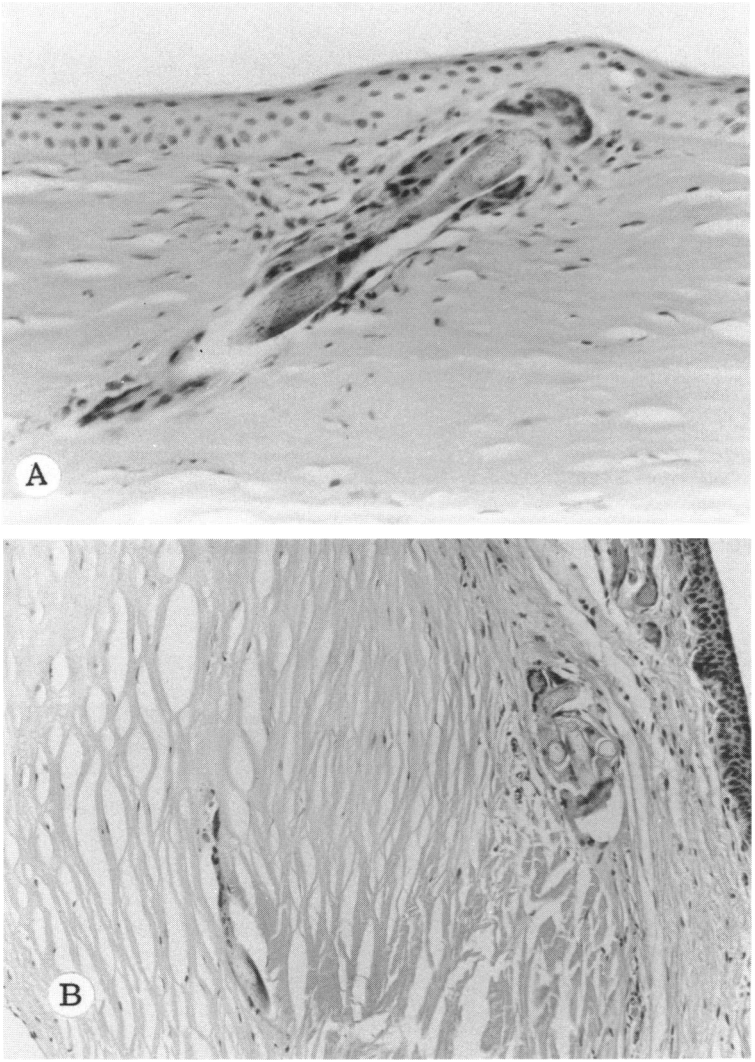
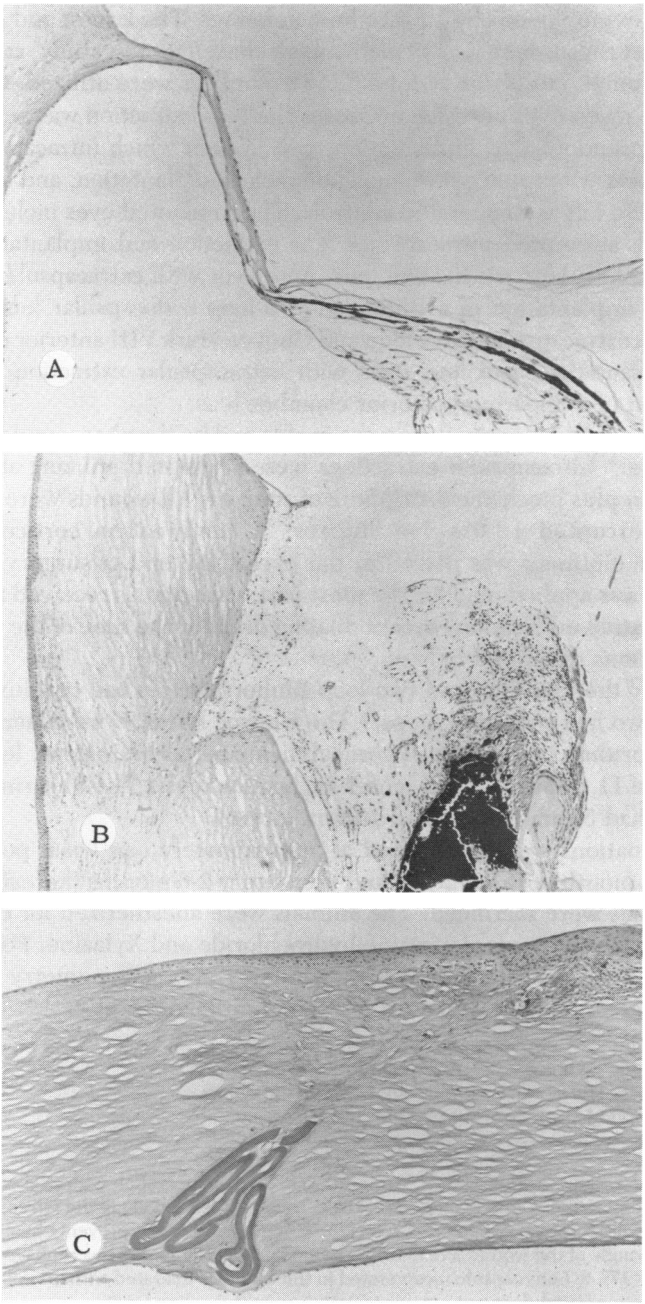


FIGURE 3
Late reaction and possible epithelialization around 10-0 nylon suture. A: Suture just below the corneal epithelium is surrounded by basophilic cells resembling epithelium (×40). B: Basophilic cells surround the 10-0 nylon knot buried beneath Tenon's capsule and line the tract of the suture deep in the corneal stroma (×40).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techniques employed clinically in human beings. The largest and presumably oldest rhesus monkeys available were chosen for this study, ranging in weight from 8.5 to 11.5 Kg. A total of 18 monkeys were utilized. Controls included seven eyes in which extracapsular lens extraction was performed without pseudophakos implantation, two eyes in which intracapsular extraction was attempted without pseudophakos implantation, and four eyes which were left as unoperated controls. The implanted eyes included two eyes with attempted intracapsular lens extraction and implantation of a Binkhorst four-loop iris fixation lens, nine eyes with extracapsular extraction and implantation of a Binkhorst two-loop iridocapsular lens, seven eyes with extracapsular extraction and Choyce Mark VIII anterior chamber lens implantation, and four eyes with extracapsular extraction and implantation of a Shearing posterior chamber lens.

All extracapsular extractions were performed by the phacoemulsification technique.* Intracapsular extractions were attempted utilizing alphachymotrypsin plus mechanical stripping of zonules. All wounds were sutured with interrupted 10-0 nylon sutures. A combination corticosteroid-antibiotic ointment was placed in the eye at the end of surgery, but no dressing was applied, and for the most part, the animals received no other postoperative medications except dilating drops at the time of the periodic examinations described below.

Most of the four-loop and two-loop Binhorst lenses had titanium loops, though two had supramid loops.† The Choyce lenses were generally fit 1 mm larger than the measured corneal diameter, as in humans, leading to the use of 11.0 and 11.5 mm lenses in the monkeys.‡ The Shearing lenses utilized had 5 mm haptics and 13 mm loops.§

Examinations were performed at approximately one week postoperative, one month postoperative, and then every 2-6 months thereafter until the animals were sacrificed. The animals were anesthetized for examination with intramuscular ketamine hydrochloride and Xylazine. Postoperative examinations included slit-lamp biomicroscopy, tonometry (Schiøtz and/or pneumotonometry), and indirect ophthalmoscopy.

*Utilizing the Cavitron phacoemulsification system.
†All Binkhorst style lenses were supplied by Cilco.
‡Choyce style lenses were supplied by Cilco and McGhan.
§Shearing style lenses were supplied by IOLAB.

FIGURE 4

Incarcerated Tissues in the Cataract Wound. A: Vitreous incarceration with peaked pupil 13 months postoperative. Corneal endothelial cells have proliferated along the vitreous strands and laid down additional fibrous tissue (×28). B: Iris incarceration prevents healing of the posterior triangle of the wound five months postoperative. Pigmented macrophages are seen in the iris (×17). C: Lens capsule incarcerated in the wound is tolerated without inflammation and does not appear to interfere with healing (×28).

