Long-term follow-up of the corneal endothelium after aphakic iris-fixated IOL implantation for bilateral cataract in children

Marije L. Sminia, MD, Monica T.P. Odenthal, MD, PhD, Liesbeth J.J.M. Prick, MD, PhD, Maarten P. Mourits, MD, PhD, Hennie J. Völker-Dieben, MD, PhD

PURPOSE: To evaluate the long-term corneal endothelial cell density (ECD) and outcomes after iris-fixated aphakic intraocular lens (IOL) implantation in children after bilateral congenital or juvenile cataract extraction and to compare the outcomes with data in the literature.

SETTING: Academic Medical Centre, Amsterdam, The Netherlands.

DESIGN: Case series.

METHODS: This retrospective study evaluated the charts and endothelial photographs of children who had Artisan aphakic IOL implantation. The main outcome measure was the ECD at the last follow-up visit.

RESULTS: The mean age of the 10 patients (20 eyes) at IOL implantation was 7.4 years (range 4.3 to 11.1 years) and at the last follow-up, 19.6 years (range 14.3 to 26.6 years). After a mean follow-up of 12.3 years (range 10.0 to 15.6 years), the mean ECD was 2702 cells/mm^2 (range 1382 to 3974 cells/mm^2). Although this is comparable to the mean normal endothelial cell counts in this age group reported in the literature, a wider range of ECD was found in the current study.

CONCLUSIONS: The mean corneal ECD after more then 10 years of follow-up was comparable to the mean normal ECD for this age group reported in the literature. The high standard deviation of the mean ECD in the current study highlights the importance of prospective studies on the ECD after iris-fixated aphakic IOL implantation in young patients.

Financial Disclosure: No author has a financial or proprietary interest in any material or method mentioned.

J Cataract Refract Surg 2011; 37:866–872 © 2011 ASCRS and ESCRS

Supplemental material available at www.jcrsjournal.org.

At present, in-the-bag fixation of a posterior chamber IOL is the first choice of pediatric cataract surgeons in almost all cases of congenital and juvenile cataract with an intact capsular bag.[1,2] An iris-fixated aphakic intraocular lens (IOL) is a suitable choice in the absence of capsule support, for example in aphakia after surgery for luxation of the crystalline lens (ie, Marfan syndrome) or traumatic cataract. In these cases, an iris-fixated aphakic IOL is preferred over implantation of an angle-supported or scleral-sutured IOL in some European countries. Several studies[3–7] report safe implantation of these IOLs in children.

A concern about iris-fixated IOL implantation is corneal endothelial cell loss. Safety to the corneal endothelium is of great importance in pediatric patients because of their long life expectancy. Studies of the corneal endothelium after iris-fixated aphakic IOL implantation in children[4–6] report promising results. However, these studies comprised small numbers of patients and the promising findings have to be confirmed in a larger group of patients. Earlier, our group published long-term endothelial cell density (ECD) results after Artisan iris-fixated aphakic IOL (Ophtec BV) implantation in unilateral cases.[5]

This current study evaluated the long-term outcomes in a larger group patients that were operated on for bilateral congenital or juvenile cataract and had implantation of an Artisan aphakic intraocular lens IOL between 1991 and 1999. At that time in our university center, aphakia after cataract removal for bilateral congenital and juvenile cataract was considered an indication for aphakic iris-fixated IOL implantation. One reason this IOL was chosen was the possibility of future IOL exchange in the growing eye.[3]

Published by Elsevier Inc.

0886-3350/$ - see front matter
doi:10.1016/j.jcrs.2010.07.040

Table 1. Patient and IOL characteristics.

