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Malaysian Journal of Ophthalmology

Volume 1 • Issue 4 • 2020

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Blue eyed Melanau boy by Dr. Oo Kok Tian, Registrar Department of Ophthalmology, University Sains Malaysia.

Malaysian Journal of Ophthalmology

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ISSN
Online: 2665-9565
Print: 2665-9557

Malaysia
Online: 2716-5329
Print: 2716-5248

Publisher

Malaysian Society of Ophthalmology
Unit #UG33, PJ Midtown, Jalan Kemajuan, Seksyen 13, 46200 Petaling Jaya, Selangor
admin@mso.org.my

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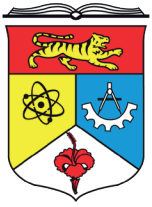

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Usage of aspheric IOL design: the way forward

Mohtar Ibrahim

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In general, surgery induces structural changes to tissues. These changes are permanent. The minimum change is scarring, and the maximum is very much dependent on the complexity of the surgery. The more delicate the tissue or organ, the more care is needed to minimize the changes that result from surgical interventions.

The eye is a delicate and intricate organ. It is a known fact that no matter how minimal an intervention on the eye there is an effect in terms of its visual function. This is due to the fact that any surgical intervention induces physical 'defects' in the form of scars. It also induces other effects, such as inflammation, especially if the surgical intervention involves intraocular tissue manipulation. In addition, implantation of artificial intraocular lenses (IOLs) adds more consequences to these issues.

Cataract surgery is probably the most common intraocular surgery performed worldwide. As this surgery involves intervention of many ocular tissues, albeit 'minimal', it is impossible to restore the eye to its normal state. According to Christopher Kent, Senior Editor of *Review of Ophthalmology,* there are at least 25 ways to maximize cataract surgery outcomes that include pre-, intra-, and postoperative steps and measures.[1] These suggestions include using a seven-variable IOL power calculation, an aspheric IOL, intraoperative aberrometry, and personalising the A-constant. It is also important that we 'individualise' every patient's precondition of the eye to predict the postoperative outcomes of cataract surgery.

In this modern and advanced era of cataract surgery, we cataract surgeons have to consider not only surgical techniques and IOL materials and design, we are also facing challenges in terms of increasing expectations on the part of patients for postoperative visual outcomes. Cataract surgery outcomes are no longer confined to improvement of distant and near visual acuity, but also other aspects of visual function, including contrast sensitivity and depth of focus. Improvement in contrast sensitivity is a function of 'restoring' the spherical aberration of the normal eye.[2]

Currently, there are many models of aspheric IOLs on the market, thanks to Bausch & Lomb who introduced the first aspheric IOL model in 2004.[3] These developments have spurred numerous studies around the globe. Using aspheric IOLs has nowadays become the gold standard in cataract management.

It is heartening to note that the study conducted locally by Mae-Lynn *et al.* — published in this issue of *Malaysian Journal of Ophthalmology* — has enlightened us on the outcomes of various IOLs that use aspheric principles. It is important to note, as I have stated earlier, that we have to cater to individual daily needs in managing every cataract patient, ensuring most of our pseudophakic patients are back to as near normal as possible.

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Malaysian Journal of Ophthalmology

Original article

Comparing the Lenstar Optical Biometer and the Verion Image-Guided System for intraocular lens power calculation

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Abstract

Introduction: This study aims to evaluate the accuracy of the measurement parameters of the new Verion Image Guided System compared with an established standard of care.
Purpose: To compare the keratometry (K) and white-to-white (WTW) measurements obtained from the Lenstar Optical Biometer (LS) with those from the Verion Image Guided System (VR) and their effect on intraocular lens (IOL) power calculation.
Design: Prospective comparative case series.
Materials and methods: Sixty patients going for cataract surgery had biometry measurements and IOL calculation with the LS. Axial length from LS was used together with K and WTW measurements from VR for IOL calculation as well. IOL selection was done using the Barrett Universal II formula targeting emmetropia. The prediction error (PE) within 0.25 D, 0.5 D, and 1 D of refractive target and the mean absolute error (MAE) were calculated for both the LS and VR.
Results: Keratometry measurements and steep axis from the VR were closely correlated with the LS (Pearson correlation coefficient K1, r = 0.958; K2, r = 0.952; axis, r = 0.950). The WTW measurements were less so (WTW, r = 0.471). The MAE was 0.317 and 0.347 for LS and VR, respectively. PE within 0.25 D was 48.3% and 40%; within 0.5 D was 83.3% and 76.7%; and within 1 D was 98.3% and 96.7% for LS and VR, respectively. There was no statistically significant difference in MAE between the LS and VR (p = 0.74)
Conclusion: Using the K and WTW measurements from the Verion Image Guided

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System for IOL power calculation did provide comparable results with the Lenstar. The Lenstar had a higher proportion of eyes within 0.5 D of refractive target but the difference was not statistically significant.

Keywords: biometry, intraocular lens power calculation, Lenstar Optical Biometer, Verion Image Guided system

Perbandingkan Biografi Optik Lenstar dan Sistem Berorientasi Imej Verion untuk pengiraan kuasa kanta intraokular

Abstrak

Pengenalan: Kajian ini bertujuan untuk menilai ketepatan parameter pengukuran Verion Image Guided System baru berbanding dengan standard penjagaan yang ditetapkan.
Tujuan: Untuk membandingkan pengukuran keratometri (K) dan putih ke putih (WTW) yang diperolehi dari Bistar Optical Lenstar (LS) dengan orang-orang dari Verion Image Guided System (VR) dan kesannya terhadap pengiraan kuasa intraokular (IOL).
Reka bentuk: Prospektif, perbandingan kes
Bahan dan kaedah: Enam puluh pesakit yang menjalani pembedahan katarak mempunyai pengukuran biometri dan pengiraan IOL dengan LS. Panjang paksi dari LS digunakan bersama dengan pengukuran K dan WTW dari VR untuk pengiraan IOL juga. Pemilihan IOL dilakukan menggunakan formula Barrett Universal II yang menyasarkan emmetropia. Kesalahan ramalan (PE) dalam 0.25 D, 0.5 D, dan 1 D dari sasaran refraktif dan ralat mutlak min (MAE) dikira untuk kedua-dua LS dan VR.
Keputusan: Pengukuran keratometri dan paksi curam dari VR dikaitkan rapat dengan LS (pekali korelasi Pearson K1, r = 0.958; K2, r = 0.952; paksi, r = 0.950). Pengukuran WTW kurang begitu (WTW, r = 0.471). MAE adalah 0.317 dan 0.347 untuk LS dan VR, masing-masing. PE dalam 0.25 D ialah 48.3% dan 40%; dalam lingkungan 0.5 D adalah 83.3% dan 76.7%; dan dalam tempoh 1 D adalah 98.3% dan 96.7% untuk LS dan VR. Tiada perbezaan statistik dalam MAE antara LS dan VR (p = 0.74)
Kesimpulan: Menggunakan pengukuran K dan WTW dari Verion Image Guided System untuk pengiraan kuasa IOL memberikan hasil yang setanding dengan Lenstar. Lenstar menunjukkan bilangan mata yang tinggi mengalami lingkungan refractive sekitar 0.5D dari sasaran refraktif tetapi perbezaannya tidak jauh berbeza.

Kata kunci: biometri, Biografi Optik Lenstar, pengiraan kuasa kanta intraokular, Verion Image Guided System

Introduction

In the current era of refractive cataract surgery, delivering on our promise of spectacle independence for our patients relies heavily on our ability to achieve the refractive target each time. We are fortunate now to have in our armamentarium a myriad of diagnostic tools that can help us achieve that target.[1,2]

The Verion Image Guided System (Alcon Laboratories Inc., Geneva, Switzerland) was recently introduced and its specifications have been described elsewhere.[3] This system can function as a cataract surgery planner and consists of a Reference Unit and a Digital Marker. The Reference Unit measures keratometry, limbus position and diameter, pupil position and diameter, but not anterior chamber depth or axial length. There is also a surgical planner that can localize corneal incisions, calculate intraocular lens (IOL) power as well as astigmatism management planning with limbal relaxing incisions, arcuate keratotomies or toric IOL calculation using its built-in Acrysof Toric Calculator. All this information is then transferred to the Digital Marker in the operating room, which is linked with an appropriate operating microscope to provide real-time intraoperative tracking of the eye. A digital overlay provides image guidance for corneal incisions, capsulorhexis, IOL centration, and IOL alignment in the cases of toric IOLs. Postoperatively, the Verion also has built-in software to calculate personalized 'A' constants, surgically induced astigmatism, and assess postoperative refractive outcomes.

The aim of our study was to compare the Lenstar biometer and the Verion system, specifically the keratometry (K) and white-to-white (WTW) measurements, and their effect on IOL power calculation in patients undergoing cataract surgery.

Materials and methods

This study was conducted in accordance to the Declaration of Helsinki for human research. This study cohort included patients listed for cataract surgery at a private eye centre in Ipoh, Malaysia. One eye of each patient was included in the study. All eyes had varying grades of cataract and underwent preoperative examination with the Lenstar as well as the Verion device. Exclusion criteria were other pre-existing ocular diseases and previous ocular surgery or injury.

All eyes were planned for implantation with a hydrophobic acrylic, aspheric monofocal IOL (Acrysof SN60WF from Alcon Laboratories Inc.) and the online Barrett Universal II formula was used to calculate the appropriate IOL power

targeting emmetropia. Each eye had one calculation using biometry measurements from the Lenstar device *i.e.* axial length (AXL), anterior chamber depth (ACD), lens thickness (LT), K readings, and WTW, while the second calculation was done using K readings and WTW from the Verion device with AXL, ACD and LT measurements from the Lenstar (as the Verion device did not provide these measurements). The target spherical equivalent (SE) for each calculation was noted.

Surgery was performed by a single surgeon and all eyes underwent routine uncomplicated phacoemulsification with a 2.2 mm temporal clear corneal incision. Postoperative refraction was carried out at one month and the prediction error (PE) was calculated by subtracting the target SE from the postoperative SE. PE within 0.25 D, 0.5 D and 1 D of target SE as well as the mean absolute error (MAE) were calculated for both Lenstar and Verion.

Statistical analysis was done using Graphpad Prism (Version 7.0) and intraclass correlation coefficient (ICC) was calculated to compare keratometry and WTW measurements between the Lenstar and Verion devices. Paired t-test was used and a p value of less than 0.05 was considered statistically significant when comparing accuracy of IOL prediction between Verion and Lenstar.

Results

Sixty eyes of 51 patients underwent cataract surgery. The mean age of patients was 68.05 ± 8.24 years (range: 48 to 85 years). Table 1 shows the measurements from the two devices, with the Verion device measuring larger values on average. The mean K1 readings were 44.30 D ± 1.50 and 44.13D ± 1.32 for the Verion and Lenstar, respectively and were well correlated (ICC = 0.958). The mean K2 readings were 45.20D ± 1.54 and 44.93 D ± 1.43 and were also well correlated (ICC = 0.952). The steep axis was moderately correlated (ICC = 0.669) and the WTW measurements were poorly correlated (ICC = 0.195) with the Verion on average, measuring larger values compared to the Lenstar.

Table 2 shows the comparison of PE between the Verion and the Lenstar. The mean arithmetic error (MArE) was calculated as an average of the difference between final SE and target SE (taking into account positive and negative values during subtraction), whereas the MAE was the average of the absolute difference between final SE and target SE. The Verion resulted in MArE very close to emmetropia (-0.058 ± 0.436), but with a wider spread of prediction errors (larger SD) compared to the Lenstar (-0.211 ± 0.323), which was statistically significantly (p = 0.001). There was, however, no significant difference (p = 0.4952) in MAE between the Verion (0.347 ± 0.266) and Lenstar (0.317 ± 0.217) (Fig. 1). When comparing prediction accuracy, the Lenstar had a higher proportion of patients within 1 D (98.3% *vs* 96.7%), 0.5 D (83.3% *vs* 76.7%), and 0.25 D (48.3% *vs* 40%) of refractive target, but this was not significantly different (Fig. 2).

Table 1. Summary of measurements from the Verion and Lenstar

(n=60)	**Verion**	**Lenstar**
K1 (D)		
Mean ± SD 95% CI Range	44.30 ± 1.50 43.92, 44.68 41.51 to 47.40	44.12 ± 1.32 43.80, 44.46 41.31 to 46.81
	ICC = 0.958	
K2 (D)		
Mean ± SD 95% CI Range	45.20 ± 1.54 44.81, 45.59 41.77 48.42	44.93 ± 1.43 44.62, 45.34 41.67 to 48.61
	ICC = 0.952	
Steep axis		
Mean ± SD 95% CI Range	86.93 ± 57.3 72.43, 101.43 4 to 176	79.28 ± 56.28 65.04, 93.52 4 to 179
	ICC = 0.669	
WTW		
Mean ± SD 95% CI Range	11.89 ± 0.40 11.79, 11.99 11.11 to 12.91	11.65 ± 0.66 11.48, 11.82 10.36 to 12.63
	ICC = 0.195	

Discussion

Precise biometry is an essential prerequisite for refractive cataract surgeons in order to meet increasingly demanding visual requirements on the part of patients.[6] Optical biometry has become the gold standard for IOL power calculation and the Lenstar LS900 has been validated in previous studies.[7,8] Evaluation of new technology as it becomes available is of vital importance before it can be safely incorporated into our daily practice. The Verion Image Guided System has been subject to various comparative studies looking at keratometry and repeatability of measurements[3,4,9] as well as IOL power calculation.[5] Thomas *et al.*[5] found no significant difference between the Lenstar and Verion when using the corneal radii measurements from the respective systems for IOL prediction. As their study was theoretical in nature and used only one eye of ophthalmologically healthy volunteers, they did elude to the fact that true reliability of IOL prediction with the Verion will have to be assessed

Table 2. Summary of PE calculations from Verion and Lenstar

(n=60)	**Verion**	**Lenstar**
Arithmetic error		
Mean ± SD 95% CI Range	-0.058 ± 0.436 -0.16, 0.06 -1.045 to 1.14	-0.211 ± 0.323 -0.29, -0.13 -1.125 to 0.54
	p = 0.001	
Absolute error		
Mean ± SD 95% CI Range	0.347 ± 0.266 0.279, 0.416 0 to 1.14	0.317 ± 0.217 0.261, 0.373 0.01 to 1.12
	p = 0.429	
Prediction accuracy		
± 0.25 D ± 0.5 0D ± 1.00 D	40% (p = 0.3612) 76.7% (p = 0.4476) 96.7% (p = 0.6390)	48.3% 83.3% 98.3%

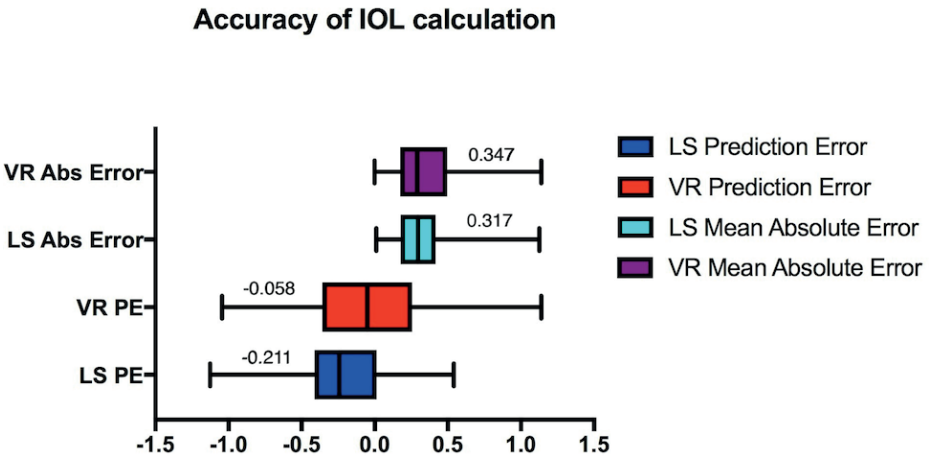

Fig. 1. The Verion had a PE closer to emmetropia, but the Lenstar had a lower MAE.

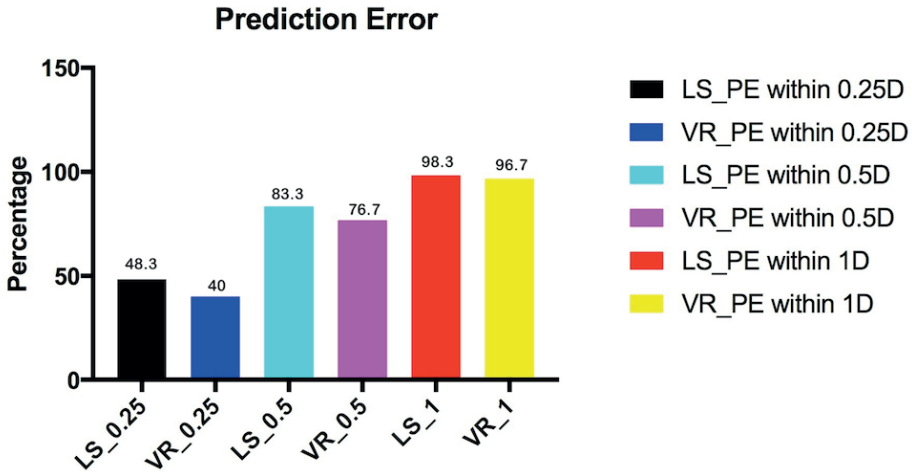

Fig. 2. The Lenstar was superior in terms of accuracy within 0.25 D, 0.5 D, and 1 D of refractive target (not statistically significant).

after actual IOL implantation and evaluation of postoperative refraction. Therefore, in our study, we set out to compare the Verion's keratometry and WTW measurements with the Lenstar and to also assess the impact on IOL power calculation in cataract patients who were undergoing phacomulsification.

The Verion keratometry, axis, and WTW measurements has been previously found to be comparable and highly repeatable.[3,4] Similarly, we did find very good correlation between the keratometry measurements of the Verion and the Lenstar, but the steep axis and WTW measurements were less so. However, this did not significantly affect IOL prediction, as both devices were very comparable in this aspect. This could be a consequence of using the Barrett Universal II formula which may not require the WTW measurement for accurate IOL prediction.[10] Of note, however, the Verion did result in average prediction closer to emmetropia, but there was no difference in absolute PE between the two devices.

This study was designed as an initial assessment to evaluate the reliability of the Verion keratometry readings for spherical IOL prediction and consequently only patients scheduled for standard monofocal IOL implantation were recruited. Our study shows that the keratometry measurements from the Verion Image Guided System are reliable and capable of accurate IOL power prediction and is comparable with an established biometer like the Lenstar. Another strength of the Verion system lies in its ability to provide intraoperative digital guidance, which is particularly useful for toric IOL alignment. This was previously evaluated and showed to be superior to manual marking,[11] and this is also being further evaluated in another study in our centre comparing it with a slit lamp marking technique. Our study also shows that the steep axis from the Verion only had moderate correlation with the

Lenstar, which may have an impact on toric IOL planning. The Alcon toric calculator is incorporated into the surgical planner and the latest updates also provide the Barrett Algorithm which accounts for posterior corneal astigmatism. As the steep axis is only moderately correlated with the Lenstar, the accuracy of the toric IOL planner on the Verion is now subject to another ongoing study in our centre.

The Verion system will be a useful addition to the refractive cataract surgeon's toolbox as it allows preoperative planning, intraoperative digital guidance, and post-operative tools such as 'A' constant optimization, surgically induced astigmatism calculation, and review of refractive outcomes. All these aspects will contribute towards increased precision of cataract surgery leading to improved outcomes for patients.

