ORIGINAL ARTICLE

Comparison of Optical and Ultrasound Biometry and Assessment of Using Both Methods in Practice

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SUMMARY

Purpose: The present study compares accuracy of optical biometry (OB) and ultrasound biometry (UB) based on postoperative best corrected visual acuity (BCVA) results, and assesses the extent of the usage of the measurement methods in current practice.
Methods: 335 eyes in total were operated for cataract at Beskydské oční centrum (Beskydy Eye Centre; BOC), Frýdek-Místek hospital, in the period between 7 February 2007 and 7 April 2010. All patients were examined using both IOL-Master and Ocu-Scan prior to the surgery. All surgeries were performed using microcoaxial phacoemulsification, 2,2 mm incision, implanting IOL AcrySof SP, SPN or SPN IQ. BCVA was examined three months after the surgery. We first calculated medians of anterior-posterior axial length (AL) values measured using both methods; with both the whole set and individual subsets created according to the eye length. Difference between the two methods was calculated in mm. We calculated accurate dioptric power of the IOL, which should have been implanted in the lens bag to ensure postoperative emmetropia, using BCVA results. With each eye, we determined the size of diopter variation of the IOL's dioptric power value for emmetropia determined by an optical biometer from the accurate value of the IOL's dioptric power. Ultrasound biometry results were processed in the same way. The SRK-T formula was used for calculation with each biometry. We also calculated the number of variations above 1 D and 2 D with both biometric methods.
Results: The median of axial eye length measured using an optical biometer was 23,08 mm, and the median of axial eye length measured using ultrasound biometry was 22,93 mm. The difference between these values was 0,15 mm (150 microns), which equals the difference between average values of coincident measurement results. Average variation of dioptric power of an implanted IOL from retrospectively established optimum value of the IOL's optical power was 0,40 D lower with optical biometry and 0,16 D lower with ultrasound biometry. In the context of assessing the course of the curves of both methods created using a polynomial graph, this result confirms that the two methods correspond significantly, and therefore selecting any of the methods could not negatively impact determination of the implanted IOL's dioptric power. Comparing the frequency of variations above 1D and 2,0 D with OB and UB from the accurate value of the IOL's dioptric power, we discovered a substantially higher percentage of variations with UB – up to 25 % of the total set above 1,0 D.
Conclusion: Results of comparing accuracy and comfort of AL measurement with both methods justify unambiguous preference of optical biometry over ultrasound biometry in current practice. If measurement using ultrasound probe is done correctly, results of both methods correspond significantly, and so the methods are mutually replaceable. Using ultrasound biometry is therefore adequate in case optical biometry cannot be used..

Key words: optical and ultrasound biometry, accurate dioptric power of the IOL, formulas, polynomial graph.

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INTRODUCTION

The optimal refraction result of a surgery is closely linked to the precision of measurement of the eye, above all to the precise measurement of its anterior-to-posterior axial length and the optical density of the cornea, or the depth of the anterior chamber of the eye and the diameter of the cornea.
The axial length of the eye is defined as the distance between the centre of the surface of the cornea and the place of sharpest vision on the retina – the fovea centralis. We use biometry to measure this. The measured value in mm is required for calculation of the optical density of the intraocular lens to be implanted into the eye.
The axial length of the eye is currently measured by the developmentally younger optical biometry (OB) or the developmentally older ultrasound biometry (UB). A detailed description and analysis of both methods is presented in a range of professional studies (9, 11, 16, 21, 26). The current practice of predominantly outpatient cataract surgery requires maximum precision

of measurement conducted within a relatively short time and in relatively comfortable conditions for the patient. With regard to optical biometry, the predominant majority of ocular facilities most often use the principle of partial coherence interferometry. In our centre we have been using this optical method since 2006 with the help of an IOL-master appliance (Carl Zeiss GmbH, Jena). Measurement of the axial length of the eye by ultrasound is most frequently performed by "A-scan biometry" using the contact method. The immersion method of A-scan biometry using a flyleaf is not commonly applied at the majority of ophthalmology workplaces (10). At our facility also, in the case of necessity we use only the contact method with the help of an OcuScan appliance (Alcon Laboratories, Inc.). In our own population of operated eyes we decided to verify the precision of measurement of both methods, to conduct a comparison and to compare the results with the corresponding literary data.

THE POPULATION AND METHODOLOGY

The population contains a total of 335 eyes, which were operated on for cataract at the Beskydy Eye Centre (BOC) at Frýdek-Místek hospital in the period from 7 February 2007 to 7 April 2010. 157 eyes were right eyes and 178 left eyes. There were 211 (63%) women's eyes and 124 (37%) men's eyes. The average age of the patients in the population was 72 years, their age range on the day of the surgery was from 43 to 90 years. All patients were operated on within an outpatient cataract surgery regime.