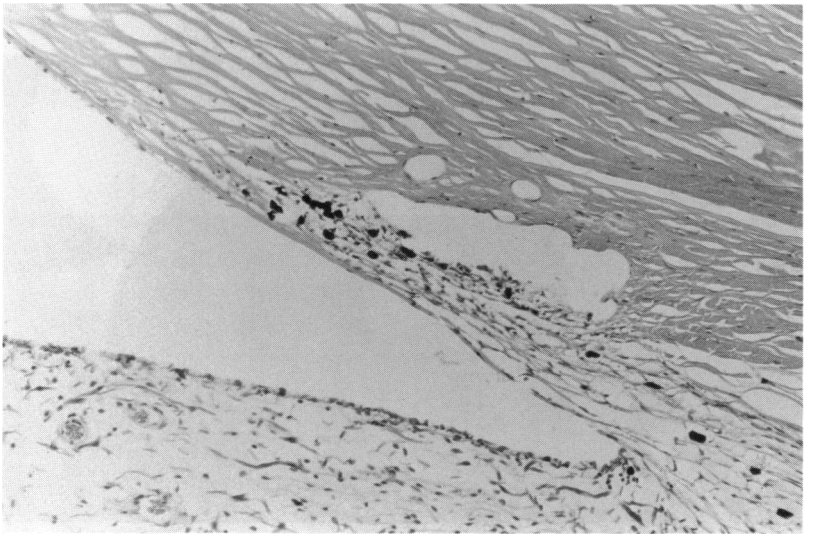


FIGURE 5
Pigmented macrophages in the trabecular meshwork 13 months following implantation of a Binkhorst 2-loop lens (×40).

Animals with Binkhorst lenses were sacrified 4-24 months after surgery and those with Choyce and Shearing lenses at 11-28 months. The eyes were enucleated and fixed in formalin. The method of sectioning the eyes varied, but in most the first cut was made in a sagittal plane, parallel to the long axis of the loops or feet of the pseudophakos. Additional horizontal cuts were made through the temporal portion of the globe to study the fovea. In some of the eyes a 7 mm corneal button was first trephined and the pseudophakos was removed through that opening. In most, it was thought the position and orientation of the loops of the pseudophakos might be best studied by sectioning the eye from the posterior and removing the implant through that sagittal section.

RESULTS

IN VIVO

There was no obvious difference in the amount of postoperative inflammation comparing the anterior chamber, pupillary, or posterior chamber lenses. In the first two weeks, there was a moderate flare and some cells in the anterior chamber and occasionally a fibrin clot was present on or behind the lens. By three to four weeks postoperatively, however, the eyes had

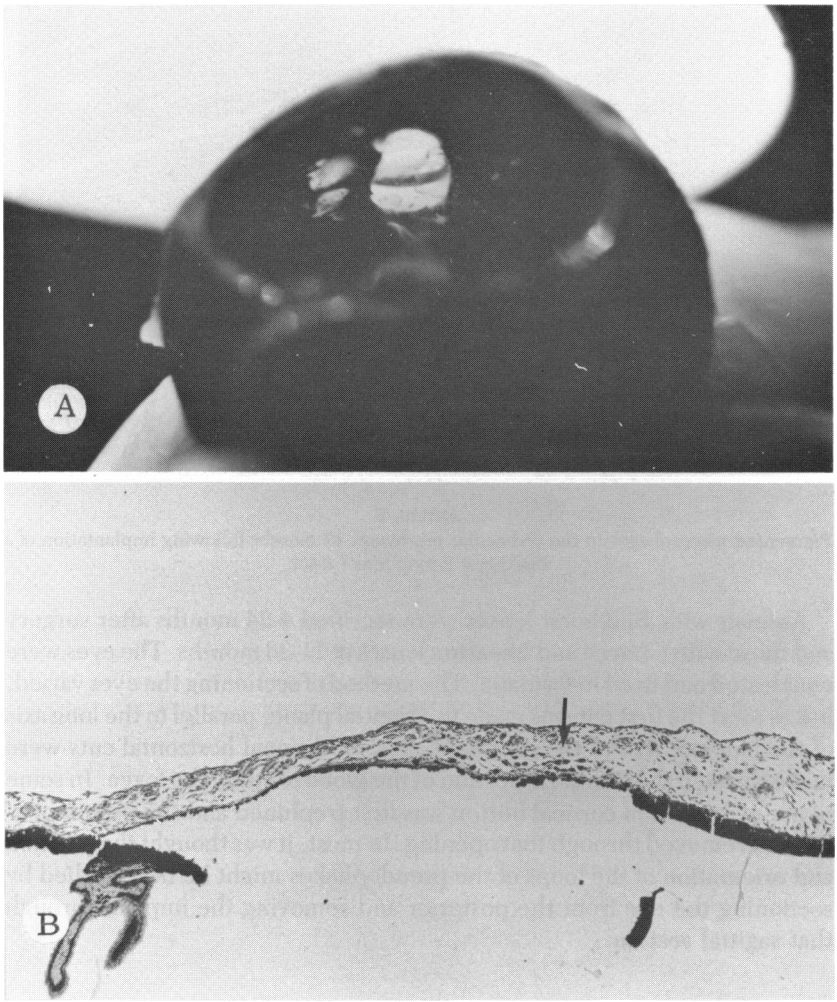


FIGURE 6

Effect of Binkhorst Style Loops on the Iris. A: Gross photograph of an eye five months after implantation of a 4-loop Binkhorst lens shows transillumination defects in the iris where the loops have rubbed the iris pigment epithelium. B: Superior loop of a Binkhorst 2-loop lens was inadvertently placed anterior to the capsular envelope. Five months following surgery there is loss of the overlying iris pigment epithelium and pigmented macrophages are seen in the iris stroma (arrow) (× 17).

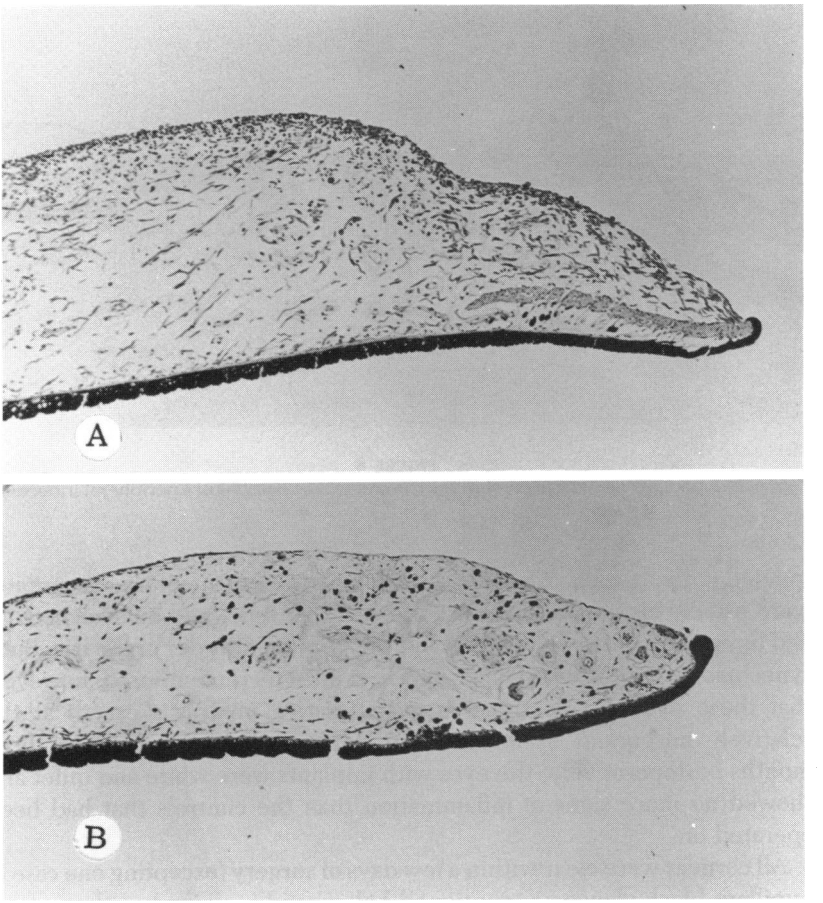


FIGURE 7

Pigmented Macrophages in the Iris. A: In unoperated control eye, pigmented macrophages ("clump cells") limited to the area adjacent to the sphincter or dilator muscles (× 22). B: In iris six months following implantation of a Binkhorst 2-loop lens, there are many pigmented macrophages throughout the iris but no acute inflammatory cells are present (× 22).

