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ARTICLE

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Accuracy of formulas for intraocular lens power for eyes undergoing descemet stripping automated endothelial keratoplasty and cataract surgery

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BACKGROUND: To compare accuracy in intraocular lens (IOL) power calculation in eyes undergoing combined cataract and Descemet stripping and automated endothelial keratoplasty (C-DSAEK) surgery of the following formulas: Barrett Universal II, EVO, Haigis, Hoffer Q, Holladay 2, Kane and SRK/T.

METHODS: 72 eyes from 72 patients (38 males, (53%)) with a mean age 68.08 ± 8.69 years (from 44 to 88 years old) underwent combined C-DSAEK were included. The IOL powers to implant were calculated with Barrett Universal II formula targeting −1 D refraction. Preoperative and postoperative data were used to obtain the median of absolute prediction errors (MAE) targeting emmetropia with every tested formula.

RESULTS: Means of MAE calculated were +1.45 D for Barrett Universal II, +1.37 D for EVO, +1.48 D for Haigis, +1.38 D for Hoffer Q, +1.37 D for Holladay 2, +1.39 D for Kane and +1.31 D for SRK/T. SRK/T MAE showed major significant ($p < 0.01$) differences compared to the other formulas.

DISCUSSION: Even if tested formulas are not able to accurately target emmetropia, SRK/T seems to be able to provide closer results in eyes undergoing C-DSAEK.

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INTRODUCTION

Today, Descemet stripping automated endothelial keratoplasty (DSAEK) and Descemet membrane endothelial keratoplasty (DMEK) largely replaced full-thickness penetrating keratoplasty to treat corneal endothelial disease, due to less post-operative suture induced astigmatism, lower rate of graft rejection and faster visual rehabilitation [1, 2]. These techniques, combined with cataract surgery are established treatment options for patients affected by Fuchs' endothelial corneal dystrophy (FECD) and cataract [3–6].

It is well known that the combined endothelial transplant (both DSAEK or DMEK) and cataract surgery, often yields an unpredictable hyperopic post-operative refraction, often ranging from +0.5 to +1.5 dioptres (D) [7–18]. Factors involved in this lack of accuracy are related to graft characteristics [19, 20].

Because patients are always more demanding for good vision without corrections, also after complex cases like cataract surgery in FECD eyes, it is important to provide them the best possible refraction. For this reason, aiming to reduce the hyperopic shift, many surgeons implant intraocular lens (IOL) targeting a refraction around −1.00 D but, despite this adjustment, individual features of patients and graft variations make it impossible to predict the accurate refractive outcome [21].

Some studies investigated the precision of the different formulas to calculate IOL power in patients undergoing combined DMEK and cataract surgery for FECD, but there are no papers that deal with the reliability of the same formulas in FECD eyes undergoing combined phacoemulsification, IOL implant and DSAEK [22, 23].

The purpose of this study is to evaluate the accuracy of the following IOL power calculation formulas: Barrett Universal II Formula (BUII), EVO, Haigis, Hoffer Q, Holladay 2, Kane and SRK/T in eyes undergoing DSAEK and cataract surgery, aiming to provide information to minimize post-operative refractive surprises.

METHODS

This retrospective multi-centre study was conducted at the Eye Unit of University of Campania Luigi Vanvitelli and at the Department of Ophthalmology, University of "Magna Graecia", Catanzaro, Italy, performing a chart review on consecutive cases of patients who underwent a combined surgical procedure including DSAEK and cataract surgery from January 2018 to January 2021. The study received institutional review board approval (Azienda Ospedaliera Universitaria, Università degli Studi della Campania Luigi Vanvitelli", 0012575/2020) and conformed to the tenets of the Declaration of Helsinki. All patients provided informed consent for both the surgical procedures and the data analysis.

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Table 1. Percentage of eyes within ±0.5 D, ±1 D, ±1.5 D and ±2 D of the predicted error using the different formulas tested in the study.