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Malaysian Journal of Ophthalmology

© Malaysian Journal of Ophthalmology 2019; 4:244-258
Original article

Preoperative keratometry agreement: vector comparison between the IOLMaster 500, Galilei G2, and a Takagi autorefractor

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Abstract

Introduction: Preoperative cataract assessment may involve multiple biometric instruments and it is important that clinicians are aware of the accuracy, limitations, and interchangeability of keratometry measurements conducted on these instruments.
Purpose: The purpose of the current study was to determine the agreement of keratometry magnitude and axis measurements obtained using three commonly used clinical keratometers.
Design of the study: Prospective, comparative study.
Materials and methods: One-hundred eyes of 100 prospectively enrolled patients listed for cataract phacoemulsification were recruited. Preoperative keratometry magnitude and axis measurements were obtained using the Galilei-G2 Dual Scheimpflug Analyzer (Ziemer Ophthalmic Systems AG, Port, Switzerland), IOLMaster 500, and Takagi ARKM-200 autokeratometer (Takagi Seiko Co., Ltd, Nagano-ken, Japan). Inter-device agreement in corneal spherical equivalent, corneal cylinder vectors, and corneal cylinder magnitude was assessed using the Bland-Altman method.
Results: One participant was excluded because of incomplete data. The Galilei-G2 reported the lowest mean keratometry (43.96 ± 1.71 D) and the IOLMaster reported the highest (43.99 ± 1.65 D). A single statistically significant difference occurred in

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the corneal cylinder vector analysis between the IOLMaster 500 and the three-instrument pooled mean (mean difference = -0.238 D, P = 0.04). No other statistically significant differences were observed for any instrument for any measured parameter. Excluding the vector difference analysis (range = -0.175 – -0.238 D), mean differences between individual instruments and the three-instrument pooled mean did not exceed 0.025 D (P > 0.05).
Conclusion: The Galilei-G2, IOLMaster 500 (Carl Zeiss Meditec AG, Oberkochen, Germany), and Takagi ARKM-200 autokeratometer produce accurate keratometry and axis measurements that are comparable between instruments. The instruments could be used interchangeably in clinical practice in scenarios where accurate examinations cannot be obtained using one of the instruments.

Keywords: biometry, cataract, keratometry, refraction instruments, residual refractive error

Persefahaman keratometri praoperasi: perbandingan vektor antara IOLMaster 500, Galilei G2, dan autorefractor Takagi

Abstrak

Pengenalan: Penilaian katarak preoperatif mungkin melibatkan pelbagai instrumen biometrik dan adalah penting untuk doktor mengetahui ketepatan, batasan, dan penukaran pengukuran keratometri yang dilakukan pada instrumen ini.
Tujuan: Tujuan kajian semasa adalah untuk menentukan persefahaman magnitud keratometry dan pengukuran paksi yang diperoleh menggunakan tiga keratometer klinikal yang biasa digunakan.
Reka bentuk kajian: Prospektif, kajian perbandingan.
Bahan dan kaedah: Satu ratus seramai 100 pesakit yang didaftarkan secara prospektif yang disenaraikan untuk phacoemulsification katarak direkrut. Magnitud keratometri pra operasi dan ukuran paksi diperoleh dengan menggunakan Analyzer Scheimpflug Galilei-G2 (Ziemer Ophthalmic Systems AG, Port, Switzerland), IOLMaster 500, dan Takagi Seiko Co., Ltd, Nagano-ken, Jepun. . Persefahaman antara peranti dalam kornea silinder bulat yang setara, vektor silinder kornea, dan magnitud silinder kornea dinilai menggunakan kaedah Bland-Altman.
Keputusan: Satu peserta dikecualikan kerana data tidak lengkap. Galilei-G2 melaporkan keratometri min terendah (43.96 ± 1.71 D) dan IOLMaster melaporkan tertinggi (43.99 ± 1.65 D). Satu perbezaan statistik yang ketara berlaku dalam analisis vektor silinder kornea antara IOLMaster 500 dan min yang disatukan tiga

instrumen (perbezaan bermakna = -0.238 D, P = 0.04). Tiada perbezaan statistik lain yang diperhatikan untuk mana-mana instrumen untuk sebarang parameter yang diukur. Tidak termasuk analisis perbezaan vektor (julat = -0.175 - -0.238 D), perbezaan antara instrumen individu dan instrumen gabungan tiga instrumen tidak melebihi 0.025 D (P > 0.05).
Kesimpulan: The Galilei-G2, IOLMaster 500 (Carl Zeiss Meditec AG, Oberkochen, Jerman), dan Takagi ARKM-200 autokeratometer menghasilkan keratometri tepat dan ukuran paksi yang boleh dibandingkan antara instrumen. Instrumen ini boleh digunakan secara bergantian dalam amalan klinikal dalam senario di mana peperiksaan yang tepat tidak boleh diperoleh menggunakan salah satu alat.

Kata kunci: biometri, instrumen pembiasan, katarak, keratometri, kesilapan biasan baki

Introduction

Accurate keratometry is essential for intraocular lens (IOL) power and toricity selection, predetermining the precise IOL axis alignment prior to surgery, and the measurement of residual refractive error following cataract surgery.[1] During IOL selection, keratometry errors of as minimal as one dioptre (D) may be associated with up to 2–4 lines of uncorrected visual acuity loss due to residual refractive error.[1,2] Residual refractive error can have a significant detrimental impact on quality of life before and after cataract surgery.[3,4] Patient expectations of outstanding visual outcomes following cataract surgery are increasingly common.[4] These ever growing expectations place a premium on obtaining a high degree of accuracy during pre- and postoperative keratometry, which can significantly influence the IOL power selected and residual refractive error following surgery.[3,5,6]

It is not possible to get universal accurate and precise preoperative keratometry for every patient and often several keratometry instruments may be used for assessment prior to cataract surgery. Approximately 35% of patients undergoing cataract surgery have at least 1.00 D of corneal astigmatism and will benefit from toric IOL implantation.[7] Failure to implant toric lenses in these cases has the potential to reduce visual acuity by 1.5 lines per D of uncorrected corneal cylinder.[8,9] The magnitude and axis of astigmatism must be accurately and reproducibly characterised in order to select the IOL toricity and axis of IOL implantation.[10] The ability to accurately verify the magnitude, axis, and regularity of astigmatism on a second keratometer is a useful and reassuring strategy when considering implantation of a toric IOL. Without data to guide clinicians on the expected agreeability between instruments, interpreting differences in expected cylinder axis and magnitude can be a major issue when deciding on the most appropriate toric IOL to select to optimise the visual outcome following surgery.

It is therefore important that all clinicians that assess refractive error are aware of the accuracy, limitations, and interchangeability of keratometry measurements conducted on different instruments and how these measurements may affect patient outcomes. The aim of the current study was to determine the agreement between the keratometry measurements of the Zeiss IOLMaster 500 (Carl Zeiss Meditec AG, Oberkochen, Germany), the Galilei-G2 Dual Scheimpflug Analyzer (Ziemer Ophthalmic Systems AG, Port, Switzerland), and the Takagi ARKM-200 autokeratometer (Takagi Seiko Co., Ltd, Nagano-ken, Japan), and to evaluate if the measurements could be used interchangeably when selecting IOL power or determining corneal astigmatic magnitude and axis.

Materials and methods

The current study was registered in the Australian New Zealand Clinical Trials Registry (ANZCTR) under registration number ACTRN12616001593426. Prior to surgery, all patients provided written informed consent and the current study was conducted in accordance with the Declaration of Helsinki, as well as the New Zealand National Ethics Advisory Committee guidelines. Formal approval was obtained from the New Zealand Health and Disability Ethics Committee (16/CEN/132). Patients undergoing cataract surgery at the department of Ophthalmology at Greenlane Clinical Centre, Auckland District Health Board, New Zealand were prospectively enrolled for the current study. The current study aimed to recruit patients most representative of all patients undergoing cataract surgery in New Zealand. Exclusion criteria included pre-existing corneal pathology, previous ocular surgery, contact lens use, strabismus, and a postoperative target other than emmetropia. Enrolled patients underwent a full medical and ophthalmic history, and a complete ophthalmic slit lamp examination.

Keratometry for all patients was measured using the Zeiss IOLMaster 500, the Galilei-G2 Dual Scheimpflug Analyzer, and the Takagi ARKM-200 autokeratometer. The original equipment manufacturer for the Takagi branded instrument is Tomey Corporation (Aichi, Japan). All measurements for each patient were conducted on the same day, within a 30-minute interval, by an experienced technician in accordance with the instructions of the manufacturer, at the University of Auckland Ocular Imaging Unit. No eye drops were applied prior to keratometry and measurements were repeated, if required, until each keratometer reported a scan of adequate quality as determined by quality metrics reported by each keratometer. Simulated K values were extracted from the Galilei-G2 to ensure consistency in the corneal index of refraction utilised for corneal power calculations across all instruments (n = 1.3375).

Statistical analysis

Statistical analysis was conducted using R Version 3.4.2 (R Foundation for Statistical Computing, Vienna, Austria). Data were tested for normality using the Wilks-Shapiro test. The following keratometric parameters were assessed: flat, steep, and mean keratometry, and corneal astigmatism.

Bland-Altman style analysis was used to calculate the difference between measurements from single instruments and the three-instrument pooled mean. Differences between measurements were then plotted against their mean along with lines representing the 95% limits of agreement.[11] The 95% limits of agreement (mean difference ± 1.96 × standard deviation) were used to define the confidence interval within which most differences between measurements from the pairwise comparisons will occur. To review the agreement, one-sample t-tests were conducted with the test value equal to zero. No statistical corrections for multiple analyses were performed.

Corneal astigmatism was compared using power vector analysis.[12-15] The astigmatism value was converted to rectangular vectors J0 and J45, using the following equations: $J0 = -(C/2)\cos(2Ø)$ and $J45 = -(C/2)\sin(2Ø)$, where J0 is the Jackson cross-cylinder axes at 90 and 180°, J45 is the Jackson cross-cylinder axes at 45 and 135°, C is the negative cylinder (flattest – steepest meridian), and Ø is the axis of flattest meridian. Corneal cylinder magnitude alone as well as corneal vectors calculated according to Retzlaff were also compared to facilitate comprehension of the results for clinicians typically using these metrics.[16]

Results

One-hundred eyes (53 left) of 100 participants met the criteria for inclusion in the study. One participant was excluded because a reliable scan from the autokeratometer could not be acquired. The remaining 99 participants were included in the final analysis. The mean age of participants was 74.4 ± 9.1 years**.** Fifty-six eyes (56%) were female. All measurements included in the statistical analysis individually passed all keratometer-reliability tests. Mean values for each parameter measured by each of the three keratometers are summarised in Table 1.

Mean differences for all analyses are summarised in Table 2. The largest mean difference occurred between the IOLMaster 500 cylinder vector and the mean cylinder vector of the three-instruments (MD = -0.238 D, P = 0.04). No other statistically significant differences were noted for any instrument for any measured parameter. No mean difference exceeded 0.025 D, excluding the vector difference analysis (range = -0.175 – -0.238). Bland-Altman plots for difference between individual instrument measurements and the three-instrument pooled means are demonstrated in Figure 1 (corneal spherical equivalent), Figure 2 (corneal power vectors), Figure 3 (corneal cylinder magnitude), and Figure 4 (Jackson cross-cylinders).

Table 1. Summary values from three commonly used clinical keratometers

	Autokeratometer		IOLMaster 500		Galilei-G2	
Parameter	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Mean K (D)	43.98	1.60	43.99	1.65	43.96	1.71
Flat K (D)	43.60	1.60	43.59	1.65	43.57	1.72
Steep K (D)	44.36	1.64	44.39	1.68	44.34	1.75
J0 (D)	-0.06	0.41	-0.03	0.39	-0.06	0.41
J45 (D)	0.00	0.23	0.02	0.24	0.02	0.23

D: dioptres; K: keratometry; J0: Jackson cross-cylinder, axes at 90 and 180°; J45: Jackson cross-cylinder, axes at 45 and 135°; SD: standard deviation

Table 2. Summary values from Bland-Altman analyses

Analysis	Instrument	M.	P-value	T-value	Lower LoA	Upper LoA
Cylinder magnitude difference	Autokeratometer	-0.014	0.654	-0.450	-0.631	0.603
Cylinder magnitude difference	Galilei	-0.013	0.712	-0.370	-0.722	0.695
Cylinder magnitude difference	IOLMaster 500	0.028	0.317	1.007	-0.509	0.564
Flat keratometry	Autokeratometer	-0.008	0.708	-0.375	-0.407	0.392
Flat keratometry	Galilei	-0.001	0.966	-0.043	-0.551	0.549
Flat keratometry	IOLMaster 500	0.009	0.717	0.363	-0.468	0.486
J0	Autokeratometer	-0.014	0.432	-0.789	-0.363	0.335
J0	Galilei	-0.010	0.644	-0.464	-0.427	0.407
J0	IOLMaster 500	0.024	0.171	1.379	-0.316	0.364
J45	Autokeratometer	-0.011	0.315	-1.010	-0.219	0.198
J45	Galilei	0.003	0.824	0.223	-0.234	0.204
J45	IOLMaster 500	0.008	0.529	0.632	-0.241	0.257
Mean keratometry	Autokeratometer	-0.015	0.388	-0.867	-0.348	0.318
Mean keratometry	Galilei	-0.008	0.750	-0.320	-0.491	0.475
Mean keratometry	IOLMaster 500	0.023	0.275	1.099	-0.381	0.426
Steep keratometry	Autokeratometer	-0.022	0.397	-0.850	-0.525	0.481
Steep keratometry	Galilei	-0.015	0.658	-0.443	-0.659	0.629
Steep keratometry	IOLMaster 500	0.037	0.150	1.451	-0.455	0.528
Vector difference	Autokeratometer	-0.210	0.063	-1.882	-2.390	1.969
Vector difference	Galilei	-0.175	0.140	-1.488	-2.472	2.121
Vector difference	IOLMaster 500	-0.238	0.039	-2.093	-2.451	1.976

LoA: 95% limit of agreement; MD: mean difference between the instrument and the three-instrument pooled mean for a given analysis; vector difference: difference in corneal cylinder vectors according to Retzlaff[16]

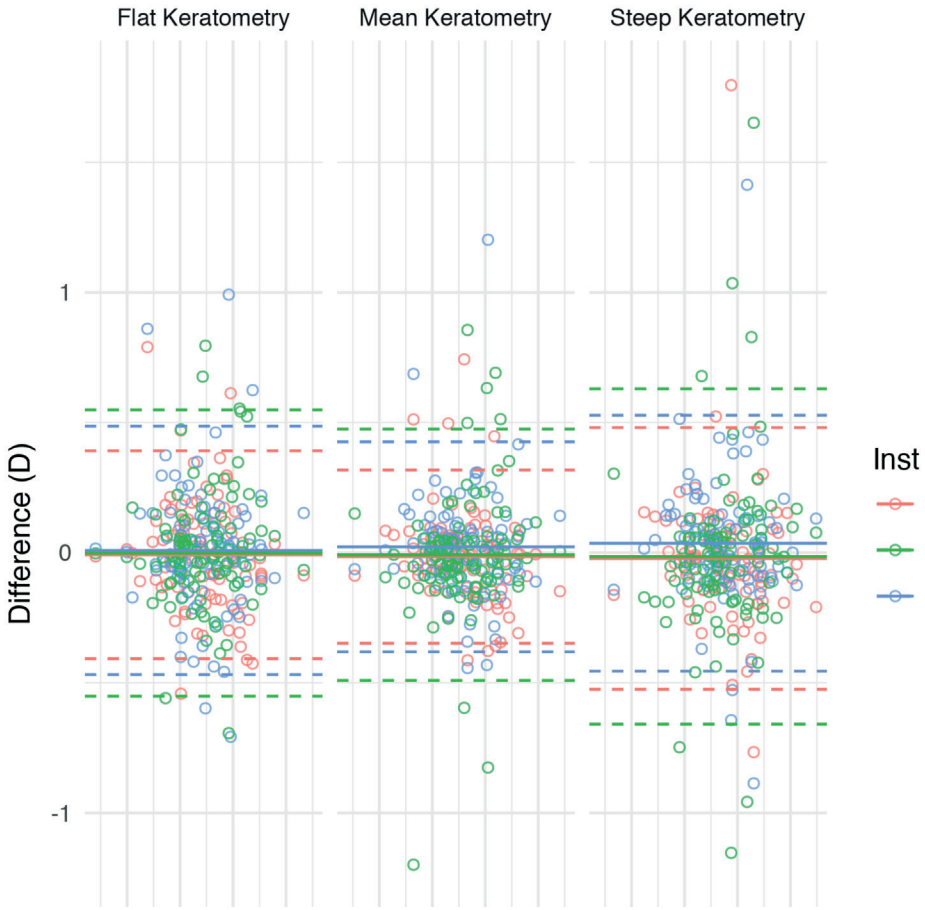

Fig. 1. Bland-Altman plots showing the agreement in flat, mean, and steep keratometry measurements (dioptres). Circles represent single measurements from single instruments in unilateral preoperative eyes of participants. Red: autokeratometer; blue: Galilei G2; green: IOLMaster 500. The central lines represent the mean of the difference between the instrument and the three-instrument pooled mean. Dashed lines represent 95% limits of agreement.

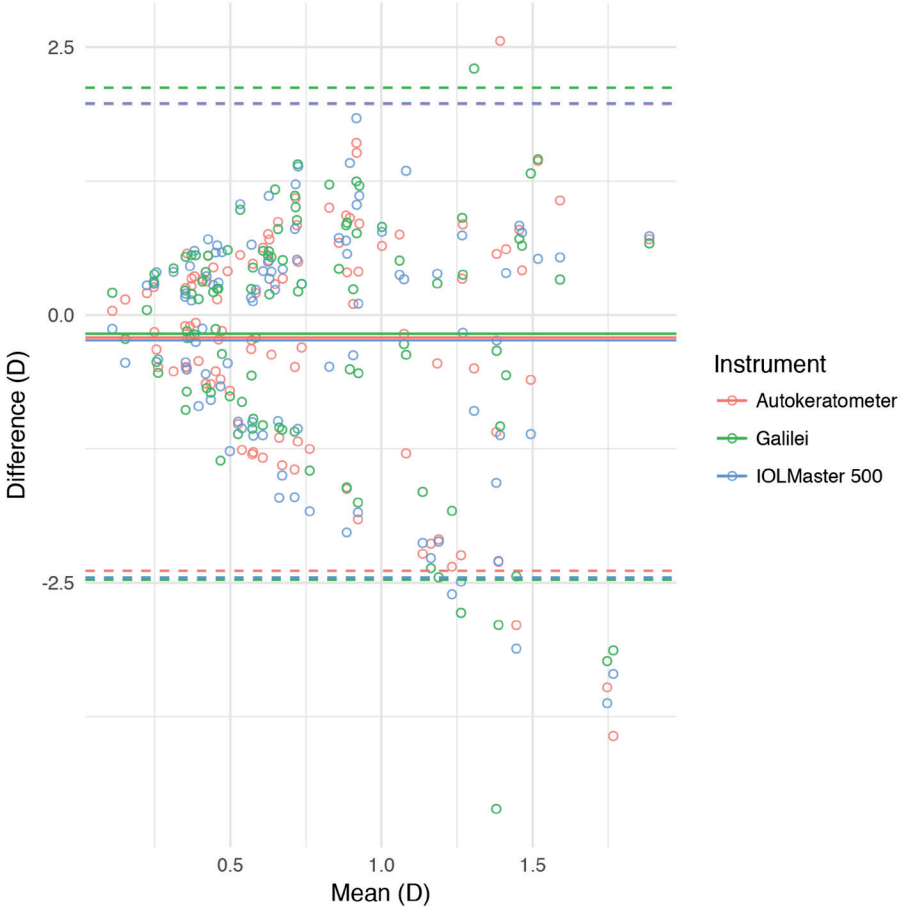

Fig. 2. Bland-Altman plot showing the vector difference in corneal cylinder between three commonly used clinical keratometers and the three-instrument pooled cylinder mean, calculated according to Retzlaff.16 Circles represent single measurements from single instruments in unilateral preoperative eyes of participants. Red: autokeratometer; blue: Galilei G2; green: IOLMaster 500. The central lines represent the mean of the difference between the instrument and the three-instrument pooled mean. Dashed lines represent 95% limits of agreement.

