Anterior Ciliary Sclerotomy for Treatment of Presbyopia

A Prospective Controlled Study

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Purpose: To examine the safety and efficacy of anterior ciliary sclerotomy to restore accommodation in the presbyopic eye.

Design: Prospective nonrandomized comparative single-center clinical trial.

Participants: Nine presbyopic subjects with no prior ocular surgery except corneal refractive procedures were enrolled.

Methods: One eye from each subject was chosen, in consultation with the patient, to undergo anterior ciliary sclerotomy. The contralateral eye of each subject served as a control. Examinations were performed preoperatively, and at 1 day, 1 week, 1 month, and 6 months after surgery.

Main Outcome Measures: (1) Accommodative amplitude, measured by two methods, (2) Jaeger reading vision at 14 inches wearing best distance correction, (3) manifest refraction, (4) assessment of operative complications.

Results: For the nine study eyes, there was no statistically significant change between the average accommodative amplitude at the preoperative visit (1.11 diopter [D]) and the 1-month postoperative visit (1.19 D, $P = 0.55$) nor at the 6-month postoperative visit (1.31 D, $P = 0.21$) in the study eyes. There was no significant difference between the study and control eyes' change in accommodative amplitude at 6 months ($P = 0.43$). Logarithm of the minimum angle of resolution equivalent of Jaeger reading vision in the study eyes at 14 inches wearing best distance correction showed no statistically significant change from the preoperative visit (0.53 [20/70]) at the 1-month postoperative visit (0.41 [20/50], $P = 0.07$) or at the 6-month postoperative visit (0.48 [20/60], $P = 0.22$). There was no significant change in manifest refraction spherical equivalent in the study eyes at 1 and 6 months postoperatively. One eye experienced a perforation of the anterior chamber during surgery. A second eye experienced mild postoperative anterior segment ischemia manifested by sectoral iris akinesis.

Conclusions: Anterior ciliary sclerotomy does not restore accommodation in presbyopic eyes and can cause significant complications. *Ophthalmology 2002;109:1970–1977 © 2002 by the American Academy of Ophthalmology, Inc.*

Presbyopia, the gradual loss of accommodation that becomes clinically significant during the fifth decade of life, is a physiologic inevitability. Although the optical and physical properties of the human crystalline lens have been extensively studied,[1] the pathophysiology of presbyopia remains poorly understood. The theory of Helmholtz[2] proposes that accommodation occurs as a result of the elastic properties of the lens and possibly the vitreous that allow the lens to round up and increase its power when zonular tension is relieved during ciliary muscle contraction. As the lens changes with age, the ability to round up and increase refractive power is lost.

Sclerosis of the lens as the causative factor of presbyopia has been challenged in recent years by Schachar.[3] The Schachar theory suggests that the longitudinal muscle fibers of the ciliary muscle contract during accommodation, placing more tension on the equatorial zonules while relaxing the anterior and posterior zonules. This force distribution causes an increase in the equatorial diameter of the lens, decreasing the peripheral volume while increasing the central volume. As the central volume increases, so does the power of the lens. Under this theory, presbyopia occurs because of the increasing equatorial diameter of the aging lens. Once the lens diameter reaches a critical size, usually during the fifth decade of life, the resting tension on the zonules is significantly reduced. Thus, when the ciliary muscle contracts, insufficient tension is generated on the

Originally received: November 9, 2001. Manuscript no. 210953.
Accepted: April 10, 2002.

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Presented at the annual meeting of the American Academy of Ophthalmology, 2001.

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ISSN 0161-6420/02/$–see front matter
PII S0161-6420(02)01252-6

equatorial zonules to effect a change in central lens power, and accommodation is lost.

Credible investigators dispute Schachar's theory of accommodation,[1] but the theory has nonetheless stimulated the development of several surgical approaches for the treatment of presbyopia. Anterior ciliary sclerotomy, first suggested by Spencer Thornton,[4] involves making radial incisions in the sclera overlying the ciliary muscle. This may allow expansion of the sclera overlying the ciliary body, increasing the space between the lens equator and ciliary body. In theory, this may place more resting tension on the equatorial zonules, allowing for increased tension to develop during ciliary muscle contraction. The procedure is hypothesized to restore accommodative amplitude in presbyopic subjects. Fukasaku and Marron[5] reported a good initial effect from anterior ciliary sclerotomy, with a mean increase in accommodative amplitude of 2.2 diopters (D). The effect of surgery gradually disappeared, with only 0.8 D of gain in accommodative amplitude remaining at 1 year postoperatively. The authors attributed the loss of effect to healing of the sclera and proposed placement of silicone plugs in the incisions to prevent scleral healing. They reported that the silicone plugs reduced this regression, yielding a mean accommodative amplitude gain of 1.5 D at 12 months.

