Case Report

Cataract Surgery with a New Fluidics Control Phacoemulsification System in Nanophthalmic Eyes

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Abstract

Purpose: To report visual outcomes and complications after cataract surgery in nanophthalmic eyes with a phacoemulsification system using the active fluidics control strategy. **Methods:** This is a retrospective case series. All eyes with an axial length of less than 20 mm that underwent cataract surgery or refractive lens exchange using the Centurion Vision System (Alcon Laboratories Inc.) in Hong Kong Sanatorium and Hospital were evaluated. The visual acuity and intraoperative and postoperative complications were reported. Prior approval from the Hospital Research Committee has been granted. **Results:** Five eyes of 3 patients were included. The mean follow-up period was 10.2 ± 5.3 months (range, 4–18). Two eyes (40%) had a one-line loss of corrected distance visual acuity. No uveal effusion and posterior capsular tear developed. An optic crack and haptic breakage in the intraocular lens developed in 1 eye (20%) and 2 eyes (40%), respectively. Additional surgeries to treat high postoperative intraocular pressure were required in 1 eye (20%). **Conclusion:** The use of a new phacoemulsification system, which actively monitors and maintains the intraoperative pres-

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sure, facilitated anterior chamber stability during cataract surgery in nanophthalmic eyes. This minimized the risk of major complications related to unstable anterior chambers such as uveal effusion and posterior capsular tear. Development of intraoperative crack/breakage in a high-power intraocular lens was common.

Introduction

Nanophthalmos is a rare condition characterized by a small globe with short axial length (AL) and no ocular malformation [1–8]. Typical features of nanophthalmic eyes include thickened sclera [6–8], high hyperopia [2, 4, 6–8], a proportionally very shallow anterior chamber (AC) [1, 3, 4, 6, 7], and narrow AC angle [1, 4, 6, 8]. Cataract surgery is challenging in these eyes because of the small working space, which increases the risk of damaging the intraocular tissues [3, 5]; uveal effusion may occur more easily because of the inherent scleral properties [2, 5, 9]. To avoid these complications, maintaining a stable AC intraoperatively is critical [7].

The Centurion Vision System (Alcon Laboratories Inc.) is a new phacoemulsification system that actively monitors and maintains a constant pressure change in the eye during cataract surgery. A recent laboratory study reported that this system effectively reduces post-occlusion surge [10]. In the current study, we evaluated the safety of performing cataract surgery in nanophthalmic eyes with this system followed by implantation of a single high-power intraocular lens (IOL).

Methods

This retrospective, observational case series included nanophthalmic eyes defined as having an AL of <20 mm [4, 7] without ocular malformation [2, 6] that underwent cataract surgery or refractive lens exchange with the Centurion Vision System and implantation of the aspira-aA IOL (HumanOptics AG) between July 2013 and December 2014 at the Hong Kong Sanatorium and Hospital. Ethical approval was obtained from the hospital.

All eyes underwent a comprehensive eye examination preoperatively. The keratometry was obtained by a manual keratometer. The IOLMaster (Carl Zeiss Meditec AG) was used to acquire the AL and AC depth for IOL power calculation using the Hoffer-Q formula (personalized A-constant, 118.7). All patients were informed about the increased risk of refractive surprise and complications due to the small eyes.

The same surgeon (J.S.M.C.) performed all surgeries. Preoperatively, intravenous mannitol was administered to lower the intraocular pressure (IOP) in 3 eyes (both eyes, patient 1; and right eye, patient 3). A 2.2-/2.75-mm temporal/superior clear corneal incision was created with a keratome. Healon GV Ophthalmic Viscosurgical Device (OVD) (Abbott Medical Optics Inc.) was injected into the AC. A continuous curvilinear capsulorhexis was created. After hydrodissection and nucleus spitting, coaxial phacoemulsification was performed using the Centurion Vision System. The Active Fluidics strategy was selected to improve the stability of the surgical environment. A target IOP of 60 mm Hg, equivalent to a bottle height

