Rahman, Rubina, Kolb, Simon, Bong, Chun Xiao and Stephenson, John

Accuracy of user-adjusted axial length measurements by optical biometry in eyes having combined phacovitrectomy for macular-off rhegmatogenous retinal detachment

Accuracy of user-adjusted axial length measurements by optical biometry in eyes having combined phacovitrectomy for macular-off rhegmatogenous retinal detachment

Abbreviated title: Shifted biometry in retinal detachments

Key words:

Biometry; macula off rhegmatogenous retinal detachment; phacovitrectomy; rhegmatogenous retinal detachment

Authors: [1]Rubina Rahman, FRCOphth, FRCS [1]Simon Kolb, FRCOphth; [1]Chun Xiao Bong, MBChB; [2]John Stephenson, PhD

Institution:

[1]Department of Ophthalmology, Calderdale Royal Hospital, West Yorkshire, United Kingdom

[2]School of Human and Health Sciences, University of Huddersfield, Queensgate, Huddersfield HD1 3DH, United Kingdom

This paper has been presented at the British and Eire association of vitreoretinal surgeons annual meeting on 6th November 2015.

Author for correspondence:

Ms R Rahman

Department of Ophthalmology, Calderdale Royal Infirmary, Salterhebble, Halifax, West Yorkshire HX3 0PW

Email: rubina.rahman@nhs.net

The authors have no financial or proprietary interest in any material or method mentioned.

No grants or financial support received for this study.

Summary Statement:

Accurate measurement of axial length is essential for preventing refractive surprises postoperatively. This can often be difficult in eyes with RRDs. Optical biometry may underestimate axial length in macula off rhegmatogenous retinal detachments; however, we present a novel way of adjusting the optical biometry to accurately measure the axial length.

ABSTRACT

PURPOSE: To evaluate the accuracy of user-adjusted axial length measured by optical biometry (OB) for intraocular lens (IOL) power calculations in eyes having combined phacovitrectomy for macula-off rhegmatogenous retinal detachment (RRD).

SETTING: Department of Ophthalmology, Calderdale Royal Hospital, Halifax, UK.

DESIGN: ~~Prospective~~ Retrospective case series review of 22 consecutive eyes that underwent phacovitrectomy for macula-off RRD.

METHODS: Axial lengths (ALs) were measured using OB with user adjustment to identify a posterior peak corresponding to the eye's AL and ultrasound (US). These measurements were compared and analysed for accuracy to each other and the post-operative OB as a more accurate indication of the eye's AL.

RESULTS: User-adjusted OB was similar to US and post-operative OB measurements. There was no statistically significant difference between the means of the AL measurements derived from user-adjusted OB and ultrasound AL (*p*=0.964). User-adjusted OB was not statistically significantly different to post-operative OB (*p*=0.242). Compared to post-operative OB, IOL power was within 0.5 Dioptre in 12 out of 13 cases (92%; 95% confidence interval (77.8%, 100.0%) for user-adjusted OB, and in only 10 out of 13 cases (77%; 95% confidence interval (54.0%, 99.8%) of US measurements.

CONCLUSIONS: User-adjusted OB may be used as an alternative method for the measurement of AL in macula-off RRD for primary repair by combined phacovitrectomy. OB will, however, require assessment of agreement with US AL in cases where a posterior peak is not easily identifiable. We have also shown that user-adjusted OB may outperform US AL when calculating IOL power; however, a larger study may be needed to confirm this.