Because of the dearth of controlled trials of anterior ciliary sclerotomy, the significant disability that presbyopia poses for many patients, and the pervasiveness of presbyopia in the population, we undertook a prospective single-center controlled trial of anterior ciliary sclerotomy to determine whether it induces a short-term improvement in accommodative amplitude and to determine whether the effect regresses with time.

Subjects and Methods

Seven males and two females were enrolled in the trial. In consultation with the patient, one eye was selected to undergo anterior ciliary sclerotomy. The fellow eye served as a control. Each eye had to meet the inclusion and exclusion criteria separately to enroll the patient. Inclusion criteria were age greater than or equal to 40 years, symptoms of presbyopia, spherical equivalent manifest refraction between −0.75 and +0.75 D inclusive, manifest refractive cylinder of 1.00 D or less, and preoperative manifest best-corrected acuity (Snellen) of 20/25 or better. Eyes with previous refractive surgery whose last procedure was at least 6 months before the date of the preoperative evaluation were also accepted into the study. Exclusion criteria were any previous ocular surgery except corneal refractive procedures; anterior segment pathology except pingueculae; history of herpes simplex virus keratitis in the eye; presence of diabetes mellitus or other collagen vascular disease, including rheumatic disorders; and women who were pregnant, planned to become pregnant, or who were pregnant within 2 months of the date of the preoperative evaluation.

Preoperative and postoperative assessment included manifest refraction, best spectacle-corrected distance acuity, applanation tonometry, and dilated slit-lamp and funduscopic examination. Because depth of focus and reading acuity are affected by ambient illumination, the room illumination during the examinations was standardized. The only light on in the examination room was an incandescent overhead floodlight over a desk next to the examination chair. The light scattered off the buff-colored desktop, dimly illuminating the entire room, including the eye chart.

The eye chart used for measurement of near acuity with best distance correction was the Rotochart (Reichert Ophthalmic Instruments, Depew, NY) placed at a distance of 40 cm using the extension rod on the phoropter. The manifest best distance correction was placed in the phoropter. Right and left eyes were measured separately. Near acuity was measured in each eye by two different observers. The two measurements were converted to logarithm of the minimum angle of resolution (logMAR) and averaged. Near vision is reported in logMAR units and Snellen equivalent. One Snellen line is approximately equivalent to 0.1 logMAR units in an inverse relationship; a smaller logMAR value equates to a higher visual acuity in Snellen equivalent.

Accommodative amplitude was measured using the method of spheres using two different targets. For the first method of measuring accommodative amplitude (method 1), the heavy grid on the Rotochart was placed at 40 cm, with the grid lines oriented horizontally and vertically. For each eye separately, with best distance correction in the phoropter, the subject viewed the target through the ±0.50 D fixed cross cylinder in the phoropter with the plus axis vertical and the minus axis horizontal. Plus sphere was added until the horizontal lines, followed by the vertical lines became clear. Plus sphere was then pushed in increments of 0.25 D until the vertical lines began to blur. Once this point was confirmed by backtracking with minus sphere, the sphere power in the phoropter was recorded. One half diopter was subtracted from this value to adjust the far point to the circle of least confusion of the cross cylinder. This result was recorded as the far point. Next, minus sphere was then pushed until the patient reported the horizontal lines to be sharper than the vertical lines. Minus sphere was then pushed in increments of 0.25 D until the horizontal lines began to blur. Then, at each increment, the patient was asked whether they could still bring the horizontal lines into clear focus. Once the patient was no longer able to bring the horizontal lines into clear focus, and the point had been confirmed by backtracking, the sphere power in the phoropter was recorded. One half diopter was added to this value to adjust the circle of least confusion to give the near point. The difference between the far point and near point was recorded as the accommodative amplitude using method 1. A second technician, masked to the results of the first technician's measurements, repeated the procedure, resulting in two data points for method 1.