Parameter	Right Eye (n = 10)	Left Eye (n = 10)	Both Eyes (n = 20)
Age (y) at IOL implantation			
Mean ± SD	7.2 ± 1.9	7.6 ± 1.9	7.4 ± 1.9
Range	4.3, 11.1	4.3, 11.1	4.3, 11.1
Follow-up (y)			
Mean ± SD	12.5 ± 1.9	12.2 ± 1.7	12.3± 1.7
Range	10.0, 15.6	10.0, 15.5	10.0, 15.6
Age (y) at follow-up			
Mean ± SD	19.6 ± 3.5	Same	Same
Range	14.3, 26.6	Same	Same
Primary IOL implant, n (%)	12 (60)	12 (60)	NA
Secondary IOL implant, n (%)	8 (40)	8 (40)	NA
Mean time (y) between LE and IOL implant ± SD (n = 4)	4.9 ± 1.0	5.0 ± 1.0	NA
Sex			
Male	3	3	6
Female	7	7	14
Preop AL (mm)			
Mean ± SD	22.5 ± 1.7	22.6 ± 1.4	22.5 ± 1.5
Range	20.2, 24.8	20.4, 24.7	20.2, 24.8
Preop ACD (mm)*			
Mean ± SD	3.5 ± 0.5	3.5 ± 0.4	3.5 ± 0.5
Range	2.9, 4.6	3.2, 4.3	2.9, 4.6
Range of IOL power (D)	12, 27	13, 27	12, 27
Target SE refraction (D)			
Mean ± SD	+0.50 ± 1.50	+0.50 ± 1.50	+0.50 ± 1.50
Range	−0.50, +3.50	−0.75, +3.75	−0.75, +3.75
SE refraction (D) at last follow-up			
Mean ± SD	−3.50	−3.00	−3.25
Range	−12.5, −0.25	−9.25, 0.00	−12.50, 0.00

ACD = anterior chamber depth; AL = axial length; implant = implantation IOL = intraocular lens; LE= lens extraction; SE = spherical equivalent
*n = 12

PATIENTS AND METHODS

This retrospective chart review comprised all children who had bilateral congenital and juvenile cataract extraction with Artisan aphakic IOL implantation at the time of the primary surgery or as a secondary procedure. All included patients were recruited for a recent follow-up visit, at which time endothelial cell photographs were taken. None of the children had persistent fetal vasculature, glaucoma, or trauma. All patients or their parents provided informed consent.

Surgical Technique

Cataract extraction was performed by irrigation/aspiration (I/A) by the same surgeon. Planned anterior vitrectomy was not a standard procedure and when not performed, the posterior capsule was left intact. In some cases with an intact posterior capsule, Elschnig pearls obscuring the visual axis developed during follow-up. These were surgically removed through the anterior segment with the pupil dilated. One or 2 paracenteses were made, and the Elschnig pearls were removed with a cannula using I/A. The posterior capsule was always left intact during this procedure. Sodium hyaluronate 1.0% (Healon) was used in all cases.

The axial length (AL) of the eye was measured using applanation A-scan biometry at the time of surgery.

Endothelial Cell Density and Central Corneal Thickness

Endothelial photographs were taken with a noncontact autofocus SP-2000P specular microscope (Topcon Corp.) at the last follow-up visit. At least 2 corneal endothelial photographs were taken of each eye. The analysis was performed

Submitted: July 10, 2010.
Final revision submitted: November 18, 2010.
Accepted: November 29, 2010.

From the Departments of Ophthalmology, Academic Medical Centre (Sminia, Prick, Mourits), and Vrije Universiteit Medical Centre (Völker-Dieben), Amsterdam, and Diaconessenhuis (Odenthal), Leiden, The Netherlands.

N. Gortzak-Moorstein, who performed all surgeries described in this article, died on December 27, 2004.

Corresponding author: Marije L. Sminia, MD, Department of Ophthalmology, Room D2-129, Academic Medical Centre, Meibergdreef 9, 1105 AZ, Amsterdam, The Netherlands. E-mail: m.l.sminia@amc.uva.nl.

Table 2. Endothelial cell results at the last follow-up.

