Pseudophakic accommodation? A study of the stability of capsular bag supported, one piece, rigid tripod, or soft flexible implants

S J Hardman Lea, M P Rubinstein, M P Snead, S M Haworth

Abstract
A group of pseudophakic patients was investigated to determine whether their implants shift along an anteroposterior axis under different conditions of ciliary muscle stimulation. There was no statistically significant change in refraction after either cyclopentolate or pilocarpine administration. A change in anterior chamber depth between the position after pilocarpine and that after cyclopentolate was found. It appears that rigid posterior chamber implants do move backwards on ciliary muscle relaxation, but by a maximum 0.25 mm. This is not thought to represent a mechanical threat to ocular health. It is also not enough to account for the apparent accommodative ability of some pseudophakic patients. The possible causes for this phenomenon are discussed.

Recent research in cataract surgery has demonstrated the concept of using an elastic polymer injected into the capsular bag to provide an implant which can accommodate. In addition multifocal implant lenses are being developed for widespread use. It is already known that some pseudophakic patients fitted with conventional implants may have good near and distance vision using their distance correction only. This phenomenon has been termed 'apparent accommodation' and is ascribed to a number of different optical properties of the eye/implant lens system. An alternative explanation for this observation is that the implant lens may shift relatively to the nodal point of the eye along the anteroposterior axis (z axis) during an effort to accommodate, particularly when the lens is placed entirely within the capsular bag. If correct, such movement might represent optical convenience. However, the required lens movement could also pose a threat to ocular health through lens displacement, pupil distortion, and iris chafe, thereby negating many of the advantages of the posterior chamber lens.

In this study a group of patients was assessed for intraocular lens (IOL) position and objective refraction under various conditions of ciliary muscle stimulation. All 29 pseudophakic eyes had either one-piece tripod rigid PMMA lens (Haworth Equilimb type, Rayner Co. Ltd, UK) or a lens made of flexible PolyHEMA (Jogel type, Alcon Ltd, UK). ALL these lenses were placed within the capsular bag at surgery. The object of this examination was to determine whether either type of lens moves with the eye, thereby causing a change in refractive power.

Materials and methods
A group of 17 patients was examined, comprising nine males and 8 females, aged 35–72 with mean age 68. All had undergone cataract surgery with IOL implantation performed by a single surgeon within the preceding five years. Twenty one eyes were fitted with rigid tripod PMMA lenses and eight had soft flexible PolyHEMA lenses. Four patients were monocular pseudophakics, and one had one eye.

Each patient had retinoscopy and refraction measured and the optimal distance and near vision recorded; all measurements were made by a single observer. Anterior chamber (AC) depths were then estimated with the Haag-Streit slit-lamp pachymeter using the recommended +6.00 D overcorrection in the observer eyepiece. Depths were measured from the corneal endothelial surface to the anterior surface of the

Fig. 1A
Figure 1: Change in anterior chamber depth from baseline after either cyclopentolate (——) or pilocarpine (– – – –).
1A shows the results for rigid lenses. 1B shows the results for flexible lenses.
IOL on the optic axis. On all occasions three successive estimates were made and then averaged with no access to the previously recorded refraction.

These measurements of refraction and AC depth were made on four separate occasions. Firstly, a base-line set of measurements was made. The examination was repeated following the instillation of 2\% pilocarpine three times a day for two days to provide ciliary muscle stimulation. One week later the measurements were repeated following the instillation of cyclopentolate at 15-minute intervals for 45 minutes to relax the ciliary muscle. Finally, to provide an estimate of observer reliability, the measurements of refraction and AC depth, after cyclopentolate administration were repeated after a further seven days and the results compared with those obtained the preceding week.

On all occasions measurements were made without reference to any previously determined values of refraction and AC depth. All values were derived with the patient sitting with head vertical and eyes level to eliminate any possible effect of gravity on the antero-posterior lens position.

Results
In Figure 1 the change in AC depth after pilocarpine and then cyclopentolate instillation into pseudophakic eyes is shown by comparison with the base-line measure. Figure 1A shows the numbers of patients with rigid lenses, while Figure 1B displays the equivalent results for flexible implants. (The average value for baseline AC depth was found to be 4.35 mm for rigid lenses and 4.05 mm for flexible implants.)