For the second method of accommodative amplitude measurement (method 2), the subject viewed a row of letters (#4 on the Rotochart corresponding to 20/40 Snellen) placed at 40 cm through best distance correction in the phoropter. For each eye separately, plus sphere was added until the letters became legible. Plus sphere was then pushed in increments of 0.25 D until the patient reported the letters were no longer legible. This setting was recorded as the far point. Minus sphere was then added until the letters became legible again. Then, as minus sphere was added in increments of 0.25 D, the patient was asked whether they could still bring the letters into clear focus. Once the patient was no longer able to bring the letters into clear focus, and the point had been confirmed by backtracking, the result was recorded as the near point. The difference between the far point and near point was recorded as the accommodative amplitude using method 2. A second technician, masked to the results of the first technician's measurements, repeated the procedure, resulting in two data points for method 2.

The final accommodative amplitude for each eye and each time point is the average of the four data points measured.

Measurements of the subject eye were made preoperatively and at 1-month and 6-month postoperative time points. Measurements of the control eye were made preoperatively and at the 6-month

Table 1. Preoperative Characteristics of Study Subjects

Subject	Age (years)	Gender	Prior Surgery	Manifest Spherical Equivalent (Diopters)		Near Visual Acuity through Best Distance Correction	
				Study Eye	*Control Eye*	*Study Eye*	*Control Eye*
1	53	M	None	0.5	0.25	20/25	20/40
2	52	M	None	0.5	0.625	20/60	20/80
3	54	F	None	0.75	0.625	20/200	20/200
4	46	F	LASIK OU	0.625	0.625	20/40−	20/40
5	45	M	RK OU	−0.625	0.25	20/30−	20/25
6	49	M	RK OU	0.375	−0.125	20/100	20/100
7	47	M	LASIK OU	0.5	0.375	20/50	20/40
8	52	M	LASIK OU	0.125	0.125	20/200	20/200
9	55	M	None	0.25	0.125	20/80	N/A
Average	50.3 ± 3.7*	—	—	+0.33 ± 0.41*	+0.32 ± 0.27*	20/68 [+0.53 ± 0.32]†	20/71 [+0.55 ± 0.33]†

* Mean ± standard deviation.
† Snellen equivalent [logarithm of the minimum angle of resolution ± standard deviation].
F = female; LASIK = laser in-situ keratomileusis; M = male; OU = both eyes; RK = radial keratotomy.

postoperative time point. The preoperative control eye data for subject 9 and the 6-month postoperative control eye data for subject 5 were not recorded. Data for these subjects were excluded from the statistical analysis of the change in accommodative amplitude and near vision through best distance correction between control and study eyes at 6 months. Manifest refraction for the control eye was not recorded at the 6-month postoperative examination for subject 5. Manifest refraction for the study eye was not recorded at the 6-month postoperative examination for subject 6. Data for these subjects were excluded from the statistical analysis of the change in manifest refraction between control and study eyes at 6 months.

The preoperative measurements served as primary controls for statistical comparison with postoperative values. The control eye served as a secondary control for comparison with the study eye accommodative amplitude and near vision through best distance correction at 6 months. Statistical analysis comparing the preoperative and postoperative eyes with respect to near acuity through best-spectacle distance correction and accommodative amplitude was performed using a repeated measures analysis of variance. Results were considered significant at a P value of <0.05. Intermethod and interobserver reliability of accommodative amplitude measurement and interobserver reliability of near vision measurement are also reported. All values reported are mean ± standard deviation unless otherwise stated.

The study was conducted under review by the Western Investigational Review Board, which gave approval to enroll 60 eyes. Informed consent was obtained from all subjects after the risks, benefits, and experimental nature of the study had been fully explained, and all questions were answered. Enrollment was discontinued after nine eyes had been treated when two operative complications were encountered. These complications are discussed in the following.

Anterior Ciliary Sclerotomy: Procedure

The surgical procedure used in this study has been previously described.[4] After the eye was prepped and draped in the usual sterile fashion, topical anesthetic drops were applied. A hemilimbal peritomy was performed superiorly and inferiorly. A guarded dual track diamond keratotomy knife was set for 550 or 600 μm and used to make an incision starting from the surgical limbus and continuing posteriorly 3 mm then returning to the limbus. A total of 12 incisions were made, 3 in each quadrant. No cautery was used. Considerable bleeding occurred at each incision. Because of the bleeding, incision depth could not be reliably determined. The conjunctival peritomies were then closed using an absorbable suture. All surgeries were performed by one surgeon (RKM).