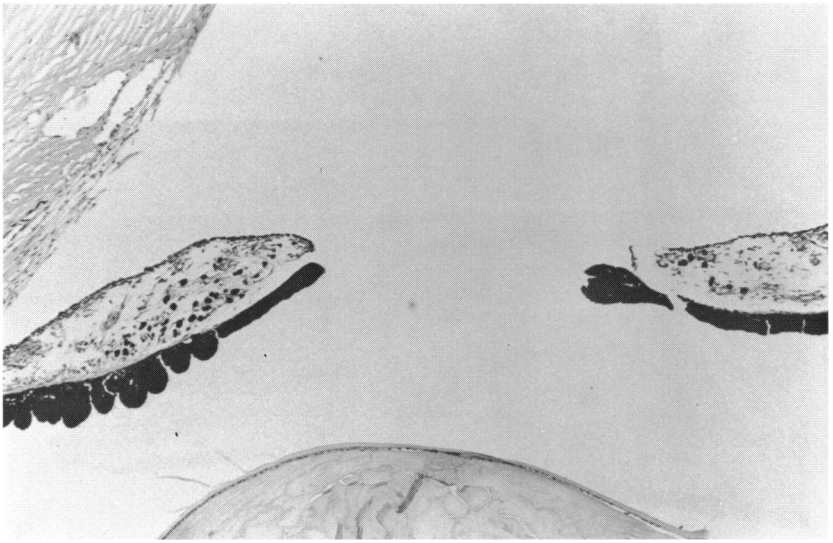


FIGURE 8
Pigmented macrophages are present in the iris around the margins of a peripheral iridectomy (× 17).

quieted without corticosteroids. Multiple small inflammatory precipitates were usually visible on the lens surface at that time, and many synechiae had developed between the lens and the pupillary border of the iris. Such synechiae were seen with all lens types. It must be remembered, however, that these eyes did not receive postoperative mydriasis except at the relatively infrequent examinations under anesthesia. By two to three months postoperatively, the eyes with implants were white and quiet and showed no more signs of inflammation than the controls that had been operated on.

All corneas were clear within a few days of surgery (excepting one case of pupillary block glaucoma mentioned below) and remained so throughout the study.

Intraocular pressures in the operated eyes were equal to or slightly lower than the unoperated controls, and there was no significant difference between those eyes with pseudophakos implantation and those with lens extraction alone. Two cases of pupillary block occurred, both with Choyce lenses. One was enucleated after six weeks with a flat chamber and the other was cured by an extra iridectomy performed on the third postoperative day. It became clear that eyes with Choyce lenses were more prone to this complication than those with the other implants, but once care was

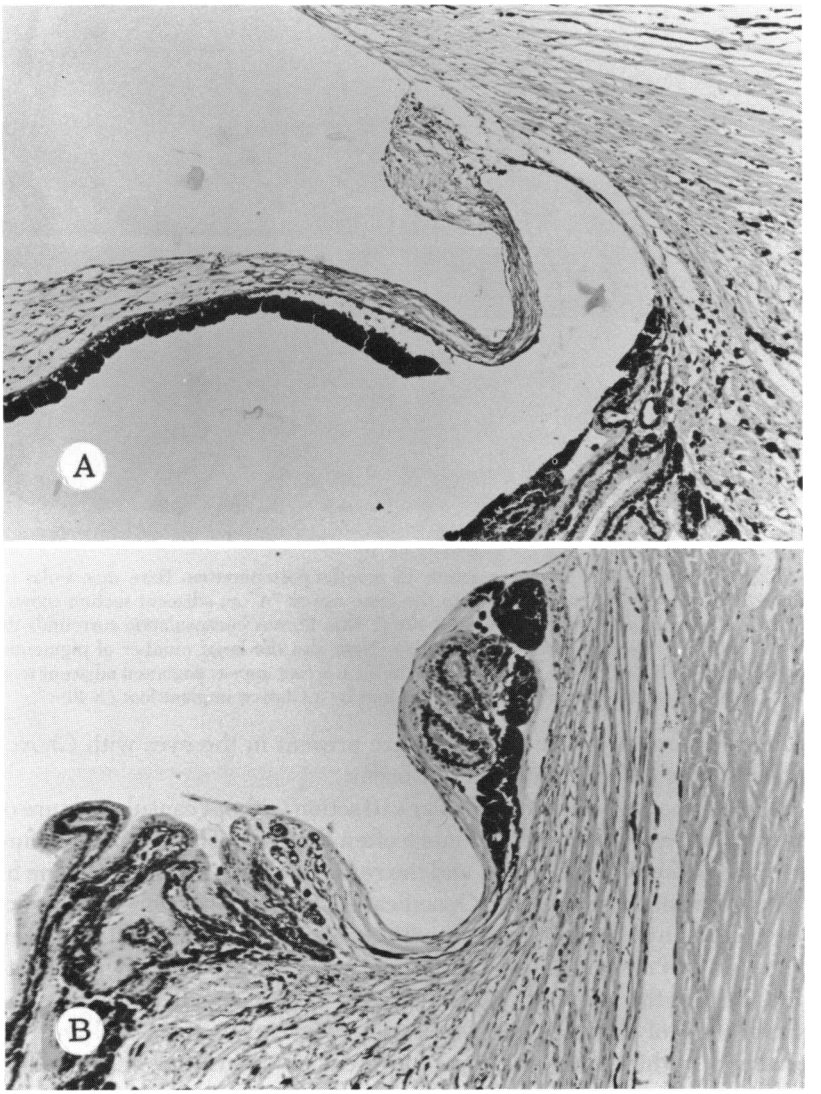


FIGURE 9

A: Marked thinning and distortion of the iris root under the Choyce lens foot 18 months following implantation (×28). B: Indentation of the ciliary body by the foot of a Choyce lens which protruded through the iridectomy. At 13 months following implantation there is fibrous incarceration around the implant foot but no evidence of active inflammation (×28).

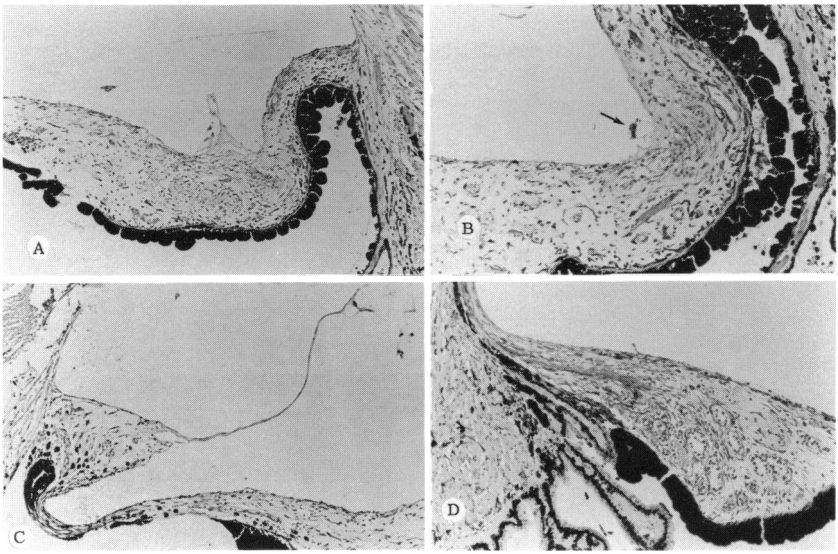


FIGURE 10

A: Mild inflammation and fibrous reaction 15 months postoperative. Rare monocular inflammatory cells are present (×28). B: In the same eye as "A" an adjacent section shows a single multinucleated giant cell (arrow) (×40). C: Thin fibrous encapsulation surrounds the Choyce implant foot 13 months postoperative. Note also the large number of pigmented macrophages in the iris (×28). D: The vessels in the iris root appear engorged adjacent to an area of marked compression of the iris root by a Choyce implant foot (×40).

taken to assure three iridectomies were present in the eyes with Choyce implants, this complication did not occur.