Figure 2 shows the changes in refractive error after pilocarpine or cyclopentolate compared with the baseline measurement. Figure 2A demonstrates the results for rigid lenses and Figure 2B the results for flexible implants. The only consistent shift in any measurement seems to be a deepening of the anterior chamber of those eyes with rigid tripod implants after cyclopentolate administration, as seen in Figure 1A.

Figure 3 combines the information from Figures 1 and 2 to demonstrate the maximal change in AC depth by comparing the AC depth values obtained after pilocarpine administration directly with those recorded after cyclopentolate. If there were no change in AC depth, all eyes would show results plotted on the 45° leading diagonal. Both rigid and flexible implants are shown in this graph.

A paired Student’s t test showed that for rigid tripod lenses there is a significant difference between the AC depths with pilocarpine and cyclopentolate (p<0.01). Deeper anterior chambers were found with cyclopentolate than after pilocarpine, with a maximum recorded difference of 0.25 mm in the case of rigid lenses only. There was no significant difference between AC depths for flexible lenses (p=>0.2).

Figure 4 compares the refractive error found after pilocarpine administration with that found after cyclopentolate. There was no significant difference in the refractive error in these two conditions for either type of implant (p=>0.2 by student’s t test), as illustrated by the fact that the points are evenly scattered about the leading diagonal.

Table 1 shows details of 24 eyes for which full details of baseline visual capability were obtainable. The lens type and best corrected distance visual acuity are shown together with the refractive correction necessary to achieve that acuity. In the adjacent column the reading acuity achieved by the distance spectacle correction is shown. This column therefore gives some indication of the extent of apparent accom-
Table 1: Near and distance vision of pseudophakic eyes using distance correction only

<table>
<thead>
<tr>
<th>Eye</th>
<th>Implant</th>
<th>Distance correction</th>
<th>Near VA</th>
<th>Distance for near VA (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eq 6/6</td>
<td>$-3.25$</td>
<td>N8</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Eq 6/6</td>
<td>$-3.50+0.50\times0.90$</td>
<td>N14</td>
<td>23</td>
</tr>
<tr>
<td>3</td>
<td>Eq 6/9</td>
<td>$+4.50+1.50\times105$</td>
<td>N14</td>
<td>34</td>
</tr>
<tr>
<td>4</td>
<td>Eq 6/12</td>
<td>$0+1.50\times175$</td>
<td>N14</td>
<td>38</td>
</tr>
<tr>
<td>5</td>
<td>Eq 6/5</td>
<td>$+1.00$</td>
<td>N12</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>log</td>
<td>$+1.25+1.00\times180$</td>
<td>N10</td>
<td>34</td>
</tr>
<tr>
<td>7</td>
<td>Eq 6/9</td>
<td>$0+1.50\times165$</td>
<td>N14</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
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<td>$-0.50+1.00\times175$</td>
<td>N5</td>
<td>34</td>
</tr>
<tr>
<td>9</td>
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<td>N18</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
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<td>18</td>
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<tr>
<td>11</td>
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<td>N8</td>
<td>35</td>
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<tr>
<td>12</td>
<td>log</td>
<td>$-0.75+2.00\times90$</td>
<td>N10</td>
<td>32</td>
</tr>
<tr>
<td>13</td>
<td>log</td>
<td>$-1.25+2.75\times180$</td>
<td>N18</td>
<td>30</td>
</tr>
<tr>
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<td>N18</td>
<td>38</td>
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<tr>
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<tr>
<td>16</td>
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<td>25</td>
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<tr>
<td>20</td>
<td>Eq 6/6</td>
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<td>N12</td>
<td>26</td>
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<tr>
<td>21</td>
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<td>N24</td>
<td>20</td>
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<tr>
<td>22</td>
<td>log</td>
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<td>N8</td>
<td>20</td>
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<td>23</td>
<td>Eq 6/5</td>
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<td>18</td>
</tr>
<tr>
<td>24</td>
<td>Eq 6/5</td>
<td>$0+5.00\times50$</td>
<td>N18</td>
<td>18</td>
</tr>
</tbody>
</table>

*Eq* = eyes with Haworth Equilimb type rigid lenses. *log* = eyes with soft flexible logel implants.