Results

Table 1 summarizes the demographic and baseline characteristics of the nine subjects. The ages at the time of surgery ranged from 46 to 55 (mean 50.3 ± 3.7 years). Three patients had undergone previous laser in situ keratomileusis surgery, and two patients had undergone previous radial keratotomy surgery. Slit-lamp examination was normal for all other eyes except for subject 6, who demonstrated a Krukenberg spindle in both eyes with normal intraocular pressures. There were no differences between the study and control eyes with respect to mean manifest refraction spherical equivalent, mean best-corrected distance vision (20/20 or better for all eyes), or mean near vision through best distance correction.

Accommodative Amplitude

Accommodative amplitude was tested by two different methods, with independent measurements by two different observers for each method. No significant difference was found between the mean accommodative amplitudes in the study eye at 1 month (1.19 ± 0.35 D; 95% confidence interval [CI], 0.89, 1.48; $P = 0.55$) or 6 months (1.31 ± 0.41 D; 95% CI, 1.16, 1.86; $P = 0.21$) postoperatively compared with the preoperative value (1.11 ± 0.38 D) in the study eye (Fig 1). The control eye also showed no significant difference between the mean accommodative amplitude at 6 months postoperatively (1.38 ± 0.47 D; 95% CI, 1.13, 2.35; $P = 0.20$) compared with the preoperative value (0.99 ± 0.37 D). A comparison between the study and control eyes of the accommodative amplitude change at 6 months compared with preoperatively showed no significant difference between the two groups (0.07 ± 0.22 D favoring the control eye, 95% CI, −0.28, +0.13; $P = 0.43$).

Table 2 summarizes the intermethod and interobserver reliability of the two methods of accommodative amplitude measurement. The mean difference between methods (method 1—method 2) was −0.08 ± 0.40 D, with a reliability coefficient of 0.68. The mean difference between observers was 0.17 ± 0.45 D, with a reliability coefficient of 0.57.

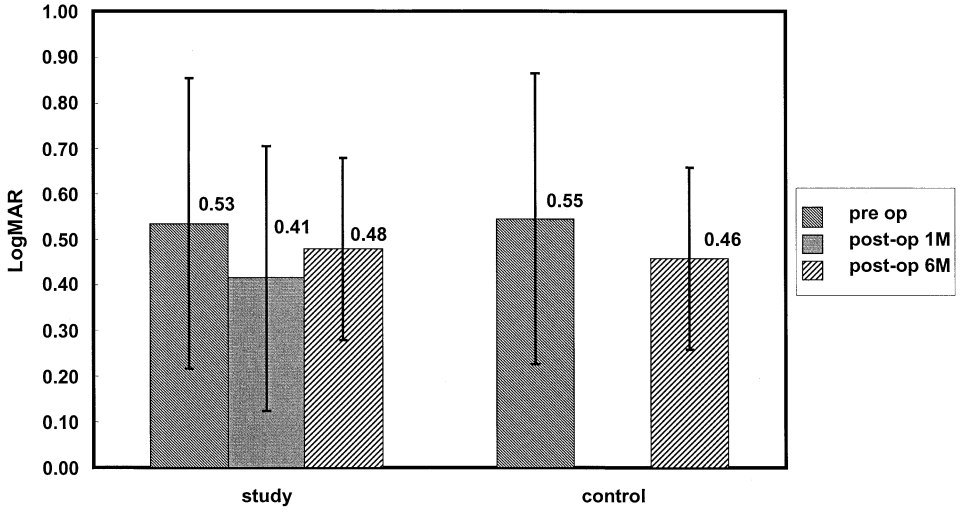

Figure 1. Mean accommodative amplitude of the study and control eyes measured at the preoperative, 1-month, and 6-month postoperative examinations after anterior ciliary sclerotomy. There was no significant difference between the mean accommodative amplitudes in the study eye at 1 month (1.19 ± 0.35 diopters [D], $P = 0.55$) or 6 months (1.31 ± 0.41 D, $P = 0.21$) postoperatively compared with the preoperative value (1.11 ± 0.38 D) in the study eye. The control eye also showed no statistical difference between the mean accommodative amplitude at 6 months postoperatively (1.38 ± 0.47 D, $P = 0.20$) compared with the preoperative value (0.99 ± 0.37 D). Error bars demonstrate the standard deviation.