Parameter	Right eye (n = 10)	Left eye (n = 10)	Both eyes (n = 10)
ECD (cells/mm^2)			
Mean ± SD	2634 ± 746	2769 ± 800	2702 ± 757
Range	1382, 3831	1796, 3974	1382, 3974
Mean coefficient of variation in cell size	30.0	29.8	29.9
Mean % hexagonal cells	61.7	65.9	63.8

ECD = endothelial cell density

once on the qualitatively best image using IMAGEnet 2000 software (Topcon Corp.). The software automatically denoted the cell borders. Before endothelial cell parameters were computed, an examiner (M.L.S) fully trained in the technique interactively corrected errors in cell border imaging. The validity of such evaluation using the combined specular microscope and software has been reported.[8] Analysis of at least 75 cells per image is needed for accurate estimates of the ECD when assessing the corneal endothelium by noncontact specular microscopy.[9]

The central corneal thickness (CCT) was measured with the same specular microscope.

Statistical Analysis

Statistical analysis was limited because of the small number of patients. Results are reported as the mean ± SD. The results were compared with data in the literature.

RESULTS

Patient Characteristics

Between 1991 and 1999, 14 children had bilateral congenital or juvenile cataract extraction and aphakic IOL implantation. Four children were excluded from the study because endothelial photographs could not be taken due to nystagmus (2 patients) or psychomotor retardation (2 patients). All 8 eyes of the 4 children had a clear cornea at the last follow-up visit. The remaining 10 patients (20 eyes) were included in this study. The ethnicity was white in 7 patients and part white or not known in 3 patients. Table 1 shows the patients' characteristic.

One patient had X-linked Nance-Horan syndrome, characterized by the association of congenital cataract

Table 3. Clinical outcomes at last follow-up.

	ECD (Cells/mm^2)		CCT (mm)			FU (Y)		
Pt	OD	OS	OD	OS	Age (Y)	OD	OS	Complications
1	2538	2272	545	548	19.2	12.0	11.1	—
2	1382	2385	562	561	22.1	15.6	13.5	OD: Traumatic IOL dislocation 2× (10 & 12 y after IOL implant)
3	1863	1796	500	486	26.6	15.5	15.5	—
4	2126	2187	437	453	22.0	12.9	13.4	—
5	2322	2380	492	488	18.6	11.9	11.1	OD: blunt trauma (football) 8 y after IOL implant; no dislocation
6	3323	2835	510	495	17.5	11.5	11.2	OD: blunt trauma (football) 10 y after IOL implant; no dislocation; pigment on endothelium
7	3279	3769	540	557	22.0	13.3	13.3	—
8	3040	3859	558	609	16.7	10.8	10.8	—
9	3831	3974	659	633	14.3	10.0	10.0	—
10*	2639	2227	619	660	17.4	11.2	11.0	—

CCT = central corneal thickness; CDVA = corrected distance visual acuity (spectacle); ECD = endothelial cell density; EP = Elschnig pearls; FU = follow-up; IOL = intraocular lens.LE = lens extraction; OD = right eye; OS = left eye; OU = both eyes; Pt = patient; YAG = neodymium:YAG laser capsulotomy
*Nance Horan syndrome

