Central corneal thickness and intraocular pressure in children undergoing congenital cataract surgery: a prospective, longitudinal study

Graziela Massa Resende, Álvaro P C Lupinacci, Carlos Eduardo Leite Arieta, Vital P Costa

ABSTRACT

Aim To investigate changes in central corneal thickness (CCT) and intraocular pressure (IOP) in children after congenital cataract surgery, as well as risk factors associated with these changes.

Methods 37 eyes of 26 children with congenital cataract undergoing surgery were prospectively recruited. IOP and CCT measurements were performed before the surgery and 6, 12, 18, 24 and 36 months after the procedure.

Results Among the 37 eyes, 15 became aphakic and 22 pseudophakic. Mean CCT significantly increased from 556.24±44.19 to 585.07±56.45 μm (p=0.003) after 3 years, whereas mean IOP significantly increased from 12.05±2.3 to 13.89±2.96 mm Hg (p=0.037). Aphakic eyes underwent surgery at an early age (15.16±32.02 months) compared with pseudophakic eyes (71.48±53.14 months) (p<0.001). After 3 years, mean CCT change in aphakic eyes (56.10±46.97 μm) was significantly higher than in pseudophakic eyes (12.71±38.41 μm) (p=0.015). Age at the time of surgery was inversely correlated to CCT change (r=−0.34, p=0.04), but not to IOP change (r=−0.18, p=0.27). When surgery was performed between 0 and 1 year of age, mean CCT change at 3 years was 70.11±42.3 μm, compared with 6.27±28.09, −17.0±8.04 and 48.33±34.99 μm when surgeries were performed at 1−5, 5−10 and >10 years old, respectively (p<0.001). IOP change was not correlated to CCT change (r=0.31, p=0.06).

Conclusions CCT increases in eyes undergoing congenital cataract surgery, especially when the surgery is performed at an early age.

Central corneal thickness and intraocular pressure in children undergoing congenital cataract surgery: a prospective, longitudinal study

Graziela Massa Resende, Álvaro P C Lupinacci, Carlos Eduardo Leite Arieta, Vital P Costa

ABSTRACT

Aim To investigate changes in central corneal thickness (CCT) and intraocular pressure (IOP) in children after congenital cataract surgery, as well as risk factors associated with these changes.

Methods 37 eyes of 26 children with congenital cataract undergoing surgery were prospectively recruited. IOP and CCT measurements were performed before the surgery and 6, 12, 18, 24 and 36 months after the procedure.

Results Among the 37 eyes, 15 became aphakic and 22 pseudophakic. Mean CCT significantly increased from 556.24±44.19 to 585.07±56.45 μm (p=0.003) after 3 years, whereas mean IOP significantly increased from 12.05±2.3 to 13.89±2.96 mm Hg (p=0.037). Aphakic eyes underwent surgery at an early age (15.16±32.02 months) compared with pseudophakic eyes (71.48±53.14 months) (p<0.001). After 3 years, mean CCT change in aphakic eyes (56.10±46.97 μm) was significantly higher than in pseudophakic eyes (12.71±38.41 μm) (p=0.015). Age at the time of surgery was inversely correlated to CCT change (r=−0.34, p=0.04), but not to IOP change (r=−0.18, p=0.27). When surgery was performed between 0 and 1 year of age, mean CCT change at 3 years was 70.11±42.3 μm, compared with 6.27±28.09, −17.0±8.04 and 48.33±34.99 μm when surgeries were performed at 1−5, 5−10 and >10 years old, respectively (p<0.001). IOP change was not correlated to CCT change (r=0.31, p=0.06).

Conclusions CCT increases in eyes undergoing congenital cataract surgery, especially when the surgery is performed at an early age.

Central corneal thickness and intraocular pressure in children undergoing congenital cataract surgery: a prospective, longitudinal study

Graziela Massa Resende, Álvaro P C Lupinacci, Carlos Eduardo Leite Arieta, Vital P Costa

ABSTRACT

Aim To investigate changes in central corneal thickness (CCT) and intraocular pressure (IOP) in children after congenital cataract surgery, as well as risk factors associated with these changes.