Near Vision through Best Distance Correction

Near vision was tested at 40 cm with the eye viewing through the manifest best distance correction by two different observers. There was no significant difference between the near vision in the study eye at 1 month (+0.41 ± 0.29 [20/51]; 95% CI, +0.32, +0.54; $P = 0.07$) or 6 months (+0.48 ± 0.26 [20/60]; 95% CI, +0.38, +0.57; $P = 0.22$) postoperatively compared with the preoperative value (+0.53 ± 0.41 [20/68]) in the study eye (Fig 2). The control eye also showed no significant difference between the mean near vision at 6 months postoperatively (+0.46 ± 0.18 [20/58]; 95% CI, +0.18, +0.60; $P = 0.11$) compared with the preoperative value (+0.55 ± 0.33 [20/71]). A comparison between the study and control eyes of the near vision change at 6 months showed no significant difference between the two groups (0.07 logMAR units favoring the control eye; 95% CI, −0.11, +0.25; $P = 0.38$).

Table 2 summarizes the interobserver reliability of the near vision through best distance correction measurement. The mean difference between observers was 0.01 ± 0.08 logMAR units, with a reliability coefficient of 0.96.

Table 2. Intermethod and Interobserver Reliability of Accommodative Amplitude and Near Vision Measurements

Intermethod reliability of accommodative amplitude measurements	
Mean difference (method 1 − method 2) ± standard deviation	−0.08 ± 0.40 D
Reliability coefficient*	0.68
Interobserver reliability of accommodative amplitude measurements	
Mean difference between observers 1 and 2 ± standard deviation	0.17 ± 0.45 D
Reliability coefficient	0.57
Interobserver reliability of near vision measurements	
Mean difference between observers 1 and 2 ± standard deviation	0.01 ± 0.08 logMAR units
Reliability coefficient	0.96

* Perfect reliability = 1.0.
D = diopters; logMAR = logarithm of the minimum angle of resolution.

Manifest Spherical Equivalent

Table 3 summarizes the mean manifest spherical equivalent for study and control eyes at the preoperative and the 1-month and 6-month postoperative examinations.

No significant difference was found between the manifest spherical equivalent in the study eye at 1 month (−0.03 ± 0.95 D; 95% CI, −0.51, +0.45; $P = 0.12$) or 6 months (+0.56 ± 0.66 D; 95% CI, +0.23, +0.90; $P = 0.14$) postoperatively compared with the preoperative value (+0.33 ± 0.41 D) in the study eye. The control eye also showed no significant difference between the mean manifest spherical equivalent at 6 months (+0.44 ± 0.36 D; 95% CI, +0.23, +0.63; $P = 0.23$) compared with the preoperative value (+0.32 ± 0.27 D). A comparison between the study and control eyes of the change in manifest spherical equivalent at 6 months (study–control) showed no significant difference between the two groups (+0.25 ± 0.37 D; 95% CI, −0.09, +0.59; $P = 0.12$).

Complications

An anterior chamber perforation with aqueous leakage occurred intraoperatively during anterior ciliary sclerotomy on subject 4. The perforation occurred during the fourth of the 12 scleral incisions and was closed using a single suture. The procedure was completed without incident after the depth of the diamond blade was reduced by 50 μm. Postoperatively the subject did well with normal anterior chamber anatomy, normal intraocular pressure, and no evidence of aqueous leakage or anterior synechiae formation. Uncorrected vision remained 20/20 at distance.