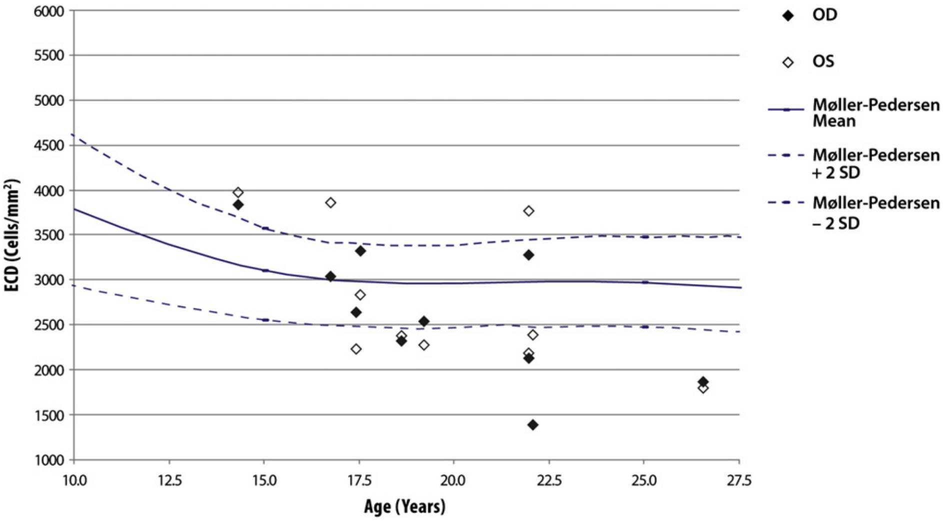

Figure 1. Individual ECDs of the 20 study eyes. Curve created from data of Møller-Pedersen[13] (OD = right eye; OS = left eye).

with microcornea, dental abnormalities, and facial dimorphism. At the time at of the IOL implantation, the corneal diameter was 10.0 mm in the right eye and 11.0 mm in the left eye and the AL was 20.2 mm and 21.0 mm, respectively.

Planned anterior vitrectomy was performed 3 eyes. Eight eyes had surgical removal of Elschnig pearls. The aphakic refractive error before secondary aphakic IOL implantation was corrected with aphakic glasses in 3 patients and with contact lenses in 1 patient.

In 9 patients (18 eyes), the aphakic IOL had a 5.0 mm optic diameter and 8.5 mm overall diameter. In the 2 eyes of the patient with Nance-Horan syndrome, the aphakic IOL had a 4.0 mm optic diameter and 7.4 mm overall diameter. The target refraction ranged from slight myopia to + 3.75 D depending on the child's age at the time of the surgery.

Table 3. (Cont.)

Additional surgery	IOL claw	CDVA OD	CDVA OD
OU: EP aspiration EP (OS 2×), YAG; OS: claw (earring) reposition during EP aspiration	Earring nasal OS	20/50	20/25
OD: IOL reposition 2×, YAG	—	20/200	20/30
OS: YAG	—	20/25	20/25
OU: EP aspiration, YAG	—	20/25	20/25
OS: EP aspiration; OU: YAG	—	25/20	20/20
OS: YAG	Earring temporal OD	20/25	20/20
OU: LE before secondary IOL, YAG; OD: EP aspiration 2× before secondary IOL	Earring temporal OD	20/60	20/30
OU: LE before secondary IOL	—	20/60	20/40
OU: LE and EP aspiration before secondary IOL	Earring nasal OS	20/40	20/30
OU: LE before secondary IOL	—	20/40	20/30

Endothelial Cell Density and Central Corneal Thickness

The mean endothelial cell count (ECC) per image in the 20 study eyes was 184 cells (range 95 to 273 cells per image). Table 2 shows the mean ECD at the last follow-up as well as the coefficient of variation in cell size and percentage of hexagonal cells.

Table 3 shows the corneal ECD and the CCT by individual eye. Figure 1 shows the individual corneal ECD in all 20 eyes by patient age. Supplement A (available at www.jcrsjournal.org) shows the nonparametric variables.

Clinical Outcomes

A neodymium:YAG (Nd:YAG) laser capsulotomy was performed for posterior capsule opacification in 11 eyes during the follow-up. All patients had a clear cornea and a clear visual axis at the last follow-up. Table 3 shows the corrected distance visual acuity (CDVA), complications, details about the IOL claws, and additional intraocular surgery.

Four of the 40 claws of the IOLs eroded through the bridge of iris tissue, resulting in a closed claw that had pierced through the anterior iris stroma (ie, earring claw) (Figure 2). In 1 patient, the claw was surgically repositioned during surgery for Elschnig pearl aspiration. In the other 3 cases, repositioning the claw was not necessary because the IOL optic was well centered, there was minimal or no IOL movement, and the anterior chamber was clear. None of the claws dislocated further.