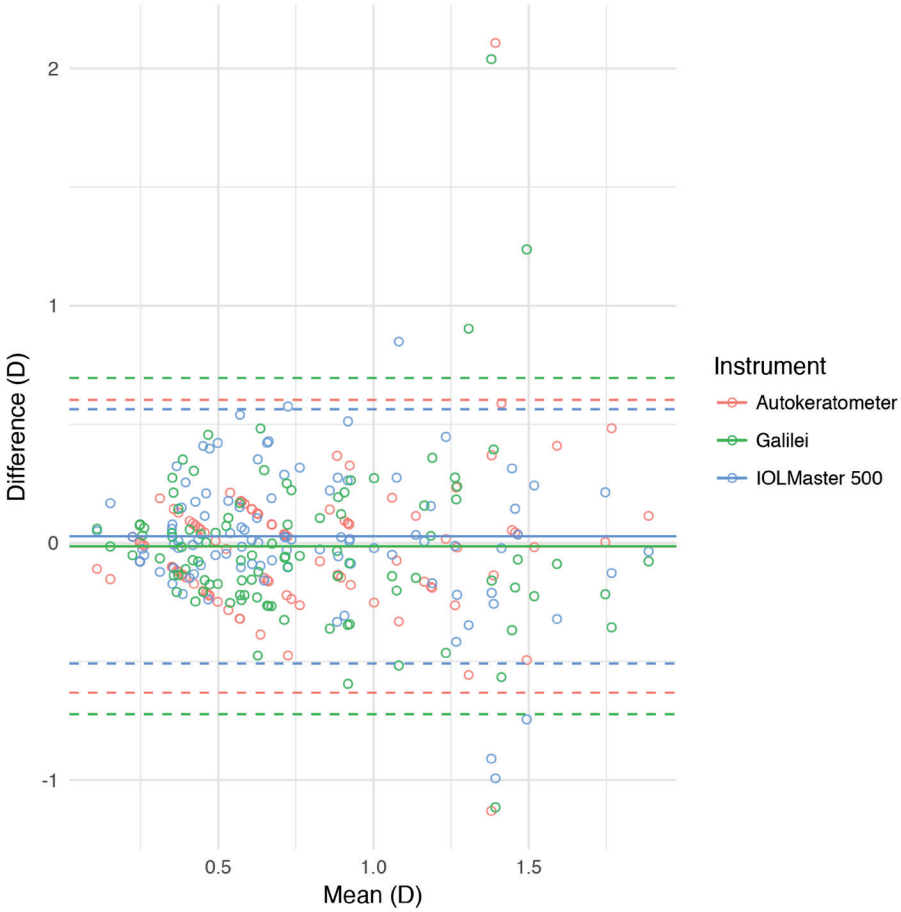

Fig. 3. Bland-Altman plot showing difference in cylinder magnitude between three commonly used clinical keratometers and the three- instrument pooled mean. Circles represent single measurements from single instruments in unilateral preoperative eyes of participants. Red: autokeratometer; blue: Galilei G2; green: IOLMaster 500. The central lines represent the mean of the difference between the instrument and the three-instrument pooled mean. Dashed lines represent 95% limits of agreement.

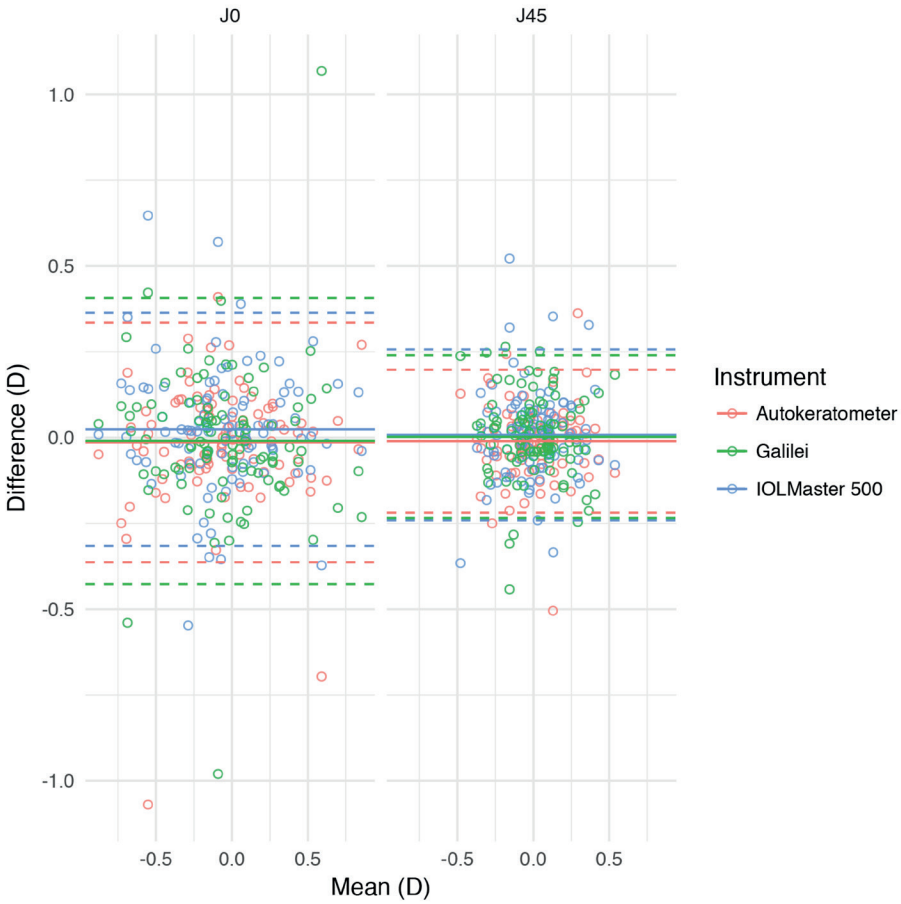

Fig. 4. Bland-Altman plots showing the agreement in J0 (Jackson cross-cylinder, axes at 90 and 180°) and J45 (Jackson cross-cylinder, axes at 45 and 135°). Circles represent single measurements from single instruments in unilateral preoperative eyes of participants. Red: autokeratometer, blue: Galilei G2, green: IOLMaster 500. The central lines represent the mean of the difference between the instrument and the three-instrument pooled mean. Dashed lines represent 95% limits of agreement.

The Galilei-G2 had the widest 95% confidence intervals for each of the keratometry parameters, except for the J45 analysis in which the IOLMaster had wider confidence intervals (± 0.249 D). The 95% limits of agreement for corneal spherical equivalent (mean keratometry) were all within 0.5 D. In the analyses of corneal cylinder, the largest limits of agreement did not exceed 2.30 D in the vector magnitude analysis (Fig. 2) and 0.75 in the cylinder magnitude analysis (Fig. 3).

Discussion

Accurate keratometry is essential to select an appropriately powered IOL to achieve optimised visual outcomes and patient satisfaction following cataract surgery. Most modern clinics that offer cataract surgery have several instruments capable of keratometry assessment and manufacturers typically claim high degrees of accuracy and repeatability despite different keratometry modalities. In cases where results from one instrument are suboptimal or of poor reliability, the use of an alternative source of keratometry is often required to ensure the IOL power selection is appropriate. An understanding of the accuracy and interchangeability of keratometry values obtained using different instruments is essential for clinicians to accurately predict and objectively quantify visual outcomes or surgically induced astigmatism in patients who may be difficult to measure using one modality alone.

The current study is the first to directly compare keratometry measurements obtained using the IOLMaster 500, the Galilei-G2 tomographer, and the Takagi ARKM-200 autokeratometer. After statistical analysis, no clinically significant differences were detected between any of the instrument pairs, for any measured parameter.

The Zeiss IOLMaster 500, although now superseded by a newer model, is still widely used in clinical settings for keratometry and axial length assessment prior to cataract surgery. This instrument uses 6 radial Purkinje images to calculate corneal curvature at a diameter of 2.5 mm.[17] Biometry measurements from the IOLMaster 500 have historically been considered gold-standard for the prediction of postoperative refractive outcomes.[18] Autokeratometers also assume the cornea to be a convex mirror and also use the size and separation of infrared Purkinje images from the cornea to derive curvature.[19] The autokeratometer in the current study used Purkinje images with 16 radial points, 8 points at 1.5 mm and 8 points at 3.0 mm radii from the corneal apex, to calculate curvatures at both 3 mm and 6 mm diameter (Tomey Corporation, 2017, unpublished data). For the current study, 1.5 mm radius measurements were used for comparison as they were most clinically relevant and directly comparable to the other two instruments.

In contrast to the other two instruments, the Galilei-G2 tomographer combines information from a Placido disc and Scheimpflug images to determine anterior corneal curvature.[1] In the current study, simulated keratometry indices were used (as opposed to the keratometry indices) in order to ensure consistency in the keratometric index of refraction utilised for all corneal power calculations across instruments (n = 1.3375). The values labelled "Flat K" and "Steep K" in the Galilei-G2 interface refer to values calculated using the refractive index of the cornea (n = 1.376).

Each instrument in the current study uses a different method for alignment with the cornea. The autokeratometer automatically adjusts to a set reference distance before completing the measurement and the G2 requires manual alignment prior to completing a scan. In contrast, the IOLMaster 500 is the only instrument of the triad to that uses a telecentric optical configuration which allows distance-independent keratometry. The measurement radius of the IOLMaster 500 is therefore consistent, regardless of the distance between keratometer and eye.

The radius of measurement of an instrument is critical as it will affect its recorded keratometry values. Despite similar measurement methods, the IOLMaster 500 and autokeratometer have different radii of measurement (r) at 1.25 mm and 1.5 mm, respectively. In contrast, the Galilei-G2 has an arithmetic mean radius of measurement of 1.25 mm (range = 0.5–2.0mm) from its combined Placido disc and Scheimpflug camera technologies.[1] The radius affects the data because keratometry values are generated from best-fit spheres, and if the points the sphere is fitted to are further apart, the radius of the sphere is inevitably larger, and the curvature of the sphere naturally flatter. These data are in keeping with the prolate nature of the cornea, where the steepest radii of curvature are located at the apex. This effect was evident in the current study. The IOLMaster 500, which takes measurements at r = 1.25 mm, reported the steepest keratometry and astigmatism values, while the Galilei-G2, which takes 16 measurements between a 0.5 mm and 2.0 mm radius (arithmetic mean = 1.25 mm), reported the flattest values. The autokeratometer (r = 1.5 mm) reported data which were often in the middle of the other two data sets. Despite this trend, differences between the data sets were non-significant ($P > 0.15$).

Bland-Altman analysis demonstrated tight clustering of data around the line of no difference for all analyses as expected (Figs. 1-4).[20-22] The only statistically significant mean difference observed in the current study occurred in the vector analysis of corneal cylinder (Fig. 2). The statistically significant difference may have occurred due to outliers resulting from small differences in axis measurement (range 7°) in patients with large amounts of corneal cylinder (mean = 1.74 D). The limits of agreement were generally narrow for all three instruments; however, the Galilei had the widest limits of agreement in 6 of 7 analyses. This may occur due to the Galilei's substantially different mechanism of measurement compared to the other two instruments. Figure 2 also demonstrates the increasingly large importance of accurate axis measurement as the corneal cylinder increases in magnitude and shows why it may be worthwhile for clinicians to verify corneal cylinder axes with

a second instrument in some patients. In the current study, the consistency of astigmatic axis between instruments was also assessed using J0 and J45 vector analysis.[12] No significant differences for these factors were noted with Bland-Altman analysis (Fig. 4). These instruments can therefore be used interchangeably for clinical applications where axis is critical, including selection of toric IOL in patients with pre-existing corneal astigmatism, and the measurement of surgically induced astigmatism.[21,22]

With speed of measurement and ease of use, the autokeratometer is an ideal tool for swiftly measuring postoperative objective refractive outcomes. Achievement of predicted refraction is an objective, quantitative indicator of surgical outcomes, which are contributed to by a multidisciplinary team. Visual acuity alone is not an ideal indicator of refractive success as poor postoperative visual acuity will still occur in patients whose vision is limited by non-refractive pathology such as retinal or optic nerve disease despite successfully achieving the predicted refractive target.[23-26] Residual refractive error associated with keratometry measurement errors has been estimated at 8–8.59% of total residual refractive error.[27,28] The clinically insignificant differences in the keratometry measurements from the three instruments in the current study show that the keratometry values from each of the instruments could be interchanged in IOL calculation formulae with relatively low impact on residual refractive error.

Limitations of the current study include the lack of repeatability data; however, the repeatability of these instruments have been demonstrated elsewhere.[17,29-32] Although newer versions of some of the instruments are available, the instruments analysed remain in widespread clinical use. The variation of each instrument from the pooled mean (of the three instruments) for each compared parameter is outlined in the 95% confidence intervals (Table 2, Figs 1-4). The autokeratometer had the lowest variation for the majority of analyses, lending further weight to the hypothesis that it is an accurate keratometer. Another consideration is that the participants in the current study were free from corneal pathology, which may limit generalisation of the results. Strengths of the current study are that it is a relatively large, prospective study. Additionally, measurements were acquired according to a predefined protocol by experienced operators.

The current study has shown that the keratometry data, including magnitude and axis, from the Galilei-G2, IOLMaster 500, and a Takagi autokeratometer are agreeable. These data could be used interchangeably in everyday clinical practice.

Acknowledgements

The authors wish to acknowledge Professor Charles McGhee for his mentorship and the provision of resources to support this research.

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Malaysian Journal of Ophthalmology

© Malaysian Journal of Ophthalmology 2019; 4:259-283
Original article

Comparison of contrast sensitivity between three aspheric acrylic monofocal intraocular lenses: a prospective randomised trial

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Abstract

Introduction: Evolution of cataract surgery and implantation of intraocular lenses (IOL) with new technological designs to optimise functional vision has been the aim of cataract surgery today. Aspherical lens design is a new lens technology to counteract spherical aberration exerted by a conventional IOL.
Purpose: To compare the contrast sensitivity after cataract surgery between aspheric IOLs with negative spherical aberration (Tecnis ZA9003™ and AcrySof IQ™) and zero spherical aberration IOLs (Akreos Adapt Advance Optic [AO]™).
Study design: Interventional, single-blinded, randomised controlled trial.
Methods: Ninety-six patients were recruited with 32 eyes in each study arm. All patients underwent standard phacoemulsification with implantation of an aspheric acrylic IOL randomised to one of the three lens models by a single experienced surgeon. Pre- and postoperative contrast sensitivity was analysed using the CSV1000E chart under photopic and mesopic conditions with and without glare testing.

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Results: All three lenses showed statistically significant improvement in contrast sensitivity postoperatively at all spatial frequencies under photopic, mesopic, and scotopic conditions with glare. There was no statistically significant difference between the groups. Tecnis ZA9003™ showed marked improvement in mesopic contrast sensitivity at 18 cycles/degree (cpd) at 12 weeks ($p < 0.05$). The zero aberration Akreos Adapt AO™ showed better photopic contrast sensitivity compared to mesopic contrast sensitivity ($p > 0.05$).
Conclusion: AcrySof IQ™, Akreos Adapt AO™, and Tecnis ZA9003™ performed equally well in contrast sensitivity at all spatial frequencies under photopic and mesopic conditions with and without glare testing. All lenses had statistically significant improvement in contrast sensitivity after cataract surgery. The negative aberration IOL Tecnis ZA9003™ showed marked improvement in mesopic contrast sensitivity at 18 cpd at 12 weeks. The zero aberration IOL, Akreos Adapt AO™ showed better photopic contrast sensitivity compared to mesopic contrast sensitivity.

Keywords: aspheric intraocular lenses, cataract, contrast sensitivity, CSV1000E chart, glare

Perbandingan kepekaan kontras di antara tiga kanta intraokular monofocal akrilik aspherik: Kajian prospektif rawak

Abstrak

Pengenalan: Evolusi pembedahan katarak dan implantasi kanta intraokular (IOL) dengan reka bentuk teknologi baru untuk mengoptimumkan fungsi penglihatan telah menjadi matlamat pembedahan katarak hari ini. Reka bentuk kanta aspherikal adalah teknologi kanta baru untuk mengatasi penyimpangan sfera yang diberikan oleh IOL konvensional.
Tujuan: Untuk membandingkan kepekaan kontras selepas pembedahan katarak antara IOL aspherik dengan penyimpangan sfera negatif (Tecnis ZA9003TM dan AcrySof IQTM) dan sifar sfera IOL (Akreos Adapt Advance Optic [AO] TM).
Reka bentuk kajian: Kajian terkawal intervensi, single-blinded, terkawal.
Kaedah: Sembilan puluh enam pesakit direkrut dengan 32 mata di setiap kumpulan kajian. Semua pesakit menjalani fakoemulsifikasi rutin dengan implantasi IOL akrilik asfera dirawak daripada salah satu daripada tiga model kanta oleh satu pakar bedah berpengalaman. Kepekaan kontras pra dan pasca operasi dianalisis dengan menggunakan carta CSV1000E di bawah keadaan photopic dan mesopic dengan dan tanpa ujian silau.

Hasil: Semua tiga kanta menunjukkan peningkatan ketara secara statistik dalam sensitiviti kontras selepas operasi di semua frekuensi spatial di bawah keadaan photopic, mesopic, dan scotopic dengan silau. Tiada perbezaan statistik secara signifikan antara kumpulan. Tecnis ZA9003TM menunjukkan peningkatan sensitiviti sensitiviti kontras mesopik pada 18 kitaran / darjah (cpd) pada 12 minggu ($p < 0.05$). Kesalahan sifar Akreos Adapt AOTM menunjukkan kepekaan kontras fotopik yang lebih baik berbanding kepekaan kontras mesopik ($p > 0.05$).
Kesimpulan: AcrySof IQTM, Akreos Adapt AOTM, dan Tecnis ZA9003TM dilakukan sama rata dengan kepekaan kontras di semua frekuensi spasial di bawah keadaan photopic dan mesopic dengan dan tanpa ujian silau. Semua kanta mempunyai peningkatan ketara secara statistik dalam kepekaan kontras selepas pembedahan katarak. Penyimpangan negatif IOL Tecnis ZA9003TM menunjukkan peningkatan yang ketara dalam kepekaan kontras mesopik pada 18 cpd pada 12 minggu. IOL penyimpangan sifar, Akreos Adapt AOTM menunjukkan kepekaan kontras fotopik yang lebih baik berbanding kepekaan kontras mesopik.

Kata kunci: carta CSV1000E, kanta intraokular aspherik, katarak, kepekaan kontras, silau

Introduction

Opacification of the crystalline lens or cataract is responsible for sixteen million cases of blindness worldwide, resulting in visual disability and decreased quality of life.[1] Studies show an increasing prevalence with age, from 7% in the mid-forties to more than 90% in those 70 years and older.[1] Zainal *et al.* reported that cataract accounted for nearly 40% of the total estimated cases of bilateral blindness, making cataract the major cause of blindness in Malaysia.[2] The 10th Malaysian National Eye Database (MNED) Report in 2018 stated that the total number of cataract surgeries had increased from 18,426 in 2007 to 50,624 in 2016.[3]

The MNED also reported a change in type of cataract surgery from predominantly extracapsular cataract extraction (ECCE) at 30.1% in 2007 to phacoemulsification at 89.6% in 2016.[3] The best corrected visual outcome of cataract surgery in the Ministry of Health Malaysia hospitals (MOH) likewise improved with 92.9% of operated eyes achieving best corrected vision of 6/12 with phacoemulsification compared to 81.4% of ECCE patients at 12 weeks postoperative.[3]

For decades, the aim of ophthalmic surgeons worldwide has been to achieve a visual acuity of 6/6. However, visual acuity is only one component of functional vision. Postoperatively, patients with 6/9 vision or better may still complain of haziness, glare, and poor night vision despite good visual acuity.[4] Conventional methods of evaluating the optical performance of intraocular lens (IOL) postoperatively using high-contrast letters on white background, such as the Snellen chart,

describes only one part of the patient's functional vision.[5,6] Measuring contrast sensitivity under different lighting conditions and various spatial frequencies provides a better picture of the patient's functional vision.[5,7,8]

Contrast sensitivity is a measure of the difference in brightness between two points of an image. It is the ratio between the minimum luminance subtracted from the maximum luminance and the average luminance, expressed in values ranging from 0 to 1. It is also defined as the inverse of the measured contrast threshold.