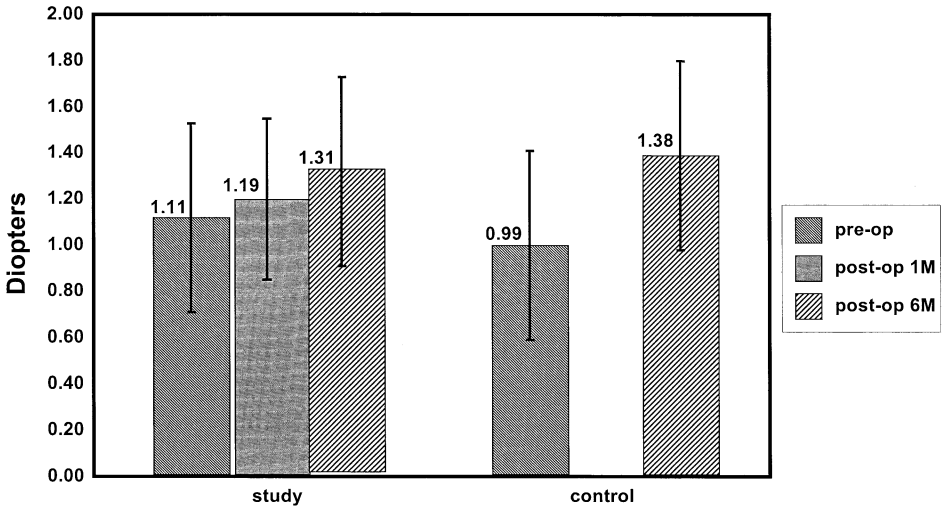

Figure 2. Mean logarithm of the minimum angle of resolution (logMAR) near vision through best distance correction of the study and control eyes at the preoperative, 1-month, and 6-month postoperative visits after anterior ciliary sclerotomy. There is no significant difference between the near vision in the study eye at 1 month (+0.41 ± 0.29 [20/51], $P = 0.07$) or 6 months (+0.48 ± 0.26 [20/60], $P = 0.22$) postoperatively compared with the preoperative value (+0.53 ± 0.41 [20/68]) in the study eye. The control eye also showed no statistical difference between the mean near vision at 6 months postoperatively (+0.46 ± 0.18 [20/58], $P = 0.11$) compared with the preoperative value (+0.55 ± 0.33 [20/71]). Error bars demonstrate the standard deviation.

Subject 8 developed mild intraocular inflammation manifested by 1+ cell and flare in the immediate postoperative period in the study eye. Sectoral iris akinesis with mild transillumination defects developed in the area of ischemia 2 weeks postoperatively (Figs 3 and 4). The best spectacle-corrected visual acuity remained at 20/20. The cell and flare resolved, but the iris akinesis persisted. A diagnosis of mild anterior segment ischemia was made. No further eyes were enrolled in the study after this complication was diagnosed.

Discussion

We can evaluate two parameters to assess presbyopia: accommodative amplitude and near vision through best distance correction. This prospective controlled study used both a primary and a secondary control to assess changes in these two parameters. The primary control consisted of the preoperative measurements on the study eye. The secondary control consisted of the contralateral unoperated eye. The anterior ciliary sclerotomy procedure failed to produce a statistically significant improvement in either accommodative amplitude or near vision through best distance correction compared with either primary or secondary controls.

What would be a clinically significant improvement in near acuity with best distance correction? Newspaper print held at 14 inches represents a Snellen equivalent of approximately 20/30, or 0.20 logMAR units. The patients in our study started with a mean near vision through best distance correction of approximately 20/70, or 0.55 logMAR units. Thus, a decrease of 0.35 logMAR units would be a clinically significant improvement. None of the nine study eyes achieved such an improvement at 6 months (range, +0.05 to −0.33 change in logMAR units). In addition, the anterior ciliary sclerotomy procedure examined in this study failed to produce a statistically significant improvement in near vision through best distance correction at 6 months (0.06 logMAR units, $P = 0.22$).

In the early (fifth and sixth decades) presbyopic popula-

Table 3. Manifest Refraction Spherical Equivalent for Study and Control Eyes

	Preoperative	1 Month Postoperative	6 Months Postoperative
Study eyes (mean ± standard deviation)	+0.33 ± 0.41	−0.03 ± 0.95	+0.56 ± 0.66
Control eyes	+0.32 ± 0.27	NA	+0.44 ± 0.36
Change in manifest spherical equivalent			
Study eyes	—	−0.36	+0.23
95% confidence interval	—	−0.84 to +0.12	−0.10 to +0.57
P value (postoperative vs. preoperative)	—	0.12	0.14
Control eyes	—	NA	+0.11
95% confidence interval	—	NA	−0.09 to +0.31
P value (postoperative vs. preoperative)	—	NA	0.23

NA = control eyes not tested at 1 month.