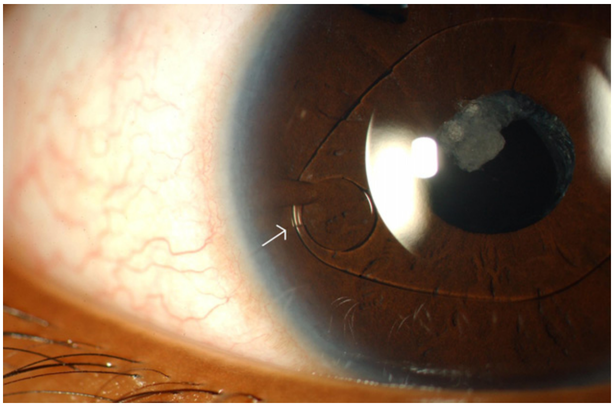

Figure 2. Earring claw (*arrow*) in patient 7. Elschnig pearls are present at 11 o'clock after 2 Elschnig pearl aspiration procedures and an Nd:YAG capsulotomy.

DISCUSSION

Shortly after birth, the human cornea has approximately 6000 endothelial cells per square millimeter of posterior corneal surface. This number decreases rapidly during infancy.[10] The literature[11,12] reports that the normal ECD ranges from 3160 to 3727 cells/mm^2 at a mean age of 7.5 years of age and from 2695 to 3342 cells/mm^2 at a mean age of 13.0 years of age. One study[13] measured a mean ECD of 3110 cells/mm^2 in the second decade in normal donor corneas. A normal ECD ranging from 2407 to 2977 cells/mm^2 (mean 2692 cells/mm^2) in the third decade of life are found in normal human eyes in different populations.[14]

One concern about iris-claw IOLs, including the Artisan, is the possible long-term negative effect on the corneal ECD. Children have a long mean life expectancy. Long-term follow-up of the corneal endothelium is therefore of great importance.

Lifshitz et al.[4] found no significant difference in ECD between the operated eye and the unoperated eye in 2 children after lens extraction and Artisan aphakic IOL implantation for subluxated crystalline lenses after 8 months of follow-up. Our group also found no significant difference in a study of pediatric patients after unilateral cataract extraction and Artisan aphakic IOL implantation after a mean follow-up of 9.5 years.[5]

Studies of the corneal endothelium in human donor corneas[15–17] indicate that corneal endothelial cells in younger donor eyes have a higher proliferative capacity than older human corneal endothelial cells. This might explain for the limited endothelial cell loss in studies by Lifshitz et al.[4] and Odenthal et al.[5]

In the current study, the mean ECD (2702 cells/mm^2) last the follow-up (mean age 19.6 years) was comparable to the mean normal ECD in this age group reported in the literature.[11–14] Yet, there was a large range in ECD in our patients. The curve in Figure 1 represents the mean ECD as a function of age in healthy eyes without surgery and was created to allow a comparison of our data with the mean ECD data from normal corneas in the same age group by Møller-Pedersen.[13] Møller-Pedersen performed manual cell counts on photographs of the central corneal endothelium of donor corneas; the photographs were taken through a light microscope after alizarin red staining. They report data from 98 corneas of donors ranging in age from 30 weeks of gestation to 90 years of age. Preferably, our noncontact specular microscopy data would be compared with other available noncontact specular microscopy data. However, studies that provide data on noncontact specular microscopy in young patients describe groups of patients up to 15 years of age.[11,12] Because only 1 of our patients was younger then 15 years at the last follow-up, the outcomes in these studies are not shown in Figure 1.