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220

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Chang et al.: Cataract Surgery with a New Fluidics Control Phacoemulsification System in Nanophthalmic Eyes

of 72 cm of water, was chosen to balance patient comfort and irrigation pressure. An irrigation factor of 1.2 (an increase of pressure on the balanced salt solution [BSS] bag by 20% more than the intended IOP) was used intraoperatively to compensate for the increased posterior pressure in the nanophthalmic eyes. Irrigation and aspiration of the residual cortex and posterior capsular (PC) polishing were performed with coaxial technique using the same phacoemulsification system. The IOL was loaded and injected into the capsular bag. At the end of surgery, a surgical peripheral iridotomy was performed in 2 eyes (left eye, patient 1; and right eye, patient 3). All incisions were hydrated and intracameral moxifloxacin (Vigamox; Alcon Laboratories Inc.) was administered. The postoperative medications included topical neomycin and polymyxin B sulfates and dexamethasone ophthalmic ointment (Maxitrol; Alcon Laboratories Inc.), 0.1% nepafenac ophthalmic suspension (Nevanac; Alcon Laboratories Inc.), 1% prednisolone acetate ophthalmic suspension (Econopred Plus; Alcon Laboratories Inc.), and 0.5% moxifloxacin hydrochroide ophthalmic solution (Vigamox; Alcon Laboratories Inc.) for the operated eye. Postoperatively, prophylactic pressure lowering topical medication was not used.

In 1 patient (patient 1), the small pupil of the left eye was stretched first with injection of OVD and then manually with a Sinskey Hook (Bausch & Lomb) to release the posterior synechiae before the continuous curvilinear capsulorhexis was created. Five 1-mm self-sealing paracenteses were created followed by insertion of 5 iris retractors (Alcon Laboratories Inc.) to mechanically dilate the pupil. The leakage compensation was set at 10 ml/min to allow for extra loss of fluid at the 5 leaking incisions intraoperatively. At the end of surgery, the iris retractors were withdrawn. In the right eye of the same patient, a Malyugin ring (Microsurgical Technology) was implanted first to mechanically dilate the small pupil. Manipulation of the Malyugin ring was difficult due to the shallow AC and bulging anterior lens capsule. Trypan blue stain was applied to aid visualization of the anterior lens capsule while implanting the Malyugin ring and creating the continuous curvilinear capsulorhexis. The Malyugin ring was withdrawn at the end of surgery.

Results

Table 1 shows the demographics of the 3 patients (5 eyes) and the preoperative ocular findings.

Visual Acuity and Refraction
Table 2 shows the postoperative uncorrected and corrected distance visual acuities. Two eyes (40%) had a one-line loss in corrected distance visual acuity. Table 2 shows the postoperative manifest refractions.

Table 2 also shows the IOL powers and predictability of the postoperative refraction using different IOL formulas. Back-calculation showed that 3 (60%), 2 (40%), and 0 eyes (0%) achieved a manifest refraction spherical equivalent from the target refraction of within 0.50 D using the Hoffer-Q, Haigis, and SRK/T formulas, respectively.

Intraoperative Complications

The AC remained stable and hardly any posterior pressure was experienced in any eyes intraoperatively. No uveal effusion or PC tear developed.

Optic crack was found in 1 eye (left eye, patient 1) (20%) when unfolding the IOL in the eye. No intervention was required because the crack occurred at the periphery of the IOL optic and did not affect the implantation. The patient was asymptomatic postoperatively.

Haptic breakage at the junction between the optic and haptic was found in 2 eyes (right eye, patients 1 and 3) (40%) when unfolding the IOL in the eye. In the former case, the haptic broke partially but did not come off the IOL. However, the IOL (+55 D) was too thick to be folded and cut for removal and therefore was explanted through an enlarged 6-mm incision and a new IOL was implanted in the capsular bag. In this eye, a capsular tension ring (type-14C; Morcher GmbH) was implanted in the capsular bag after IOL implantation. During incision suturing, iris prolapse occurred and the iris was pushed back into the AC by injecting OVD. In the latter case, one haptic was missing and was found in the cartridge injection system. The optic of the IOL (+41 D) was cut partially and the IOL was folded and removed through an enlarged 3-mm incision. No suturing was required.