Efforts to perform an intracapsular extraction without capsule rupture or vitreous loss were unsuccessful more often than not. They were therefore terminated after four attempts, and the remainder of the eyes were done by the extracapsular technique. Opacification of the posterior capsule occurred in many of the eyes both with and without implant. It has been suggested by Praeger[8] that a posterior chamber lens, by lying in immediate apposition to the posterior capsule, might inhibit "pearl" formation and opacification of the capsule. Our series of eyes was too small and the variability within each lens type too great to determine this. Grading capsule opacification in just the central 2 mm of the pupil on a 0-4 scale (0 = no opacity, 4 = very dense opacity) by slit-lamp examination at one year postoperative, gave results in 15 eyes as follows:

Shearing lens —	0,0,0,1
Choyce lens —	0,0,2,0,2
Binkhorst 2-loop lens —	0,0,2,2,3,0

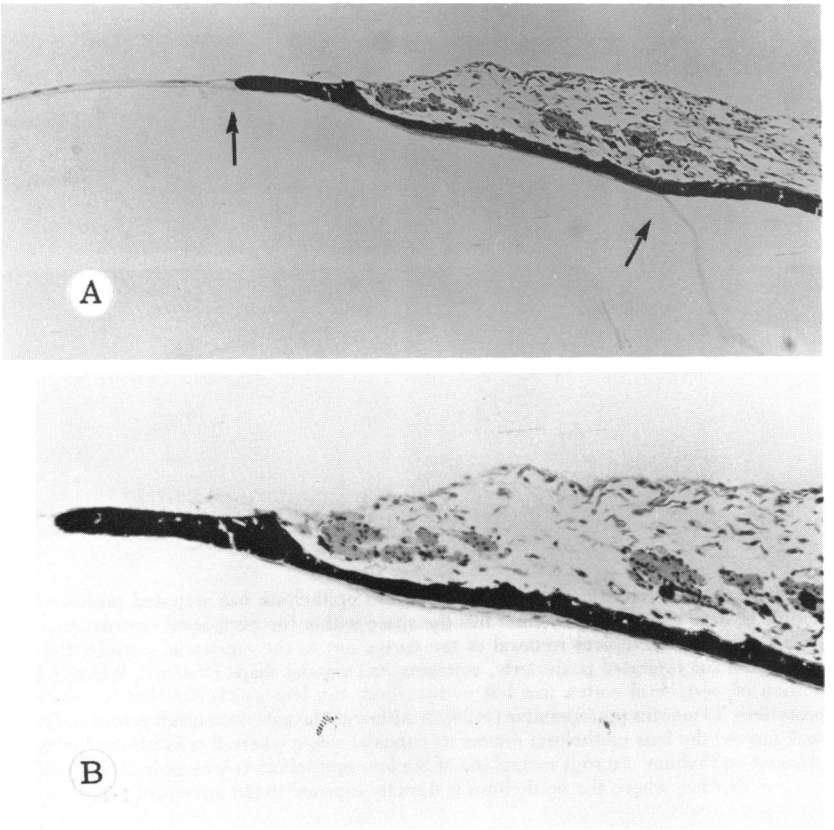


FIGURE 11
A: Anterior hyaloid is firmly adherent to the iris near the pupillary border (between the arrows) (×28). B: Cellular proliferation along the anterior hyaloid seems to bind it to the iris (×40).

Histologic findings on the nature of the posterior capsular opacification are discussed below. They would seem to offer theoretical support for Praeger's suggestion only if the posterior capsule were firmly adherent to the pseudophakos, so that no aqueous could reach the anterior surface of the posterior capsule.

Severe complications such as lens dislocation, retinal detachment, and endophthalmitis did not occur in any of the eyes. In general, all implanted eyes were judged "successful" except the one which was lost to pupillary block and mentioned above. In all cases the eyes were not inflamed, the lenses in proper position, the fundus visible, and the monkeys apparently comfortable and sighted at the time of sacrifice.

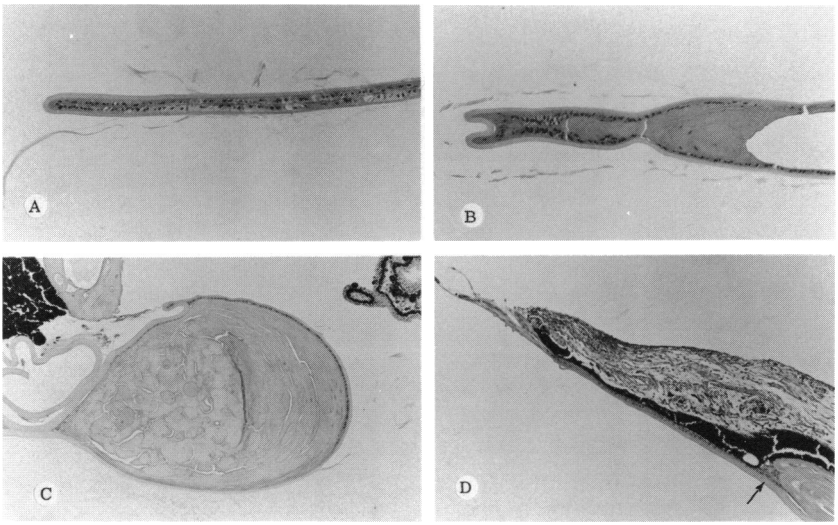


FIGURE 12

A: After complete removal of the cortex, the lens epithelium has migrated posteriorly. A double layer of cuboidal epithelium fills the space within the peripheral capsular envelope (×40). B: After incomplete removal of the cortex out to the equatorial capsule, the lens epithelium has migrated posteriorly, retaining its cuboidal shape (×40). C: Where a large portion of peripheral cortex was left undisturbed, the lens epithelium has not migrated posteriorly 13 months postoperative (×28). D: Although the anterior capsule is torn and rolled back (arrow) the lens epithelium retains its cuboidal shape where it is firmly applied to iris pigment epithelium. Fibrous metaplasia of the lens epithelium is seen only at the pupillary border, where the epithelium is directly exposed to the aqueous (×28).

HISTOLOGY

Cornea—The corneal endothelial layer appeared to have a grossly normal density of cells on cross section in all eyes. The first group of four monkeys underwent Binkhorst lens implantation and in these eyes a central corneal button was trephined and the endothelium examined in flat preparation. These endothelial preparations showed a surprisingly normal pattern (Fig 1). Four to six months following surgery, there was no gross difference detected between the eyes with lens implants and the control eyes which had undergone extracapsular extraction without implantation. Eyes with Binkhorst lenses were thereafter opened from the posterior in order to better evaluate the fixation of the lenses and to allow dissection of the loops from the capsule with minimal damage to the iris.