Methods 37 eyes of 26 children with congenital cataract undergoing surgery were prospectively recruited. IOP and CCT measurements were performed before the surgery and 6, 12, 18, 24 and 36 months after the procedure.

Results Among the 37 eyes, 15 became aphakic and 22 pseudophakic. Mean CCT significantly increased from 556.24±44.19 to 585.07±56.45 μm (p=0.003) after 3 years, whereas mean IOP significantly increased from 12.05±2.3 to 13.89±2.96 mm Hg (p=0.037). Aphakic eyes underwent surgery at an early age (15.16±32.02 months) compared with pseudophakic eyes (71.48±53.14 months) (p<0.001). After 3 years, mean CCT change in aphakic eyes (56.10±46.97 μm) was significantly higher than in pseudophakic eyes (12.71±38.41 μm) (p=0.015). Age at the time of surgery was inversely correlated to CCT change (r=−0.34, p=0.04), but not to IOP change (r=−0.18, p=0.27). When surgery was performed between 0 and 1 year of age, mean CCT change at 3 years was 70.11±42.3 μm, compared with 6.27±28.09, −17.0±8.04 and 48.33±34.99 μm when surgeries were performed at 1−5, 5−10 and >10 years old, respectively (p<0.001). IOP change was not correlated to CCT change (r=0.31, p=0.06).

Conclusions CCT increases in eyes undergoing congenital cataract surgery, especially when the surgery is performed at an early age.
RESULTS

In all, 37 eyes of 26 children were included. Mean follow-up was 30.5±10.6 months (range 6–36 months). Overall, 15 eyes (40.5%) became aphakic and 22 (59.5%) pseudophakic. One eye (2.7%) developed glaucoma after 2 years and had to undergo an Ahmed valve implantation. This child was excluded from the analysis after the diagnosis of glaucoma. One child died after 1 year of follow-up, and four children (six eyes) lost to follow-up after 1 year. Among the 22 pseudophakic eyes, 4 (18.2%) were younger than 2-years-old at surgery, whereas 2 (13.3%) of the 15 aphakic eyes were older than 2-years-old. In all, 81% of IOP assessments were made at the surgical centre in the beginning of the follow-up, with only 7% of IOP assessments were made at the surgical centre at the end of 3 years.

Among the 26 patients, 15 (57.7%) were male and 11 (42.3%) female subjects. In the aphakic group, there were significantly more male subjects (n=8, 88.9%) than in the pseudophakic group (n=7, 41.2%) (p=0.008). There was no statistically significant difference in race distribution between the phakic and pseudophakic groups (p=0.388) (table 1).

The mean age at the time of surgery was 48.6±53.2 months (range: from 2.1 to 178.6 months). As expected, the mean age at the time of surgery was significantly lower in the aphakic versus the pseudophakic group (15.2±32.0 and 71.5±53.1 months, respectively) (p<0.001) (table 1). There was no statistically significant difference between the mean follow-up in the aphakic and pseudophakic groups (28.4±12.3 and 31.9±9.3 months, respectively) (p=0.539).

Table 1: Demographics and mean follow-up in aphakic and pseudophakic groups

<table>
<thead>
<tr>
<th></th>
<th>Aphakic (n=15)</th>
<th>Pseudophakic (n=22)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male to female)</td>
<td>14:01</td>
<td>10:12</td>
<td>0.008*</td>
</tr>
<tr>
<td>Race (cc to aa)</td>
<td>08:07</td>
<td>16:05</td>
<td>0.388*</td>
</tr>
<tr>
<td>Age (months)</td>
<td>Mean (SD)</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.16±32.0</td>
<td>71.48–53.14</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td></td>
<td>2.07–128.57</td>
<td>5.83–178.63</td>
<td></td>
</tr>
<tr>
<td>Mean follow-up (months)</td>
<td>Mean (SD)</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.40 (12.31)</td>
<td>31.91 (9.33)</td>
<td>0.359†</td>
</tr>
<tr>
<td></td>
<td>6–36</td>
<td>6–36</td>
<td></td>
</tr>
</tbody>
</table>

*p Pearson χ² test. †Student t test for independent samples.