	BUII	HAIGIS	HOFFER Q	HOLLADAY 2	EVO	KANE	SRK/T
% with PE ≤ ± 0.50 D	16.67	15.28	19.44	25.00	19.72	19.72	19.44
% with PE ≤ ± 1.00 D	33.33	31.94	36.11	35.94	39.44	38.03	38.89
% with PE ≤ ± 1.50 D	54.17	51.39	58.33	57.81	56.34	56.34	59.72
% with PE ≤ ± 2.00 D	80.56	73.61	79.17	76.56	76.06	78.87	81.94

PE predicted error, *BUII* Barrett Universal II.

Table 2. Mean absolute error with standard deviation and Median absolute error with standard deviation for each formulas tested in the study.

	BUII	HAIGIS	HOFFER Q	HOLLADAY 2	EVO	KANE	SRK/T
MAE (D)	1.449 ± 0.872	1.478 ± 0.922	1.382 ± 0.889	1.372 ± 0.897	1.375 ± 0.869	1.386 ± 0.894	1.312 ± 0.856
MedAE (D)	1.455	1.490	1.335	1.355	1.370	1.390	1.283

MAE Mean absolute error, *MedAE* Median absolute error, *BUII* Barrett Universal II.

Each patient included in the study had FECD with cataract and corneal oedema not responder to medical therapy. Patients with post-operative best corrected distance worse than 20/40, with other ophthalmic or systemic diseases that could interfere with visual acuity and/or refraction, those requiring ultrasound biometry to measure axial length, who used contact lens in the previous month, those that experienced complications during planned surgery and those that had undergone previous ophthalmic surgery were excluded from the evaluation.

If both eyes of a patient were eligible for inclusion in the study, only the one undergoing surgery as first was included.

A total of 72 eyes from 72 patients (38 males, 34 females) with a mean age 68.08 ± 8.69 years (from 44 to 88 years old) were included in the study.

All patients had a complete preoperative visit including biometry with partial coherence interferometry with the IOLMaster 500 (software version 4.08.002, Carl Zeiss Meditec AG, Jena, Germany) to measure axial length, anterior chamber depth (ACD, measured from epithelium to lens) and mean corneal curvature (MK).

The mean axial length (AL) was 23.46 ± 1.14 mm (range: 20.7 mm to 26.41 mm); the mean MK was 44.00 ± 1.98 D (range: 36.8 D to 51.5 D); the mean ACD was 2.74 ± 1.98 mm (range: 2.46 mm to 3.62 mm).

Mean graft thickness implanted was 89.06 ± 19.44 mm, ranging from 55 to 108 mm; mean graft diameter was 8.42 ± 0.12 m, ranging from 8.25 to 8.50 mm.

The same surgical technique was used for every case included in the study: local anaesthesia was administered with a peribulbar injection of a mixture of lidocaine hydrochloride 2.0% and bupivacaine hydrochloride 0.5%. Standard phacoemulsification was performed through a 2.2 mm clear corneal tunnel on the temporal side. The IOL was implanted in the capsular bag, then the pupil was constricted with acetylcholine chloride, and the clear corneal tunnel was widened to 4.0 mm. The anterior chamber was filled with air, and the Descemet membrane and endothelium were peeled off in a single piece. The donor lenticule, prepared using the automated lamellar therapeutic keratoplasty system, was then placed on a Barron punch, endothelial side up, and trephined to 8.5 mm in diameter. An anterior chamber maintainer was placed at the 12 o'clock position for continuous irrigation, and the donor tissue was inserted into the anterior chamber with the pull-through technique using the Busin glide. Both the clear corneal tunnel and the side entries were sutured tightly with interrupted 10-0 nylon sutures, and the anterior chamber was filled with air injected through the temporal side entry. Triamcinolone acetonide and gentamicin were injected subconjunctivally at the end of the procedure. The patient was pressure-patched overnight and instructed to lie supine for 6–8 h. Postoperatively, dexamethasone phosphate 0.1% and tobramycin antibiotic eye drops were administered initially every 2 h and then tapered over 3–4 months. All sutures were removed 3 weeks after surgery.