Although earlier studies describe large ranges of interindividual ECDs,[11–13] the SD usually falls within 350 cells/mm^2 in the second decade of life and within 400 cells/mm^2 in the third decade of life. The SD in the current study was close to 800 cells/mm^2. However, the literature reports values for healthy, unoperated eyes. In a prospective study, Basti et al.[18] report the endothelial cell loss after cataract surgery in 20 eyes of 14 children with congenital or developmental cataract and posterior chamber IOL implantation. The mean age of their patients at surgery was 9.3 years. Endothelial images taken with a noncontact specular microscope were analyzed using the semiautomated cell analysis software program of the IMAGEnet digital imaging system. The postoperative ECD had an SD of 427 cells/mm^2 in a subgroup without anterior vitrectomy and 400 cells/mm^2 in a subgroup with anterior vitrectomy after a follow-up of 36 weeks. Odenthal et al.[5] report 3 unilateral cataract patients who had implantation of an Artisan aphakic IOL; the SD of the ECD at a mean age of 19.0 years (range 18.1 to 20.5 years) was 205 cells/mm^2 in unoperated eyes and 410 cells/mm^2 in operated eyes after a mean follow-up of 9.5 years (range 4.7 to 14.5 years). Lifshitz et al.[4] describe 2 eyes operated on for crystalline lens subluxation that had Artisan aphakic IOL implantation. After a mean follow-up of 6.5 months (range 1 to 9 months) at a mean age of 7.9 years (range 4.8 to 12.5 years), the mean SD of the ECD was 79 cells/mm^2.

The high SD in our study encouraged us to look for variables in the clinical course to explain this wide variation. One eye in our series (right eye, patient 2) had a marked decreased ECD (1382 cells/mm^2) when the patient was 22.1 years old. The fellow left eye had an ECD of 2385 cells/mm^2 (Figure 3, *A* and *B*). In the right eye, the temporal claw of the aphakic IOL dislocated 2 times as a result of blunt trauma that occurred 10 years and 12 years after IOL implantation. Because the patient did not present immediately after the first dislocation, the IOL remained dislocated for 2 weeks. At the first examination after the 2 weeks, there was no endothelial touch. During examination, the patient was in an upright position and it is likely that endothelial touch was present when he was supine, such as when sleeping.

In patient 3, the oldest patient with the longest follow-up, the ECD in both eyes was lower than 2000 cells/mm^2 at the age of 26.6 years after a follow-up of 15.5 years. The lower than expected ECD in this patient cannot be explained by findings in the medical history, such as additional intraocular surgery, the preoperative ACD, or complications. Both eyes had a CDVA of 20/25 and a CCT less than 500 μm at the last follow-up visit.

In 4 eyes (patient 7 left eye, patient 8 left eye, patient 9 both eyes (Figure 3, *C* and *D*), we found a higher then expected ECD (above 2.00 SD,). All 4 eyes had secondary Artisan IOL implantation after earlier intraocular surgery for the cataract extraction at a very young age. Müller and Doughty[11] found that ECD values in children are significantly correlated with the corneal diameter and they advise taking the corneal diameter in consideration when unexplained ECD values are encountered. No information about the corneal diameter was available for these 3 patients. The mean AL in the 4 eyes with a high ECD was 23.5 mm (range 22.0 mm to 25.1 mm) at last follow-up visit.

In a study of contact lens wearers, Doughty et al.[19] noted a correlation between the change in ECD values and the change in CCT. As CCT decreased, the apparent ECD decreased. We calculated the correlation coefficient of the CCT and ECD values in our patients using the Spearman nonparametric correlation test. Although we found no significant correlation