Before the operation, the patients were examined according to the stipulated procedure by an instructed secondary physician, and checked by one of the operating surgeons before going to the operating theatre. An examination using an optical and ultrasound biometer was performed by only one person, a manually highly dextrous and carefully trained technician (Fig. 1, Fig. 2).

The population did not include eyes with severe amblyopia, severe corneal dystrophies or severe retinal findings in the area of the macula, which could significantly influence the precision of measurement of the axial length of the eye or the precision of examination of visual acuity post surgery, e.g. findings of epiretinal membranes, advanced or cicatrical stage of ARMD, advanced maculopathy of various aetiology with manifest oedema etc. The sample also did not include eyes following surgeries of the posterior segment or following refractive corneal procedures. With regard to the aim of the work, it was not possible to include in the population eyes in which it was not possible to conduct optical biometry due to serious optical obstacles.

All the surgeries were performed by a total of three ophthalmological microsurgeons in approximately equal proportions, using the same surgical procedure with the help of the same phacoemulsification instrument (Infinity System, Alcon Research Ltd., USA, 2007), by the method of microaxial phacoemulsification via an opening with a diameter of 2.2 mm located by no. 12 and implantation of a soft intraocular lens AcrySof SP, SPN or SPN IQ via an equally wide opening (22).

From the population we excluded eyes with surgical complications which could have caused a non-standard position of the IOL in the lens sac upon its scarring, above all radial ruptures of the anterior capsule or implantation of a distance ring for a loose suspended apparatus of the lens. Eyes with complications which caused the necessity of implantation of an intraocular lens (IOL) outside of the sac were also excluded. Placement of an IOL in the sulcus or in the anterior chamber of the eye would significantly influence the results of postoperative refraction of the eye, in conflict with the sense of the set targets of the study. As a result, all eyes in which a rupture of the posterior capsule occurred peroperatively were excluded.

3 months after the operation, the patient was examined as an outpatient using the same instruments in the same eye clinic of our centre, according to the procedure set in advance for the operated eye. With regard to the aim of the study, stress was laid on a precise examination of best corrected visual acuity (BCVA).

We carried out an analysis of the data of the studied population and a statistical and graphic assessment thereof with the help of the application Microsoft Excel® 2003. In addition to the Excel application we used a McNemar test for an assessment of the significance of the difference in the number of deviations in the comparison of the measuring methods of optical and ultrasound biometry.

First of all we calculated medians of the values of axial length of the eye (AL) measured by both methods, in both the full population and in the individual subpopulations created according to the length of the eye. We calculated the difference in mm between both methods and presented the results in a table.

Fig. 1 Examination with optical biometer IOL-Master at BOC

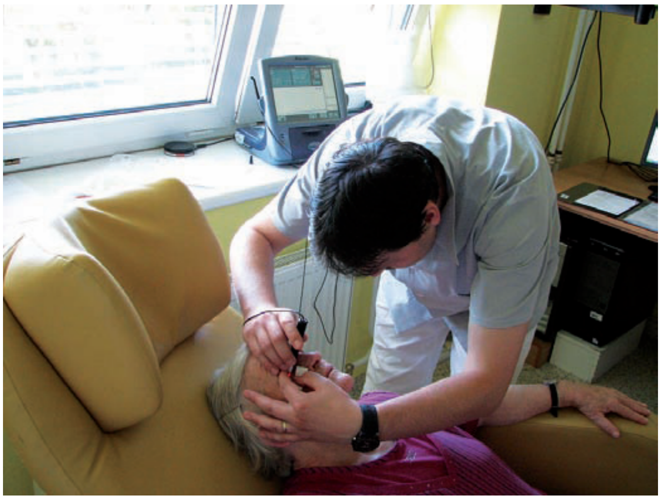


Fig. 2 Examination with ultrasound biometer Ocu-Scan at BOC

For each specific eye we converted the additional correction in spherical dioptres to an additional correction for the implanted intraocular lens according to quotient 1.0 D in glasses = 1.23 D in IOL. We obtained this quotient from the UB software, which enables determination of the dioptric power of the IOL according to the required postoperative refraction. We then converted the dioptric value of this additional correction to the actual value of the dioptric power of the implanted IOL.
Thus obtained resulting value in dioptres can be considered to be the optimised value of the dioptric power of the IOL which was to be implanted into the lens sac in order to ensure postoperative emmetropia. We did not deal with astigmatism of the cornea because we started out from the assumption that a surgical incision with a width of 2.2 mm is astigmatically mute.
For each specific eye we calculated the size of the dioptric deviation of the determined value of the dioptric power of the IOL for emmetropia from the optimised value of the dioptric power of the IOL as determined by the optical biometer. We proceeded with the same method in the case of the dioptric values offered by the ultrasound biometer. In both biometries we used the SRK-T formula for calculation. For the sake of clarity we illustrated the mathematical results of the deviation in a polynomial graph, which is formed by the average of the resulting calculations.
We also calculated the absolute number of deviations above 1 D and above 2 D from the optimised dioptric power of the IOL for both methods, and incorporated the results into a table.