The same IOL has been implanted in every case: Acrysoft SN60WF (Alcon Laboratories), the power of the IOL has been calculated using the Barrett Universal II Formula (BUII) aiming to target a refraction of −1 D. Further, the same preoperative data have been used to calculate the IOL power to implant with the following formulas: BUII, EVO, Haigis, Hoffer Q, Holladay 2, Kane and SRK/T, always targeting a −1 D refraction.

The prediction error for each formula was calculated as the actual postoperative refraction (calculated as spherical equivalent at 6 months follow up) minus the predicted refraction for each formula. The mean absolute prediction error (MAE) with standard deviation and median absolute prediction error (MedAE) were calculated for each formula as well as the percentages of eyes that had a prediction error of ±0.50; ±1.00 and ±2.00 D (Table 1).

Statistical analysis

As recommended by previous studies, regarding the accuracy of formulas to calculate IOL power, statistical analysis was performed using the Friedman test to assess for differences in absolute error between formulas, and in the event of a significant result, post hoc analysis was performed using the Wilcoxon signed-rank test with Bonferroni correction [24, 25]. The McNemar test with Bonferroni correction was used to assess statistical significance between the percentage of eyes within ±0.50 D, ±1.00 D and ±2.00 D prediction error. Pearson univariate correlation test was adopted to assess correlation among refractive results and morphological parameters. All statistical analyses were performed using SPSS (IBM Corp. Armonk, New York, version 21.0).

RESULTS

According to the observed results, in most cases, the formula tested provided refractive results out of the ±1 D range (Table 1). Indeed, every formula evaluated in this study provided an underestimation of IOL of about 1 D, that would have determined a final refraction higher than +1 D. (Tables 2 and 3).

Observing the overall results, after surgery 29 eyes had a myopic refraction, 8 of them had emmetropic result and 35 of them had a hyperopic refraction.

No significant correlations have been observed between graft thickness and refractive results obtained with BUII ($R^2 = 0.28$), EVO ($R^2 = 0.31$), Haigis ($R^2 = 0.17$), Hoffer Q ($R^2 = 0.19$), Holladay 2 ($R^2 = 0.42$), Kane ($R^2 = 0.37$) and SRK/T ($R^2 = 0.25$).

Several studies report a mean post-operative hyperopic shift of approximately +0.5 to +1.5 dioptres (D) due to an increase in the posterior corneal power [15–18]. In particular, the hyperopic shift has been shown to be correlated with central graft thickness, graft morphologies and graft trephine diameter [19, 20].

Even if SRK/T showed lower MAE and MEDAE values, this formula did not provide refractions statistically different from EVO, Hoffer Q, Holladay 2 and Kane formulas (Table 2).

The BUII and Haigis formulas, showed lower accuracy in targeting emmetropia in the eyes evaluated in this study (Table 2).

Table 3. Significance of the differences observed among the different formulas tested in the study.

	BUII	HAIGIS	HOFFER Q	HOLLADAY 2	EVO	KANE	SRK/T
BUII		0.098	0.051	0.093	**<0.001**	**<0.001**	**<0.001**
HAIGIS	0.098		**<0.001**	0.003	**0.001**	**0.001**	**0.001**
HOFFER Q	0.051	**<0.001**		0.429	0.689	0.709	0.27
HOLLADAY 2	0.093	0.003	0.429		0.324	0.543	0.01
EVO	**<0.001**	**0.001**	0.689	0.324		0.053	0.068
KANE	**<0.001**	**0.001**	0.709	0.543	0.053		0.013
SRK/T	**<0.001**	**0.001**	0.27	0.01	0.068	0.013	

BUII Barrett Universal II.
Bold values are the ones showing a significant difference.

DISCUSSION

Calculation of IOL power to implant in eyes undergoing combined DMEK or DSAEK and cataract procedures have been reported to have hyperopic refraction and this study confirms these results [7–14,17]. Moreover, this study has, for the first time, compared the results of different formulas' aiming to identify the most accurate ones.

