Axial Length, Myopia, and the Severity of Lens Opacity at the Time of Cataract Surgery

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Objective: To investigate the relationship between axial length, myopia of the eye, and the severity of lens opacity at the time of cataract surgery.

Methods: We retrospectively reviewed a consecutive series of 198 eyes of patients aged older than 50 years at Fukui University Hospital (Fukui, Japan) from June 2004 to December 2005. Patient age at the time of surgery, axial length, spherical equivalent, and the subtypes and severity of cataract (as classified according to the modification of the Lens Opacities Classification System, version III) were recorded.

Results: Axial length was significantly associated with age at the time of cataract surgery ($P<.001$). Regarding the severity of nuclear cataract, a significant correlation was seen between a higher score of nuclear cataract and longer axial length ($P<.001$). The relationship between the severity of nuclear cataract and spherical equivalent at the time of surgery showed a significant association between grading nuclear color and nuclear opalescence 4-6 and higher myopia ($P<.001$).

Conclusion: An increase in axial length or myopia of the eye was associated with a lower mean age at the time of surgery and higher grade of nuclear cataract.

Arch Ophthalmol. 2006;124:1586-0

Although an association between high myopia and the development of cataract has been proposed, it is unclear whether myopia predisposes a person to cataract formation. Longer axial length is a risk factor for lenticular progressive myopia. Furthermore, nuclear cataract is associated with presumed acquired myopia. The Salisbury Eye Evaluation Project and the Tanjong Pagar Study found that posterior subcapsular cataract was significantly associated with myopic refraction.

Patients with axial myopia are more likely to develop cataracts at an earlier age than those with shorter axial lengths. In addition to increasing the risk for cataract development, longer axial length may also be associated with age at cataract surgery. We evaluated the association between axial length, subtype, and severity of cataract (as classified according to the modification of the Lens Opacities Classification System, version III [LOCS III]; refractive status; and age in Japanese patients undergoing cataract surgery.

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Mean age at the time of cataract surgery was $74.1 \pm 7.8$ years (range, 51-95 years). Sex distribution showed a higher ratio of female (123 eyes in 101 patients) to male patients (75 eyes in 65 patients). Mean axial length was $23.3 \pm 1.3$ mm (range, 20.5-31.0 mm), and spherical equivalent at the time of surgery was $-1.3 \pm 4.7$ diopters (D) (range, $-20.8$ to $+6.4$ D).

A strong association was seen between longer axial length in patients with higher myopia (Pearson correlation coefficient, $-0.704$; $P<.001$) (Figure 1). A scatterplot of axial length against age at surgery showed a weak correlation between earlier surgery and longer axial length (Pearson correlation coefficient, $-0.236$; $P<.001$) (Figure 2A), while a second plot of spherical equivalent against age at surgery showed a weak correlation between earlier surgery in patients with higher myopia (Pearson correlation coefficient, $0.233$; $P<.001$) (Figure 2B). No significant association was seen between visual acuity (logMAR) and spherical equivalent or axial length at surgery (Pearson correlation coefficient, 0.009; $P<.89$).

The relationship between the severity of nuclear cataract (NO and NC) and age at the time of surgery showed a significant correlation between a higher grading of nuclear cataract and older age (Spearman rank correlation, $P<.001$; Pearson correlation coefficient, 0.253; $P<.001$) (Table 1). The association between the severity of cortical cataract and age at surgery showed a significant correlation between a higher grading of cortical cataract and older age (Spearman rank correlation, $P<.05$; Pearson correlation coefficient, 0.17; $P<.02$) (Table 1). No significant correlation was seen between the severity of posterior cataract and age at surgery (Table 1).

The relationship between the severity of nuclear cataract (NO and NC) and axial length at surgery showed a significant association between a higher grading (NO or NC 4-6) of nuclear cataract and longer axial length ($P<.001$) (Table 2). The relationship between the severity of nuclear cataract (NO and NC) and spherical equivalent at surgery showed a significant association between a higher grading of nuclear cataract and higher myopia (1-factor analysis of variance, $P<.001$) (Table 2). There was no significant correlation between the severity of cortical cataract or posterior cataract and axial length, or cortical cataract or posterior cataract and spherical equivalent at surgery (Table 2).

