Influence of Optional Biometric Variables on Refractive Outcomes Predicted Through the Barrett Universal II Formula

Influência dos Parâmetros Biométricos Opcionais nos *Outcomes* Refrativos Obtidos Através da Fórmula Barrett Universal II

Telmo Cortinhal [1,2], Pedro Pereira [1,2], Nuno Gouveia [1,2], Inês Figueiredo [1,2], Miguel Raimundo [1,2,3], Conceição Lobo [1,2,3], Joaquim Murta [1,2,3]

[1] Department of Ophthalmology, Hospitais da Universidade de Coimbra, Unidade Local de Saúde de Coimbra, Coimbra, Portugal
[2] Clinical Academic Center of Coimbra (CACC), Coimbra, Portugal
[3] Faculty of Medicine, University of Coimbra (FMUC), Coimbra, Portugal

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ABSTRACT

INTRODUCTION: Modern intraocular lens (IOL) calculation formulas depend on a set of mandatory biometric parameters – axial length (AL), keratometry, anterior chamber depth (ACD) – as well as optional biometric parameters. The Barrett Universal II (BUII) formula considers two optional parameters - lens thickness (LT) and white-to-white distance (WTW). These parameters may not be measurable using older optical biometry devices, and there is currently a lack of evidence regarding their effect on refractive outcomes. We compared refractive outcomes of uncomplicated cataract surgery with and without the use of optional parameters.

METHODS: Retrospective consecutive case study of eyes that underwent uncomplicated cataract surgery with single piece monofocal IOL implantation (Alcon Acrysof SN60AT). We compared the predicted spherical equivalent (SE) for the implanted lens obtained through the BUII formula, with and without optional parameters, to the postoperative SE obtained by subjective refraction performed 6-12 weeks post-operatively. The primary outcome variable was the absolute prediction error (AE) evaluated by the median (MedAE) and interquartile range (IQR). A multivariate logistic regression model for the odds of improving the predictions was fitted with biometric variables.

RESULTS: We included 1346 eyes with mean AL 23.36±1.08 mm (20.87-29.73), ACD 3.32±0.39 mm (2.12-4.36), mean anterior keratometry 44.10±1.54D (38.48-49.63), LT 4.59±0.42 mm (3.12-6.00) and WTW 11.85±0.41 mm (10.51-13.36). After optimization, the median AE with optional parameters was significantly lower than without (with optional: MedAE 0.283D, IQR 0.310; without 0.289, IQR 0.326; p=0.005). The postoperative SE prediction changed by more than 0.1D (absolute values) in 26.15% (n=352). In this subset, a more accurate prediction was seen in 44.9% of cases (n=158), notably with lower LT (LT < 4.17 mm, 1SD cutoff, OR 2.00, p=0.014) and more extreme WTW (WTW > 12.67 or < 11.03, 2SD cutoff, OR 3.43, p=0.007).

CONCLUSION: In our sample, the inclusion of optional biometric variables in the Barrett UII formula significantly improved outcomes. A greater benefit was observed for lower-than-average pre-operative LT and extreme pre-operative WTW.

KEYWORDS: Biometry; Cataract; Lens Implantation, Intraocular; Lenses, Intraocular; Outcome Assessment, Health Care; Refractive Errors; Refractive Surgical Procedures.

RESUMO

INTRODUÇÃO: As fórmulas modernas de cálculo de potência da lente intraocular (IOL) dependem de um conjunto de parâmetros biométricos obrigatórios – comprimento axial (AL), queratometria, profundidade da câmara anterior (ACD) – bem como parâmetros opcionais. A fórmula Barrett Universal II (BUII) contempla 2 parâmetros opcionais – espessura do cristalino (LT) e a distância branco-branco (WTW). Estes parâmetros podem não ser mensuráveis ao utilizar aparelhos de biometria ótica mais antigos, e existe atualmente uma lacuna científica relativamente ao seu efeito nos resultados refrativos. O presente estudo comparou os resultados refrativos de cirurgia de catarata não complicada, com e sem o uso de parâmetros opcionais.