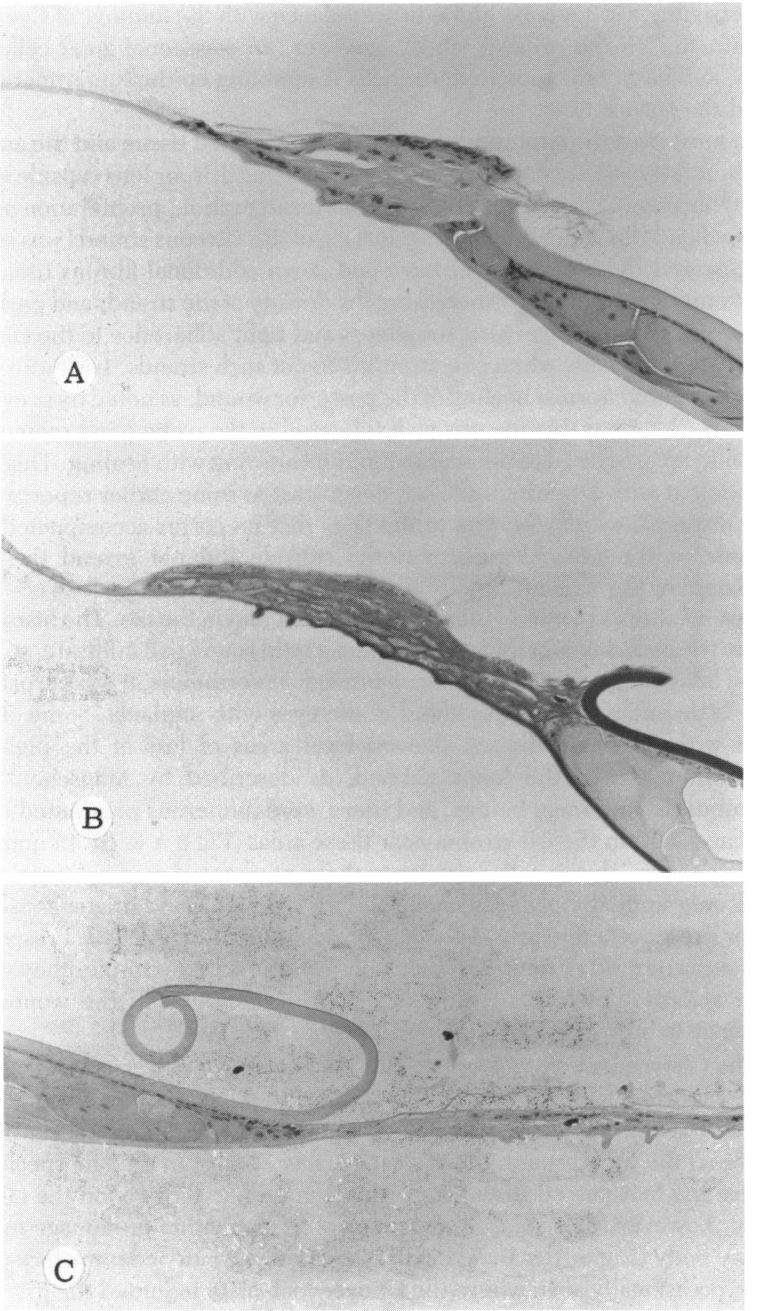
The corneal wounds were well healed with essentially complete "remodeling" of the stromal lamellae in the scar by 4-6 months postoperatively (Fig 2). The lack of acute inflammation or necrosis around 10-0 nylon sutures

was striking (Fig 3 A & B), and is in accordance with the findings of Eve and Troutman.[9] In the present study, however, an occasional giant cell was seen, and basophilic mononuclear cells resembling epithelium sometimes lined the suture tract.

In most eyes the wounds were free of incarcerated tissue and the angles open. A few instances of incarceration of vitreous, iris, or lens capsule were seen, however (Fig 4 A-C). With vitreous incarceration, proliferation of the corneal endothelial cells along the surface of the vitreous strands was seen. It appeared these cells might have laid down additional fibrous tissue or Descemet's membrane,[10] increasing the density of the strands and perhaps accounting for the surprising toughness and tight adherence to the cornea often seen clinically when one attempts to cut such strands. Iris incarceration prevented normal healing of the posterior wound, as noted by previous authors.[10-13] Lens capsule was well tolerated in the wound and seemed to become incorporated in the scar without interfering with healing. This is in agreement with Dunnington[13] but in contrast to some earlier reports.[10-12] The discrepancy may be due to the facts that no cortex accompanied the capsule in the present case, and the capsule did not extend the full thickness of the wound.

Iris—Little evidence of inflammation was found in the iris. The histology of the iris makes it very difficult to detect a mild round cell infiltrate, so that some inflammation could have been missed; nevertheless, it was surprising how little inflammation was found in the eyes with implants. Some of the eyes with Binkhorst lenses showed focal areas of loss of the pigment epithelium where the loops rubbed, as described by Manschot[3] and Rifenburgh[4] in human beings, and there were numerous pigmented macrophages within the iris stroma near these areas (Fig 6 A & B). In unoperated controls "clump cells" similar to these pigmented macrophages were seen only immediately adjacent to the iris sphincter and dilator muscles. Their presence anteriorly in the iris stroma seemed to indicate a response to trauma or mild chronic irritation (Fig 7 A & B). For example, they were seen ajacent to areas of iris or vitreous incarceration in the wound or adjacent to an iridectomy (Figs 4 B, 8, and 10 B).

The Choyce lens often produced marked distortion of the iris root, as has been reported in human beings and primates.[2,15] In some areas the iris root seemed so thinned one questioned whether the foot might eventually erode all the way through the iris to the ciliary body. In the one specimen where the foot passed through an iridectomy to lie directly on the ciliary body, however, there was no evidence of inflammation or damage to the ciliary body (Fig 9 A & B). A small number of chronic inflammatory cells were occasionally seen where the Choyce foot-plate indented the iris, and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in two instances there was evidence of the beginning of a very fine fibrous encapulation of the Choyce foot (Fig 10 A, B & C). It should be noted that this fine encapsulation was not recognized on slit-lamp examination prior to sacrifice. In one eye there was focal engorgement of the iris vessels adjacent to the point where the iris root was compressed by the foot of the Choyce lens, as though the foot was obstructing local vascular flow (Fig 10 D).

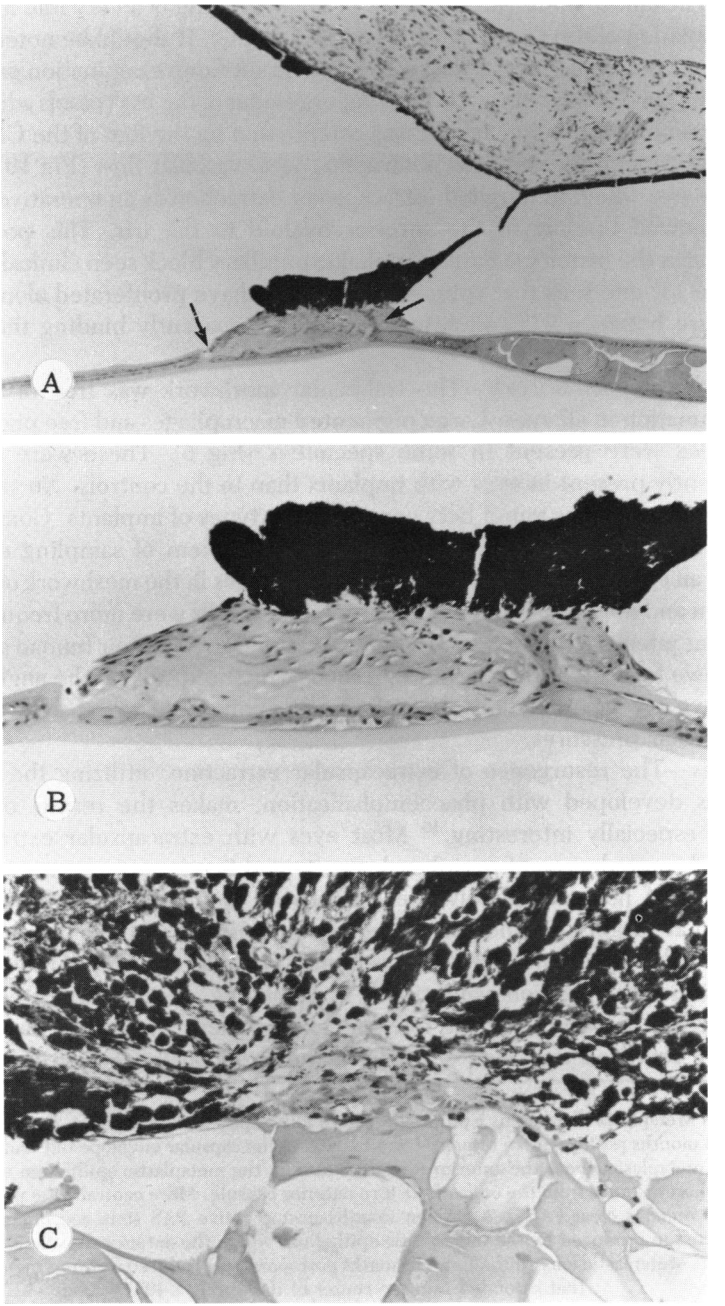
One eye which underwent intracapsular extraction as an operative control showed binding of the anterior hyaloid to the iris. This possibly illustrates the histologic basis for aphakic pupillary block seen clinically. In Figure 11, one sees that spindle shaped cells have proliferated along the juncture between iris and anterior hyaloid, apparently binding the two together.