**STATISTICAL METHODS**

Because some patients have different values for refraction, axial length and type, and grading of cataract in each eye, analyses were run according to eye rather than patient. Correlations between axial length score, age, and spherical equivalent were analyzed using the Pearson correlation coefficient. Correlations between the LOCS III score and axial length, age, and spherical equivalent were analyzed by 1-factor analysis of variance. Multiple logistic regression analysis was used to determine the effects of categories of refraction or axial length on the odds ratio (OR) of each type of cataract, with similar adjustment made for age, gender, and grading of other subtypes of cataract in multivariate analyses. For multiple logistic regression analysis, LOCS III scores of 4.0 or more were defined as a significant nuclear cataract for NO or NC; scores of 3.0 or more as significant for cortical cataract; and scores of 3.0 or more as significant for posterior subcapsular cataract. Definitions were based on similar criteria published elsewhere. All analyses were performed using StatView, version 5.0 (SAS Institute Inc, Cary, NC).
In multiple logistic regression analysis, a statistically significant increase in the risk of incident NO or NC 4-6 nuclear cataract (OR, 45.30 or 42.20; P < .001) was found in highly myopic eyes (spherical equivalent < −6.0 D) compared with low myopic and hyperopic eyes (spherical equivalent > −0.5 D) at the time of cataract surgery, after adjustment for age and sex or multivariate adjustment (OR, 45.30 or 42.20, respectively; P < .001) (Table 3). An association between longer axial length (> 24.00 mm) and incidence of NO or NC 4-6 nuclear cataract at surgery was statistically significant, after adjustment for age and sex or multivariate adjustment (OR, 5.15 or 5.77, respectively; P = .01) (Table 3). No statistically significant associations were found at the time of surgery between spherical equivalent or axial length and the incidence of cortical or posterior 3-5 cataract after multivariate adjustment.

Many population-based studies have shown an association between myopia and the onset of cataract. In the present study, we analyzed the association between axial length and cataract type and severity as classified according to the LOCS III in cataract patients at the time of cataract surgery. Results showed no significant relationship between posterior or cortical cataract and myopic refractive change or axial length. In contrast, patients with NO and NC 4-6 nuclear cataract had a longer axial length and higher myopic refractive change than those with NO and NC 1-3. Younger patients had a longer axial length and higher myopia than older patients at surgery. In our study, there was no significant association between visual acuity and refractive change, because we did not select cataract surgery for a refractive benefit at an earlier age. These findings suggest that patients with longer axial length and/or higher myopia may have a greater risk of developing severe nuclear cataract, leading to cataract surgery at a younger age. Finally, our study supports the findings of previous studies, that an increase in the axial length of the eye is associated with a lower mean age at the time of cataract surgery.

The Tanjong Pagar Survey found that there was no significant difference in axial length between eyes with NO or NC 1-3 nuclear cataracts and those with NO or NC 4-6 nuclear cataracts in a cross-sectional study. However, Chen et al had suggested that longer axial length may be an important factor predisposing a person to lenticular progressive myopia. In 1987, Reeves et al described a form of nuclear cataract that induces myopic refractive changes, resulting in lenticular progressive myopia. Nuclear sclerosis and cataract may result in significant myopic refractive changes. In the present study, because most patients had mixed types of cataract, we performed multivariate adjustment for age, sex, and the severity of other types of cataract to study the association between the prevalence of NO or NC 4-6 nuclear cataract, or cortical or posterior 3-5 cataract, and myopia severity or axial length. On the basis of the results, we suggest that higher myopia and longer axial length (> 24.00 mm) may be risk factors for NO or NC 4-6 nuclear cataract, given ORs of 42.20 for myopia of 6.0 D or more and of 5.77 for an axial length of 24.0 mm or more on multivariate study. Although a previous study has found that longer axial length and nuclear sclerosis also cause myopic refractive changes, we were unable to determine whether myopia causes nuclear cataract. Nuclear sclerotic cataract as a cause of visual loss in young patients with axial myopia was described as early as 1980. Furthermore, consistently higher lens opacity values in myopic eyes with axial myopias than in emmetropic eyes have been reported.

The Tanjong Pagar Survey found that myopia was associated with nuclear and posterior subcapsular, but not cortical, cataracts in adult Chinese patients. Eyes with posterior subcapsular cataract were more likely to have deeper anterior chambers, thinner lenses, and longer vitreous chambers, although no relationship was seen between posterior subcapsular cataract and axial length. In our study, no relationship was seen between posterior cataract and spherical equivalent or axial length. To analyze the primary effect of axial length, myopia, and cataract at the time of cataract surgery, we excluded eyes with ocular risk factors for the development of cataract.