MÉTODOS: Estudo retrospetivo incluindo olhos submetidos a cirurgia de catarata não complicada com implante da IOL monofocal (Alcon Acrysof SN60AT). Comparámos o equivalente esférico (SE) previsto para a IOL implantada utilizado a fórmula BUII, com e sem parâmetros opcionais, ao SE obtido através de refração subjetiva, realizado às 6-12 semanas após a cirurgia. O *outcome* primário foi o erro preditivo absoluto (AE), avaliado pela mediana (MedAE) e pelo intervalo interquartis (IQR). Um modelo de regressão logística multivariado incluindo as variáveis biométricas foi utilizado para calcular a probabilidade de melhoria do erro preditivo.

RESULTADOS: Foram incluídos 1346 olhos, com um AL médio de 23,36±1,08 mm (20,87-29,73), ACD 3,32±0,39 mm (2,12-4,36), queratometria anterior média 44,10±1,54D (38,48-49,63), LT 4,59±0,42 mm (3,12-6,00) e WTW 11,85±0,41 mm (10,51-13,36). Após otimização, o MedAE com utilização de parâmetros opcionais foi significativamente menor que sem o seu uso (com parâmetros opcionais: MedAE 0,283D, IQR 0,310; sem: 0,289, IQR 0,326; p=0,005). O erro preditivo do SE foi alterado mais que 0,1D (valor absoluto) em 26,15% dos olhos (n=352). Neste subgrupo, uma previsão mais acertada foi conseguida em 44,9% dos casos (n=158), correspondendo a olhos com menor LT (LT < 4,17 mm, *cutoff* de 1 SD, OR 2,00, p=0,014) e valores de WTW mais extremos (WTW > 12,67 ou < 11,03, *cutoff* de 2SD, OR 3,43, p=0,007).

CONCLUSÃO: Na nossa amostra, a inclusão de parâmetros biométricos opcionais na fórmula BUII melhorou significativamente os *outcomes* refrativos. O maior benefício da sua utilização foi encontrado em olhos com menor LT ou valores extremos de WTW.

PALAVRAS-CHAVE: Avaliação de Resultados em Cuidados de Saúde; Biometria; Catarata; Erros de Refração; Implantação de Lentes Intraoculares; Lentes Intraoculares; Procedimentos Cirúrgicos Refractivos.

INTRODUCTION

Patients undergoing cataract surgery have increasingly higher expectations towards spectacle independency, as trends have shifted in recent years towards operating progressively younger patients, with better preoperative visual acuity.[1] Although the choice of intraocular lens (IOL) and its technology (monofocal, extended depth of focus, multifocal) may vary according to patient's needs and ocular comorbidities, a common goal for all cases is to minimize the postoperative prediction error.

In this context, modern IOL calculation formulas are capable of providing good outcomes, as when they are used, around 80% of eyes are expected to be within a prediction error of ±0.50 diopters (D).[2,3] These formulas rely on a set of mandatory biometric parameters, which include axial length (AL), anterior keratometry (K) and anterior chamber depth (ACD). Optional parameters can also be used in several modern formulas, however, evidence regarding their actual effect towards a more accurate prediction is thus far lacking. Also, such parameters may not be measurable using older optical biometry devices.[4]

The Barrett Universal II (BUII) formula is by now a well-known method for IOL calculation, with proven performance across multiple large cohort studies.[2,3,5,6] It considers two optional parameters in the input form, the lens thickness (LT) and white-to-white distance (WTW). A recent study has reported a significant difference in the prediction error when using these parameters.[7] However, as the authors acknowledge, a medium-sized cohort was

used, and also a subgroup analysis was not performed in order to determine which eyes would most benefit from the use of these parameters. As such, using a large cohort, we aimed to compare refractive outcomes of uncomplicated cataract surgery using the BUII formula with and without the use of optional parameters.