Studies have shown a relationship between contrast sensitivity and visual performance. Loss of scotopic vision in older adults has been correlated with an increase in the risk of falling with hospitalization[9] and difficulties in night driving.[10] Postoperative contrast sensitivity can be affected by various factors such as optic design,[4] decentration, and tilt of IOL.[11]

The conventional spherical IOL has positive spherical aberration. Therefore, its implantation does not counteract the positive spherical aberration of the cornea. This will result in poor postoperative image.[12-14] Aspherical IOLs are designed to counteract the positive aberration of the cornea,[5] thus simulating the conditions in a young patient with a functioning, clear crystalline lens.[15] The negative aberration aspherical IOL is designed to leave no residual aberration. Aberration zero aspheric IOLs are designed to leave a small amount of positive aberration from the cornea.

Several studies[5,6,14,16-19] comparing contrast sensitivity between spherical IOLs and aspherical IOLs have shown that aspherical IOLs provide better contrast sensitivity, especially at mesopic contrast and higher spatial frequencies. Other studies,[20,21] however, reported no significant difference in visual function between spherical and aspherical IOLs. Therefore, for this study, an aspheric IOL with zero spherical aberration (Akreos Advance Optic™ [AO], Bausch and Lomb, Quebec, Canada) and aspheric IOLs with negative spherical aberration (Tecnis ZA9003™, Advanced Medical Optics, CA USA and AcrySof IQ™, Alcon Laboratories, TX, USA) were selected for study. These lenses are popular and still widely used in Malaysia.

All these lenses are monofocal and made of acrylic material. The material is cross-linked copolymer consisting of an acrylate/methacrylate copolymer producing a flexible property which enables it to unfold in a controlled manner.[22] The AcrySof IQ™ and Tecnis ZA9003™ are hydrophobic lenses. The Akreos Adapt AO™ is a hydrophilic lens.

The aim of this study is to compare the contrast sensitivity and visual outcomes of patients with an IOL with zero spherical aberration (Akreos Adapt AO™) and patients with an aspheric IOL with negative spherical aberration (Tecnis ZA9003™ and AcrySof IQ™) after standard uneventful phacoemulsification in Malaysian patients.

Materials and methods

This study was an interventional, single-blinded, randomised, controlled trial study. Patients attending the outpatient ophthalmology clinic at Hospital Pulau Pinang planned for cataract operation from June 2007 to March 2010 were recruited. Hospital Pulau Pinang, located in Penang, Malaysia, is a busy public general hospital managed by the Ministry of Health. Ethical approval for the study was obtained from the Secretariat National Institutes of Health (NIH), Ministry of Health Malaysia under project code MRG-2007-04. Written, informed consent was obtained from all patients.

The criteria for inclusion into the study was cataract with preoperative best corrected visual acuity (BCVA) of 6/60 or better and postoperative vision of 6/15 (logMAR 0.40) at 6 weeks postoperative in patients aged 55–75 years. Study patients provided written consent and were able to communicate and follow up with contrast sensitivity tests postoperatively.

Patients who had any ocular abnormalities or systemic diseases that could interfere with or affect contrast sensitivity such as diabetes mellitus, glaucoma, and any macular disease, such as age-related macular degeneration, were excluded from the study. Patients who had intraoperative complications such as posterior capsule rupture and anterior chamber lens or sulcus lens implantation, patients with post-operative complications such as postoperative endophthalmitis, secondary inflammatory glaucoma, postoperative cystoid macula oedema, significant posterior capsular opacification, and corneal decompensation were likewise excluded.

The visual acuity test, A-scan, refraction, and K-reading were performed by a trained optometrist. Routine preoperative investigations also included blood investigations for blood urea and serum electrolyte, full blood count and random blood sugar, electrocardiograms and a physical examination to exclude diabetics and ensure fitness for surgery. Preoperative ocular examinations included lid and anterior segment examination, intraocular pressure measurement, and lens and dilated fundal examinations. All patients had baseline contrast sensitivity testing prior to surgery. An algorithm showing the flow of the data collection is in Figure 1.

Visual acuity was tested using the logarithm of minimum angle of resolution (logMAR) chart. Contrast sensitivity was measured using the sine-wave grating CSV-1000E contrast sensitivity chart (VectorVision, Inc., OH, USA) (Fig. 2). This contrast sensitivity test uses sine-wave grating on a calibrated illuminated wall chart. It provides four rows of sine-wave gratings at spatial frequencies of 3, 6, 12, and 18 cycles/degree (cpd). Each cycle contains 17 round circles with sine-wave gratings. The test patches are arranged in upper and lower rows with eight levels of contrast.

The contrast levels decrease from left to right in logarithmic steps of 0.17 log units for steps 1 to 3 and 0.15 log units for steps 3 to 8.23 Logarithmic contrast sensitivity was used for analysis. The measurements were performed with a 5.0 mm artificial

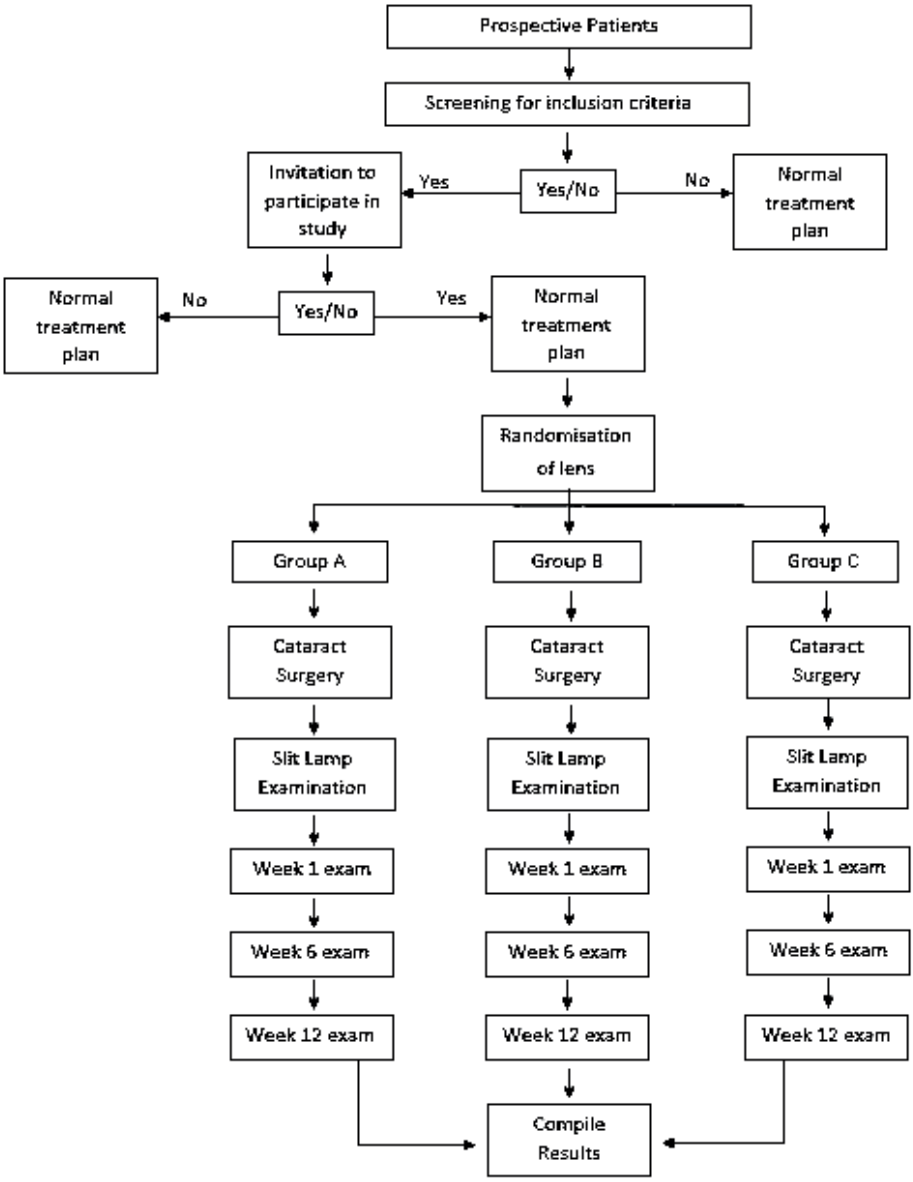

Fig. 1. Algorithm of data collection.

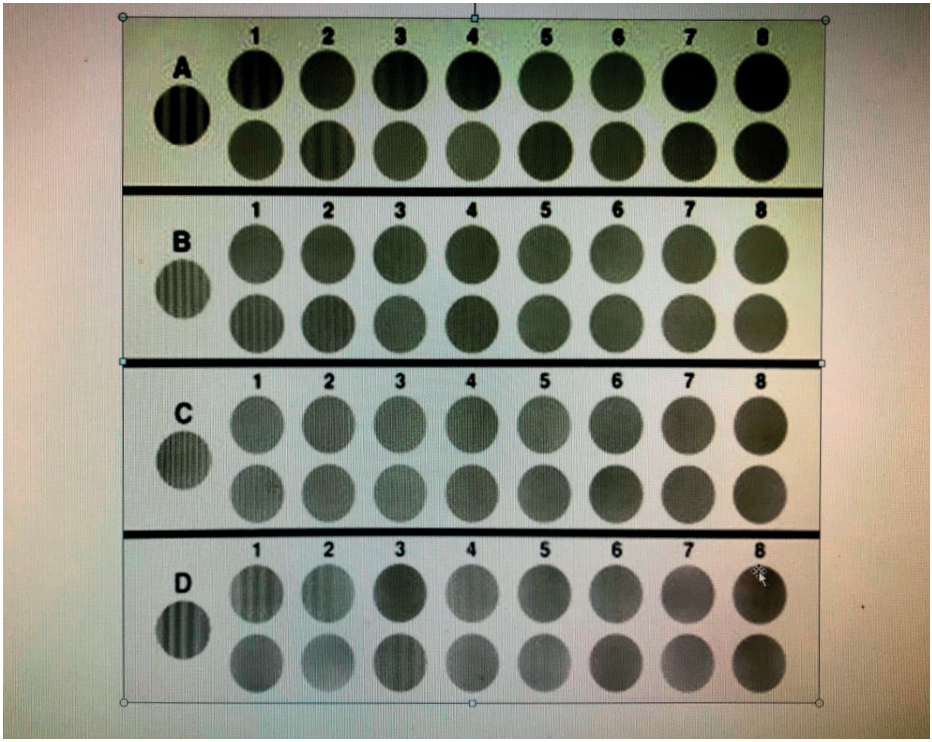

Fig. 2. CSV-1000e contrast sensitivity chart.

pupil in a trial frame. The pupil was dilated with two drops of tropicamide 0.5% and two drops of phenylephrine 2.5%. Once the pupil was dilated, the contrast sensitivity testing began with a corrective lens and artificial pupil in place.

The patient was positioned at 2.5 metres from the chart and was asked to report which grating on the chart was the clearest. The test was conducted under photopic conditions and mesopic conditions, the latter with and without glare. Photopic testing was performed with standard lighting, which was provided by the internal fluorescent luminance console calibrated to 85 candelas per square metre (cd/m2). Mesopic testing without glare (5 cd/m2) was performed by turning off the room light with the test conducted in a fully darkened room. Mesopic testing with glare was performed with a halogen light source of 200 lux positioned at the side of the console.

The patient reported whether the upper or lower circle had sine-wave gratings and the investigator recorded the last correct response as the contrast threshold. If the patient was unable to see the sample gratings, 0.30 log value was subtracted from the lowest score on the row. For example, Row A is (0.70 – 0.30) = 0.40 log unit (Table 1).

Table 1. Contrast sensitivity values for CSV-1000E in log units

Row (cpd)	Plate								
	Sample	1	2	3	4	5	6	7	8
A (3.0)	0.70	1	1.17	1.34	1.49	1.63	1.78	1.93	2.08
B (6.0)	0.91	1.21	1.38	1.55	1.70	1.84	1.99	2.14	2.29
C (12.0)	0.61	0.91	1.08	1.25	1.40	1.54	1.69	1.84	1.99
D (18.0)	0.17	0.47	0.64	0.81	0.96	1.10	1.25	1.40	1.55

The grating pattern contrast in the CSV-1000E test is expressed in Michelson contrast = $(L_{max} - L_{min})/(L_{max} + L_{min})$, where L_{max} is the maximum luminance of the bright bars and L_{min} is the minimum luminance of the dark bars. The sample and plate results are shown in Table 1.

There are several other test tools to evaluate contrast sensitivity. Contrast sensitivity can be tested either by using optotype letters with decreasing contrast or sine-wave gratings with different ranges of spatial frequencies. An example of letter-contrast sensitivity test is the Pelli-Robson test, which has been used in several studies.[23,24] However, one of the disadvantages of the Pelli-Robson test is that it only tests at one spatial frequency.[23,25] Sine-wave gratings tests can be either generated by computer and displayed on a monitor or presented with wall chart tests. Each of these modes has its own advantages and disadvantages. The computer-generated tests are more time-consuming and expensive. However, they offer the advantage of continuous control of contrast testing levels at a wide range of spatial frequencies.[26]

All phacoemulsification surgeries were performed by a single surgeon with more than five years of experience (BG) in order to minimize differences in surgically induced aberration. The phacoemulsification procedures were performed using the Infiniti phacoemulsification device (Alcon, TX USA) with a 2.75 mm clear corneal incision. No attempts were made to correct pre-existing corneal astigmatism. The corneal wound was either hydrated or closed with nylon 10/0 and the paracentesis wound closed using the hydration method. The patients were operated as a day case under local anaesthesia.

The eyes included in the study were randomly assigned to receive either Tecnis ZA9003™, AcrySof IQ™, or Akreos Adapt AO™ IOLs. There was no financial interest in any of the lenses used and the patients paid for the lenses unless they were government employees, in which case they were able to obtain reimbursement from the government. The cost of all the three lenses is similar in the local market.

Table 2. IOL types and specifications

	Tecnis ZA9003™	**AcrySof IQ™**	**Akreos Adapt AO™**
Material	Hydrophobic acrylic	Hydrophobic acrylic	Hydrophilic acrylic
Refractive index	1.47	1.55	1.458
Aspheric optic design	Round anterior edge Square posterior edge Sloping side edge	Anterior increase in edge	Biconvex aspheric anterior and posterior Optic body is 6 mm
Aberration correction	Cornea and lens	Cornea and lens	Lens
Edge thickness	Approximately 0.50 mm	0.21 mm	0.31 mm
Light filtration	UV	UV and blue light	UV
Design	Multi-piece	Single-piece	Single-piece, 0° angulation
Delivery system	UNFOLDER	MONARCH II	Al-27/PS-27 inserter

Randomisation was achieved using a computerized randomization program by the Centre of Clinical Research in Penang, Malaysia. The primary investigator (CCYA), who evaluated the contrast sensitivity, was blinded to the type of IOL used.

Table 2 shows the specifications of the three different IOL types compared in this study. The Tecnis ZA9003™ is a three-piece IOL with biconvex design that improves contrast sensitivity by reducing unwanted aberration. It has a square posterior edge (360° capsular contact) which stabilizes the lens. In addition, it has a rounded anterior edge designed to scatter light and reduce internal reflections. The sloping side reduces unwanted aberration and glare. It introduces -0.27 µm of spherical aberration to the eye measured at the 6 mm optical zone.

The AcrySof IQ™ is a single-piece, yellow-tinted acrylic hydrophobic IOL with blue light filtration that is designed for uncompromised colour perception. It reduces corneal and lens aberration by its aspheric posterior surface reduction design. Its blue light filter absorbs light wavelengths between 300 and 500 nm, thus protecting the retinal pigment epithelium from blue light damage. Reduction of blue light on the retinal pigment epithelial cells reduces the risk of macular degeneration. It adds -0.20 µm of spherical aberration to the eye.

The Akreos Adapt AO™ is an acrylic hydrophilic IOL. It is an aberration-free lens that has aspheric anterior and posterior surfaces. They are neutral to the cornea, therefore suitable for all patients regardless of corneal shape. This aberration-free IOL leaves a small amount of positive spherical aberration from the cornea, thus increasing the depth of field compared to negative aberration lenses. Its anti-glare

Table 3. Postoperative procedure

Postoperative follow-up	Examinations and parameters recorded
Day 1	Slit lamp and visual acuity
Week 1	Slit lamp, visual acuity, and retina examination
Week 6	Slit lamp and retina examination LogMAR visual acuity Contrast sensitivity Refraction
Week 12	Slit lamp and retina examination LogMAR visual acuity Contrast sensitivity Refraction

technology reduces glare by having a low refractive index material and a steeper curvature of the anterior lens surface.

Routine postoperative care was a fixed combination of dexamethasone, neomycin, and polymyxin B eye drops (Maxitrol, Camberley, UK) at three hourly intervals, which was then tapered to four times a day after one week and discontinued after one month. The examinations and parameters recorded at each postoperative follow-up is summarised in Table 3. Subjects were reviewed on day 1, week 1, week 6, and week 12. LogMAR visual acuity and anterior segment examination were performed at all visits. Dilated fundus examination was performed at weeks 1, 6, and 12. This included refraction and contrast sensitivity examinations with the CSV-1000 contrast sensitivity test at weeks 6 and 12 only with BCVA by the primary investigator (CCYA).

A power and sample size calculation (PS) computer software program was used to calculate the sample size. The subjects were assigned to three groups. The level of significance, α value, was taken as 0.05 (confidence level of 95%). The power of the study was 80%. The σ standard deviation of mean was 0.14. The δ value, which is the detectable difference, was taken as 0.10 log units between tests at a given spatial frequency. The ratio of control to experimental patients was m = 1. By using the PS computer software program, the sample size for each for each of the IOLs was set at 32.

Analysis of variance (ANOVA) was used to determine the differences in the contrast sensitivity between the Tecnis ZA9003™, AcrySof IQ™, and Akreos Adapt AO™ groups. If the one-way ANOVA revealed a significant difference, *post hoc* tests with Bonferroni corrections were used to determine the differences between the specific means. A general linear model was used to analyse the pre- and postoperative contrast sensitivity for each IOL. The Statistical Package for Social Sciences (SPSS) version 17.0 was used for the statistical analysis. The accepted level of significance was set at $p < 0.05$.

Results

We were able to recruit one hundred patients in this study. However, only 96 eyes were finally analysed. Two patients were randomised but were unable to proceed with surgery because the assigned IOLs could not be obtained in time. Another patient had a medical illness and was lost to follow-up. The fourth had a posterior capsule rupture and the IOL was inserted in the sulcus. All 96 patients completed 3 months of follow-up. All groups had the same number of eyes, that is, 32 eyes. Demographical data of the patients analysed in the study are shown in Table 4.

Figure 3 shows the results of the pre- and post-operative best corrected visual acuity measured at 6 and 12 weeks for the 3 groups. There was no statistically significant difference between the groups at each postoperative period.