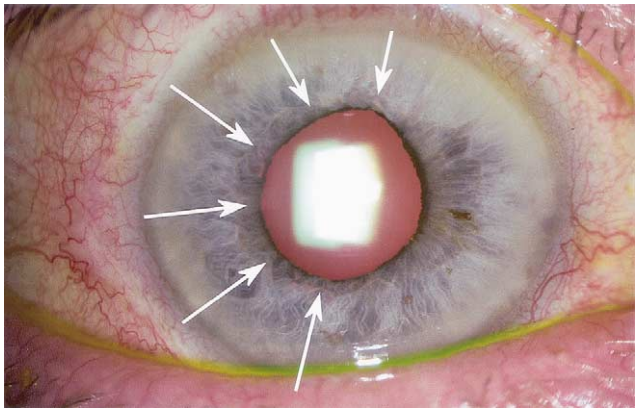

Figure 3. Sectoral iris akinesis resulting from anterior segment ischemia after anterior ciliary sclerotomy. Arrows delineate the 180° segment of immobile iris.

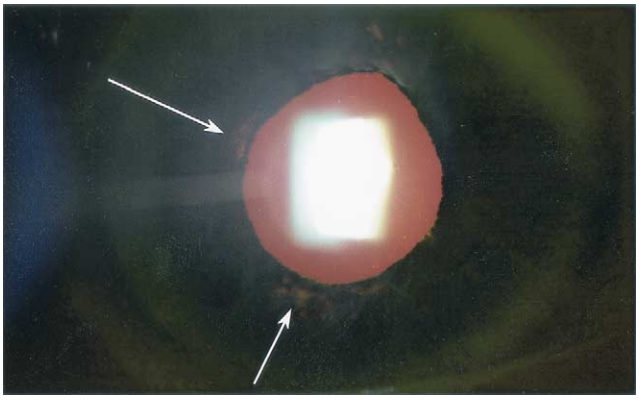

Figure 4. Iris transillumination defects (arrows) in the eye with anterior segment ischemia and iris akinesis.

tion, as in the subjects examined in this study, accommodative amplitude is typically 1.0 to 1.5 D. For late presbyopes, in their eighth and ninth decades, the accommodative amplitude decreases to near 0 D. A surgical technique addressing presbyopia should provide a gain of 1.5 D in accommodative amplitude. This would allow the early presbyope to read at 40 cm through best distance correction. It would also allow the late presbyope to see the dashboard of their car through best distance correction. None of the nine study eyes achieved such an improvement of 1.5 D gain in accommodative amplitude at 6 months (range, −0.25 to +0.81 change in diopters of accommodative amplitude). In addition, the anterior ciliary sclerotomy procedure examined in this study failed to produce a statistically significant improvement in accommodative amplitude at 6 months (0.20 D, $P = 0.20$).

The results of this study need to be qualified by the relatively small sample size of nine subjects. The statistical power to evaluate the clinical efficacy of anterior ciliary sclerotomy depends not only on the sample size but also on the expected improvement in accommodative amplitude. For example, if we assume the average preoperative accommodative amplitude of a presbyope is similar to that found in our study, 1.11 ± 0.40 D and a clinically significant increase in accommodative amplitude is 1.5 D, as discussed previously, the study would require less than five subjects to achieve a statistical power of 95%. With nine subjects, as in our study, the power to detect an improvement of 1.5 D is more than 95%. On the other hand, if we are trying to detect an improvement of only 0.2 D 6 months after the procedure, the study must enroll 52 subjects to achieve a statistical power of 95%. However, because clinical relevance requires an improvement in accommodative amplitude of at least 1.5 D, the current study has enough statistical power to conclude that the anterior ciliary sclerotomy technique used in this study fails to provide such an improvement.

Reliability of Accommodative Amplitude and Near Vision Measurements

Measurement of accommodative amplitude in this study was carried out using two subjective techniques, each based on the method of spheres. Table 2 summarizes the intermethod reliability of the accommodative amplitude measurements. The mean difference between the two methods is 0.08 D. The reliability coefficient is 0.68. The interobserver reliability of the accommodative amplitude measurements shows a mean difference between observers of 0.17 D. There was no evidence of a systematic error in accommodative amplitude measurement in this study that would bias the result toward a falsely low outcome. On the contrary, subjective techniques of accommodative amplitude measurement, especially in older subjects with small pupil diameters, tend to overestimate accommodation because of pseudoaccommodation.

Table 2 also summarizes the interobserver reliability of the logMAR near vision measurements. The interobserver reliability of the near vision measurements is excellent, with a reliability coefficient 0.96, very near a perfect reliability coefficient of 1.0.

Complications

We encountered two complications during this study. In one eye, an anterior chamber perforation occurred that resolved without sequelae after suturing. The intraoperative complication of a perforation is not a surprising occurrence, given that the goal of the anterior ciliary sclerotomy technique used here was to make an incision that is as near full scleral thickness as possible to achieve a maximal therapeutic result.