Postoperative Complications

Table 2 shows the postoperative complications. No uveal effusion or retinal detachments developed postoperatively in any eyes. The IOP value in any eyes were 21 mm Hg or lower at all follow-up visits after 1 month. All ACs and IOLs were unremarkable at the last visit.

In 1 eye (right eye, patient 1) (20%), additional surgeries were performed because of an IOP of 27.3 mm Hg at postoperative day 1. After fluid release from the AC, the IOP remained high (24 mm Hg). Since the AC was very shallow, aqueous misdirection was suspected. Intravenous mannitol and topical antiglaucoma medications were administered, but this was unsuccessful. Therefore, vitreous tapping with a 30-guage needle through the pars plana with injection of air bubbles into the AC were performed to deepen the AC. At postoperative day 3, iris repositioning and re-suturing of incisions were performed. Diffuse macula edema was present in both eyes of this patient at the last visit. The IOP was 10 mm Hg in both eyes.

Discussion

Cataract surgery in nanophthalmic eyes differs from normal eyes because of the decreased intraocular space, increased risk of intraoperative complications, and decreased accuracy in IOL power prediction. Implantation of a single high-power IOL in the capsular bag [2–9, 11] and piggybacking IOLs in the capsular bag [12] or in both the capsular bag and ciliary sulcus [1, 12] have been commonly attempted in small eyes. In the current study, we implanted a single high-power IOL in the capsular bag in nanophthalmic eyes with an AL of <20 mm without major complications.

The current patients had a few characteristics that increased the difficulties during cataract surgery. First, the very shallow AC (range, 1.94–2.27 mm) increased the risk of damaging the corneal endothelium intraoperatively. Healon GV, a cohesive, highly viscous OVD, was therefore injected to create and maintain the AC during capsulorhexis and IOL insertion.

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A recent meta-analysis [13] that compared the protective effects of different OVDs on the corneal endothelium intraoperatively reported that viscoadaptives and a soft-shell technique performed the best; however, superviscous cohesive OVDs, e.g., Healon GV, is still superior to dispersive OVDs.

Second, the pupils of patient 1 were small and could not be dilated because of posterior synechiae. Malyugin ring can be used for mechanical pupillary dilation during cataract surgery in eyes with small pupil and deep AC. However, during the first-eye surgery, the Healon GV injected was forced out of the eye by the high posterior pressure [7, 8]. There was insufficient space to place the Malyugin ring in the eye. The excessive anterior iris bulging also made the peripheral AC insufficiently deep for implantation. To avoid touching the corneal endothelium in eyes with a shallow AC, more downward force than usual had to be applied to the Malyugin ring to capture the iris, but this can increase the risk of anterior capsular tear and subsequent development of a radial tear. We instead used iris retractors, but this resulted in 5 partially leaking wounds. This potentially made the already shallow AC even more difficult to maintain during phacoemulsification. The Centurion Vision System that we used allows surgeons to customize the estimated leakage compensation with different incision sizes and numbers. In the current case, we set it at 10 ml/min to compensate for the extra fluid loss from the 5 paracenteses. In the second-eye surgery of the same patient, although the AC was shallow, it had less posterior pressure and a Malyugin ring was used.

Maintaining a stable IOP intraoperatively is critical to prevent major complications such as uveal effusion [9] and PC tear [7] in nanophthalmic eyes. The reported rates of uveal effusion and PC tear in nanophthalmic eyes were up to 9.3% [2, 3, 5, 7, 8] and 11.7% [2, 3, 5, 7, 8], respectively. Intravenous mannitol is often administered preoperatively to lower the vitreous pressure prophylactically to decrease the posterior pressure [1, 3, 5–7, 9]. When the phacoemulsification tip becomes occluded by a nuclear fragment, the vacuum increases. Once the occlusion breaks, the surge can lead to a sudden decrease in IOP and ocular collapse. Maintaining a higher bottle height increases infusion pressure, therefore making the AC more stable [7]. During surgeries performed in small eyes, we used to employ the Infiniti Vision System (Alcon Laboratories Inc.) and raised the infusion bottle to the highest level (110 cm), corresponding to an IOP of about 80 mm Hg to control surge. The downside is that patients are less comfortable. The AC is maintained passively and the response to pressure change is slow. The IOP fluctuates a lot and the frequently lowered IOP increases the risk of uveal effusion and PC tear.