Table 2: Preoperative CCT and mean CCT change in all time intervals

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Pseudophakic</th>
<th>Aphakic</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative CCT</td>
<td>n=37</td>
<td>n=22</td>
<td>n=15</td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>556.24 (44.19)</td>
<td>553.77 (40.43)</td>
<td>559.87 (50.45)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>470–671</td>
<td>512–637</td>
<td>470–671</td>
<td></td>
</tr>
<tr>
<td>CCT 6 m-0 (µm)</td>
<td>n=33</td>
<td>22</td>
<td>11</td>
<td>0.196</td>
</tr>
<tr>
<td>Mean change</td>
<td>13.33 (22.15)</td>
<td>9.77 (17.14)</td>
<td>20.45 (29.48)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>–13 to 83</td>
<td>–13 to 76</td>
<td>–9 to 83</td>
<td></td>
</tr>
<tr>
<td>CCT 12 m-0 (µm)</td>
<td>n=22</td>
<td>18</td>
<td>04</td>
<td></td>
</tr>
<tr>
<td>Mean change</td>
<td>21.23 (30.54)</td>
<td>13.5 (26.04)</td>
<td>56.0 (26.77)</td>
<td>0.008</td>
</tr>
<tr>
<td>Range</td>
<td>–35 to 83</td>
<td>–35 to 70</td>
<td>27–83</td>
<td></td>
</tr>
<tr>
<td>CCT 18 m-0 (µm)</td>
<td>n=19</td>
<td>15</td>
<td>04</td>
<td>0.304</td>
</tr>
<tr>
<td>Mean change</td>
<td>26.16 (60.44)</td>
<td>18.6 (58.21)</td>
<td>54.5 (68.94)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>–92 to 157</td>
<td>–92 to 135</td>
<td>12–157</td>
<td></td>
</tr>
<tr>
<td>CCT 24 m-0 (µm)</td>
<td>n=16</td>
<td>9</td>
<td>07</td>
<td>0.021</td>
</tr>
<tr>
<td>Mean change</td>
<td>17.69 (45.82)</td>
<td>–4.67 (23.91)</td>
<td>46.43 (52.67)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>–35 to 109</td>
<td>–35 to 44</td>
<td>–23 to 109</td>
<td></td>
</tr>
<tr>
<td>CCT 36 m-0 (µm)</td>
<td>n=27</td>
<td>17</td>
<td>10</td>
<td>0.015</td>
</tr>
<tr>
<td>Mean change</td>
<td>28.78 (46.13)</td>
<td>12.71 (38.41)</td>
<td>56.1 (46.97)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>–26 to 147</td>
<td>–26 to 105</td>
<td>–20 to 147</td>
<td></td>
</tr>
</tbody>
</table>

*p Comparison between aphakic and pseudophakic groups—Student t test.

ANOVA.

CCT, central corneal thickness; n, number of patients.
Mean IOP significantly increased from 12.05±2.3 to 13.89±2.96 mm Hg (p=0.057) (table 3). There was no statistically significant difference in mean IOP change (final IOP—initial IOP) between the aphakic (2.80±4.61 mm Hg) and pseudophakic groups (1.33±4.16 mm Hg) (p=0.396).

At 36 months of follow-up, mean CCT change was 70.11±42.3 μm compared with 6.27±28.09, −17.0±3.04 and 48.33±34.99 μm when surgeries were performed between 0 and 1, 1−5, 5−10 and >10 years old, respectively (p<0.001). Mean IOP change also was significantly different between these groups (4.89±2.8, 0.27±3.13, 1.80±7.01 and −1.33±3.58 mm Hg, respectively) (p=0.045). Age at the time of surgery was inversely correlated to CCT change (r=−0.54, p=0.04) (figure 1), but not to IOP change (r=−0.18, p=0.27) (figure 2).