RESULTS

a) Comparison of medians of measured values by methods OB and UB

The median of the axial length of the eye from the values measured by means of optical biometry (OB) is 23.08 mm, whilst the median of the axial length of the eye measured by means of ultrasound biometry (UB) is 22.93 mm. The difference in these values came to 0.15 mm, which is 150 microns.
For comparison we also calculated the average value of AL OB in the entire population, which is 23.15 mm, and the average value of AL UB, which is 23.00 mm. The difference between the two values is again 0.15 mm, i.e. 150 microns.
The difference between the axial length of the eye measured by OB and UB was evaluated using a pair T-test as statistically significant (p = 0.021). A practically identical difference between the medians as in the entire population of 335 eyes resulted also in the subpopulations of ordinary length of the eye (22.00-24.49 mm) and very short eyes (21.99 mm and less). In the subpopulations of long eyes (24.50-25.99 mm), as well as very long eyes (26.00 mm and more), the difference between the medians is quite different from the value of the entire population. However, this concerns very small populations, so it is necessary to view the differences in the medians of measured AL with a considerable reservation.

b) Comparison of average deviations of dioptric power of IOL measured by OB and UB with retrospectively determined optimised value of dioptric power of IOL

The average deviation of the dioptric power of an implanted IOL from the retrospectively determined optimised value of optic density of the IOL is by 0.40 D lower in optic biometry, and by 0.16 lower in ultrasound biometry. In all subpopulations this average deviation is always lower in eyes measured by UB than in eyes measured by OB. In the subpopulation of very long eyes (26.00 mm and more), the average difference in the deviations is higher than the dioptric interval of production of intraocular lenses 0.5 D, however this concerns a very small population. In the subpopulation of long eyes (24.5 to 25.99 mm), this is the case only for eyes measured by optical biometry. The difference in the deviations of both methods in the entire studied population was evaluated using a pair T-test as statistically significant (p = 0.032).
Averaging of all the deviations of dioptric values of IOL from the optimised values of IOL in both methods of measurement of AL and their illustration in a polynomial graph (Graph 3) provides us with clearly presented information about the similar shape and course of both resulting curves. These however differ in their distance from axis x. Both curves are to be found along the entire course above axis x, thus in values lower than the optimised value of dioptric power of IOL. Both curves are the closest to this axis with ordinary length of the eye (interval 22.0 mm to 25.00 mm), whilst in lengths of the eye outside of this interval the curves diverge from axis x. The curves are closest to one another in the case of short lengths of eyes.

c) Comparison of frequency of deviations above 1.0 D and above 2.0 D obtained by both methods of measurement of AL from the optimised dioptric power of IOL

Graph 1 Difference in medians between OB and UB

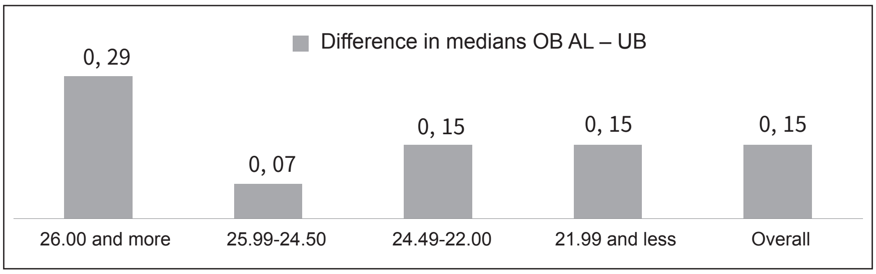


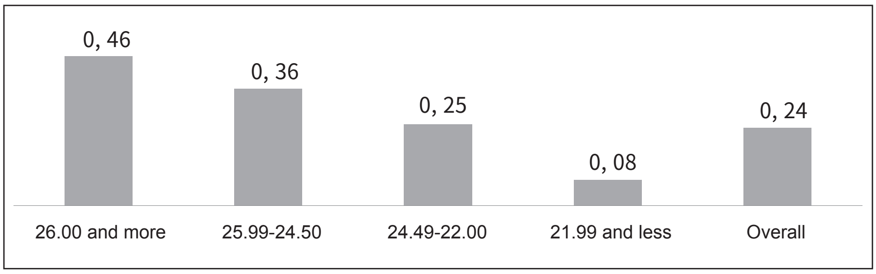
Table 1 Comparison of medians of measured values using OB and UB methods