Table 4. Demographical data at baseline showing the mean age and gender distribution of patients implanted with the three lenses

	Tecnis ZA9003TM	**AcrySof IQTM**	**Akreos Adapt AOTM**	**P-value**
Mean age (years) ± SD (Range)	66.90 ± 5.53 (55-75)	66.5 ± 5.58 (56-75)	66.18 ± 5.36 (57-74)	0.80
Ratio of percentage of male: female	37:63	56:44	31:69	0.11

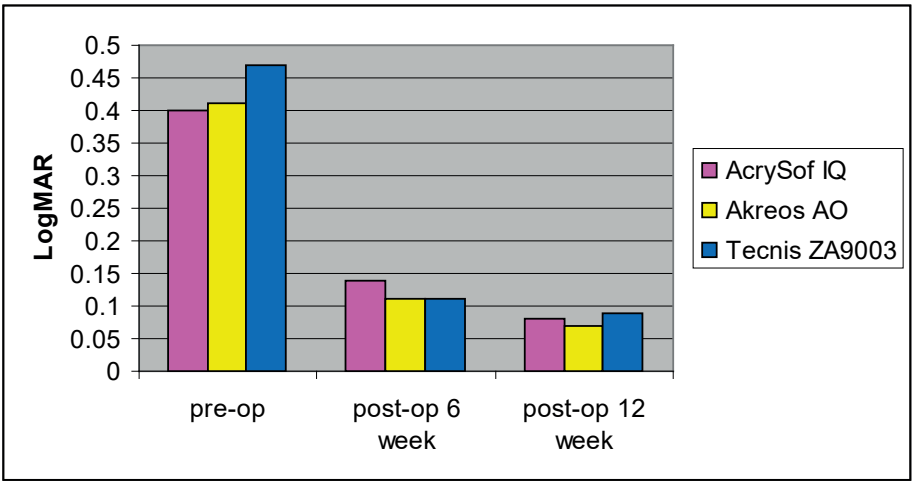

Fig. 3. Pre- and postoperative BCVA at 6 and 12 weeks. One-way repeated measure ANOVA, $p > 0.05$

Table 5. Postoperative vision and spherical equivalent (SE)

	Tecnis ZA9003TM	AcrySof IQTM	Akreos Adapt AOTM	P-value
Mean uncorrected preoperative distance visual acuity (UCVA) ± SD (logMAR)	0.59 ± 0.19	0.60 ± 0.25	0.56 ± 0.23	0.70 (F = 0.357)
Mean corrected preoperative distance visual acuity (BCVA) ± SD	0.47 ± 0.12	0.40 ± 0.15	0.41 ± 0.14	0.15 (F = 1.896)
Postoperative UCVA Week 6	0.35 ± 0.16	0.35 ± 0.15	0.31 ± 0.16	0.54 (F = 0.605)
Postoperative BCVA Week 6	0.11 ± 0.10	0.14 ± 0.10	0.11 ± 0.10	0.48 (F = 0.744)
Postoperative UCVA Week 12	0.37 ± 0.25	0.28 ± 0.17	0.27 ± 0.20	0.17 (F = 1.80)
Postoperative BCVA Week 12	0.09 ± 0.09	0.08 ± 0.08	0.07 ± 0.09	0.71 (F = 0.342)
Mean preoperative SE (range)	0.37 ± 1.45 D (-3.50–4.38)	0.83 ± 1.89 D (-2.75–4.25)	0.87 ± 1.96 D (-3.50–4.38)	0.46 (F = 0.789)
Mean postoperative SE Week 6 (range)	0.13 ±0.98 D (-1.50–0.98)	0.45 ± 0.67 D (-0.38–2.25)	0.50 ± 1.01 D (-1.50–3.75)	0.20 (F = 1.598)
Mean postoperative SE Week 12 (range)	0.22 ± 1.02 D (-1.75 – 3.00)	0.45 ± 0.68 D (-0.75–2.25)	0.60 ± 0.96 D (-1.75–3.00)	0.26 (F = 1.382)

Table 5 shows the changes in post-operative vision and spherical equivalent. There is no statistical significance between the 3 lenses. (F value = variance of the group means (Mean Square Between) / mean of the within group variances (Mean Squared Error)

Pre-operative contrast sensitivity

The preoperative mean distance contrast sensitivity scores for all spatial frequencies under photopic conditions and mesopic conditions with and without glare were not statistically significant between the lenses ($p > 0.05$) (Table 6). Our results showed that mesopic contrast sensitivity with glare was the lowest compared to photopic contrast sensitivity at 3, 6, 12, and 18 cpds.

Postoperative contrast sensitivity

There was no statistically significant difference between the three groups at all spatial frequencies at 6 weeks postoperative ($p > 0.05$) (Table 7). There was no sta-

Table 6. Preoperative mean contrast sensitivity scores in logarithmic value in the three IOL groups.

Conditions	Mean contrast sensitivity			
	AcrySof IQTM	Akreos Adapt AOTM	Tecnis ZA9003TM	P-value
Photopic				
3 cpd	1.28	1.27	1.23	0.77
6 cpd	1.21	1.27	1.21	0.68
12 cpd	0.89	0.74	0.79	0.15
18 cpd	0.45	0.40	0.38	0.63
Mesopic, no glare				
3 cpd	1.19	1.25	1.20	0.71
6 cpd	1.18	1.23	1.20	0.13
12 cpd	0.81	0.78	0.76	0.76
18 cpd	0.41	0.41	0.39	0.92
Mesopic, with glare				
3 cpd	1.13	1.16	1.03	0.22
6 cpd	1.06	1.16	1.01	0.10
12 cpd	0.77	0.74	0.72	0.69
18 cpd	0.36	0.36	0.36	1.00

tistically significant difference between groups in the mean contrast sensitivity at 12 weeks postoperative ($p > 0.05$). (Table 7)

Peak sensitivity occurs near 6 cpd, which corresponds to the most sensitive part of the contrast sensitivity curve.15 The trend of the line graph showed that all 3 lenses had comparable mean contrast sensitivity value at 3 and 6 cpds (Fig 4). Akreos AOTM, a zero aberration IOL, showed better contrast sensitivity at 12 cpd under photopic testing, but this was not statistically significant ($p = 0.48$). The two negative aberration IOLs, AcrySof IQTM and Tecnis ZA9003TM, showed comparable mean contrast sensitivity at 12 cpd under photopic conditions.

Even though the data analysis showed no significance in contrast sensitivity between the lenses postoperatively, the line graph showed that the zero aberration IOL (Akreos AO™) had the lowest mean contrast sensitivity under mesopic testing without glare at 18 cpd (Fig. 5). Tecnis ZA9003™ had the highest mean contrast sensitivity at higher frequency testing at 18 cpd under mesopic conditions without glare. The mean difference between the Tecnis ZA9003™ and Akreos Adapt AO™ at 18 cpd under mesopic testing was 10.3%. However, this was not statistically

Table 7. Postoperative mean contrast sensitivity scores in logarithmic value in the 3 IOL groups at 6 and 12 weeks

Conditions	Mean contrast sensitivity							
	AcrySof IQTM		Akreos Adapt AOTM		Tecnis ZA9003TM		P-value	
	Week 6	Week 12	Week 6	Week 12	Week 6	Week 12	Week 6	Week 12
Photopic								
3 cpd	1.70	1.76	1.75	1.76	1.74	1.77	0.47	0.94
6 cpd	1.62	1.99	1.94	1.99	1.94	2.00	1.00	0.99
12 cpd	1.62	1.66	1.67	1.72	1.59	1.66	0.53	0.48
18 cpd	1.18	1.25	1.19	1.26	1.21	1.31	0.81	0.55
Mesopic, no glare								
3 cpd	1.68	1.70	1.66	1.70	1.72	1.67	0.35	0.82
6 cpd	1.88	1.91	1.86	1.90	1.88	1.95	0.94	0.65
12 cpd	1.59	1.63	1.58	1.64	1.57	1.67	0.95	0.77
18 cpd	1.15	1.26	1.19	1.21	1.20	1.35	0.78	0.09
Mesopic, with glare								
3 cpd	1.66	1.69	1.63	1.67	1.65	1.68	0.75	0.88
6 cpd	1.91	1.80	1.85	1.85	1.84	1.90	0.49	1.39
12 cpd	1.55	1.62	1.60	1.58	1.50	1.62	0.28	0.80
12 cpd	1.11	1.24	1.14	1.19	1.13	1.26	0.85	0.58

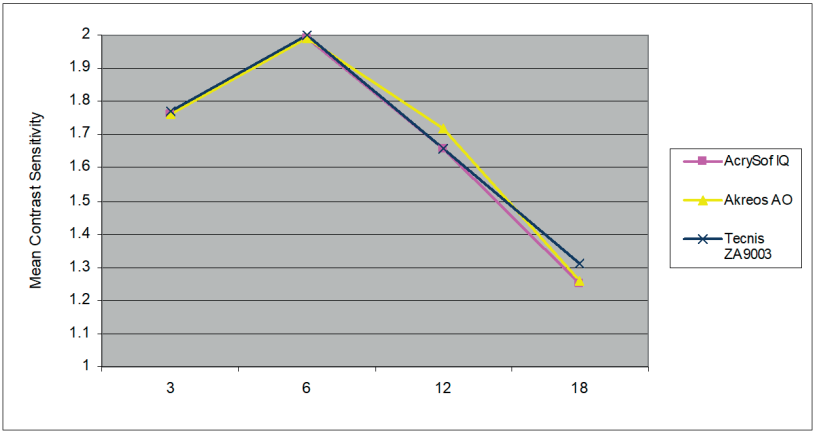

Fig. 4. Comparison of mean contrast sensitivity values between the 3 IOL groups under photopic conditions at week 12. One-way ANOVA test, $p > 0.05$.

significant (p = 0.09).

All three lenses showed comparable mean contrast sensitivity at all spatial frequencies under mesopic testing with glare. There was no significant difference between the groups (p > 0.05) (Fig. 6).

General linear model with post hoc Bonferroni test:

1. AcrySof IQTM, F = 26.75, p = 0.0;
2. Akreos Adapt AOTM, F = 17.99, p = 0.0; and
3. Tecnis ZA9003TM, F = 17.00, p = 0.0

There was statistically significant improvement in the uncorrected postoperative mean logMAR at weeks 6 and 12 compared with preoperatively for all IOL groups. There were no significant changes found between the week 6 and week 12 mean

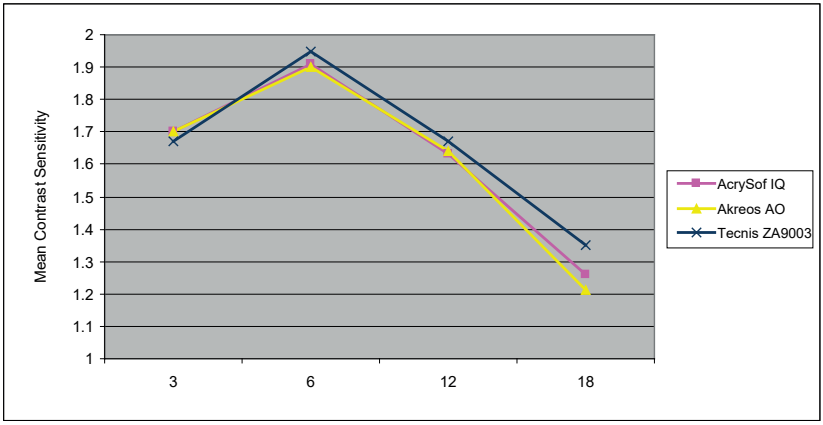

Fig. 5. Comparison of mean contrast sensitivity values between the 3 IOL groups under mesopic conditions without glare at week 12. One-way ANOVA test, p > 0.05.

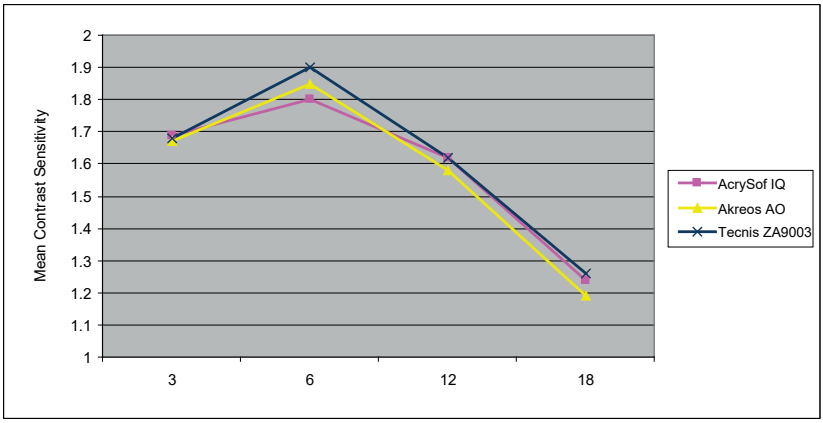

Fig. 6. Comparison of mean contrast sensitivity values between the three IOL groups under mesopic conditions with glare at week 12. One-way ANOVA test, p > 0.05.

logMAR (p1 = 0.24, p2 = 0.28, p3 = 1.0) (Fig. 7).

General linear model with post hoc Bonferroni test:

1. AcrySof IQTM, F = 84.96, p = 0.0;
2. Akreos Adapt AOTM, F = 86.99, p = 0.0;
3. Tecnis ZA9003TM, F = 131.57, p = 0.0

Our data analysis showed statistically significant improvement between pre- and postoperative BCVA at weeks 6 and 12 for all IOL groups (Fig. 8). Both the AcrySof

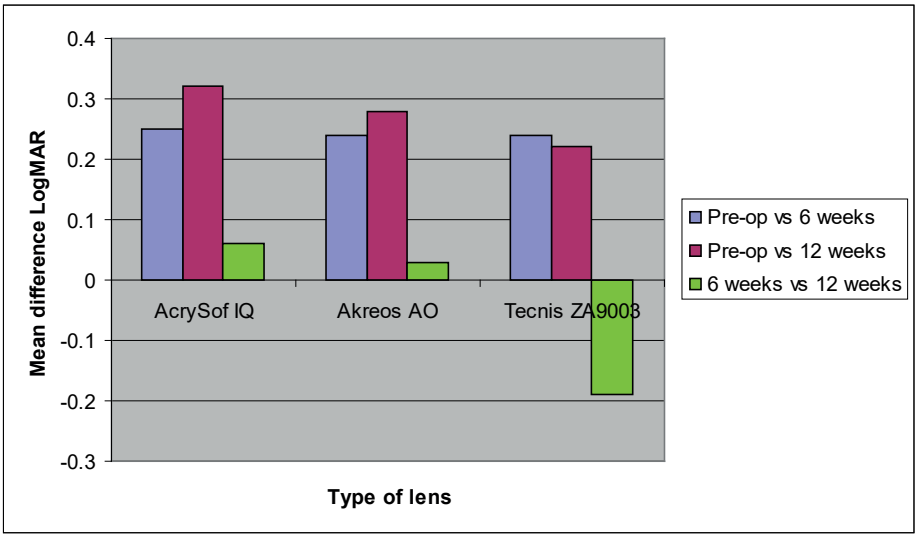

Fig. 7. Comparison of mean difference between uncorrected pre- and postoperative logMAR vision for each of the three IOL groups.

IQTM and Akreos Adapt AOTM groups also showed significant improvement in visual acuity between 6 and 12 weeks (p1 = 0.00, p2 = 0.04). There were no statistically significant changes found in the Tecnis ZA9003TM group at 6 and 12 weeks (p3 = 0.57).

In comparing pre- and postoperative contrast sensitivity, our analysis showed that all three IOLs showed statistically significant improvement at all spatial frequencies under photopic, mesopic without glare, and mesopic with glare conditions following surgery at week 12 compared to baseline preoperative levels ($p < 0.05$) (Fig. 9 A-C).

Figure 10 illustrates that Tecnis ZA9003™ showed a statistically significant improvement of 12% in the contrast sensitivity at 18 cpd under mesopic testing without glare between week 6 and 12 week postoperatively. Akreos Adapt AO™ and AcrySof IQ ™ showed slight improvement, but not statistically significant, from week 6 to week 12.

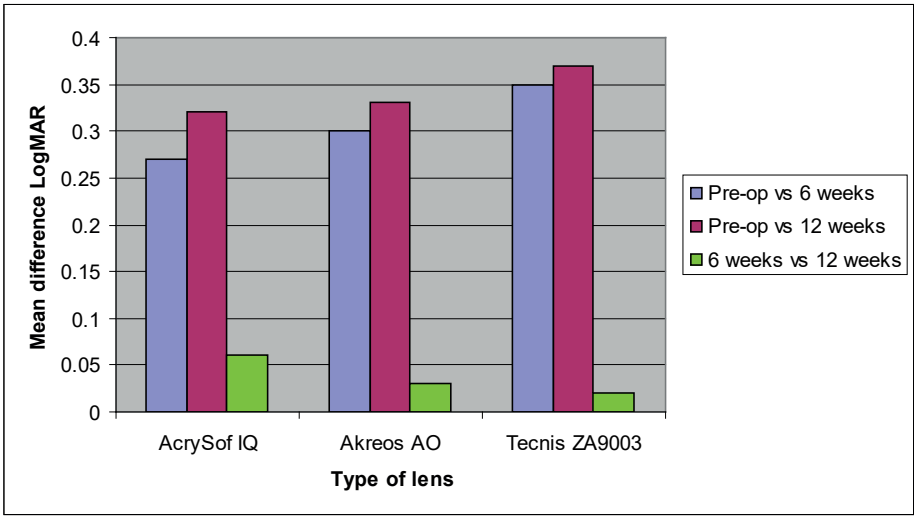

Fig. 8. Comparison of mean difference between corrected pre- and postoperative logMAR vision for each of the three IOL groups.

Akreos Adapt AOTM, a zero aberration IOL, showed slightly higher contrast sensitivity at photopic testing in comparison to the negative aberration IOLs (AcrySof IQTM and Tecnis ZA9003TM) (Fig. 11). However, this was not significant as the difference was only 3.5% ($p = 0.48$).

In studying the performance of Akreos Adapt AOTM, we found that the contrast sensitivity drop from photopic to mesopic testing (with and without glare) was statistically significant at 12 cpd at 12 weeks (Fig. 11). There was a 4.6% drop in contrast from photopic to mesopic without glare and 3.6% drop at mesopic with glare. The total drop of contrast sensitivity from photopic to mesopic with glare was 8%. The negative aberration IOLs, Tecnis ZA9003TM and AcrySof IQTM, did not show any statistically significant drop at mesopic testing with or without glare.

Tecnis ZA9003TM showed a slight improvement of 5.8% at 12 weeks in contrast sensitivity from photopic to mesopic testing without glare. However, this was not statistically significant ($p = 0.79$).

Discussion

Cataract surgery has evolved over the years from only removing the cataract and implanting an IOL in order to improve visual acuity to improving functional vision in terms of better contrast sensitivity and correction of astigmatism with toric IOLs with various lens designs and materials. Contrast sensitivity of patients with spherical IOL implants was found to be the same as those with crystalline lens.[12]

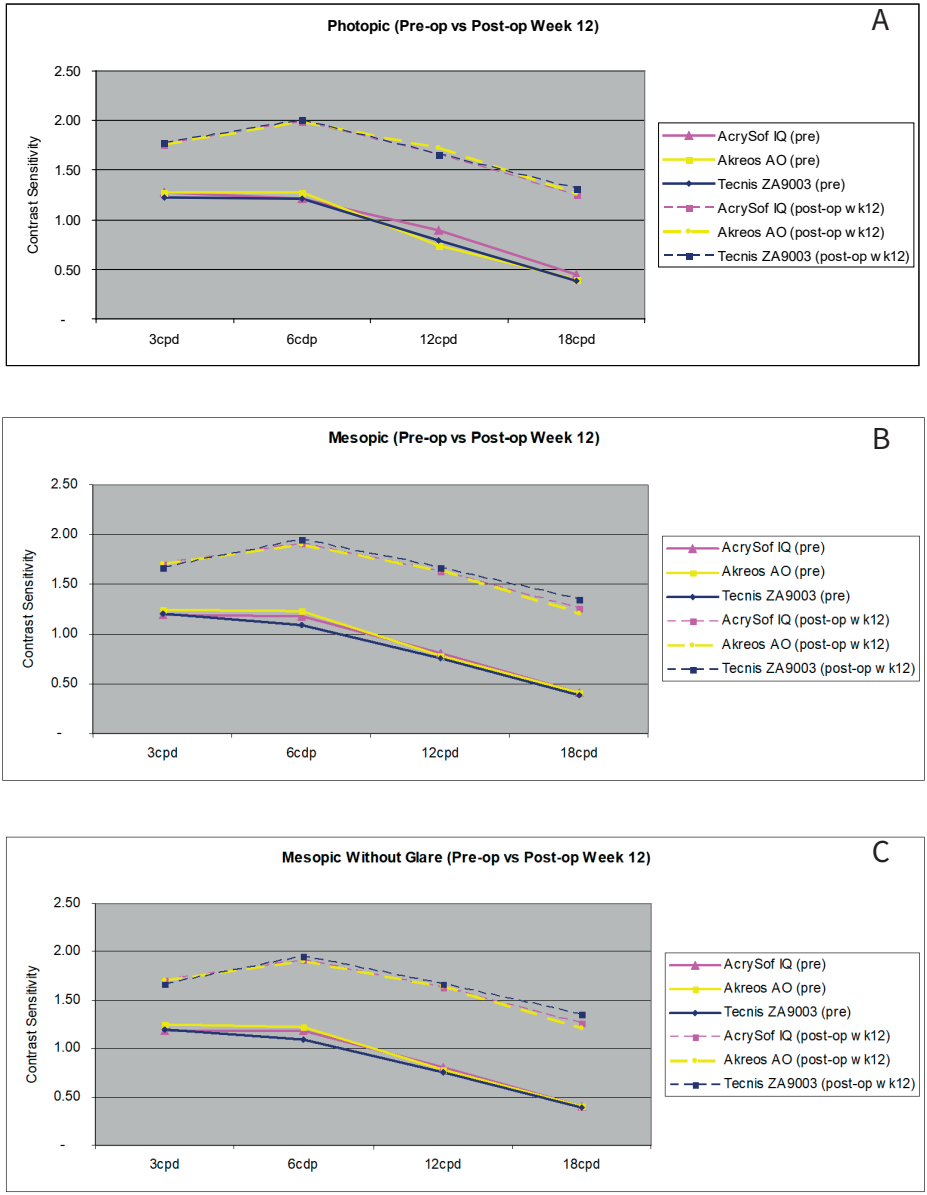

Fig. 9. (*A-C*) Comparison between pre- and postoperative combined lens mean contrast sensitivity under photopic, mesopic without glare, and mesopic with glare at different spatial frequencies.