When all patients were analysed, the correlation between CCT change and IOP change almost reached statistical significance (r=0.51, p=0.06). The CCT change was directly correlated with IOP change in the aphakic group (r=0.54, p=0.04) (figure 3), but not in the pseudophakic group (r=0.09, p=0.68) (figure 4).

**DISCUSSION**

Several retrospective studies have demonstrated that there is an increase in CCT readings in eyes following congenital cataract extraction. In some studies, aphakic and pseudophakic eyes were compared. The influence of an IOL on CCT measurements varies in the literature. Muir et al observed that CCT is higher in aphakic than in pseudophakic children, a finding that was not confirmed by Simon et al. On the other hand, Simsek et al demonstrated that secondary IOL implantation does not influence the CCT measurements. As mentioned below, this is probably explained by the different ages at the time of surgery. In some studies, glaucomatous and non-glaucomatous subjects were included. However, it is well known that increased IOP and the use of antiglaucomatous medications may influence CCT readings and corneal endothelial cell function.

In a recent short-term longitudinal study, Lim et al studied 66 patients with unilateral congenital cataract and reported that CCT of both eyes were similar before cataract removal (mean CCT 552±32.9 and 550.9±40.4 μm, respectively, p=0.78). However, these measurements increased 6.5 months after cataract extraction (mean CCT increase 29.7±43.1 μm, p=0.05 in unilateral cases and 27.4±59.4 μm, p=0.01 in bilateral cases). An important limitation of this study is the fact that it included patients with glaucoma, some of them using antiglaucomatous medications. Furthermore, the short-term follow-up could not exclude a possible transient CCT increase due to corneal oedema.

Our study is one of the first longitudinal studies in the literature and has the longer mean follow-up (30.5 months) of patients undergoing congenital cataract surgery. In accordance with previously mentioned studies, we observed a CCT increase in aphakic children after cataract removal (56.1±46.97 μm).

### Table 3 Mean IOP change in all time intervals

<table>
<thead>
<tr>
<th>Preoperative IOP (mm Hg)</th>
<th>All</th>
<th>Pseudophakic</th>
<th>Aphakic</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>37</td>
<td>22</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>12.05 (2.3)</td>
<td>12.00 (1.95)</td>
<td>12.13 (2.80)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>8–19</td>
<td>8–16</td>
<td>09–19</td>
<td></td>
</tr>
<tr>
<td>IOP 6 m-0 (mm Hg)</td>
<td>33</td>
<td>22</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Mean change (SD)</td>
<td>2.06 (3.5)</td>
<td>2.64 (2.26)</td>
<td>0.91 (5.13)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>−7 to 9</td>
<td>0 to 9</td>
<td>−7 to 9</td>
<td></td>
</tr>
<tr>
<td>IOP 12 m-0 (mm Hg)</td>
<td>22</td>
<td>18</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Mean change (SD)</td>
<td>0.82 (3.69)</td>
<td>0.11 (3.60)</td>
<td>4.00 (2.31)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>−5 to 9</td>
<td>−5 to 9</td>
<td>2 to 6</td>
<td></td>
</tr>
<tr>
<td>IOP 18 m-0 (mm Hg)</td>
<td>18</td>
<td>14</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Mean change (SD)</td>
<td>3.11 (4.73)</td>
<td>2.43 (3.46)</td>
<td>5.50 (8.06)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>−6 to 12</td>
<td>−4 to 8</td>
<td>6−12</td>
<td></td>
</tr>
<tr>
<td>IOP 24 m-0 (mm Hg)</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Mean change (SD)</td>
<td>1.38 (4.21)</td>
<td>0.22 (3.42)</td>
<td>2.86 (4.91)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>−4 to 13</td>
<td>−4 to 6</td>
<td>−2 to 13</td>
<td></td>
</tr>
<tr>
<td>IOP 36 m-0 (mm Hg)</td>
<td>28</td>
<td>18</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mean change (SD)</td>
<td>1.86 (4.30)</td>
<td>1.33 (4.16)</td>
<td>2.80 (4.61)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>−8 to 14</td>
<td>−4 to 14</td>
<td>−8 to 8</td>
<td></td>
</tr>
</tbody>
</table>