AL (IOL-Master)	Number of eyes	Median OB AL in mm			Median UB AL in mm			Difference of medians OB AL – UB AL
mm		median	from	to	median	from	to	mm
26.00 and more	5	26.49	26.2	27.2	26.20	26.0	27.68	0.29
25.99 – 24.50	27	24.81	24.7	25.4	24.74	24.1	25.75	0.07
24.49 – 22.00	265	23.09	22.9	24.5	22.94	22.8	23.97	0.15
21.99 and less	38	21.62	19.7	21.5	21.47	19.7	22.80	0.15
Overall	**335**	**23.08**	**22.9**	**27.2**	**22.93**	**22.8**	**27.68**	**0.15**

Table 2 Comparison of average deviations of dioptric power of IOL measured by OB and UB with retrospectively determined optimised value of dioptric power of IOL

AL (IOL-Master)	Number of eyes	Optim IOL 3 months	OB SRK-T		UB SRK-T		Difference of deviations OB v UB
Mm		Average in D	Average in D	Deviation from optim. IOL in D	Average in D IOL	Deviation from optim. in D	in D
26.00 and more	5	13.03	11.59	1.44	12.04	0.99	0.45
25.99 – 24.50	27	17.81	17.21	0.60	17.57	0.24	0.36
24.49 – 22.00	265	21.83	21.47	0.35	21.72	0.11	0.24
21.99 and less	38	25.99	25.53	0.46	25.61	0.38	0.08
Overall	335	21.84	21.44	0.40	21.68	0.16	0.24

Table 3 and Graph 4 clearly imply that a fundamentally larger number of deviations are recorded in the values of SRK-T obtained from measurement of AL using ultrasound biometry as compared to optical biometry (19). From the observed population of deviations above 1.0 D, the number of deviations in the results of SRK-T is slightly above 25% of the total number of eyes in the population! We subjected the numbers of deviations to a special McNemar statistical test, the result of which (0.001) means that the number of deviations between both methods of measurement of AL is statistically significantly biased towards a larger number of deviations of the results obtained using ultrasound biometry.



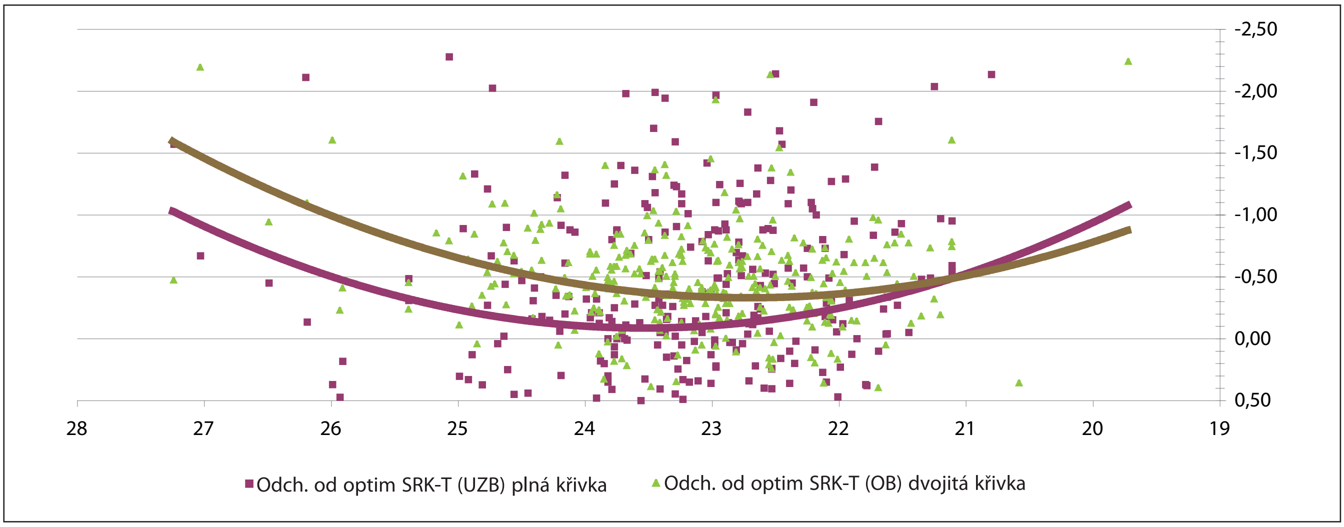
Graph 2 Difference in deviations of OB and UB