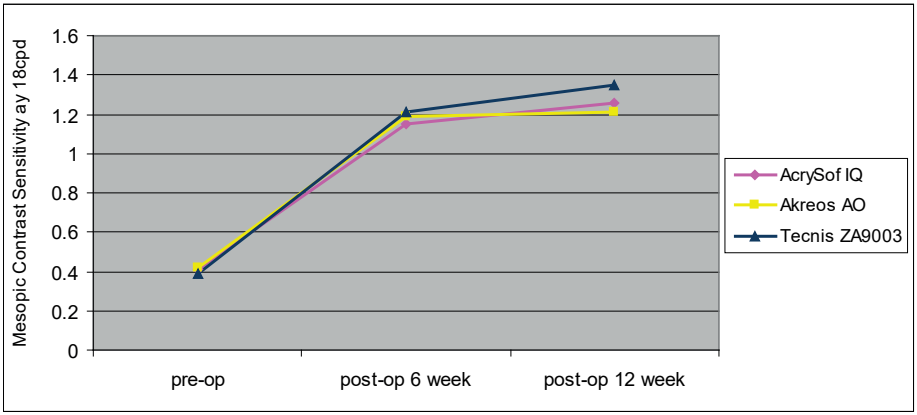

Fig. 10. Comparison between contrast sensitivity at pre- and postoperative weeks 6 and 12 under mesopic conditions without glare at 18 cpd. One-way ANOVA, (test within subject effect). For Tecnis ZA9003TM, F = 189.03, p = 0.001 for week 6 vs week 12.

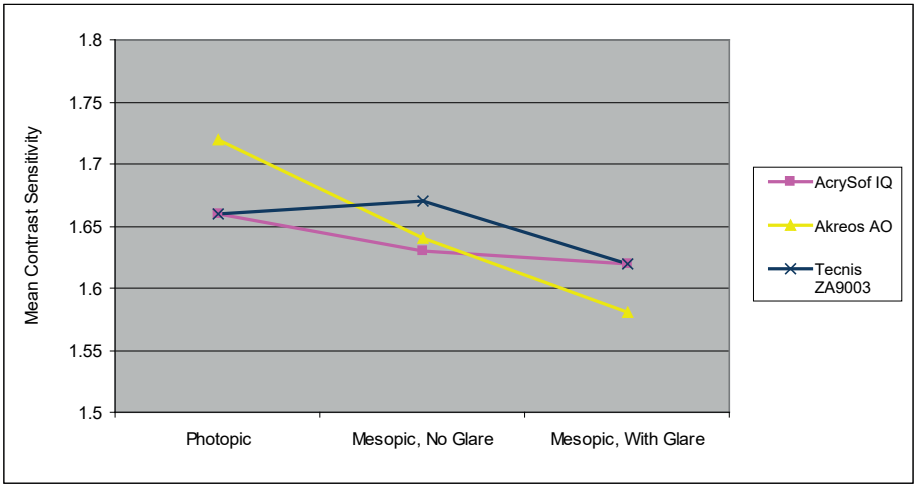

Fig. 11. Comparison between postoperative contrast sensitivity under photopic, mesopic without glare, and mesopic with glare at 12 cpd for each IOL group at week 12. Paired T-test (2-tailed). For Akreos Adapt AOTM, t = - 2.55 (mesopic without glare vs photopic), p = 0.16, t = - 3.94 (mesopic with glare vs photopic), p = 0.00.

Contrast sensitivity as measured with the CSV 1000 has been used as a research tool in various studies.[4,14,16,18,27,28] In addition, the halogen light source from the CVS 1000 HGT allows the measurement of glare at mesopic testing, which provides additional assessment for the optical performance of these lenses. Contrast sensitivity has been reported to decrease with age, affecting mesopic contrast sensitivity.[29]

Our results show that, preoperatively, there were no statistically significant differences between the three groups in terms of visual acuity, spherical equivalent, cylindrical powers, and age. Postoperatively, all three IOLs showed significant improvement in UCVA and BCVA. All three IOLs performed equally well in distance visual acuity postoperatively. This result concurs with the findings of other investigators.[13,17,30] Nabh *et al.,* who also studied the Tecnis ZA90003™, AcrySof IQ™, and Akreos Adapt AO™ similarly found that postoperative gains in visual acuity were comparable.[23]

Preoperatively, all patients in the three IOL groups had the lowest level of contrast sensitivity in all lighting conditions, especially in mesopic testing with glare. The poorer contrast sensitivity reflects the effect of cataract on the loss of contrast sensitivity. Many patients with cataract have reported worsening of visual performance when associated with glare at night while driving.[8] Our results showed that, at mesopic testing with glare at 3, 6, 12, and 18 cpds, the contrast sensitivity result was the lowest compared to photopic testing.

Our study showed that the postoperative mean log contrast sensitivity was not statistically significant between these three aspheric IOLs. This concurs with other studies[17,23,30] that showed equal performance in contrast sensitivity between aspheric lenses. Nabh *et al.* conducted a similar study comparing contrast sensitivity between Tecnis ZA9003™, AcrySof IQ™, and Akreos Adapt AO™. However, they used the Pelli-Robson contrast sensitivity chart, which only measures contrast sensitivity at one spatial frequency and without mesopic testing with and without glare. They similarly found no statistically significance between the mean contrast sensitivity values.[23] Johannsson *et al.* reported that Akreos Adapt AO™ and Tecnis ZA9000™ gave similar photopic and mesopic contrast sensitivities.[30] They used the Functional Acuity Contrast Test charts under photopic and mesopic testing without glare. However, they did not test for contrast sensitivity with glare. Despite the equal performance in contrast sensitivity, they found that Tecnis Z9000™ gave significantly less spherical aberration compared to Akreos Adapt AO™ using an aberrometer.[30] This could explain better mesopic contrast sensitivity results with Tecnis in our study. However, we could not confirm this finding without a wavefront analysis. Our study reinforces the findings in previous studies using the CSV 1000 tool for measuring contrast sensitivity.

Even though our study did not show statistically significant differences between the IOLs, our data analysis showed that negative aberration IOLs (Tecnis ZA9003™ and AcrySof IQ™) had better contrast sensitivity values at mesopic testing at higher

frequencies compared to the zero aberration IOL (Akreos Adapt AO™). In our study, Tecnis ZA9003™ showed significant improvement (12%) at mesopic testing without glare at 18 cpd between weeks 6 and 12 postoperative. In studying mesopic contrast sensitivity at 12 cpd, we found that negative aberration lenses, Tecnis ZA9003™ and AcrySof IQ™, did not show any statistically significant drop in contrast sensitivity. On the contrary, Akreos Adapt AO™ showed 8 % contrast sensitivity drop from photopic to mesopic testing with glare, which was statistically significant. This useful information may influence IOL selection for patients who frequently move between light and dark environments, including retinal surgeons.

A study conducted by Denoyer *et al.* found similar results to our study.[13] They compared a negative-aberration IOL (Tecnis Z9000, Advanced Medical Optics, CA, USA) and a zero aberration IOL (SofPort AO, Bausch and Lomb, Quebec, Canada). Their results showed that mesopic contrast sensitivity was statistically better in the negative-aberration IOL group at intermediate and high frequencies.[12] In addition, they also found that the zero aberration group (SofPort AO) performed better at photopic contrast sensitivity. This result is similar to our study at week 12, where Akreos Adapt AO™ had the highest contrast sensitivity at 12 cpd under photopic testing. However, this finding was not statistically significant in our study. This could be due to our smaller sample size compared to Denoyer *et al.*, which had 40 patients in each group.

AcrySof IQ™ is a yellow-tinted IOL designed with a modified posterior surface for improving contrast sensitivity. It has been proposed that yellow filters can improve contrast sensitivity at medium spatial frequencies under mesopic testing,[6,14,18] reducing glare and increasing apparent brightness in daylight conditions.[29] However, other studies showed no difference in the contrast sensitivity between the yellow-tinted Alcon SN60AT (Alcon Laboratories, TX, USA) and clear Alcon SA60AT4.[27] Our study showed that AcrySofIQ ™ with the yellow tint performed equally well in contrast sensitivity with clear aspheric IOLs. This result is similarly found in a study conducted by Nabh *et al.* comparing the AcrySofIQ™ and Tecnis ZA9003™.[23]

There have been concerns among some researchers that yellow-tinted IOLs may affect visual function negatively. It has been reported that patients with yellow-tinted lens, in this case the Alcon SN60AT have lower luminance and require more blue light to perceive the same amount of luminance.[31] Schwiegerling *et al.* showed that there is a reduction in scotopic vision of 14% in yellow- tinted IOLs compared to clear IOLs.[32] AcrySof IQ uses the same platform as SN60AT. We can assume that AcrySof IQ™ would also have lower luminance contrast. In our study, however, AcrySof IQ™ showed no statistically significant decrease in mesopic contrast sensitivity. In fact, our results demonstrate that the yellow-tinted Acrysof IQ™ showed comparable performance with a clear negative aberration aspheric IOL (Tecnis ZA9003™) at mesopic testing with and without glare. This is interesting and useful information for patients who have a family history of age-related macular degeneration who would like to have a blue light-blocking IOL implantation. Patients can be reassured

of the comparable luminance contrast to clear lenses.

The effect of pupil bias, whereby larger pupils result in greater spherical aberration, was overcome by using of a 5 mm artificial pupil in this study. We limited the study of contrast sensitivity by using a standard 5 mm pupil size in dilated eyes. Our results may have shown more significant difference had we used a larger pupil size, for example, a 6 mm pupil. Larger pupils have been shown to have greater higher-order aberration,[17,30] the true aspherical value of the IOLs being more evident during mesopic testing with a larger pupil.

There were several limitations to this study. One of the limitations is that the extreme range of cylindrical power and spherical powers were not excluded. Although all study subjects were examined with the best-corrected spectacles in place to ensure optimal performance, we were unable to assess the effect of corrective lenses on the contrast sensitivity evaluation. Postoperative cystoid macula oedema can also affect contrast sensitivity. Even though we examined the macula postoperatively for macula oedema, we are unable to exclude any occult cystoid macular oedema, as we did not perform any fundus fluorescence angiography or ocular coherence tomography.

There was no objective assessment of postoperative posterior capsular opacification (PCO) using any grading method. However, the follow-up period for this study was relatively short, only up to three months. The literature has reported that the incidence of PCO and rate of Nd-Yag capsulotomy is low, and the mean time of surgery to documentation PCO was 10.3 ± 5.3 months for Acrysof IQ™. It would be ideal to follow up for more than one year to assess the long-term visual outcomes of these IOLs.

Another limitation includes comparing Tecnis ZA9003™ which is a three-piece IOL, with AcrySof IQ™ and Akreos Adapt AO™, which are single-piece IOLs. The three-piece design is more stable in the bag. In our study, we did not assess for any degree of decentration and tilt. It has been reported that negative aberration IOLs are more sensitive to decentration and tilt and may perform worse than conventional IOLs.[11] Recently, a new single-piece Tecnis IOL has been released in the market. Future studies involving the new Tecnis would be ideal to standardize the IOLs to single-piece design in order to avoid bias.

In this study, we only assessed the contrast sensitivity as a measure of functional vision. It would be ideal to correlate the contrast sensitivity outcome with the wavefront analysis of the postoperative spherical aberration in future studies. Baseline measurement of the patient's corneal spherical aberration and customising the selection of aspheric IOL perhaps will allow us to better assess the performance of these lenses.

Conclusions

This study showed that AcrySof IQ™, Akreos Adapt AO™, and Tecnis ZA9003™ have comparable visual performance in terms of BCVA and contrast sensitivity. The visual outcomes were excellent, with significant better BCVA and contrast sensitivity after surgery than at baseline. AcrySof IQ™, Adapt Akreos AO™, and Tecnis ZA9003™ performed equally well in contrast sensitivity at all spatial frequencies under photopic, mesopic without glare, and mesopic with glare testing. The negative aberration Tecnis ZA9003™ showed marked improvement in mesopic contrast sensitivity at 18 cpd at 12 weeks. The zero aberration IOL, Akreos Adapt AO™, showed better photopic contrast sensitivity compared to mesopic contrast sensitivity.

Acknowledgements

This study is registered with the Secretariat National Institutes of Health (NIH), Ministry of Health Malaysia under project code MRG-2007-04.

We would like to acknowledge Dr. Intan Hafizah binti Hamzah and En Mohd Hairul Nizam bin Harun, our research officers, for their efforts in formatting and preparing this manuscript for publication.

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Malaysian Journal of Ophthalmology

© Malaysian Journal of Ophthalmology 2019; 4:284-288
Case report/Case series

A rare presentation of eyelid tuberculosis

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Abstract

Mycobacterium tuberculosis is transmitted through aerosolization, hence commonly infects the lungs. The occurrence of extrapulmonary tuberculosis is rare. We report a case of eyelid tuberculosis in a 45-year-old gentleman with a history of treated testicular tuberculosis three years ago. He had insidious onset of painless swelling in the right upper eyelid associated with erythema for one month. He did not have other constitutional symptoms. Initially, he was treated as chalazion and given topical antibiotics. However, the swelling worsened despite medication. His best corrected visual acuity was 6/9 in both eyes. Examination showed an elevated ulcerative growth with broad base which bled easily upon touch. The clinical presentation varies from an eyelid infection as an eyelid tumour can be a diagnostic challenge. A slow response to oral and topical antibiotic warrants an excision biopsy. The results showed chronic granulomatous infection in acid-fast bacilli. An antituberculosis (anti-TB) therapy was started and the patient showed a positive clinical response.

Althrough rare, tuberculosis of eyelid should be considered as differential diagnosis of chalazion. Any suspicious case should be confirmed by biopsy followed by anti-TB if indicated.

Keywords: acid-fast bacilli, chalazion, eyelid, tuberculosis

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Manifestasi ganjil tuberculosis kelopak mata

Abstrak

Mycobacterium tuberculosis ditularkan melalui aerosol, dan biasanya menjangkiti paru-paru. Kejadian tuberkulosis extrapulmonary jarang berlaku. Kami melaporkan kes tuberkulosis kelopak mata pada lelaki berusia 45 tahun dengan sejarah tuberkulosis testicular yang dirawat tiga tahun yang lalu. Dia mengalami permulaan bengkak yang tidak menyakitkan di kelopak mata sebelah kanan berserta eritema selama sebulan. Dia tidak mempunyai gejala lain. Pada mulanya, dia dianggap sebagai chalazion dan diberikan antibiotik topikal. Bagaimanapun, bengkak menjadi lebih teruk walaupun diberi ubat. Ketajaman penglihatannya yang terbaik adalah 6/9 di kedua-dua mata. Pemeriksaan menunjukkan satu ulser yang menimbul dengan dasar yang luas mudah berdarah apabila disentuh. Manifestasi klinikal ini berbeza dari jangkitan kelopak mata sebagai tumor kelopak mata yang boleh menjadi cabaran diagnostik. Tindakbalas yang perlahan terhadap antibiotik oral dan topikal memerlukan biopsi untuk pengesahan. Hasilnya menunjukkan jangkitan granulomatous kronik dalam bakteria bersifat bacilli asid cepat. Terapi antituberculosis (anti-TB) bermula dan pesakit menunjukkan tindak balas klinikal yang positif.

Walaupun jarang, tuberkulosis kelopak mata perlu dipertimbangkan sebagai diagnosis dan membezakan dengan chalazion. Mana-mana kes yang mencurigakan perlu disahkan oleh biopsi diikuti dengan anti-TB jika disahkan.

Kata kunci: bacilli asid-cepat, chalazion, kelopak mata, tuberculosis

Introduction

Mycobacterium tuberculosis is transmitted through aerosolization, hence commonly infects the lungs. The occurrence of extrapulmonary tuberculosis is rare: only 1–2% of patients with ocular tuberculosis have an existing systemic manifestation.[1] Ocular tuberculosis commonly presents with anterior uveitis and choroiditis due to haematogenous spread or hypersensitivity response to the tuberculosis antigen followed by systemic infection. Eyelid tuberculosis is a rare presentation of ocular tuberculosis, usually secondary to orbital involvement with drainage sinus.[2]

Case report

A 45-year-old gentleman presented with painless swelling in the right upper eyelid with erythema for one month (Fig. 1a). He was initially treated as internal hordeolum and given topical antibiotics by a private practitioner. However, the swelling worsened despite treatment and there was accelerated submandibular lymphadenitis. He had a history of testicular tuberculosis three years ago and completed antitubercular agents (Akurit four four tablets OD) for six months. The testicular tuberculosis resolved with treatment. He was immunocompetent and did not have other constitutional symptoms.

On examination, his best corrected visual acuity was 6/9 in both eyes. There was an elevated ulcerative growth with broad base at the right upper lid which bled easily bleeds upon touch (Fig. 1b). An excision biopsy was performed on the eyelid lesion. The histology showed granuloma with presence of epithelioid histiocytes and Langhan's giant cell (Fig. 2). On Ziehl Nelson staining, there was presence of acid-fast bacillus indicating eyelid tuberculosis. Other investigations, such as chest X-ray and Mantoux test, were normal. An antitubercular therapy (Akurit 4 four tablets OD) was started for six months and the patient showed significant improvement. There was

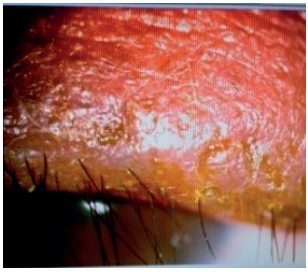

Fig. 1a. Anterior view of the lid pre-excision.

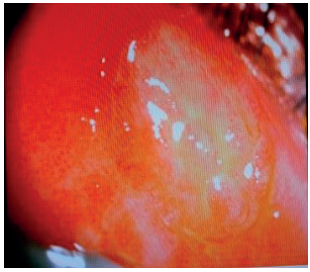

Fig. 1b. Everted lid pre-excision.

Fig. 2a. Post-excision and after initiation of antituberculosis treatment.

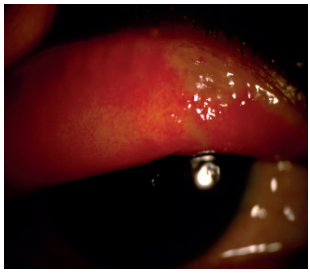

Fig. 2b. The lesion flattened two weeks post-excision and initiation of antituberculosis treatment.

regression of the lymphadenitis and the eyelid swelling resolved (Fig. 3a). The lesion at the eyelid healed and flattened (Fig. 3b) two weeks after starting therapy.