*p Value† Student t test.

| Comparison between aphakic and pseudophakic groups—Student t test. |

IOP, intraocular pressure; n, number of patients.
when compared with pseudophakic eyes (12.71±38.41 μm, p=0.015). Moreover, our study suggests that congenital cataract surgery performed earlier results in greater increases in CCT measurements. Two mechanisms could justify this finding: the absence of a lens could be harmful to the development of the cornea or surgeries performed at an earlier age could promote significant corneal changes.16 26

Our series suggests that age is probably the most important factor influencing postoperative CCT changes (figure 1). Furthermore, pseudophakic eyes operated earlier tended to present an increase of CCT measurements, whereas aphakic eyes operated later showed no increase in CCT measurements. In accordance with Lambert et al.,27 younger children undergoing congenital cataract surgery tended not to receive an IOL, which explains why aphakic eyes were significantly younger than pseudophakic eyes at the time of surgery. Although the mean CCT change in the group older than 10-years-old was high (48.53±34.99 μm), the small number of patients in this group (n=5) limits the comparison with other age groups.

In normal children, the cornea thins during the early months of life and stabilises over the following years, indicating that the corneal development continues after birth during the first year of life.27 28 Although CCT has been shown to increase physiologically in normal children until 11 years old (varying from 553 to 573 μm in white children and Hispanic children and 541 to 551 μm in African–American children),29 the mean change observed in the aphakic group in our study is significantly greater (from 560 to 602 μm).

It is believed that the mechanical stress during cataract surgery and inflammation in the anterior chamber can damage the endothelial cells, but it is uncertain whether these injuries are sufficient to cause the corneal thickening.16 Surgical trauma to the cornea during the first months of life could impair mechanisms that regulate hydration, evaporation and transparency.30 Moreover, the developing cornea could be damaged by surgical trauma, induced by long surgical time or excessive BSS usage, corneal contact and collision of lens fragments due to turbulent flow and air bubble formation.31 32 It has been suggested that vitreous factors can modify the anterior segment microstructure and corneal maturation. The IOL could function as a barrier between anterior and posterior segments, avoiding corneal changes secondary to vitreous factors.26 However, our study indicates that aphakic eyes operated later do not develop corneal thickening. This fact reinforces that earlier age at surgery (and not aphakia) is the main risk factor associated with this change.33

A reduction in endothelial cell count or endothelial cell dysfunction could be responsible for corneal thickening. Nilforushan et al.15 did not observe statistically significant differences regarding the endothelial cell count characteristics between operated eyes and the control group. However, Amino et al.16 concluded that, although there was no difference in corneal endothelial cells counts among the cataract-extracted

<table>
<thead>
<tr>
<th>Table 4</th>
<th>CCT following congenital cataract extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>CCT aphakic (n)</td>
</tr>
<tr>
<td>Muir et al13</td>
<td>642±88 μm (29)</td>
</tr>
<tr>
<td>Simon et al13</td>
<td>665 μm (38)</td>
</tr>
<tr>
<td>Simsek et al14</td>
<td>NA (33)</td>
</tr>
<tr>
<td>Nilforushan et al15</td>
<td>–</td>
</tr>
<tr>
<td>Amino et al16</td>
<td>597.3±44.1 μm (32)†</td>
</tr>
<tr>
<td>Lupinacci et al17</td>
<td>615.8±61 μm (44)‡</td>
</tr>
<tr>
<td>Resende et al18</td>
<td>602.7±69.35 μm (10)§</td>
</tr>
</tbody>
</table>

*IOL implantation was performed during the congenital cataract extraction in five eyes and secondarily in five eyes.
†Unilateral group.
‡Bilateral group—right eye.
§Mean CCT—36 months after surgery.
CCT, central corneal thickness; NA, not available.
eyes and controls (p=0.56), the frequency of hexagonally shaped endothelial cells and the coefficient of variation in the endothelial size were higher in the cataract-extracted eyes (p<0.01, p<0.001). Unfortunately, our study did not include the use of specular microscopy to measure endothelial cell count.