METHODS

A retrospective study was conducted, including consecutive eyes subjected to uncomplicated cataract surgery, with in-bag single-piece monofocal IOL implantation (Acrysof® SN60AT, Alcon Laboratories Inc., Fort Worth, TX), from January 2022 to March 2023. Only one eye per patient was included in the sample. Eyes were excluded on the presence of one of the following criteria: incomplete data, ultrasonic biometry, combined or complicated phacoemulsification surgery, pre-existing ocular diseases besides cataract conditioning low visual acuity, ocular comorbidities influencing biometric measurements and postoperative corrected distance visual acuity (CDVA) worse than 20/40.

Biometric data, including optional parameters, was obtained from a swept-source optical coherence tomography (SS-OCT) biometer (ARGOS®, Alcon Laboratories Inc., Fort Worth, TX).[8]

We compared the predicted spherical equivalent (SE) for the implanted lens obtained through the Barrett Universal II formula (available online[A]), with and without the use of optional parameters, to the postoperative SE obtained by subjective refraction 6-12 weeks post-operatively. Constant optimization was performed at the eye level using the Barrett RX online tool,[B] which then allowed for sample level optimization. Back calculation of the ideal A-constant for each case was conducted, and the mean of the A-constant was considered as the optimized constant to zero out the mean prediction error. The primary outcome variable was the absolute prediction error (AE) evaluated by the median (MedAE) and interquartile range (IQR), compared using the Wilcoxon signed-rank test. A multivariate logistic regression model for the odds of improving the predictions was fitted with biometric variables. Statistical analysis was performed using the STATA software (version 16.0; StataCorp, College Station, TX, USA).

RESULTS

In total, 1346 eyes from 1346 patients were included, with a mean age of 74.40 ± 7.80 years, of which 61.74% were female. The pre-operative biometric data is presented in Table 1.

Table 1. Pre-operative biometric data.

	Mean ± SD	Range
AL (mm)	23.36 ± 1.08	20.87 — 29.73
ACD (mm)	3.32 ± 0.39	2.12 — 4.36
K1 ant (D)	43.66 ± 1.55	38.00 — 49.04
K2 ant (D)	44.54 ± 1.59	38.97 — 50.28
Km ant (D)	44.10 ± 1.54	38.48 — 49.63
LT (mm)	4.59 ± 0.42	3.12 — 6.00
WTW (mm)	11.85 ± 0.41	10.51 – 13.36

AL – axial length; ACD – anterior chamber depth; Km – mean keratometry; LT – lens thickness; WTW – white-to-white distance.

The MedAE and IQR for the BUII formula without the use of optional parameters were 0.289D and 0.326D respectively, diminishing to 0.283D and 0.310D respectively with the use of both LT and WTW, a statistically significant difference (p=0.005). These results are summarized in Table 2. All the studied summary statistics, namely the standard deviation of the mean error, the median absolute error, and the interquartile range decrease with the addition of both optional biometric parameters, though the impact on percentage of eyes within 0.25D, 0.50D, 0.75D and 1.00D of prediction errors is negligible. However, on visual inspection of the distribution of the absolute prediction error, a tighter distribution with fewer outliers in the BU2 formula with both optional parameters is easily seen (Fig. 1).