Discussion

Ocular tuberculosis was reported as choroidal tuberculoma in 1830 by Gueneau de Mussy.[3] Ocular tuberculosis can be caused by *Mycobacteria* species such as *tuberculosis*, *bovis*, *microti*, and *africanum* surrounding the eyes.[4] Primary ocular tuberculosis is isolated from systemic infection. Secondary ocular tuberculosis is caused by direct hematogenous spread or contagious spread from infected structures by introduction of bacilli through epithelial injury.[5] Ocular tuberculosis usually present as unilateral, painless, and progressively enlarging eyelid swelling associated with injected conjunctiva and chemosis.

Eyelid involvement by tuberculosis is commonly secondary to orbital involvement and often seen in the form of drainage sinus. Diagnostic imaging, such as computed tomography (CT), was not done in this patient to evaluate the sinus cavities because the lesion was isolated at the palpebral conjunctiva and there was no discharge from the sinus. In our case, the patient presented with eyelid swelling mimicking eyelid infection or eyelid tumour. There were no other systemic infectious signs beside the presence of submandibular lymphadenitis. The diagnosis can thus be difficult and may require an orbital biopsy in which acid-fast bacilli and the characteristic histopathology may be seen. The growth of *Mycobacterium tuberculosis* from the specimen remains the gold standard for the diagnosis of tuberculosis.[6] Delay in diagnosing eyelid tuberculosis can lead to tarsal plate destruction, lagophthalmos, skin fistula, and cicatricial ectropion.[7,8] Therefore, when the patient does not respond to conventional anti-inflammatory and antibiotic therapy, a revision of the diagnosis is important.

Conclusion

Tuberculosis can affect the orbit and external eye in a wide variety of ways. Accurate diagnosis and prompt treatment are important to reduce the occurrence of associated complications.

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Malaysian Journal of Ophthalmology

© Malaysian Journal of Ophthalmology 2019; 4:289-294
Case report/Case series

Leukostatic retinopathy: a sight-threatening complication of chronic myeloid leukaemia with severe hyperleukocytosis

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Abstract

Retinopathy secondary to chronic myeloid leukemia (CML) commonly manifests as venous dilation and tortuosity, retinal hemorrhages, microaneurysms, and cotton-wool spots which are similar to features of non-proliferative diabetic retinopathy or hypertensive retinopathy. However, massive vitreous hemorrhage is rarely encountered, especially among those treated with chemotherapy. We report a case of a young CML patient in accelerated phase, presenting with bilateral painless sudden visual loss. Fundus examination showed bilateral dense vitreous hemorrhage. Laboratory results showed thrombocytopenia with a very low platelet count. Magnetic resonance imaging (MRI) of the brain and orbit showed subacute intraparenchymal hemorrhages and bilateral intraocular hemorrhages. We performed pars plana vitrectomy (PPV) and endolaser on the left eye, which had more extensive vitreous hemorrhage. At one-week follow-up, the patient unfortunately developed a retinal detachment. The patient underwent a second PPV with endolaser and insertion of silicone oil. Despite the prompt surgical intervention, the patient developed an ischemic retina resulting in poor visual prognosis. One month later, we performed PPV and endolaser on the right eye. Postoperatively, her vision improved significantly from hand movement to pinhole vision 6/45. Dense vitreous hemorrhage is a rare complication of childhood leukemia. General physicians should refer leukemic patients for ophthalmic evaluation. Awareness of potentially blinding complications of CML and prompt referral upon

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diagnosis is warranted for early detection and treatment. Reduced awareness of this potentially blinding complication may result in poor visual outcome.

Keywords: chronic myeloid leukemia (CML), pars plana vitrectomy (PPV), vitreous haemorrhage

Retinopati leukostatik: komplikasi ancam penglihatan disebabkan oleh leukemia myeloid kronik bererta hiperukositosis yang teruk

Abstrak

Retinopati sekunder untuk leukemia myeloid kronik (CML) biasanya ditunjukkan sebagai pengembangan salur vena dan tortuositi, pendarahan retina, mikroaneurisma, dan bintik-bintik kapas yang serupa dengan ciri-ciri retinopati kencing manis yang tidak proliferatif atau retinopati hipertensi. Walau bagaimanapun, pendarahan vitreous secara besar-besaran jarang ditemui, terutama di kalangan mereka yang dirawat dengan kemoterapi. Kami melaporkan kes seorang pesakit CML yang muda dalam fasa aselerasi, dengan menyaksikan kehilangan visual secara tiba-tiba tanpa rasa sakit. Peperiksaan Fundus menunjukkan pendarahan berlaku dalm kedua-dua mata. Hasil makmal menunjukkan trombositopenia dengan kiraan platelet yang sangat rendah. Pencitraan resonans magnetik (MRI) otak dan orbit menunjukkan pendarahan intraparenchymal subacute dan pendarahan intraocular bilateral. Kami melakukan vitreectomy pars plana (PPV) dan endolaser pada mata kiri, yang mempunyai pendarahan vitreus yang lebih banyak. Pada susulan satu minggu, pesakit itu malangnya mengalami lekang retina. Pesakit menjalani PPV kedua dengan endolaser dan memasukkan minyak silikon. Walaupun pembedahan dilakukan segera, pesakit mengalami pula retina iskemia yang mengakibatkan prognosis visual sangat rendah. Satu bulan kemudian, kami melakukan PPV dan endolaser di sebelah kanan mata pula. Selepas pembedahan, penglihatannya meningkat dengan ketara dari pergerakan tangan ke penglihatan pinhole 6/45. Pendarahan vitreous adalah komplikasi yang jarang berlaku pada psakit leukemia kanak-kanak.

Pakar perubatan am harus merujuk pesakit leukemia untuk penilaian oftalmik. Kesedaran tentang komplikasi CML yang berpotensi untuk meyebabkan kebutaan, dan rujukan segera adalah diperlukan setelah diagnosis untuk pengesahan awal dan rawatan. Kurangnya kesedaran tentang komplikasi yang berpotensi membutakan sebegini boleh menyebabkan hasil penglihatan yang rendah.

Kata kunci: leukemia myeloid kronik, pendarahan vitreous, vitreectomy pars plana

Introduction

Leukostatic retinopathy secondary to severe hyperleukocytosis is an uncommon complication of chronic myeloid leukemia (CML). It is a rare complication and only reported twice worldwide.[1,2] In this case report, we describe a case of CML with bilateral visual loss caused by retinal ischaemia from severe systemic leukostasis.

Case report

A 13-year-old Malay girl was diagnosed with chronic myeloid leukaemia (CML) by bone marrow aspiration and BCR-ABL1 fusion gene test. She presented with bilateral acute onset of visual loss when she was admitted into the paediatric ward for intravenous chemotherapy. At presentation, vision in both eyes was hand movement. Anterior segment examination was unremarkable and intraocular pressure (IOP) was 14 mmHg in each eye. There was no view of the optic disc and

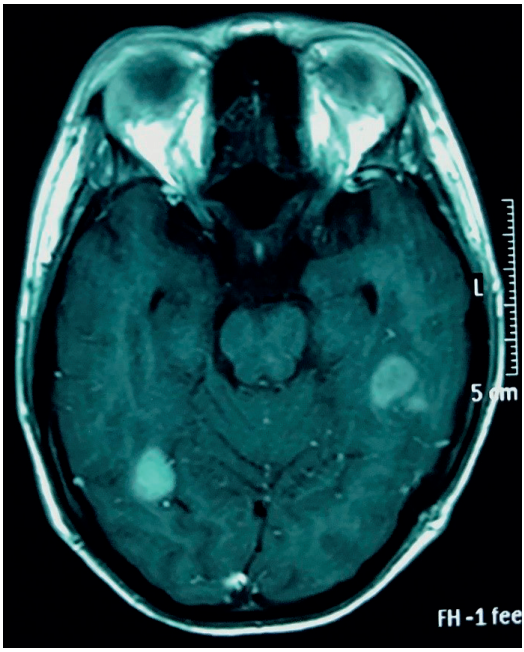

Fig. 1. Brain and orbit (axial) MRI. Intraparenchymal hemorrhages seen in the right posterior pons (pontomedullary junction), left temporal, bilateral occipital, and left thalamus (T1-weighted).

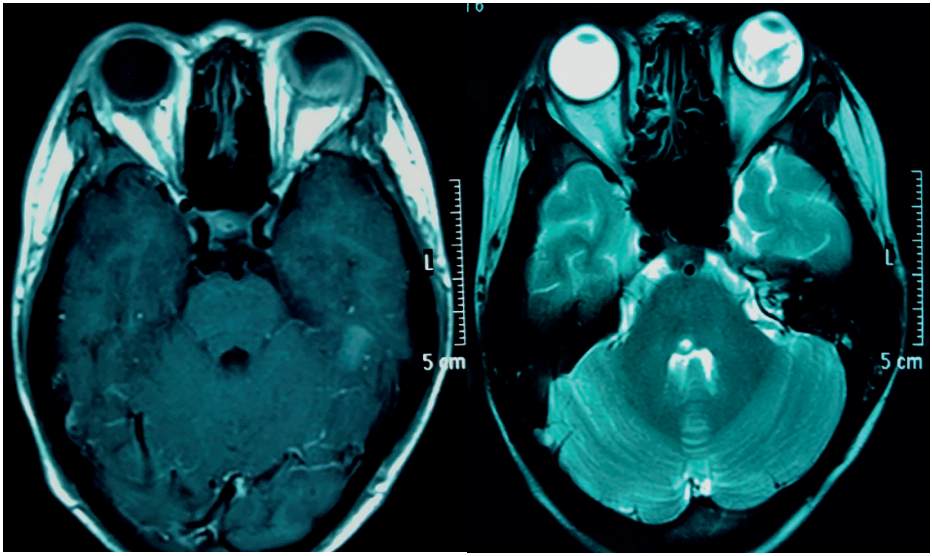

Fig. 2. Brain and orbit (axial) MRI. Heterogenous subretinal lesions seen at the posterior segment of the left eye, which are hyperintense in T1-weighted MRI image and hypointense in T2-weighted MRI image, suggestive of left eye subretinal haemorrhage.

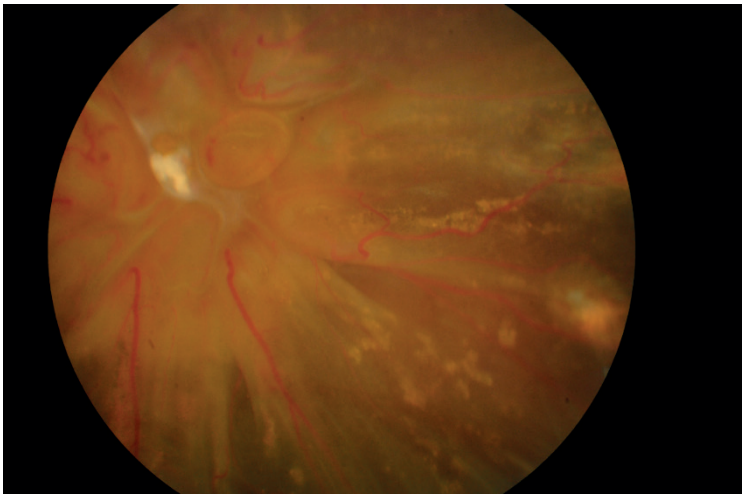

Fig. 3. Postoperative left-eye fundus photo. Retinal detachment with the retinal blood vessels appearing tortuous, dilated, and straightened due to contraction of the underlying proliferative vitreoretinopathy membrane.

macula on fundus examination. Ultrasound B scan was unable to be performed in the paediatric ward. However, magnetic resonance imaging (MRI) of the brain and orbit showed subacute intra-parenchymal white matter haemorrhages and left eye subretinal haemorrhages (Figs. 1 and 2). Laboratory results showed severe hyperleukocytosis, with total white blood cells of 678 × 10^9/L (normal range 4-10 × 10^9/L) and neutrophilia of 551 × 10^9/L (normal range: 2-7 × 10^9/L). The patient received ten cycles of intravenous chemotherapy with oral imatinib 400 mg OD and achieved haematological remission. Two months after imatinib treatment, there was persistent bilateral vitreous haemorrhage with hand movement vision. We performed *pars plana* vitrectomy (PPV) and endolaser on the left eye (worse eye). Intraoperative findings included vitreous haemorrhage, subhyaloid haemorrhage, intraretinal haemorrhage, and perivascular retinal infiltrates. Postoperatively, vision remained at hand movements. At one-week follow-up, the patient developed a retinal detachment in the operated eye (Fig. 3). The patient underwent a second PPV with endolaser and insertion of silicone oil. One month later, we performed PPV and endolaser on the right eye (better eye). Intraoperative findings were similar to the left eye. Postoperatively, her vision improved significantly from hand movement to pinhole vision of 6/45 in the right eye.

Discussion

Leukostasis is one of the fatal complications of CML, more often in the blastic phase. It is typically characterized by partial or total occlusion of systemic microcirculation by aggregation of leukemic cells and thrombi leading to respiratory or neurological symptoms. Leukostatic retinopathy is a rare ocular manifestation of CML and this term has only been recognized in recent years.[1,2] It has been reported that this ocular complication is related to local circulatory stasis, which leads to retinal ischemia and blindness.[1,2]

In the case of our patient, full blood count revealed she had hyperleukocytosis on presentation. She demonstrated ocular manifestations of retinal ischemia such as vitreous haemorrhage, subhyaloid haemorrhage, and significant tortuous veins with diffuse intraretinal haemorrhages. All of these ocular signs suggested that she might have severe retinal microvascular stasis, which led to retinal ischemia. Eventually, she ended up with poor vision after PPV. We hypothesise the mechanism of retinopathy in this case was likely caused by retinal ischemia secondary to leukostasis in CML. During follow-up in the eye clinic, optical coherence tomography of the left-eye macula was similar to chronic central retinal artery occlusion, manifested by diffuse thinning and disorganization of the inner retinal layer, which is consistent with retinal ischemia. One of the shortfalls was inability to perform fundus fluoroscein angiography in our patient due to her unfavourable systemic condition.

Performing PPV in a leukemic child is always challenging due to the high risk of retinal tears and incomplete posterior vitreous detachment. Apart from retinal tears and detachment, other rare surgical complications include epiretinal membrane formation, as well as cataract and macula hole formation. However, a recent report suggests that early vitrectomy facilitates rapid and optimal visual recovery, provided that the general condition of the child is good enough to undergo surgery.[3]

In conclusion, leukostatic retinopathy is a sight-threatening condition. General physicians should refer leukemic patients for ophthalmic evaluation early. Awareness of potentially blinding complications of CML and prompt referral upon diagnosis is warranted for early detection and treatment. Detection of early stage disease would enable vision preserving treatment to be commenced. Reduced awareness of this potentially blinding complication may result in a poor visual outcome.

Acknowledgements

We would like to thank the Director General of Health Malaysia for his permission to publish article.

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Malaysian Journal of Ophthalmology

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Case report/Case series

Complication of foldable single-piece intraocular lens sulcus implantation in a child under two years old

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Abstract

A two-and-a-half-year-old boy presented to Cipto Mangunkusumo Hospital, Jakarta, Indonesia with a white spot on his left eye. He had cataract surgery one year prior at another hospital. On examination, corectopia, anterior synechiae, white plaque between the iris and corneal endothelium, a shallow anterior chamber, and an intraocular lens (IOL) in the posterior chamber were found. As a result, anterior chamber reformation and IOL explantation was performed.

Intraoperatively, a foldable single-piece IOL was found in the ciliary sulcus. Hence, extreme inflammatory process after the operation was unavoidable. One month after the procedure, the cornea was opaque without an increase in intraocular pressure. It is recommended to perform IOL implantation only in children over two years of age with a corneal diameter more than 9 mm. A three-piece IOL might be implanted in the area of the ciliary sulcus only if the child needs an immediate IOL implant.

Keywords: congenital cataract, intraocular lens (IOL), single-piece IOL, three-piece IOL

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Komplikasi implantasi kanta intraokular tunggal yang boleh dilipat pada kanak-kanak di bawah umur dua tahun

Abstrak

Seorang budak lelaki berusia dua dan setengah tahun diserahkan kepada Hospital Cipto Mangunkusumo dengan mata putih di mata kirinya. Dia menjalani pembedahan katarak satu tahun sebelumnya di hospital lain. Pemeriksaan mendapati terdapat corectopia, synechia anterior, plak putih antara iris dan endothelium kornea, ruang anterior cetek, dan kanta intraokular (IOL) di ruang posterior. Seterusnya, ruang anterior dibentuk semula dan IOL di eksplant.

Semasa intraoperatif, IOL tunggal ditemui dalam sulcus ciliary. Disebabkan itu, proses keradangan yang banyak selepas pembedahan tidak dapat dielakkan. Sebulan selepas prosedur, kornea menjadi putih tanpa peningkatan tekanan intraokular. Adalah disyorkan untuk melaksanakan implantasi IOL hanya pada kanak-kanak berusia lebih dua tahun dengan diameter kornea lebih dari 9 mm. IOL jenis tiga-keping mungkin di implan di kawasan sulcus ciliary hanya jika kanak-kanak tersebut memerlukan implan IOL segera.

Kata kunci: IOL tiga-keping, IOL tunggal, kanta intraokular (IOL), katarak kongenital

Introduction

Congenital cataract is considered one of the most common causes of preventable childhood blindness; cataract surgery is the gold-standard treatment. However, treatment results may vary, given that many factors determine the result. This case report highlights a possible complication of single-piece intraocular lens (IOL) sulcus implantation in a one-and-a-half-year-old infant that resulted in blindness.

Case report

A two-year-old boy was brought to Cipto Mangunkusumo Hospital by his mother, who noticed a whitish lesion in his left eye. The lesion first appeared six months ago and enlarged ever since. No redness, pain, or discharge was reported. The patient was born with congenital rubella syndrome and had a history of bilateral congenital cataracts. Both cataracts had undergone surgeries at another hospital. His right eye

underwent cataract surgery when the patient was six months old, whereas his left eye underwent cataract surgery and IOL implantation when he was one-and-a-half years old. He was also prescribed with S +10.00 aphakia glasses for the right eye, for which the patient was not compliant.

Initial examination revealed that both eyes had nystagmus, good pupillary light reflex, and positive object fixation. Both corneas were 9 mm in diameter. For the right eye, the cornea was clear and no IOL was present. However, we saw multiple inhomogeneous white lesions on the left corneal endothelium, located at the 12 to 1 o'clock and at the 7 to 10 o'clock positions, all of which were associated with iris-endothelial adhesions resulting in a very shallow anterior chamber. Correctopia and peripheral iridectomy were present at the 12 o'clock postion. The IOL itself was present in the retropupillary area (Fig. 1). Fundoscopy examination of both eyes was normal with healthy discs and macula.

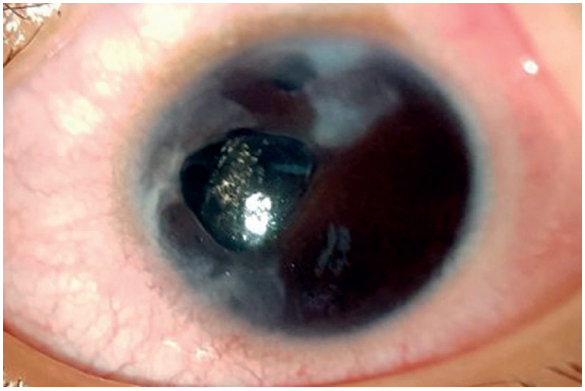

Fig. 1. IOL in the retropupillary area.