Trabecular meshwork—The trabecular meshwork was free of acute inflammation in all eyes. Large pigmented macrophages and free pigment granules were present in some specimens (Fig 5). These were more frequently present in eyes with implants than in the controls. No significant difference was found between the three types of implants. Comparison was difficult, however, because of the problem of sampling error. Often an eye would show pigmented macrophages in the meshwork on one section and none on another. These pigmented cells were more frequently present inferiorly. Like Bresnick[2] and Riffenburgh[14] in their human specimens we found that the presence of such pigmented cells in the angle did not have any apparent clinical significance, as none of the eyes had elevated intraocular pressures.

Lens—The resurgence of extracapsular extraction, utilizing the techniques developed with phacoemulsification, makes the results of this study especially interesting.[16] Most eyes with extracapsular extraction formed some degree of peripheral opacity and Soemmering's cataract regardless of how completely the cortex was thought to have been removed at surgery or whether the posterior capsule had been "scratched" clean with a roughened irrigating cannula. The effectiveness of the closed technique of irrigation-aspiration[16] in removing peripheral cortex was attested to, however, by the few specimens where the cortex was completely removed and lens epithelium migrated posteriorly so that two

FIGURE 13

Fibrous Metaplasia of the Lens Epithelium where it is Exposed to Aqueous. A: Lens epithelium 13 months postoperative remains cuboidal within the capsular envelope but undergoes fibrous metaplasia where the anterior capsule is absent, the metaplastic epithelium extends only a short distance from the edge of the torn anterior capsule. More centrally the posterior capsule remains clear (×28). B: Eleven months postoperative PAS stain accentuated the fibrous tissue produced by the metaplastic epithelium where the anterior capsule is absent (×40). C: Metaplastic lens epithelium 11 months postoperative produced a fibrous membrane that extended into the center of the pupil (×40).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layers of lens epithelium were in direct contact within the capsular "envelope" (Fig 12 A-D). The lens epithelium migrated posteriorly after surgery if most or all of the cortex had been removed out to the lens equator. If a large piece of peripheral cortex was left undisturbed in these normal lenses, however, there was no evidence of posterior migration even after two years. The migrated lens epithelium retained its normal cuboidal shape as long as it was in firm apposition with some other tissue such as lens cortex, another layer of lens epithelium, or iris pigment epithelium. If no such firm apposition was present, however, so that the lens epithelium was in direct contact with the aqueous, the epithelium underwent fibrous metaplasia (or "pseudometaplasia")[17] and grew out towards the center of the posterior capsule (Fig 13 A-C).

The late opacification of the posterior capsule which occurred in some eyes was due to this fibrous metaplasia of the lens epithelium. Very few Elschnig's pearls were seen in these animals after modern phacoemulsification and aspiration technique. In some specimens the spindle-shaped metaplastic epithelial cells crossed the entire pupil, whereas in others they stopped short, leaving a perfectly clear, acellular central posterior capsule.

Study of the posterior synechiae which formed between the iris and the lens remnants showed that tight fibrotic bonds formed where the anterior lens capsule was absent (Fig 14 A-C). Where the anterior capsule was intact, some adherence occasionally occurred between it and the iris but this was not the sort of fibrotic scar that occurred when lens cortex or lens epithelium contacted the iris directly.[17] Any attempt to remove iridocapsular lenses with such scarring might tear the iris severely. In removing such lenses clinically, it would seem safest to cut the posterior loops free and allow them to remain in the eye. This provides one argument against the use of metal loops.

Because most of the Binkhorst lenses used in this experimental study had metal loops, these loops had to be dissected free and removed with the lens prior to histologic processing. Their areas of attachment within the capsule were therefore often difficult to identify histologically.

When the Shearing posterior chamber lenses were removed, the polypropylene loops were cut free of the optical portion and left in place when the eye was sectioned. The area where the loops lay in the lens capsule could

FIGURE 14

A: Focal break in the anterior lens capsule (between the arrows) is the site of fibrous metaplasia of lens epithelium with adherence of this fibrous mound to the iris. Synechia was torn away from the iris postmortem, when a Binkhorst 2-loop lens was removed prior to histologic processing (×17). B: Higher power view of "A" shows the fibrous metaplasia and tight binding limited to the area where anterior capsule is absent (×40). C: Cellular adhesions bind iris and lens cortex where anterior capsule is absent in another eye 13 months postoperative (×40).

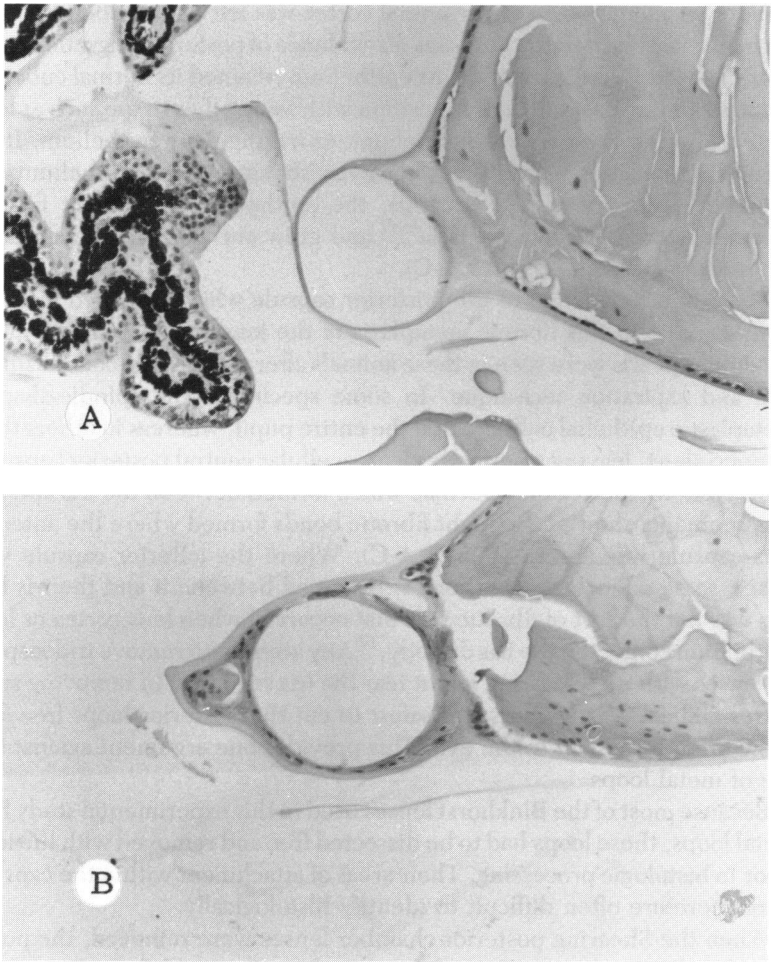
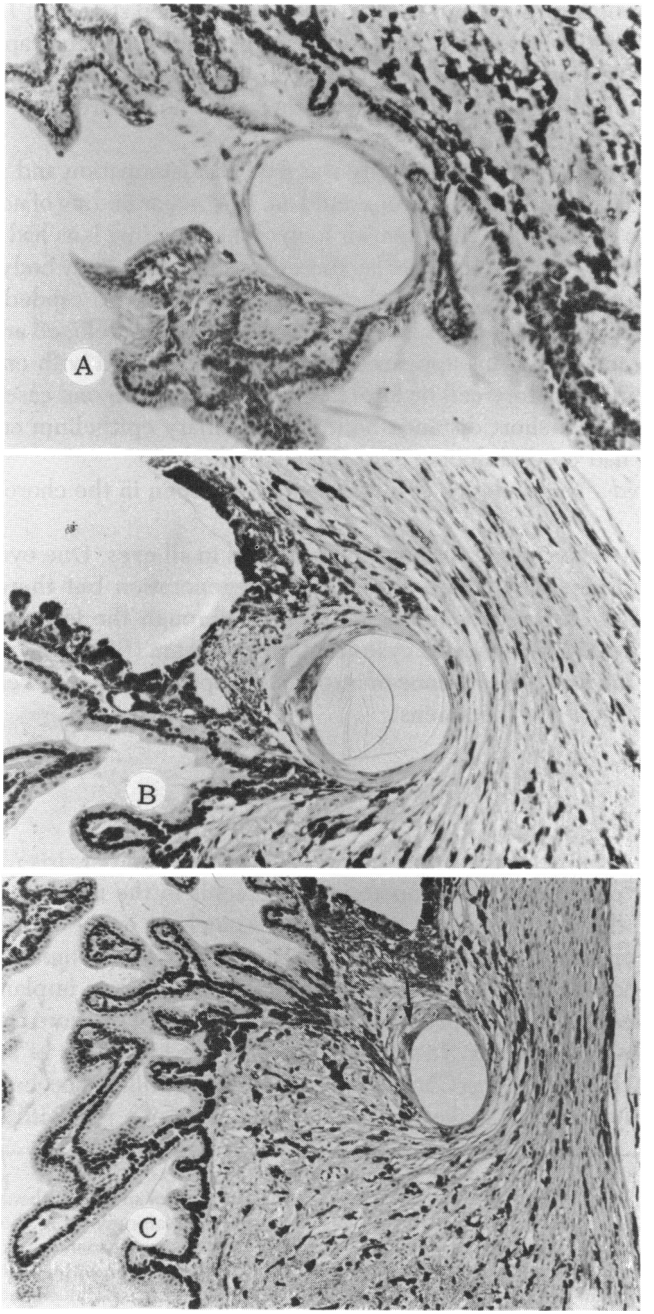