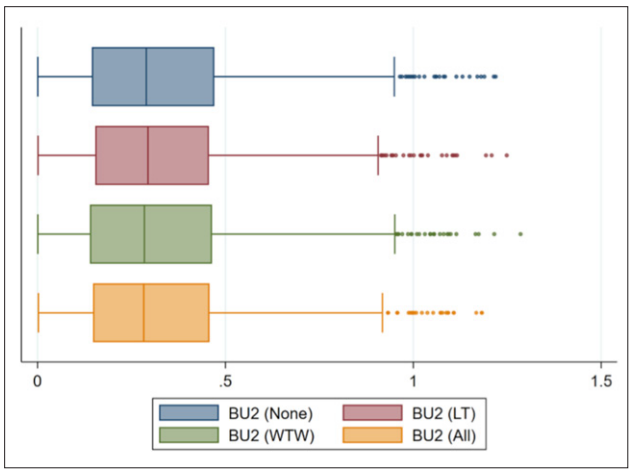

Figure 1. Distribution of the absolute prediction error within the Barrett Universal II formula with and without optional biometric parameters.

BU2 – Barrett Universal II; LT – lens thickness; WTW – white-to-white distance.

Table 2. Comparison of Barrett Universal II performance with and without optional biometric variables.

n=1346	MeanE	SD	MedAE	IQR	≤0.25D	≤0.50D	≤0.75D	≤1.00D
BU2 (None)	0	0.411	0.289	0.326	43.8%	78.1%	93.1%	98.7%
BU2 (LT)	0	0.402	0.294	0.302	43.6%	80.2%	94.0%	99.0%
BU2 (WTW)	0	0.408	0.284	0.325	44.6%	78.5%	93.5%	98.7%
BU2 (All)	0	0.400	0.283	0.310	43.9%	79.8%	94.0%	98.8%

BU2 – Barrett Universal II; MeanE – mean error; SD – standard deviation; MedAE – median absolute error; LT – lens thickness; WTW – white-to-white distance.

When using optional parameters, the prediction of the post-operative SE was changed by over 0.1D (in absolute terms) in 26.15% of eyes (n=352). This change resulted in a more accurate prediction for 44.9% of cases (n=158).

Using a multivariate logistic regression model (Table 3), we found that the odds of improving predictions this subset of 352 eyes was associated to lower LT (inferior to 4.17 mm, a 1 SD cutoff; OR 2.00; p=0.014) and extreme WTW (lower than 11.03 mm or higher than 12.67 mm, a 2 SD cutoff, OR 3.43; p=0.007), when controlling for linear variations of axial length, anterior chamber depth and mean keratometry (all non-significant predictors).

Table 3. Multivariate logistic regression model for the odds of improving predictions over 0.1D.

Parameter	OR	95% CI	p-value
LT < 4.17 mm	2.00	1.15 – 3.49	0.014
WTW < 11.03 or WTW > 12.67 mm	3.43	1.41 – 8.37	0.007
AL < 22.00 mm or AL > 26.00 mm	0.90	0.42 – 1.92	0.784
ACD < 2.50 mm or ACD > 3.50 mm	0.99	0.59 –1.67	0.973
KM	1.00	0.82 – 1.22	0.977

OR – odds ratio; 95%CI – 95% confidence interval; AL – axial length; KM – mean keratometry; ACD – anterior chamber depth; LT – lens thickness; WTW – white-to-white distance.

DISCUSSION

Newer SS-OCT biometers have facilitated the acquisition of ocular measurements. Compared to older optical biometers, they have added the capability of measuring parameters such as the central corneal thickness and LT, while also being superior in their ability to determine AL in denser cataracts.[4,8] Although good outcomes are to be expected when using modern IOL calculation formulas in average eyes, predictions may be hindered by extreme biometric measurements, as is by now well known to be the case for short or long eyes.[2,9] In this context, we aimed to determine whether the use of optional parameters (LT and WTW) leads to a significant improvement in BUII predictions, and in which cases is this improvement most noticeable.

