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Intraocular lens power calculations for complicated cases

Purposes: (a) to find out the error in the back calculation of Effective Lens Position (ELP, back calculation of ELP is abbreviated as ELP_{back}); and to describe an intraocular lens (IOL) power calculation method for refractive IOL exchange that is one of the complicated cases in IOL power calculation; (b) to find out the relation between the ray tracing method and thin-lens formula (method) in IOL power calculations; and to compare the accuracies of the two methods; (c) to find out the solutions to IOL power calculation for cases following corneal refractive surgery (CRS), one of the most complicated cases in IOL power calculation; and to find out whether ray tracing method has the same accuracy in IOL power calculation after CRS as thin-lens method.

Methods: ELP_{back} was calculated by axial length (AL), corneal power (K), power of primary IOL (PIOL) and pseudophakic refraction after primary IOL implantation. ELP of the secondary IOL (ELP2) was estimated by ELP_{back} and was used in the theoretical IOL calculation formula to calculate IOL power for IOL exchange (PIOL2). Factors influencing the accuracies of ELP_{back} and PIOL2 calculation were analyzed. A method to confine the error of PIOL2 (ER_{IOL2}) was derived and was used in the IOL power calculation for IOL exchange. IOL powers of 20 cases after primary IOL implantation were calculated by my method, Holladay, Hoffer Q, SRK T and SRK2 formulas. Absolute prediction errors (AE) of these formulas were calculated and compared by Paired-Sample-*t* tests.

52 normal cataract cases and 302 normal corneas were studied. Normal and

individual eye models were constructed using professional optical software Zemax (Zemax-EE Optical Design Program, Focus Software, Inc. USA) by importing the data measured by rotating Scheimplug camera, Pentacam (Oculus Inc., Wetzlar, Germany) and IOLMaser (Carl Zeiss Meditec AG, Jena, Germany). Individual corneal models of 302 corneas were also constructed using Zemax. Different IOL position (Olsen2, Haigis, Norrby, HofferQ) algorithms were used to predict postoperative IOL position in both thin-lens and ray tracing methods. Postoperative anterior chamber depth (ACD_{post}) was back-calculated (ACD_{back}) using both thin-lens and ray tracing methods. ACD_{back} and ELP_{back} were correlated by linear-regression. AE of ray tracing method and thin-lens formulas were compared by Paired-Sample-*t* tests.

25 eyes after CRS were studied. IOL power was calculated using ray tracing method and different thin-lens methods. In thin-lens methods, corneal power was corrected by different formulas from measured value. The accuracies of different methods were compared by Paired-Sample-*t* tests.

Results: PIOL and error of pseudophakic refraction (ER_{RE}) are the major factors influencing the errors of ELP_{back} (ER_{ELP}) and ER_{IOL2}. With defined PIOL, both ER_{ELP} and ER_{IOL2} have conic correlations with ER_{RE}, respectively: $ER_{ELP}=a\times ER_{RE}^2+b\times ER_{RE}$; $ER_{IOL2}=a\times ER_{RE}^2+b\times ER_{RE}$. With defined ER_{RE}, both ELP_{back} and ER_{IOL2} have exponential correlations with PIOL, respectively: $ER_{ELP}=a\times PIOL^b$; $ER_{IOL2}=a\times PIOL^b$. PIOL should be higher than a certain value (termed as MinIOL) to insure ER_{IOL2} lower than the tolerant value. A method to calculate MinIOL was derived. For IOL exchange cases, Mean AE of my method (0.35±0.38D) was lower than that of Holladay (0.95±0.65D), HofferQ (0.87±0.50D), SRKT (0.74 ±0.91D) and SRK2 (1.44±0.96D) formulas.

Corneal power values calculated by thin-lens and ray tracing methods were in high correlations ($R^2>0.96$). ELP used in thin-lens formula and ACD_{post} used in ray tracing method can be transformed to each other. Mean AE of Olsen2, Haigis, Norrby, HofferQ thin-lens formulas were 0.61±0.47D, 0.64±0.52D, 0.59±0.42D and 0.57±0.46D, respectively; mean AE of normal ray tracing method using Olsen2, Haigis, Norrby, HofferQ ACD predictive algorithms were 0.62±0.45D, 0.64±0.50D, 0.59±0.41D and 0.58±0.44D, respectively; Individual ray tracing method using the corresponding ACD_{post} prediction algorithms were 0.62±0.50D, 0.66±0.52D, 0.59±0.43D and 0.59±0.45D, respectively. No statistical differences were found among all the methods ($P>0.05$). AE of all methods were correlated with the prediction errors of IOL poison predictive algorithms respectively.

The relation between thin-lens and ray tracing methods for IOL power calculation following CRS possessed the analogous properties as that in normal cases. With corrected corneal power and double-K modification, thin-lens method was as accurate as ray tracing method for IOL power calculation in cases following CRS.

Conclusions: (a) ELP_{back} cannot be regarded as a benchmark. A method of confining the error in ELP_{back} calculation was developed. The method for the calculation of IOL power in IOL exchange cases developed in this study is more accurate than the previous method; (b) there were certain relations between thin-lens and ray tracing methods. Thin-lens method is as accurate as ray tracing method in IOL power calculation for normal cases; the key factor in IOL power calculation is not the selection between thin-lens and ray tracing methods, but the selection of more accurate IOL position (ELP or ACD_{post}) prediction algorithms; (c) Using corrected corneal power and double-K modification are the key points in IOL power calculation following CRS. With appropriate corneal power estimation and double-K modification, thin-lens method is as accurate as ray tracing method in IOL power calculation following CRS.