FIGURE 15
A: Shearing implant loop properly positioned in the lens capsule 13 months postoperative. Note absence of effect on the adjacent ciliary processes (×40). B: Eye with a Shearing loop within the lens capsule 13 months postoperative (×40).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therefore be identified and studied in an undisturbed state (Fig 15). A fine fibrotic capsule developed around the loop, within the lens capsular envelope. There was no sign of inflammation, and when the Shearing loop was placed in the lens capsular envelope, there was no apparent effect on the adjacent ciliary body.

Ciliary Body—The ciliary body was free of inflammation and appeared remarkably normal in all eyes operated on. The major finding of note was in those two cases where the superior loop of the Shearing lens had not gone into the lens capsule but rather lay directly against the ciliary body. In both of these cases, serial sections showed that the loop had eroded into the ciliary body (Fig 16 A-C). A fine fibrous capsule had developed around the loop in each case. This appeared quiet and uninflamed with only a rare chronic inflammatory cell or foreign body giant cell. In one case the loop was seen just a short distance beneath the ciliary epithelium and in the other, it had eroded deeper into the ciliary body.

Choroid—No evidence of inflammation was seen in the choroid in any eye.

Retina—The retinal periphery was normal in all eyes. One eye showed an area of apparent lattice vitreoretinal degeneration but there was no evidence of chronc inflammation. Sections through the fovea uniformly failed to reveal evidence of cystoid macular edema (Fig 17).

Optic Nerve—No evidence of atrophy of cupping of the nervehead was seen in any of the specimens.

DISCUSSION

Overall, all three of the implant types—anterior chamber, iris plane, and posterior chamber, caused no serious problems in the monkey eye. This occurred despite the lack of postoperative patching or the routine use of dilating or anti-inflammatory drops. The only severe clinical problem recognized was pupillary block in the first two monkeys implanted with Choyce lenses, and this problem was later eliminated by more careful and numerous iridectomies. It would seem that the large area of apposition between the iris and the Choyce lens plus the possibility of occlusion of the iridectomy by a foot makes pupillary block more of a risk with this lens.

FIGURE 16

A: Shearing loop appears to lie against ciliary body 13 months after surgery without producing inflammation or damage (× 40). B: Subsequent section from the same eye as "A" shows that the loop has eroded through the ciliary epithelium (× 40). C: In this eye 18 months postoperative, the loop has eroded deep into the ciliary body. Thin fibrous reaction encapsulates the prolene loop. A few giant cells are seen (arrow) but there are no other signs of inflammation (× 28).

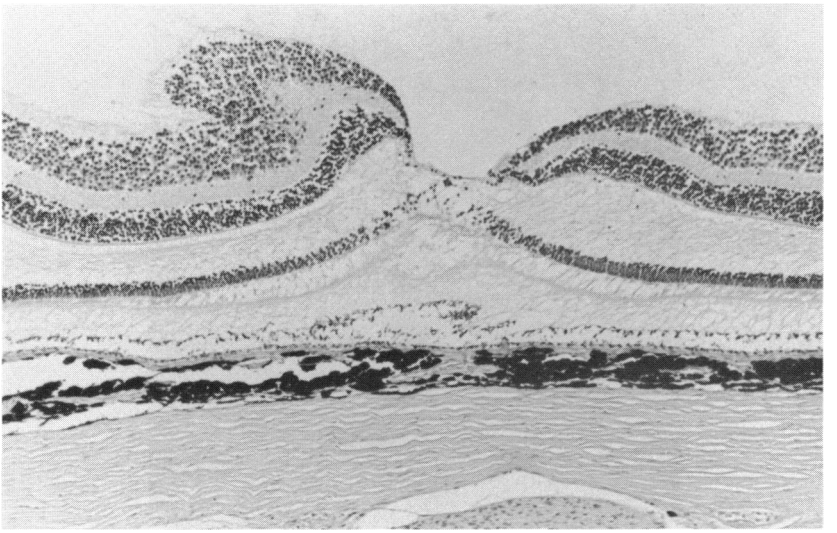

FIGURE 17
Sections through the fovea showed no cystoid edema (×28).

Capsulotomies were not performed and opacification of the posterior capsule occurred to some degree in many of the eyes, but no significant difference was appreciated between the lens types, with the high variability and small numbers in this study.

The histologic studies were of interest not only for the comparison of the implant types, but also for the opportunity to study eyes following modern cataract extraction. In the intracapsular extraction, the cellular bond found between the anterior hyaloid and the iris seems to explain the tough adherence which is seen clinically in cases of aphakic pupillary block. In these rare cases where pars plana vitrectomy is indicated, suction on the vitreous behind the iris pulls the pupillary border of the iris backwards. The vitreous has to be cut or torn free from the iris, manifesting this tight adherence.

In either intra or extracapsular cataract extraction, the fact that cells resembling epithelium sometimes lined the tract of a 10-0 nylon suture makes one leary of recommending through and through suturing.[9] This may not often cause clinical problems, however, as Dunnington and Reagan[18,19] found that epithelium lined perforating silk sutures did not invade the anterior chamber unless iris was caught in the suture.