The reasons for the lack of accuracy formulas used to calculate IOL power in these combined cases have been largely discussed [15–20]. Even if data evaluating changes in corneal shapes after endothelial keratoplasty did not provide unanimous results, a flattening of anterior corneal surface associated to an increase of posterior corneal curvature can be observed and it is more evident after DSAEK than after DMEK [12,26–28]. These modifications are associated to the reduction in precision of commonly used IOL power formulas in FECD eyes undergoing combined DSAEK and cataract surgery with IOL implant. Moreover, a role is probably played also by the dimensions and the characteristics of the corneal graft [19, 20].

In this study, the lowest prediction error has been provided by SRK/T formula, even if the observed results were not statistically different from those obtained with EVO, Hoffer Q, Holladay 2 and Kane formulas. On the other hand, BUII and Haigis formulas showed a significant underestimation of the IOL power to implant that would have led to a higher hyperopic refraction after surgery.

Even if FECD patients undergoing combined endokeratoplasty and cataract surgery are aware of the complexity compared to standard cataract surgery, nowadays, the refractive expectations are always very high. Thus, it is always important to aim to provide a refraction as close possible to zero to these patients too.

The study has several limitations such as the relatively small cohort, even if the included eyes have been accurately selected aiming to obtain the most reliable refractive data. Another limitation is the retrospective nature of the study and the fact that it is a multi-centric one, even if the same devices to measure biometric parameters were used to calculate IOL power and the same methodology have been applied. Some data that could be interesting in this study, such as a standardized evaluation of corneal oedema before surgery or the graft thickness after surgery are missing always due to the retrospective design of the study. Moreover, potential biases related to the chart reviews could be considered too, even if a double check about the accuracy of the information has been performed for every patient. Lastly, a deeper analysis evaluating the results in longer vs shorter eyes has not been conducted, because the cohort was too small to allow a reliable evaluation of this kind.

Notwithstanding the listed limitations, this is the first study that compares the refractive results of seven IOL power calculations formulas in eyes affected by FECD undergoing combined DSAEK and cataract surgery. According to the results observed, a hyperopia greater than 1 D can be observed after this combined procedure with all formulas evaluated. Thus, it is important to plan a target post-operative refraction of -1 D, according to the selected formula. Further, patients should be informed about the risk of unexpected hyperopic refraction after surgery.

Many studies report the hyperopic results after combined endokeratoplasty and cataract surgery but very few deeply analyse the results aiming to improve the accuracy of the refractive outcomes [22, 23]. Even if Knuttson et al. and Alnawaiseh et al. evaluated eyes undergoing DMEK and cataract surgery, the post-operative refraction observed in this study is similar. The previous studies adopted several methodologies to improve the accuracy of IOL calculation, such as the use of optimized ULIB A constant and the corneal power calculation using ray tracing but significant differences were not found among the IOL formulas evaluated whereas in this study some formulas showed significantly better results than others [22, 23].

The different behaviour of the formulas could be related to the different kind of endokeratoplasty performed and /or to the different methodology of analysis adopted. The results observed can be useful not just as clinical information for physicians, aiming to reduce the hyperopic refraction in these cases, but also to better design and plan further studies about this topic.

In conclusion, data observed in this study, even if further ones are needed to accurately address how to obtain a IOL power providing results always closer to emmetropia in this kind of eyes with different design and population, suggest that EVO, Hoffer Q, Holladay 2, Kane and SRK/T formulas are able to provide better refractive results compared to BUII and Haigis.

SUMMARY

What was known before

- IOL power calculation in patients undergoing cataract surgery and Descemet Stripping Automated Endothelial Keratoplasty is inaccurate. Patients are always more demanding for a good visual acuity after surgery also after the complex one. There are no published studies comparing the results of different formulas in these eyes.

What this study adds

- All the evaluated formulas struggle in targeting emmetropia in these eyes STK/T appears to be the formula providing the most accurate results. It is important to advice the patient about the difficulties of calculating an IOL able to provide emmetropia in these clinical situations.

DATA AVAILABILITY

Data is available from the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

ML, RB and VS contributed to the study design, data interpretation, and preparation of the manuscript. GL, RB and PM collected and analysed the data. VS, SS, ML and AL performed the medical interventions, AL, FS, VS and ML wrote and revised the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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