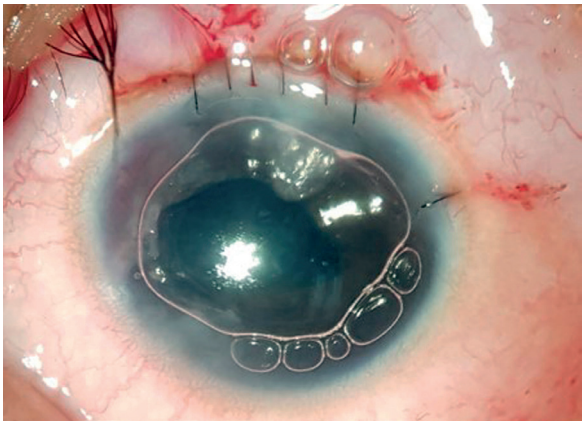

Fig. 2. Deep anterior chamber and no further iris adhesions on day 1 after surgery.

After our thorough examination, we decided to deepen the anterior chamber and to halt the progression of the opacified cornea by explanting the IOL. In addition, IOL explantation would optimize his visual function, as he had no complaint in wearing eyeglasses.

The left eye underwent explantation of IOL, synechiae release, and anterior chamber reformation procedure. The surgery was challenging, as the adhesions made it difficult to explant the IOL. Despite the odds, the synechiae release was successful. Explantation of the IOL showed that the IOL was a single-piece foldable acrylic that was placed in the ciliary sulcus.

On day 1 after surgery (Fig. 2), the anterior chamber was deep with 3+ cells and flare 1+. There were no further iris adhesions. Intraocular pressure was also within normal limits.

On one-week follow-up, the patient came with a relatively deep anterior chamber, but there was shallowing at the 7 to 1 o'clock position peripherally. The whitish lesions extended even larger than preoperatively.

One month after surgery, examination revealed that his left cornea was already fully cloudy with only vaguely visible central pupil. After one-month examination, the patient was lost to follow-up.

Discussion

There have been inconclusive debates for determining the best time for IOL implantation in patients from six months to two years of age who have undergone cataract surgery due to congenital cataract.[1,2] A study by Shamrani and Turkmani found successful IOL implantation in 120 pediatric patients under the age of two, finding the procedure beneficial to the patients' visual rehabilitation. However, close attention to another relative contraindication, such as corneal diameter < 9 mm or anterior segment dysgenesis, should be taken before implanting an IOL in pediatric patients in this age range.[1]

Aside from the timing of IOL implantation, IOL type and implantation technique also play an important role. With a 6 mm optic diameter, total length of 12.5 – 13 mm, and no haptic angulation, a foldable, hydrophobic single-piece acrylic IOL has been the ideal option for pediatric patients.[3] This IOL type is very adaptable and can easily be implanted in the small capsular bag of pediatric patients.[1,4]

In-the-bag IOL implantation should always be the choice for IOL implantation, but it is not possible to implant the IOL in the capsular bag in the presence of posterior capsular rupture, zonule rupture, or in a secondary IOL implantation.[3] In these instances, implantation can be performed in the ciliary sulcus.[2] It is advised to use a hydrophobic three-piece acrylic IOL for in-the-sulcus implantation, as it has slimmer haptic and larger overall diameter (13–13.5 mm). This IOL will have less iris-to-IOL contact and presents more stable IOL centration. Furthermore, its

posterior haptic angulation (around 5–10°) also contributes to reduced contact with surrounding tissue, as well as reduced friction between the iris and IOL.[5,6]

IOL implantation, and especially single-piece IOLs, in the sulcus area in pediatric patients is still debatable given that single-piece IOL sulcus implantation can chafe the posterior iris stroma, leading to a severe inflammatory reaction.[5,6] In addition, it increases the likelihood of IOL malposition and produces shallower anterior chamber.[3] In this case, there was a severe inflammatory reaction due to single-piece IOL sulcus implantation which chafed the posterior iris and resulted in the formation of iris-endothelial adhesions. Indisputable severe inflammatory reaction occurred at day 1 postoperative due to excessive intraocular manipulation to explant the IOL and release the adhesion. On one-month examination, the whole cornea had opacified.

In cases where implantation of a single-piece IOL in the sulcus is inevitable, long-term monitoring for signs of chronic inflammation and glaucoma is required,[7] as early management of inflammation may result in a better visual outcome.

Conclusion

IOL implantation as a treatment for pediatric cataract patients not only needs to consider the patient's age and corneal diameter at the time of implantation, but also the type of IOL type and implantation technique. As demonstrated in this case, implantation of a single-piece IOL in the sulcus area results in chronic inflammation involving the anterior structure; explantation cannot cease nor reverse the severe inflammation, which resulted in blindness for this particular patient.

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Malaysian Journal of Ophthalmology

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Case report/Case series

Rhegmatogenous retinal detachment and full-thickness macular hole induced by lightning

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Abstract

A 31-year-old gentleman was remotely struck by lightning and complained of blurred vision in his left eye. He was diagnosed with left eye anterior uveitis and full-thickness macular hole (FTMH), and subsequently referred for vitreoretinal intervention. On examination, his left-eye vision was hand movement. Anterior uveitis had resolved with no cells in the anterior chamber. Posterior subcapsular cataract 2+ was noted. There was a FTMH and partial posterior vitreous detachment (PVD) confirmed by optical coherence tomography (OCT). Right eye was normal with 6/6 vision. At one- month follow-up, the macular hole was closed spontaneously but localised rhegmatogenous retinal detachment (RRD) was noted in the inferior retina with macula-on. There were multiple holes in the inferior equatorial region surrounded by hyper- and hypopigmented retinal atrophy. The patient underwent phacoemulsification, intraocular lens implantation, vitrectomy, and gas tamponade (C3F8 14%). At one week postoperative, he had recurrent retinal detachment with multiple new atrophic holes noted. He underwent a second vitrectomy with silicone oil tamponade. Best-corrected visual acuity (BCVA) in his left eye two months after surgery was 6/45 and the retina had reattached.

Keywords: full-thickness macular hole (FTMH), lightning strike, retinal atrophy, rhegmatogenous retinal detachment (RRD)

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Lekang retina rhegmatogen dan lubang makular penuh yang disebabkan oleh kilat

Abstrak

Seorang lelaki berusia 31 tahun telah dipanah kilat dan mengadu penglihatan kabur di mata kirinya. Dia didiagnosis dengan uveitis anterior mata kiri dan lubang macular tebal penuh (FTMH), dan kemudiannya dirujuk untuk intervensi vitreoretinal. Semasa pemeriksaan, penglihatan mata kirinya adalah pergerakan tangan. Uveitis anterior telah pulih dengan tiada sel di ruang anterior. Katarak subkapsular posterior 2 + telah diperhatikan. Terdapat FTMH dan lekang vitreous posterior separa (PVD) yang disahkan oleh tomografi koheren optik (OCT). Mata kanan adalah normal dengan penglihatan 6/6. Pada satu bulan susulan, lubang makula telah ditutup secara spontan tetapi retina retina (RRD) rhegmatogenous tempatan telah diperhatikan berlaku di retina inferior dengan macula masih normal. Terdapat banyak lubang di rantau ekuator yang dikelilingi oleh atrophy retina jenis hipopigmen dan hypopigmented. Pesakit menjalani fakoemulsifikasi, implan kanta intraokular, vitrektomi, dan gas tamponade (C3F8 14%). Pada satu minggu pasca pembedahan, beliau mengalami lekang retina yang berulang dengan beberapa lubang atrophik baru yang ditemui. Dia menjalani vitrektomi kedua dengan tamponade minyak silikon. Ketajaman visual yang terbaik dengan bantuan (BCVA) di mata kirinya dua bulan selepas pembedahan adalah 6/45 dan retina telah berjaya dilekatkan.

Kata kunci: atrofi retina, lekang retina rhegmatogen, lubang makmal tebal penuh, mogok kilat

Introduction

We report a rare case of lightning strike survivor with multiple ocular manifestations including posterior subcapsular cataract, uveitis, full-thickness macular hole (FTMH), and rhegmatogenous retinal detachment (RRD). Treatment outcomes are also reported and treatment modality is suggested based on our experience of managing this case.

Case report

A 31-year-old gentleman was remotely struck by lightning and presented to the eye clinic after 1 month complained of pain, redness and progressive blurring of vision

in his left eye. He was diagnosed with anterior uveitis and FTMH in his left eye (Fig. 1), treated with guttae dexamethasone 0.1% (Alcon, Couvreur, Belgium), and was subsequently referred to our centre for vitreoretinal intervention. On examination, vision in his left eye was hand movement. Anterior uveitis had resolved with no cells in the anterior chamber. Posterior subcapsular cataract 2+ was noted. There was a FTMH and partial posterior vitreous detachment (PVD) confirmed by optical coherence tomography (OCT) (Fig. 2). Right-eye vision was 6/6 and normal. At one-month follow-up, the macular hole was closed spontaneously (Figs.3 and 4). However, localised rhegmatogenous retinal detachment (RRD) was noted in the inferior retina with macula-on (Fig. 4). There were multiple holes in the inferior equatorial region surrounded by hyper- and hypo-pigmented retinal atrophy (Fig. 5). The patient underwent phacoemulsification, intraocular lens implantation, vitrectomy, laser photocoagulation, and gas tamponade (C3F8 14%). At one week postoperative, he had recurrent retinal detachment at the same location with multiple new atrophic holes. He underwent a second vitrectomy with silicone oil tamponade. Best-corrected visual acuity (BCVA) in his left eye at two months postoperative was 6/45 and the retina had reattached.

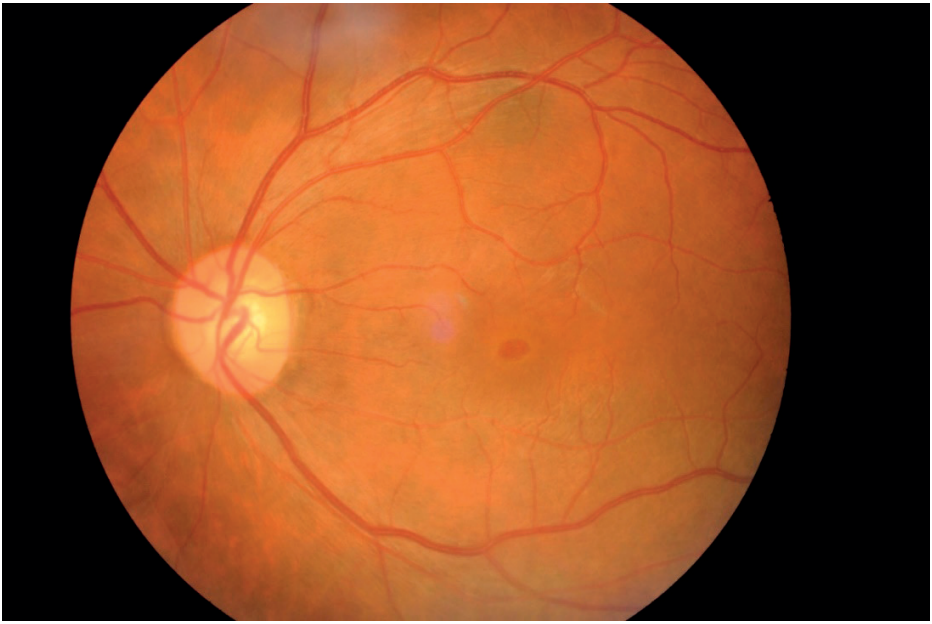

Fig. 1. Fundus photo of the left eye showing FTMH.

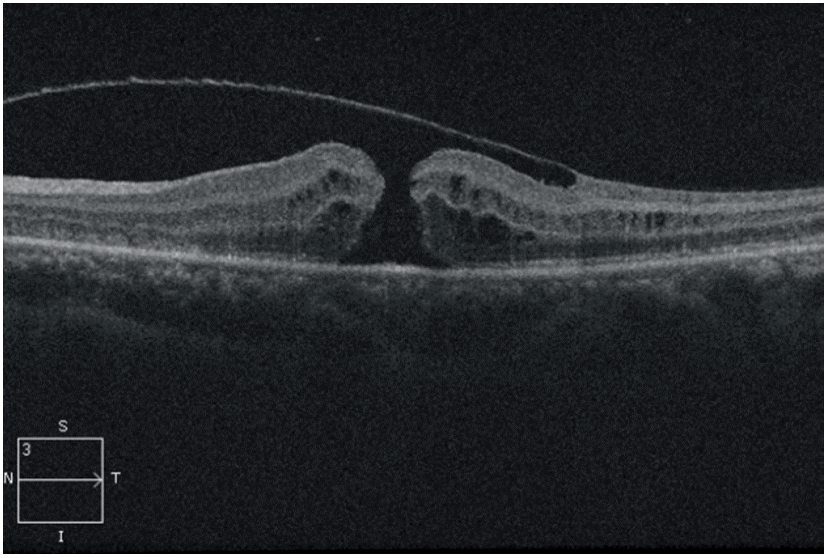

Fig. 2. Left-eye OCT showing FTMH and partial PVD.

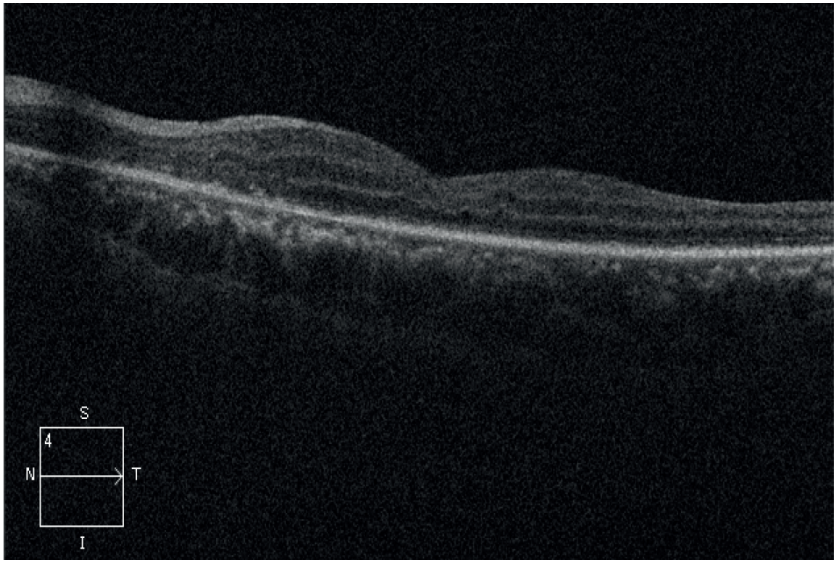

Fig. 3. Left-eye OCT at one-month follow-up showing spontaneously closed macular hole.

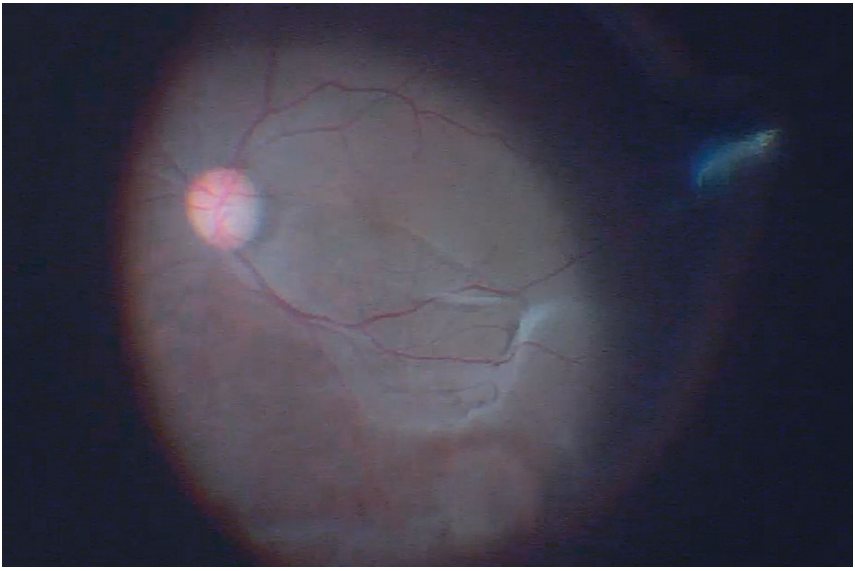

Fig. 4. Intraoperative photo showing spontaneously closed macular hole. Localized inferior RRD was noted with macula-on .

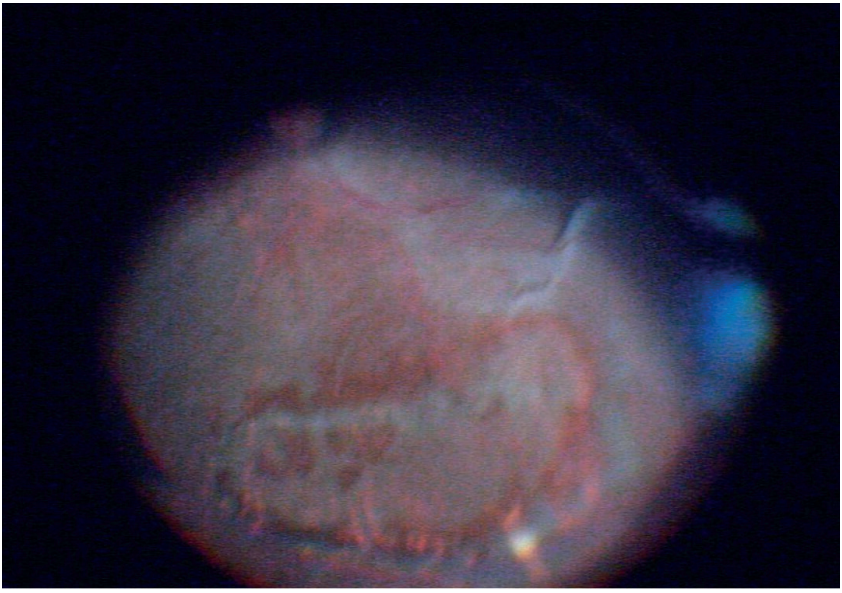

Fig. 5. Intraoperative photo showing multiple retinal holes surrounded by an area of hyper- and hypopigmented retinal atrophy.

Discussion

This is an uncommon case of multiple ocular injuries secondary to lightning. The pathogenesis of FTMH and RRD induced by lightning is not clearly understood. Besides, there are no clear guidelines for the treatment of both conditions when specifically caused by lightning. Our suggestion for treatment options and prognosis are given below based on our experience of managing this case.

Handa *et al.*[1] have reported a case of maculopathy which initially presented as retinal cysts with surrounding oedema and later evolved to simulate a full-thickness hole. This suggests that macular oedema due to lightning injury can coalesce to form a FTMH. Our patient had a spontaneously closed FTMH. Lee *et al.*[2] reported a similar case with a good visual outcome. We propose that this could be due to resolution of traction by PVD after inflammation subsides, subsequently leading to restoration of normal foveal contour and macular hole closure. There is no specific guideline regarding duration before the spontaneous closure of macular hole occurs. Nonetheless, surgery has been proven to be effective in restoring normal macular structure, but visual outcome remains poor despite anatomical closure.[3,4]

Lightning-induced retinal detachment has also been reported in the literature,[4,5] However, its occurrence is relatively rare. Espaillat *et al.*[5] postulated that "heating of the retinal surface, the concussive forces on the eye, and a sudden lateral contraction of the attached vitreous results in posterior vitreous detachment and peripheral retinal break" lead to RRD. In our patient, patches of pigmentary degeneration and retinal atrophy that resemble traumatic chorioretinitis had been observed. This phenomena has also been reported by Zsolt *Biro et al.*[6] Multiple atrophied retinal holes had been observed in our patient, which worsened progressively during follow-up. The progression of retinal atrophy and retinal holes had led to the failure of gas tamponade and recurrent detachment. A similar case of recurrent detachment after scleral buckle surgery and gas tamponade has also been reported by Espaillat *et al.*[5] Postoperative visual acuity of the reported case[5] and that of our patient are no better than 6/30.

Conclusion

In summary, we hope this report can help clinicians recognise the retinal changes after a lightning strike with the knowledge that spontaneous FTMH closure is not uncommon. Retinal pigmentary changes are at risk of developing retinal break and retinal detachment with unknown risk period. Thus, silicone oil tamponade is the preferred tamponade agent based on our experience in managing this case in view of the possibility of progressive chorioretinal atrophy and formation of more retinal holes.

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