INTRODUCTION

Combined phacoemulsification and pars plana vitrectomy (phacovitrectomy) has become a common procedure in many vitreoretinal diseases, including as primary repair surgery for rhegmatogenous retinal detachment (RRD). [1-4] This is as a result of the continual advances in both cataract and vitrectomy surgery, and favourable patient outcomes. The combined procedure reduces costs and offers quicker visual rehabilitation by avoiding the need for additional surgery allowing a single recovery period[5-7]. The aphakic state during surgery also gives excellent visibility ensuring an unimpeded view for the treatment of peripheral pathology common in RRD.[8]

As the anatomic success of combined surgery has improved, greater attention has been directed toward reducing any refractive error to maximise postoperative visual function. Our previous large case series study has shown the refractive results of phacovitrectomy for RRD to be comparable with cataract surgery outcomes.[1] Overall, although optical biometry (OB) was more accurate than ultrasound (US) (p=0.040), we noted that significantly more US measured ALs were preferentially selected over OB measurements in the macula-off group compared to macula-on group (p=0.016). We concluded that the biometry used for IOL power selection must be checked by comparing with the fellow eye and the known refraction, especially in macula-off RRD cases.

The accuracy of axial length (AL) measurement is crucial for intraocular lens (IOL) power calculation, and the presence of a bullous detached macula is likely to make AL measurements more challenging. It was our clinical observation that when used for AL measurements in macula-off RRD cases, optical biometry (OB) tended to underestimate the true AL (confirmed by the anterior position of the signal peak even in the presence of a good signal-to-noise ratio) (Figure 1~~3~~). Hence we conducted a prospective analysis of the pre- and post-operative AL measurements of all macula-off RRD cases undergoing phacovitrectomy as primary repair, to evaluate a novel technique of optimizing the accuracy of AL measurement by OB termed the 'user-adjusted OB' measurement.

METHODS

This ~~prospective~~ retrospective case series analysis ~~study~~ comprised 22 eyes of 22 consecutive macula-off RRD patients who had combined phacovitrectomy surgery from November 2012 to August 2014 by the same surgeon.

ALs were measured using both OB IOLMaster (Version 5.4, IOLMaster; Carl Zeiss, Oberkochen, Germany) and US A-scan (EchoScan US-1800; Nidek, Gamagori, Japan) prior to phacovitrectomy at presentation of macula-off RRD. Skilled operators performed 10 reliable readings using OB and US. When a posterior peak was not automatically selected in the primary OB, AL measurements were manually adjusted by the biometry operator shifting the signal peak selection from the default anterior peak to a more posterior peak with a signal-to-noise ratio greater than or equal to 2 (Figure 1). This we have termed the user-adjusted OB and has been previously described by David Steel[9]. When the OB produced a scan with multiple peaks and no defined single posterior peak, the posterior peak correlating to the AL was guided either by the fellow eye's AL or the ipsilateral US AL.

All study eyes had AL re-measured post-operatively after at least 8 weeks using OB. The user-adjusted OB was then compared to pre-operative US and with post-operative OB measurements and analysed for any statistical difference using paired samples t-tests. The variable corresponding to the difference between pre-operative and post-operative OB AL measurements was tested extensively for Normality; including: Kolmogorov-Smirnov and Shapiro-Wilk tests, evidence for skewness and kurtosis, visual inspection of distribution, similarity of mean and median etc. The variable passed all tests. Furthermore, normality of the sampling distribution should be expected in samples of this size by the central limit theorem. Secondary within- and between-group comparisons of subsets of the full sample were conducted using non-parametric tests (Wilcoxon signed rank and Mann-Whitney U) due to very low sample sizes.

Formatted: Font color: Auto

Formatted: Font: (Default) Times New Roman, 12 pt, Not Italic, Font color: Auto, (Asian) Chinese (PRC), (Other) English (United Kingdom)

Formatted: Font: (Default) Times New Roman, 12 pt, Not Italic, Font color: Auto, (Asian) Chinese (PRC), (Other) English (United Kingdom)

Formatted: Font color: Auto

RESULTS

Patients had a mean age of 62.6 years, and 17 of 22 (77.3%) were male. Post-operative AL measurements used for biometry calculation in our study ranged from 20.97 mm to 29.64 mm, with a mean AL of 25.6 mm and a standard deviation of 2.23 mm.