Mean IOP was significantly increased in our study (p=0.037) but there was no correlation between IOP and age at surgery (r=−0.18, p=0.27). The CCT change was directly correlated with IOP change in the aphakic group (r=0.54, p=0.04), but not in the pseudophakic group (r=0.05, p=0.68). This fact could be explained by the higher CCT measurements obtained in aphakic children.

There are four possible explanations for the low incidence of glaucoma (2.7%) in our series. First, our mean follow-up was short compared with other studies, where the mean follow-up was higher than 5 years.10,35 Also, the improvement in surgical techniques (smaller incisions, decreased surgical time, posterior capsulotomy with anterior vitrectomy, use of foldable IOL at earlier ages)8,31,34 may have reduced the incidence of post-operative complications, including glaucoma. Moreover, our patients underwent surgery in a later age, and early age at surgery is a known risk factor for the development of glaucoma in eyes undergoing congenital cataract surgery. Finally, we excluded eyes with persistent fetal vasculature, a risk factor for glaucoma following congenital cataract surgery. However, it is possible that subjects with elevated IOP and no optic nerve damage that were included as non-glaucomatous in our series may actually develop optic nerve changes in the future.

Although some individuals had IOP measurements performed with Perkins tonometry and others with Goldmann applanation tonometry, previous studies had shown no significant difference between their measurements.35,36 It has been shown that an anesthesia may reduce IOP in children,25 but we used a low concentration of halogenated anaesthetic and performed IOP measurements within 5 min after induction.

Functional and anatomical examination may be difficult to perform in children with congenital cataract or aphakia due to nystagmus, ambyopia and cooperation. Hence, IOP measurement is an important diagnostic variable for glaucoma.5–7 In this study, we have demonstrated that eyes undergoing congenital cataract surgery at an early age show thicker corneas after the procedure. These CCT increases (up to 147 µm) could be clinically significant and may artificially increase IOP measurements obtained with applanation tonometry.38

Contributors GMR: substantial contributions to conception and design, acquisition of data, and analysis and interpretation of data; drafting the article and revising it critically for important intellectual content and final approval of the version to be published. VPC: substantial contributions to conception and design, acquisition of data, and analysis and interpretation of data; drafting the article and revising it critically for important intellectual content; and final approval of the version to be published. Competing interests None.

Patient consent Obtained from the parents.

Ethics approval Ethics approval was provided by the Institutional Ethics Committee (number 248/2006 CAE1 0181.0146.000-06).

Provenance and peer review Not commissioned; externally peer reviewed.

Correction notice This article has been corrected since it was published Online First. The author name ‘Vital Costa’ has been updated to read ‘Vital P Costa’.

REFERENCES
Central corneal thickness and intraocular pressure in children undergoing congenital cataract surgery: a prospective, longitudinal study
Graziela Massa Resende, Álvaro P C Lupinacci, Carlos Eduardo Leite Arieta and Vital P Costa

doi: 10.1136/bjophthalmol-2012-301684

Updated information and services can be found at:
http://bjo.bmj.com/content/96/9/1190

These include:
References
This article cites 38 articles, 7 of which you can access for free at:
http://bjo.bmj.com/content/96/9/1190#BIBL

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Errata
An erratum has been published regarding this article. Please see next page or:
/content/96/9/1276.2.full.pdf

Topic Collections
Articles on similar topics can be found in the following collections
Editor’s choice (113)
Lens and zonules (807)
Paediatrics (358)
Epidemiology (1068)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/
CORRECTIONS

doi: 10.1136/bjophthalmol-2012-301684corr1