Discussion

The normal crystalline human lens changes refractive power by alteration in shape. As ciliary muscle tone increases and the tension on the lens zonule decreases, the elasticity of the lens capsule causes it to assume a more spherical shape. In the course of this change of shape the anterior surface of the lens moves forward and the anterior chamber shallows. It has been calculated that for a refractive change of 6·00 D the anterior surface of the lens moves by 0·401 mm during the alteration in shape of the lens which changes the refractive power of the eye. It is known that pilocarpine can induce an accommodative effort in man. In a similar fashion, experimental work with injectable lenses in monkeys shows shallowing of the anterior chamber after pilocarpine administration to stimulate the ciliary body.

For conventional 'in the bag' implants the putative mechanism of pseudophakic...
accommodation is different in that it involves a forward shift of the entire implant rather than the change in lens shape which the natural lens achieves. The Binkhorst formula for calculation of implant power\(^4\) has been criticised in that it requires an estimate of the anticipated AC depth with the implant in situ.\(^5\) It is a useful formula, however, for calculation of the exact change in implant position required to produce a specified change in refraction, provided other factors are constant. With this formula for a posterior chamber lens implanted into an eye of normal ocular power\(^8\) the anterior chamber depth must decrease by 2 mm to provide a change of 3.00 D.

Our results do not show a shift in lens position of more than 0.25 mm even when the situation of maximal ciliary muscle stimulation (after pilocarpine) is compared with maximal ciliary muscle relaxation (after cyclopentolate). With the Binkhorst formula this change in AC depth would account only for 0.37 D of accommodation, and is seen only with rigid tripod lenses. (Hydrogel lenses do not show any tendency to move at all. No obvious reason for this difference between the two lens types is apparent from our experiment.) In the study there was no detectable increase in refraction to accompany the movement of the rigid lenses.

Despite this lack of optically significant lens movement Table 1 shows that five eyes at least had near vision of N8 or better with distance correction only that most could read at a distance of less than 35 cm.

This result has several possible explanations. It might be that the methods of measurement used in our study were not sensitive or reliable enough to detect the lens movement. The estimate of internal reliability shows that this is not the case. Our average difference in AC depths on two occasions was 0.0825 mm for the rigid lenses. While not as accurate as the best documented test of reliability with the Haag-Streit pachymeter on normal eyes,\(^6\) where an average difference of only 0.037 mm was recorded, this is evidently sufficient to detect any optically important changes. The measurement of refraction in our study also shows good internal consistency (Fig 5B). Ideally the use of an autorefractor would be preferable to retinoscopic refraction, but autorefractometers are not reliable with the small pupil size produced by pilocarpine.\(^7\)

There must therefore be some other way to explain the phenomenon of apparent accommodation. The influence of gravity on the IOL was excluded by the study design. We do not know whether it could significantly affect lens position. Further work is required to confirm or refute this for bag supported implants. Anterior chamber lenses have been shown not to move under gravity.\(^8\)

Optical considerations have been suggested in the past.\(^9\) The pupil size may affect the depth of focus (the distance in front of or behind the retina at which a focused image is projected).\(^10\) Down to 3 mm the depth of focus increases with decrease in pupil size because of the pinhole effect. Below this size diffraction lowers the depth of focus again.\(^11\) Pupil size was not recorded in our study. Mixed astigmatism of the cornea may explain a large depth of focus, as it creates a conoid which straddles the retinal plane.\(^12\) In Table 1 eyes 8, 10 and 13 all show this effect.

This project therefore shows little evidence that lens movement contributes to pseudophakic apparent accommodation, which seems most likely to be due to a combination of optical factors. For clarity the phenomenon is better referred to simply as depth of focus, as this does not imply an active mechanism of accommodation.

Both rigid and flexible posterior chamber implants appear to be stable in the antero-posterior direction under all conditions of ciliary muscle stimulation in our patients. It could be that in our study group the patients are too old on average to have much accommodative effort in the ciliary muscle. However, Fisher has shown that accommodative effort in the ciliary muscle actually increases up to middle age,\(^7\) and that presbyopia is due to increase in the rigidity of the lens substance.\(^3\) It is thus not likely that instability of a similar implant would present problems even in a younger age group.

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