There were 18 of 22 patients with good quality interpretable OB, comprising 13 user-adjusted and 5 primary unadjusted OB measurements. The 5 patients with well-defined single peaks on OB did not require user adjustment.

Thus 13 eyes with user-adjusted OB (59%) were included in the analysis of user-adjusted OB compared to post-operative OB. Eight of these scans had a well-defined second posterior peak which did not require any assessment of agreement with the fellow eye AL or ipsilateral US AL scans. Five scans required some consideration of the fellow eye or ipsilateral US AL to shift to a correlating posterior peak amongst other more posterior peaks.

Only 4 of 22 patients (18.2%) had OB which was unusable; requiring US AL to calculate the IOL power. Two of these patients had a poor signal-to-noise ratio (SNR) of less than 2. ~~(see Figure 4).~~ Two patients had an unidentifiable second peak amongst multiple peaks, and so were excluded from the analysis.

A. Axial length comparisons

User-adjusted OB AL measurements were compared against pre-operative US AL measurements using a paired samples t-test conducted on the 13 eyes for which both readings were available. The mean pre-operative axial length recorded by the user-adjusted OB method was 25.473 mm (SD 1.755 mm). The mean pre-operative axial length recorded by the US-A scan method for these 13 eyes was 25.469 mm (SD 1.826 mm). Hence the mean difference between the two methods was 0.004 mm (4 µm) (SD 0.304 mm). There was no statistically significant difference at a significance level of 0.05 between the two methods of AL measurement compared to the postoperative OB AL (95% confidence interval for difference (-0.180, 0.188); t_{12}=0.046; p=0.964). The inference would not be affected by a correction for multiple comparisons.

A Bland-Altman plot (Figure 2) illustrates moderate consistency between the two sets of readings, with one data point outside the limits of agreement and a further data point on the limit of agreement. OB readings were higher than the corresponding A-scan readings in the majority of cases; however, the absolute values of the difference measurements (excluding the two outlying values) were low. No relationship between levels of agreement and magnitude of data values was apparent.

The differences between the user-adjusted OB AL measurements were also compared against postoperative OB AL measurements; again using a paired samples t-test conducted on the 13 eyes for which both readings were available. The mean post-operative axial length recorded by the OB method for these 13 eyes was 25.424 mm (SD 1.800 mm). Hence the mean difference between the pre- and post-operative values was 0.049 mm (SD 0.144 mm). There was no statistically significant difference at a significance level of 0.05 between the pre-operative and post-operative OB AL measurements (95% confidence interval for difference (-0.038, 0.136); t_{12}=1.23; p=0.242). The inference would not be affected by a correction for multiple comparisons.

A Bland-Altman plot (Figure 3) illustrates good consistency between the two sets of readings, with no data points outside the limits of agreement. Post-operative values were longer than corresponding pre-operative values in about half the measured cases. No relationship between levels of agreement and magnitude of data values was apparent.

A further comparison was conducted on the 13 cases for which adjusted OB values were available, plus 5 additional cases for which adjusted OB AL values were not available, but well-defined single peaked readings on the unadjusted (default) OB AL were available (a "combined" group). For these cases, the appropriate adjusted or unadjusted pre-operative OB

AL measurements were compared against the corresponding postoperative OB AL measurements; again using a paired samples t-test. The mean pre-operative AL measurement in the combined group was 25.329 mm (SD 2.081 mm). The corresponding mean post-operative AL measurement in the same group was 25.284 mm (SD 2.141 mm). Hence the mean difference was 0.044 mm (SD 0.131 mm). There was no statistically significant difference at a significance level of 0.05 between the pre-operative and post-operative OB AL measurements (95% confidence interval for difference (-0.021, 0.110); t_{17}=1.44; p=0.170). The inference would not be affected by a correction for multiple comparisons.