### Table 1. Grading of LOCS III and Age in Patients at the Time of Cataract Surgery

<table>
<thead>
<tr>
<th>Grading of LOCS III</th>
<th>No.</th>
<th>Mean ± SD Age, y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear opalescence or nuclear color</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>50</td>
<td>69.7 ± 7.6</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>74.9 ± 6.7∗</td>
</tr>
<tr>
<td>4-5</td>
<td>63</td>
<td>76.5 ± 8.1∗</td>
</tr>
<tr>
<td>Cortical cataract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>69</td>
<td>72.3 ± 8.0</td>
</tr>
<tr>
<td>3-5</td>
<td>129</td>
<td>75.0 ± 7.6†</td>
</tr>
<tr>
<td>Posterior cataract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>121</td>
<td>74.2 ± 6.9</td>
</tr>
<tr>
<td>3-5</td>
<td>77</td>
<td>73.9 ± 9.1</td>
</tr>
</tbody>
</table>

Abbreviation: LOCS III, Lens Opacities Classification System, version III.

*P<.001.
†P<.05.

### Table 2. Grading of LOCS III and Axial Length or Spherical Equivalent in Patients at the Time of Cataract Surgery

<table>
<thead>
<tr>
<th>Grading of LOCS III</th>
<th>Mean ± SD Axl, mm</th>
<th>Mean ± SD SE, diopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear opalescence or nuclear color</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>23.09 ± 1.58</td>
<td>−0.33 ± 4.06</td>
</tr>
<tr>
<td>3</td>
<td>22.93 ± 1.16</td>
<td>0.06 ± 2.99</td>
</tr>
<tr>
<td>4-5</td>
<td>23.96 ± 2.42∗</td>
<td>−3.96 ± 5.82†</td>
</tr>
<tr>
<td>Cortical cataract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>23.16 ± 1.67</td>
<td>−1.96 ± 5.07</td>
</tr>
<tr>
<td>3-5</td>
<td>23.37 ± 1.87</td>
<td>−0.97 ± 4.44</td>
</tr>
<tr>
<td>Posterior cataract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>23.22 ± 1.65</td>
<td>−0.97 ± 4.39</td>
</tr>
<tr>
<td>3-5</td>
<td>23.41 ± 2.02</td>
<td>−1.85 ± 5.09</td>
</tr>
</tbody>
</table>

Abbreviations: Axl, axial length; LOCS III, Lens Opacities Classification System, version III; SE, spherical equivalent.

∗P<.002.
†P<.01.
The mechanism of the apparent relationship between axial length and nuclear cataract at the time of cataract surgery is unclear. It has been hypothesized that decreased diffusion of metabolites or nutrients to the back of the lens as an effect of a longer vitreous cavity may inhibit the oxidative defense system and thereby promote cataract. The rapid development of nuclear cataracts in patients under hyperbaric oxygen treatment strongly supports this oxidative theory of nuclear cataract formation. Nuclear sclerosis is a frequent occurrence after successful pars plana vitrectomy. Vitrectomy surgery significantly increases intraocular oxygen tension during and for prolonged periods after surgery, exposing the crystalline lens to abnormally high oxygen levels, which may lead to nuclear cataract formation. These various findings suggest that changes in vitreous circumstances caused by longer axial length may induce nuclear or other types of cataract.

Cataractogenesis is associated with numerous changes in the genetic profile of the lens epithelial cells. For example, the expression of many features, such as transforming growth factor β-induced factor and pigment epithelium–derived factor, are altered in highly myopic eyes with choriotelial atrophy. Because pigment epithelium–derived factor genes are known to play important roles in the physiology and morphology of the transparent lens, Segev et al suggest that substantial down-regulation of pigment epithelium–derived factor expression might contribute to the formation of senile cataract. Thus, the low concentration of pigment epithelium–derived factor may contribute to cataract formation in highly myopic eyes with longer axial length.

In conclusion, our results suggest a significant association between the axial length of eyes and age at cataract surgery. Longer axial length may precede and predispose a person to nuclear cataract. A significant association exists between myopia and nuclear cataract formation. However, given that nuclear sclerosis of the lens causes a myopic shift in refractive status, it is unclear whether myopia precedes nuclear cataract. The mechanism of the development of nuclear cataract in eyes with longer axial length is still unclear, and further study is required.

**REFERENCES**