The second complication was a mild case of anterior segment ischemia, manifested by sectoral iris akinesis. This is indicative of interruption of the vascular supply to the nasal iris in this eye. We believe it is unlikely that the incisions interrupted the perforating branches of the long ciliary artery for several reasons. First, the incisions were placed in the diagonal quadrants, and the ciliary artery branches coursing over the rectus muscle were identified before making the incisions. Second, there are numerous anastamoses between the superficial anterior ciliary arteries and the deep major arterial circle of the ciliary body, so it would be surprising if interruption of one or even several anterior ciliary arteries caused anterior segment ischemia. A

more reasonable hypothesis is that the major arterial circle of the ciliary body itself was interrupted because of the depth of the anterior ciliary sclerotomy incisions. If so, this complication might have been prevented in one of two ways: by cutting down gradually over the ciliary body under direct visualization, using cautery to control bleeding, or by using ultrasound biomicroscopy to measure scleral thickness before surgery.[5]

We found no short-term or long-term effect from anterior ciliary sclerotomy. Our results are in sharp distinction to a previous study that reported significant short-lived improvements in mean accommodative amplitude of 2.2 D, with regression over the ensuing 12 months, resulting in a mean residual improvement of 0.8 D.[5] One possible explanation for the difference is that we were not sufficiently aggressive surgically, making the incisions too few, too shallow, or too short. We made more incisions than the prior study, 12 versus 8. Although the incisions seem to have been more than deep enough, judging by the two complications, significant bleeding prevented confirmation of the surgical depth in some cases. The length of the incisions was 3 mm, the standard for this procedure.

Some other explanation of this difference is needed. Unfortunately, many questions are left unanswered in the prior study. How was accommodative amplitude measured? Was there one observer or two? Was room lighting standardized? Did the surgeon measure the accommodative amplitude or was it measured by independent observers? There is a natural desire on the part of both the surgeon and subject to see success, which can influence accommodative effort. It may be that the study design affected the results of the prior study, but sufficient details are not given to answer this question.

Fukusaku and Murran[5] have suggested the use of silicone plugs to prevent regression after anterior ciliary sclerotomy. We fail to see the value in attempts to prevent regression if there is no initial improvement. The failure of this study's aggressive anterior ciliary sclerotomy procedure to improve accommodative amplitude suggests that scleral expansion may be an ineffective approach to presbyopia.[2] An alternative technique for scleral expansion uses polymethyl methacrylate bands placed in tunneled partial scleral thickness incisions overlying the ciliary body in each of the four quadrants.[6] This technique is called scleral expansion segment surgery. One well-controlled study examined accommodative amplitude before and after scleral expansion segment surgery using a dynamic infrared optometer.[7] There was no evidence of improved accommodative amplitude postoperatively. Singh and Chalfin[8] reported a case of mild iritis developing after scleral expansion segment surgery that seems to be characteristic of anterior segment ischemia. At least one other case of florid anterior segment ischemia developed after scleral expansion segments (personal communication, Ronald Schachar, MD, October 20, 2000).

In this study, the lack of efficacy of anterior ciliary sclerotomy and the potential for significant complications calls into question whether this or any other scleral surgical technique is an appropriate treatment for the correction of presbyopia. Better controlled studies are needed before widespread adoption of these techniques.

Acknowledgments. The authors acknowledge the efforts of Jeffrey Gornbein, DrPH, Senior Statistician of the Statistical/Biomathematical Consulting Clinic, UCLA Department of Biomathematics. Dr. Gornbein performed all of the statistical analysis in this study.

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Discussion

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Thomas Young first postulated that the crystalline lens was responsible for accommodation.[1] Now, exactly 200 years later, we are still arguing about the mechanism of accommodation and the possible reversal of presbyopia.

Clinical studies of techniques to ameliorate presbyopia have been plagued by imprecise methods of measuring accommodation. Adrian Glasser, PhD, has repeatedly stressed the importance of objective measures of accommodation, because subjective measurements of accommodation cannot separate numerous factors other than true accommodation of the lens. Examples of factors other than accommodation that can improve near vision include patient effort, test learning, depth of focus, and nonlenticular optical shifts.

Drs. Hamilton, Davidorf, and Maloney have explored one of the strategies recently proposed to ameliorate presbyopia, based on

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