The median pre- and post-operative AL measurements of the 5 patients with well-defined single peaks were 24.73 mm and 24.70 mm respectively. A Wilcoxon signed ranks test conducted this data found no evidence for a significant difference between pre- and post-operative AL measurements (Z=-0.948; p=0.343).

Of the 13 patients for whom user-adjusted OB values were available, the RRD morphology was documented as either bullous (n=5) or shallow (n=8) indicating the relative amount of sub-retinal fluid (SRF) at the macula. Amongst this group of patients, the median AL measurements were 26.340 mm and 25.625 mm respectively. A Mann-Whitney U test conducted on the data found no evidence for a significant difference between the AL measurements of the two groups; and hence no evidence to suggest that the amount of SRF affected the AL measurements by OB (Z=-0.732; p=0.464).

B. Potential refractive outcomes difference

The IOL power calculated using user-adjusted OB was within 0.5 Dioptre (D) in 92% (95% confidence interval 77.8% to 100.0%) of cases to the theoretical IOL power calculated using postoperative OB measurements aiming for emmetropia. However with lens powers calculated using the pre-operative US measurements, only 77% (95% confidence interval 54.0% to 99.8%) of cases had IOL power within 0.5 D of the post-operative OB AL theoretical lens power for emmetropia. All cases of single peaked primary OB lens choices were within 0.5 D of post-operative OB IOL calculations.

If the default OB AL measurements were used instead of the 13 patients with user-adjusted OB, the difference in IOL power would range from 18 D to 37.5 D, with a mean difference to post-operative OB IOL choice of 6.96 D and a sample standard deviation of 4.78 D. Using the user-adjusted OB measurements for IOL calculations, IOL power ranged from 12 D to 25 D, with a mean difference to postoperative OB IOL choice of 0.19 D and a standard deviation of 0.43 D. Such a large difference in power implies the potential for a substantive error in the refractive outcome if the more accurate user-adjusted AL had not been selected.

DISCUSSION

To the authors' best knowledge, this is the first study proposing a method of optimising the accuracy of OB measurements using user-adjusted OB to calculate the IOL implant in macula-off RRD patients undergoing phacovitrectomy as primary repair surgery.

Accurate measurement of the AL is essential for preventing significant refractive errors postoperatively. This can often be difficult in eyes with RRDs. Previous studies have shown that OB is more accurate than US in general[10-13], except in macula-off cases where the accuracy of primary OB measurements have to be assessed with caution by careful comparison to the known refraction and AL of the fellow-eye[1]. In the macula-off group of our previous study, significantly more US measured ALs were preferentially selected for IOL power estimation instead of primary OB measurements[1]. The current study however shows that mean pre-operative AL values derived from user-adjusted OB indicate no evidence for a statistically significant difference from AL values derived from US. The Bland-Altman plot indicates moderate agreement between the two methods, providing further evidence for the acceptability of the user-adjusted method as an alternative to US measurements. We have also shown in our cohort that more patients had IOL calculations based on user-adjusted OB within 0.5 D of post-operative OB IOL calculations. This may be due to the possibility of inaccuracies in US measurements from US probe applanation error on the cornea.

OB by IOLMaster is based on the principle of dual beam partial coherence interferometry.[14] Its high precision, resolution, accuracy, and reproducibility of the AL measurements of normal eyes have been demonstrated.[15, 16] However, OB is not without its limitations. It is not suitable in dense ocular media and non-optimal fixation.[17, 18] Lege et al.[19] have also reported the disadvantage of OB revealed in cases of RRD. In clinical practice, we have noticed that OB can underestimate the true AL measurements in macula-off detachments, especially in those with bullous RRD in spite of a good SNR. This was shown by our previous study in the subgroup of macula-off eyes, which had AL measured by both IOLMaster and Nidek. The default AL measured by IOLMaster without user adjustment was on average 0.98 mm (SD 1.55 mm) shorter than the corresponding recordings made by Nidek[1].