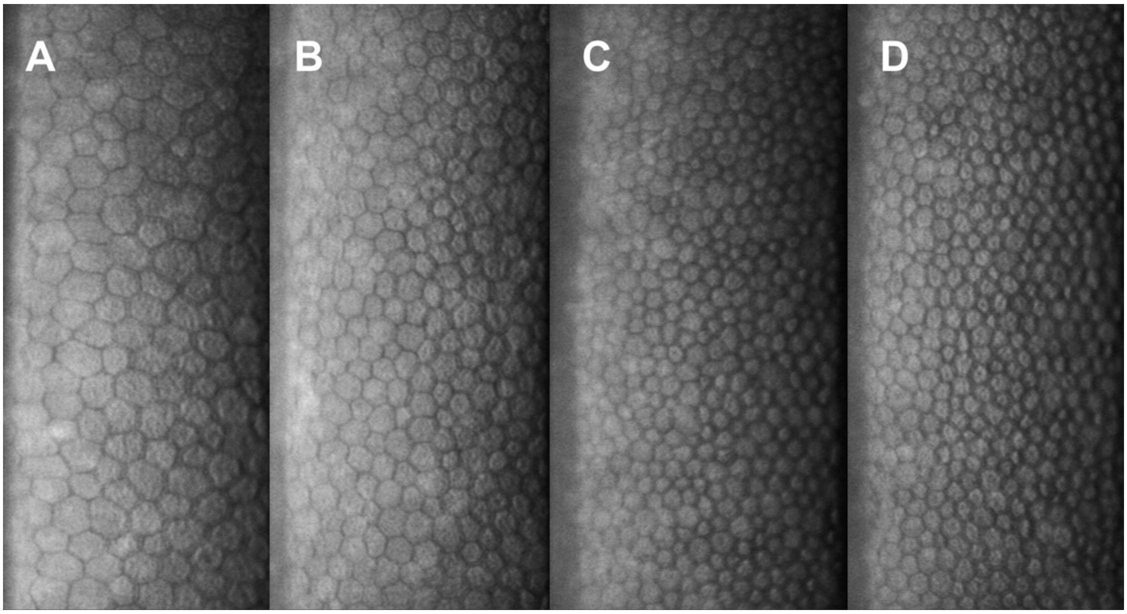

Figure 3. Endothelial cell photographs of both eyes of patient 2 (*A* and *B*) and patient 9 (*C* and *D*).

($P = .28$), there was a trend toward an increasing ECD with an increasing CCT in our patients.

Blunt trauma without IOL dislocation occurred in 2 eyes. The ECC was slightly lower than in the eye in 1 patient but was 500 cells higher than to the other eye in the second patient. Blunt trauma without IOL dislocation did not seem to cause additional cell loss in our series; nevertheless, we advise our patients to wear protective glasses during contact sports and activities to prevent traumatic IOL dislocation.

In 4 eyes, an IOL claw was attached to the iris like an earring. This complication is sometimes seen with the Artisan aphakic IOL; on slitlamp biomicroscopy, the earring claw seems less rigidly fixated than claws attached to a bridge of iris tissue and are usually situated slightly lower than the opposite claw. Because of the small number of eyes with an earring claw and the additional intraocular surgery in some of the eyes, it is hard to make conclusions about the additional cell loss caused by a claw that is attached like an earring; however, the effect seems to be limited. We do not believe it is necessary to reposition earring claws when the optic is well centered and when there is little or no IOL movement.

We found high variability in the ECD. Baseline and serial ECCs might have given an insight into the cause of the large differences between our patients; unfortunately, this information was not available. Future endothelial cell measurements and close follow-up of our patients is important to monitor the ECD into adulthood.

In conclusion, we describe the encouraging long-term clinical outcomes in 20 eyes of 10 patients after Artisan aphakic IOL implantation for congenital or juvenile cataract. The mean corneal ECD at last follow-up was comparable to the mean normal ECD in this age group reported in the literature. The high SD of the mean ECD in our study highlights the importance of prospective studies of corneal endothelium outcomes after Artisan aphakic IOL implantation in young patients.