In the current patients with shallow ACs, the Centurion responded to AC change more rapidly. The Active Fluidics strategy of the system actively monitors pressure changes with the built-in pressure sensors in the phacoemulsification cassette and responds by compressing/decompressing the BSS bag with 2 metallic plates. Hence, the system compensates for any IOP sudden changes in a timely manner (100 ms) (e-mail communication with Alcon Laboratories Inc., 2014), minimizes the surge volume, and ensures that the IOP returns to preocclusion status. Therefore, a lower target pressure of 60 mm Hg, which is predetermined by the surgeon, can be maintained to increase patient comfort and decreases the risk of postocclusion surge. A recent laboratory study [10] that compared the surge performance between the Infiniti Vision System (gravity-based fluidics) and the Centurion (Active Fluidics) found that the latter had less surge in the vacuum limit range of 200–600 mm Hg than the former.

Chang et al.: Cataract Surgery with a New Fluidics Control Phacoemulsification System in Nanophthalmic Eyes

The Active Fluidics strategy has an extra feature, the irrigation factor, in the infusion setting to increase the pressure on the BSS bag to maintain the AC stability. Since the infusion resistance is inversely proportional to the size of the phacoemulsification sleeve and incision size, higher resistance leads to a greater pressure decrease when switching the aspiration pump from off to on, because the outflow is greater than the inflow. The irrigation factor can be adjusted intraoperatively until no fluctuation in posterior capsule is seen. In the current cases, we used a value of 1.2 and found a very stable AC and the posterior capsule did not move forward.

With the use of all these features in this system, the ACs in the current study were much more stable using a target IOP of 50–60 mm Hg and there was no evidence of posterior pressure at any time, despite the 5 leaking wounds at the sites of the iris retractors. This differs from our previous experience with the passive, gravity-based system. The current surgeries were essentially performed as if the eyes had an AL of 24 mm.

A complication associated with implanting a single high-power IOL is the higher incidence of IOL breakage. The current study had a much higher rate of breakage of the IOL haptics compared to previous studies (range, 1.0–8.3%) [2, 3, 6]. Another IOL had a crack at the optic edge that possibly occurred during IOL injection. We postulated that this occurred because of the substantially thicker optic and the increased effort expended to push the IOL within the cartridge injection system. When haptic breaks, it is not always possible to refold and cut the IOL to remove it. Incision enlargement may be required to remove the IOL, thus increasing the risk of uveal effusion and iris prolapse. We suggest using a thicker OVD, e.g., Healon GV and Healon 5 (Abbott Medical Optics Inc.), with slow, small, intermittent pushing of the IOL in the cartridge, allowing time for the bulky haptic and optic to adapt to the tight cartridge tunnel.

A single high-power IOL was implanted in all current eyes, which is advantageous over piggybacking IOLs in short eyes in that it prevents interlenticular opacification [1, 12]. In extremely short eyes, the capsular bag may be too small to accommodate 2 IOLs [2]. However, placing 1 IOL in the capsular bag and the second IOL in the ciliary sulcus [1, 12] can result in iris chafing, recurrent iritis, and pigment dispersion syndrome [14]. It was particularly important in 1 of the current patients with posterior synechiae, which may indicate previous iritic episodes.