There may be several confounding factors limiting the accuracy of measurement of AL by OB. The patients' ability to fixate is essential for accurate OB measurements, as it evaluates the AL along the visual axis; whereas US biometry measures along the optical axis. Patients with RRD, particularly those with macula-off RRD, may have non-optimal fixation due to reduced vision or dense ocular media caused by vitreous haemorrhage. Usually optical biometry measures from the front of the cornea to the retinal pigment epithelium, but sometimes an even higher peak, (apparently corresponding to the inner limiting membrane) is detected anteriorly. In macula-off RRD eyes, a similar strong interference from interfaces in the detached retina will give a good SNR measurement, although the result is incorrect.[19] Light scattering of the incoming and outgoing rays can also cause inaccurate AL measurements. The advent of optical biometry has not rendered US biometry obsolete. In addition, US biometry measures from the cornea to the ILM and can have inaccuries due to applination errors. In 5 cases of user-adjusted OB we referred to the US AL to identify a posterior peak. We considered the margin of error of US biometry when identifying the posterior peak. In none of these cases were there peaks so close together that error of US biometry would have caused identification of an erroneous posterior peak. There are pearls and pitfalls as with all devices, so the surgeon must be vigilant when interpreting the readings and disregard erroneous measurements accordingly.

Intraoperative aberrometry is a new technique for accurate assessment of refractive status. This could be used in similar and future studies to assess the accuracy of biometry techniques.

Whilst our results show a higher proportion of user adjusted OB lens calculations within 0.5 D of the post-operative OB IOL calculation, these results are based on a small cohort, which is likely to be underpowered to detect a statistically significant difference between the two groups. However, we feel that the higher number of accurate IOL calculations in the user-adjusted group provide strong justification for further research with a larger cohort. Real world post-operative refractive outcomes in a larger patient cohort may also help with further analysis of this novel method.

CONCLUSION

User-adjusted OB may be used as an alternative method for the measurement of AL in macula-off RRD for combined phacovitrectomy as primary repair. It can simplify the process of biometry, as some cases may not need US AL measurement. It will, however, require agreement with US AL in cases where a posterior peak is not easily identifiable. We have also shown that user-adjusted OB may outperform US AL when calculating IOL power; however, a larger study may be needed to confirm this.

AL measurements should be correlated with the fellow eye and the known refraction. When there is clinical doubt about the validity of the OB AL measurement, the ultrasound AL measurement should be obtained for comparison or as an alternative.

We acknowledge that the choice of AL measurement in macula-off RRD remains challenging; there will be cases where neither OB nor US are deemed accurate and the surgeon may have to resort to using the fellow eye's AL measurements, or abandon the option of combined surgery. This study provides an additional method of optimising the accuracy of AL measurement in such a group. It is our hope that by introducing this new method of interpreting OB scans in macula-off RRD cases we can further optimise the accuracy of biometry and expand the usability of OB in this challenging group.

What was known:

- OB is an accurate method for measuring AL for IOL calculations. Inaccuracies in measuring the AL for a macula-off RRD may be caused by sub-retinal fluid elevating the fovea or poor fixation due to reduced acuity. This potential inaccuracy may contribute to the deferral of cataract extraction and lens implantation.
- User adjustment of OB has been previously described but its accuracy has not yet been studied.

What this paper adds:

- User adjustment of OB in macula-off RRD is comparable to post operative OB measurements with an attached retina.
- Combined phacovitrectomy for macula off RRD can be performed with accurate adjustment of OB. This may facilitate inter-operative conditions for detachment repair, improve the patient's visual recovery without a second surgery for cataract and maintain accurate refractive outcomes.