In extracapsular extraction by the phacoemulsification technique,[16] posterior capsular opacification was found to be due to fibrous metaplasia

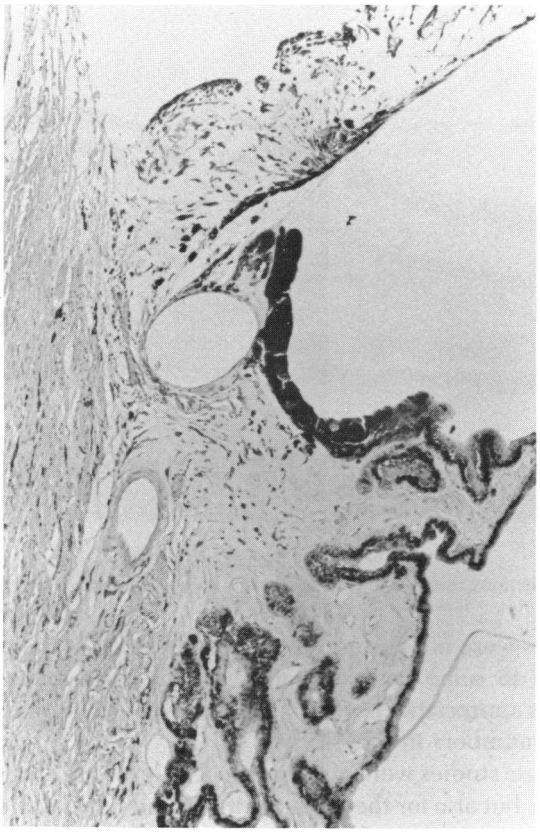

FIGURE 18
Human eye obtained at autopsy one year after Shearing lens implantation shows erosion of the loop into the ciliary body identical to that in the monkeys in this study. Note the proximity of the long ciliary artery (× 28).

and migration of the lens epithelium as described by Roy[20] in cats. In the present study it appeared that lens epithelium underwent fibrous metaplasia only when it was in contact with aqueous and not firmly apposed to some other tissue, such as another layer of lens epithelium, cortex, or iris. It is possible that a posterior chamber lens which was firmly apposed to the posterior capsule could similarly inhibit fibrous metaplasia, but there was not sufficient evidence in this study to support that theory.

The fact that very few Elschnig's pearls, or "bladder cells," were found in this study supports Gunderson's[21] theory that such pearls are "not formed by proliferation of the capsular epithelium, but simply represent lens cells

which are left behind at the time of operation and subsequently become swollen and globular." This contradicts the earlier view, expressed by Duke-Elder,[22,23] that such pearls "probably represent attempts of the epithelium to form new fibers."

In addition to insulating the lens epithelium from the aqueous and preventing fibrous metaplasia, the presence of an intact anterior capsule also seemed to play a role in preventing firm cellular adhesion between the iris and the lens remnants. Where the anterior capsule was intact, adhesions were not of the strong, cellular, fibrotic type so often seen when it was missing.

Histologically all three lens types were well tolerated with surprisingly little inflammatory reaction. When this is compared with the histologic findings on earlier lens types such as the Ridley posterior chamber lens,[1] the "collar button" iris plane lens,[24] or the earlier anterior chamber lenses,[2] one feels reassured that the "second generation" of intraocular lenses does indeed represent a real improvement.

Histologic studies of human eyes have shown the tendency for the loops of the Binkhorst lens to knock loose iris pigment epithelium and have shown that this tendency is decreased with the iridocapsular 2 loop lens properly placed in the capsular envelope as opposed to a 4 loop lens placed following an intracapsular extraction.[17] It is very difficult to be certain that the upper loop is placed in the capsular envelope, however, and often it lies anterior to the capsule against the iris pigment epithelium. In their experimental study in rabbits, Eifrig and Dougman[25] found that only 62.5% of the loops were properly placed in the capsular envelope. Manschot[17] found that in 3 of 7 autopsy cases, one or more of the loops lay anterior to the anterior capsule. In our study, even when the loop lay outside the capsular envelope, however, the inflammatory reaction seemed minimal. In most cases the only sign of inflammation was the presence of pigment laden macrophages in the iris stroma. Only rarely could any chronic inflammatory cells be identified. There were also pigment laden macrophages in the trabecular meshwork in many cases with Binkhorst lenses, but these were present in only a limited distribution and did not produce any elevation of intraocular pressure.

The marked distortion of the iris root often produced by the feet of the Choyce lens was identical to that previously reported in human beings[2] and in primates.[15] Although in some instances the iris seemed so thinned that one wonders whether the foot might eventually erode all the way through the iris to touch the ciliary body. The one case where a foot passed through an iridectomy and rested directly on the ciliary body showed no ill effect. The very faint early fibrous encapsulation seen around

the Choyce foot plates in two of the monkeys is certainly much less than that reported by Bresnick[2] with earlier style anterior chamber lenses, but nonetheless would seem the same type reaction.

The Shearing posterior chamber lens provided the greatest surprise, primarily because so little is known about this lens despite its recent wide clinical popularity. One study implanting the lens in cadaver eyes pointed out that fixation was more stable if both loops were in the capsular envelope.[26] If one loop was in the capsule and the other anterior to it, there was a tendencey to misalignment of the lens. These authors therefore recommended that care be taken to place both loops in the capsular envelope and joined Shearing in warning against use of this lens in an intracapsular extraction. Some surgeons, however, have recently advocated purposely placing both feet anterior to the capsule.[8] The present study indicates that loops placed within the capsule become well fixed and have no discernible effect on the adjacent ciliary body. Those outside the capsule, however, have a strong tendency to erode into the ciliary body. Although they seem well tolerated there, it is unknown whether they might cause later complications by eroding into the major arterial circle or even out through the sclera. In vitro studies with these prolene loops indicate that they loose their elastic "spring" and should cease pushing outward after only two months in tissue fluid. (Shearing SP: personal communication.) It might, therefore, be implied that they cease to erode further into the ciliary body after that period. Our series is too small to state whether the depth of penetrating into the ciliary body continues to increase progressively with time. It would seem safter at this time, however, to design better methods for insuring that both feet are in the capsular envelope rather than to purposely place both feet outside the capsule.

The applicability of these monkey studies to humans is borne out by the only human eye with a Shearing lens in our Ophthalmic Pathology Laboratory. This eye was removed at autopsy one year after implantation. The erosion of one foot into the ciliary body is identical to that seen in the monkeys (Fig 18).

Even assuming that the loops embedded in the ciliary body may be tolerated indefinitely, these findings emphasize potential dangers involved in removing such a lens. If one attempted to pull on the lens in hopes of dislodging the loop, the ciliary body could be torn. Any Shearing lens loop which cannot be fully visualized should be assumed to lie in the ciliary body and should be cut free and left in the eye when the lens is removed. Shearing has recommended this method of removal, and the present study manifests the wisdom of his advice.

The dense fibrotic adhesions which have been shown to develop be-

tween lens remnants and iris, especially where the anterior capsule is missing, make this same principle of cutting loops free apply to iridocapsular lenses as well as to the Shearing posterior chamber lenses. Any pulling or "teasing" at the lens without cutting these loops might lead to tearing of the iris. I have seen one clinical case where this led to severe intraocular hemorrhage.

SUMMARY

Eighteen Rhesus monkeys underwent lens implantation with Choyce Mark VIII, Binkhorst iridocapsular, and Shearing posterior chamber lenses. They were sacrificed 4 to 28 months following surgery. The eyes were compared clinically and histologically. Controls included unoperated eyes and eyes with lens extraction without implantation.

Several histologic findings pertained equally to cataract extraction with or without lens implantation. Late opacification of the posterior capsule was caused by migration and fibrous metaplasia of the lens epithelial cells. These cells appeared to undergo such metaplasia only when exposed directly to aqueous, never when they were in firm apposition to another tissue such as another layer of capsular epithelium, lens cortex, or iris. Also strong fibrous posterior synechiae between the iris and lens remnants occurred only where the anterior lens capsule was missing.

All implants were well tolerated clinically. Histologically they showed remarkably little inflammation. The eyes with Binkhorst lenses had a mild tendency to focal loss of iris pigment epithelium and some showed pigmented macrophages in the iris stroma and trabecular mesh. The Choyce lenses frequently displayed marked displacement and thinning of the iris root, and occasionally showed a few chronic inflammatory cells and thin fibrous encapsulation around the implant feet. The Shearing lenses had no effect on the adjacent ciliary body when the loops were well seated in the lens capsule, but when a loop was anterior to the capsule, it eroded into the ciliary body. The loops developed a thin fibrous capsule within the ciliary body with very little chronic inflammatory reaction, but the long term effect of such loops lying in the ciliary body is undetermined. At present it is recommended that, if such a lens is implanted, every effort be made to ensure both loops lie in the capsular envelope. On the basis of this study, it is also recommended that in removing such a lens, one must assume that a loop might lie embedded in the ciliary body and cut the lens free from the loops before removing it.

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