REFERENCES

1. Wilson ME, Bluestein EC, Wang XH. Current trends in the use of intraocular lenses in children. J Cataract Refract Surg 1994; 20:579–583
2. Wilson ME, Trivedi RH. Choice of intraocular lens for pediatric cataract surgery: survey of AAPOS members. J Cataract Refract Surg 2007; 33:1666–1668
3. van der Pol BAE, Worst JGF. Iris-claw intraocular lenses in children. Doc Ophthalmol 1996-1997; 92:29–35
4. Lifshitz T, Levy J, Klemperer I. Artisan aphakic intraocular lens in children with subluxated crystalline lenses. J Cataract Refract Surg 2004; 30:1977–1981
5. Odenthal MTP, Sminia ML, Prick LJJM, Gortzak-Moorstein N, Völker-Dieben HJ. Long-term follow-up of the corneal endothelium after Artisan lens implantation for unilateral traumatic and unilateral congenital cataract in children; two case series. Cornea 2006; 25:1173–1177
6. Sminia ML, Odenthal MTP, Wenniger-Prick LJJM, Gortzak-Moorstein N, Völker-Dieben HJ. Traumatic pediatric cataract: a decade of follow-up after Artisan® aphakia intraocular lens implantation. J AAPOS 2007; 11:555–558
7. Aspiotis M, Asproudis I, Stefaniotou M, Gorezis S, Psilas K. Artisan aphakic intraocular lens implantation in cases of subluxated crystalline lenses due to Marfan syndrome. J Refract Surg 2006; 22:99–101
8. van Schaick W, van Dooren BTH, Mulder PGH, Völker-Dieben HJM. Validity of endothelial cell analysis methods and recommendations for calibration in Topcon SP-2000P specular microscopy. Cornea 2005; 24:538–544
9. Doughty MJ, Müller A, Zaman ML. Assessment of the reliability of human corneal endothelial cell-density estimates using a noncontact specular microscope. Cornea 2000; 19:148–158
10. Bahn CF, Glassman RM, MacCallum DK, Lillie JH, Meyer RF, Robinson BJ, Rich NM. Postnatal development of corneal endothelium. Invest Ophthalmol Vis Sci 1986; 27:44–51. Available at: http://www.iovs.org/content/27/1/44.full.pdf. Accessed December 27, 2010
11. Müller A, Doughty MJ. Assessments of corneal endothelial cell density in growing children and its relationship to horizontal corneal diameter. Optom Vis Sci 2002; 79:762–770. Available at: http://journals.lww.com/optvissci/Fulltext/2002/12000/Assessments_of_Corneal_Endothelial_Cell_Density_in.8.aspx. Accessed December 27, 2010
12. Nucci P, Brancato R, Mets MB, Shevell SK. Normal endothelial cell density range in childhood. Arch Ophthalmol 1990; 108:247–248. Available at: http://archopht.ama-assn.org/cgi/reprint/108/2/247. Accessed December 27, 2010
13. Møller-Pedersen T. A comparative study of human corneal keratocyte and endothelial cell density during aging. Cornea 1997; 16:333–338
14. Hashemian MN, Moghimi S, Fard MA, Fallah MR, Mansouri MR. Corneal endothelial cell density and morphology in normal Iranian eyes. BMC Ophthalmol 2006; 6:9. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1456995/pdf/1471-2415-6-9.pdf. Accessed December 27, 2010
15. Joyce NC. Proliferative capacity of the corneal endothelium. Prog Retin Eye Res 2003; 22:359–389
16. Kikuchi M, Zhu C, Senoo T, Obara Y, Joyce NC. p27kip1 siRNA induces proliferation in corneal endothelial cells from young but not older donors. Invest Ophthalmol Vis Sci 2006; 47:4803–4809. Available at: http://www.iovs.org/content/47/11/4803.full.pdf. Accessed December 27, 2010
17. Mimura T, Joyce NC. Replication competence and senescence in central and peripheral human corneal endothelium. Invest Ophthalmol Vis Sci 2006; 47:1387–1396. Available at: http://www.iovs.org/content/47/4/1387.full.pdf+html. Accessed December 27, 2010
18. Basti S, Aasuri MK, Reddy S, Rao GN. Prospective evaluation of corneal endothelial cell loss after pediatric cataract surgery. J Cataract Refract Surg 1998; 24:1469–1473
19. Doughty MJ, Aakre BM, Ystenaes AE, Svarverud E. Short-term adaptation of the human corneal endothelium to continuous wear of silicone hydrogel (lotrafilcon A) contact lenses after daily hydrogel lens wear. Optom Vis Sci 2005; 82:473–480. Available at: http://journals.lww.com/optvissci/Fulltext/2005/06000/Hypoxic_Effects_on_the_Anterior_Eye_of_High_Dk.10.aspx. Accessed December 27, 2010

First author:
Marije L. Sminia, MD

Department of Ophthalmology, Academic Medical Centre, Amsterdam, The Netherlands