The influence of optional parameters on BUII predictions was previously investigated by Wendelstein *et al*, who found a significant difference (p=0.028) in the AE when LT and WTW were used, in their medium-sized cohort (n=251).[7] Our study confirmed these findings in a much larger sample size (n=1346), having observed a significant, yet slight improvement in the MedAE from 0.289D to 0.283D when using both LT and WTW. However, the question stands whether this is clinically relevant in real world practice. Thus, we identified the subset of eyes where predictions were changed over 0.1D with the use of optional parameters (26.15%; n=352) and found that, in this subgroup, only approximately 45% of eyes had a more accurate prediction. These were in essence, eyes with lower LT or extreme WTW. While 0.1D is a small refractive change, changing predictions by this magnitude may be enough to trigger a decision to change IOL power selection pre-operatively (usually in 0.50D intervals). Nevertheless, our results show that good formula performance can be achieved even without the use of optional parameters in the Barrett Universal II formula, which is relevant in a scenario of using an older optical biometer that may not be able to measure these variables.

As for why the inclusion of optional parameters is more impactful in eyes with lower LT or extreme WTW, one could assume that since vergence formulas like the Barrett UII use internal assumptions for biometric properties of the schematic eye, the use of explicit extreme optional values over internal "mean" assumptions could be beneficial. However, since the formula itself is not published it is impossible to confirm or extend this hypothesis. Nevertheless, the present study is helpful in quantifying its clinical significance.

The real-world effect of optional parameters was also studied by Vega *et al*,[10] who reported their effect on the suggested IOL power for an emmetropic refractive outcome and found that the difference in suggested power is higher in short eyes (AL≤22 mm), where in 32% of cases there would be a power difference over 0.25D. On the other hand, optional parameters would have little effect in long eyes (AL≥26 mm). Meanwhile, in our study, axial length, anterior chamber depth and mean keratometry did not have a significant influence on subset of eyes where predictions were changed over 0.1D.

All eyes had pre-operative biometry performed by the same SS-OCT biometer (ARGOS) and were implanted with the same IOL (SN60AT). Although this is a necessary condition for such a study, one needs to take into account that biometric measurements have been shown to vary significantly according to different biometer devices.[11,12] Hence, our results may not be interchangeable for other IOL platforms or biometers. Finally, these results only apply to the Barrett Universal II formula, which was chosen for this study as it is one of the most commonly used formulas for IOL power calculation. Therefore, the influence of optional parameters in other modern formulas warrants further study.

In summary, the inclusion of optional biometric variables in the Barrett UII formula significantly improved outcomes in our sample. A greater benefit was observed for lower-than-average pre-operative LT and extreme pre-operative WTW.

CONTRIBUTORSHIP STATEMENT / DECLARAÇÃO DE CONTRIBUIÇÃO

TC, PP, NG, IF, MR: Responsible for data gathering. and analysis.

TC, MR: Responsible for drafting the manuscript.

MR, CL, JM: Supervised this project and contributed with their expertise to its conclusion.

All authors revised and approved the final manuscript.

TC, PP, NG, IF, MR: Responsável pela recolha e análise dos dados.

TC, MR: Responsável pela redação do manuscrito.

MR, CL, JM: Supervisionaram este projeto e contribuíram

com os seus conhecimentos para a sua conclusão.

Todos os autores reviram e aprovaram o manuscrito final.

RESPONSABILIDADES ÉTICAS

Conflitos de Interesse: Os autores declaram a inexistência de conflitos de interesse na realização do presente trabalho.

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Confidencialidade dos Dados: Os autores declaram ter seguido os protocolos da sua instituição acerca da publicação dos dados de doentes.

Proteção de Pessoas e Animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pela Comissão de Ética responsável e de acordo com a Declaração de Helsínquia revista em 2013 e da Associação Médica Mundial.

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ETHICAL DISCLOSURES

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Confidentiality of Data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.

Protection of Human and Animal Subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2013).

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Corresponding Author/
Autor Correspondente:

Telmo Cortinhal
Centro de Responsabilidade Integrado em Oftalmologia, Centro Hospitalar e Universitário de Coimbra,
Praceta Professor Mota Pinto
3000-075 Coimbra, Portugal
E-mail: telmojc@gmail.com

ORCID: 0000-0002-9016-9031