REFERENCES:

1. Rahman R, Bong CX, Stephenson J. Accuracy of intraocular lens power estimation in eyes having phacovitrectomy for rhegmatogenous retinal detachment. Retina 2014; 34:1415-1420
2. Thompson JT, Glaser BM, Sjaarda RN, et al. Progression of nuclear sclerosis and long-term visual results of vitrectomy with transforming growth factor beta-2 for macular holes. Am J Ophthalmol 1995;119:48-54

3. Jeoung JW, Chung H, Yu HG. Factors influencing refractive outcomes after combined phacoemulsification and pars plana vitrectomy: results of a prospective study. J Cataract Refract Surg 2007; 33:108-114
4. Iwase T, Sugiyama K. Investigation of the stability of one-piece acrylic intraocular lenses in cataract surgery and in combined vitrectomy surgery. Br J Ophthalmol 2006; 90:1519-1523
5. Demetriades A-M, Gottsch JD, Thomsen R, Azab A, et al. Combined phacoemulsification, intraocular lens implantation, and vitrectomy for eyes with coexisting cataract and vitreoretinal pathology. Am J Ophthalmol 2003; 135:291-296
6. Smiddy WE, Mady M, Anagnoste S. Acrylic intraocular lens placement in conjunction with pars plana vitrectomy. Am J Ophthalmol 2001; 131:748-750
7. Scharwey K, Pavlovic S, Jacobi KW. Combined clear corneal phacoemulsification, vitreoretinal surgery, and intraocular lens implantation. J Cataract Refract Surg 1999; 25:683-698
8. Suzuki Y, Sakuraba T, Mizutani H, et al. Postoperative refractive error after simultaneous vitrectomy and cataract surgery. Ophthalmic Surg Lasers 2000;31:271-275
9. Steel DHW. Chapter 20D, Refractive Outcome and Possible Errors following Combined Phaco-Vitrectomy in: Complications of Vitreo-Retinal Surgery. Lippincott Williams & Wilkins 2013. Editors N Lois and D Wong. ISBN/ISSN: 9781451119381
10. Finsl O, Drexler W, Menapace R, et al. Improved prediction of intraocular lens power using partial coherence interferometry. J Cataract Refract Surg 2001; 27:861-867
11. Olsen T. Improved accuracy of intraocular lems power calculation with the Zeiss IOLMaster. Acta Ophthalmol 2008; 19:13-17

12. Wang JK, Hu CY, Chang SW. Intraocular lens power calculation using the IOLMaster and various formulas in eyes with long axial length. J Cataract Refract Surg 2008; 34:262-267
13. Eleftheriadis H. IOLMaster biometry: refractive results of 100 consecutive cases**.** Br J Ophthalmol 2003;87:960-963
14. Lee AC, Qazi MA, Pepose JS. Biometry and intraocular lens power calculation. Curr Opin Ophthalmol 2008;19:13-17
15. Findl O, Kriechbaum K, Sacu S, et al. Influence of operator experience on the performance of ultrasound biometry compared to optical biometry before cataract surgery. J Cataract Refract Surg 2003;29:1950-1955.
16. Rajan MS, Keilhorn I, Bell JA. Partial coherence laser interferometry vs conventional ultrasound biometry in intraocular lens power calculations. Eye 2002;16:552–556.
17. Hill W, Angeles R, Otani T. Evaluation of a new IOLMaster algorithm to measure axial length. J Cataract Refract Surg 2008;34:920–924
18. Lege BAM, Haigis W. Laser interference biometry versus ultrasound biometry in certain clinical conditions. Graefe’s Arch Clin Exp Ophthalmol 2004;242:8-12
19. Falkner-Radler CI, Benesch T, Binder S. Accuracy of preoperative biometry in vitrectomy combined with cataract surgery for patients with epiretinal membranes and macular holes: results of a prospective controlled clinical trial. J Cataract Refract Surg 2008;34:1754-1760

Legends:

Figure 1: Composite optical Biometry illustrating a posterior retinal peak

Figure 2: Bland-Altman plot indicating differences between pre-operative OB and A-scan axial length measurements as a function of averages

Figure 3: Bland-Altman plot indicating differences between pre-operative OB and post-operative OB axial length measurements as a function of averages