Predicting the IOL power in nanophthalmic eyes is more difficult than in normal eyes. Although the assumption of proportionality between the AC depth and AL still holds in nanophthalmic eyes [1, 3], when a high-power IOL was used, even a small axial malposition can lead to a substantial refractive error [8, 11]. The Hoffer-Q formula has been generally recommended for IOL power calculations in short eyes to better predict the postoperative refraction [1]. Two studies [11, 15] have reported that the performances of IOL formulas (Haigis, Hoffer-Q, Holladay-1, Holladay-2, and SRK/T) in short eyes were similar after optimization of the IOL constant. Nevertheless, we found that the Hoffer-Q formula generally provided the least hyperopic error, except in patient 1, who had a very short AL of approximately 16 mm and an average keratometry of >50 D bilaterally. Since we did not have a sufficiently large sample size for IOL constant optimization for short eyes, we warned the patients about the uncertainty of predicting the postoperative refraction and that monovision (targeting for –2 D for the first-eye surgery) might be helpful.

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224

Chang et al.: Cataract Surgery with a New Fluidics Control Phacoemulsification System in Nanophthalmic Eyes

In conclusion, we report the results of cataract surgery in nanophthalmic eyes using Active Fluidics technology in a new phacoemulsification system, which is designed to avoid the commonly reported unstable AC-related complications. One high-power IOL was implanted in the capsular bag, but there is an increased risk of development of intraoperative IOL cracks/breakage. Monovision can be offered to patients targeting myopia in the first eye to avoid excessive postoperative hyperopia.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Disclosure Statement

No authors have financial interests in any aspect of this report. Dr. Chang has received travel expenses from Abbott Medical Optics, Inc., Alcon Laboratories Inc., and Technolas Perfect Vision and lecture honorarium from Alcon Laboratories Inc. For the remaining authors none were declared.

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Table 1. Patient demographic data and preoperative ocular parameters and findings

Patient/eye	Gender	Age, years	AL, mm	ACD, mm	Average K (D)	WTW diameter, mm	Manifest refraction	CDVA	IOP, mm Hg	Slit-lamp findings
1/R	F	62	16.12	1.94	51.56	11.3	+8.75/+0.50×20	20/80^{-2}	13.3	Posterior synechiae, grade 3+ NS, small non-dilating pupil
1/L	F	62	16.04	1.97	52.06	11.4	+9.00/+0.50×125	20/150^{+2}	12.7	Posterior synechiae, grade 3+ NS, small non-dilating pupil
2/R	M	41	19.23	1.96	43.69	12.0	+8.50/+1.00×65	20/25^{+2}	20.0	Grade 2+ NS
2/L	M	41	19.22	1.99	43.13	12.1	+9.25	20/20^{-2}	18.7	Grade 2+ NS
3/R	F	52	19.11	2.27	44.38	11.1	+8.50/+0.75×100	20/40^{-1}	–	Grade 2+ NS

AL, axial length; ACD, anterior chamber depth; CDVA, corrected distance visual acuity; D, dioptre; IOP, intraocular pressure; K, keratometry; L, left; NS, nuclear sclerosis; R, right; WTW, white-to-white.

Table 2. Postoperative manifest refraction, visual acuities, complications, and prediction error from the target refraction using different IOL formulas

Patient/ eye	Follow-up, months	Manifest refraction	Manifest refraction spherical equivalent (D)	Uncorrected (corrected) distance VA	Postoperative complication	IOL power (D)	Prediction error from target refraction (D)[a]		
							Haigis	Hoffer-Q	SRK/T
1/R	12	−8.00/+1.00×170	−7.50	20/200 (20/100^{-2})	High IOP; diffuse macular edema	55.0	−1.15	−7.80	−0.81
1/L	18	−3.50/+2.50×95	−2.25	20/150 (20/150^{+1})	Diffuse macular edema	53.5	2.70	−3.85	3.00
2/R	4	−0.25/+0.75×90	0.13	20/30^{+2} (20/20^{-2})	–	39.0	0.83	0.43	2.08
2/L	7	−2.25/+0.50×10	−2.00	20/60^{+2} (20/25^{+2})	–	42.0	0.47	0.10	2.01
3/R	10	−2.75/+2.25×80	−1.63	20/30 (20/30^{+2})	–	41.0	0.50	0.18	2.85

D, dioptre; L, left; R, right; VA, visual acuity. [a] A positive value indicates hyperopic error and vice versa.