DISCUSSION

In the study we initially compared the axial length of eyes measured by optical and contact ultrasound biometry. The determined difference was statistically evaluated as significant. Both methods of measurement of AL show a high correlation. The median axial length of eyes measured by optical biometry was larger in all the observed length intervals than the median AL measured by ultrasound biometry. The overall average deviation of both medians in our population is 150 microns. This deviation has the character of a systematic difference and is linked to the various points of reflection of the optical and ultrasound signal on the retina – see Fig. 3 (5, 9, 26).

In studies conducted by the majority of authors who have also dealt with this issue (7, 8, 9, 24 26), the average value of this systematic difference is within the range of 100 to 150 microns. This number differs slightly in populations of varying sizes (4, 8, 9). In our population we recorded markedly different average heights of differences in long and very long eyes. The finding is most probably linked to a statistical error of the very small number of eyes in our subpopulations and to subjective errors in measurement of AL by ultrasound, rather than to the thickness of the retina. Our result of 150 microns above all confirms the similar precision of our measurement with both appliances as at other ophthalmology workplaces which also deal with the stated issue (1, 2, 7, 8, 12, 13, 14, 15, 23, 26).

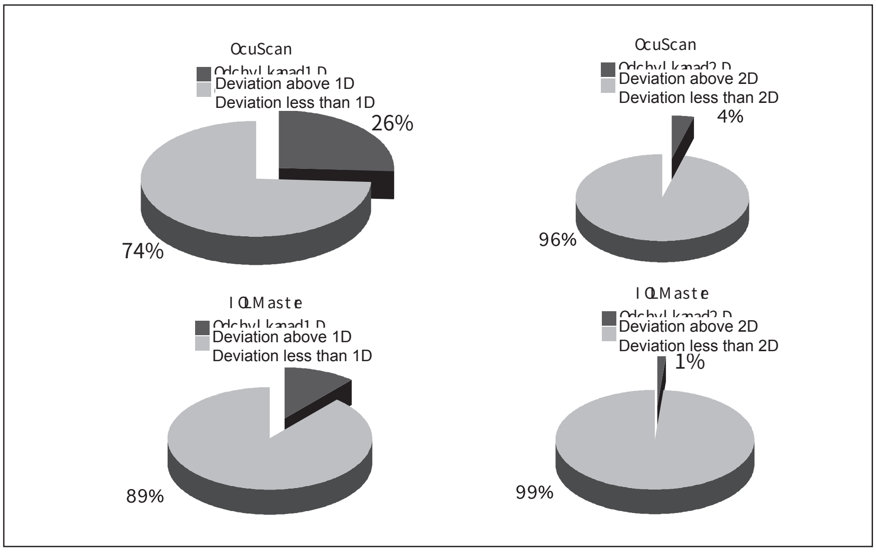
We further assessed the precision of measurement of both biometric methods by means of a comparison of the values of the dioptric power of the lens, which we obtained by entering



Graph 3 Polynomial graph of deviations of optimised dioptric power of IOL and dioptric powers of IOL calculated according to formula SRK-T using both methods of measurement of AL.

Table 3 Comparison of frequency of deviations above 1D and above 2.0 D in the case of OB and UB from the optimised value of dioptric power of IOL

	Deviation above 2D		Deviation above 1D		Total eyes
OcuScan	14 eyes	4.2%	87 eyes	26.1%	335 eyes
IOL-Master	5 eyes	1.4%	38 eyes	11.4%	100%



Graph 4 Comparison of frequency of deviations above 1D and above 2.0 D in the case of OB and UB from the optimised value of dioptric power of IOL

the results of measurement of AL into the formula SRK-T. The results are recorded in Table 2 and in polynomial Graph 3. A comparison was made between both methods of measurement mutually and also with regard to the optimised value of subjective refraction of the eyes. From the results it is evident that the average difference between the optimised subjective refraction and the expected refraction is smaller than 0.5 D in both methods of measurement. This value is the ordinary smallest interval of production of intraocular lens. Upon a comparison of the results of the formula SRK-T of both methods mutually, the average dioptric value of the deviation is 0.24 D. This result, in connection with the evaluation of the course of the curves of both methods created with the help of the polynomial graph represents confirmation that both methods correlate to a large extent, and that the determination of the dioptric power of the implanted IOL was not negatively influenced by the choice of method (4, 6, 8, 9, 10, 19, 24, 25).

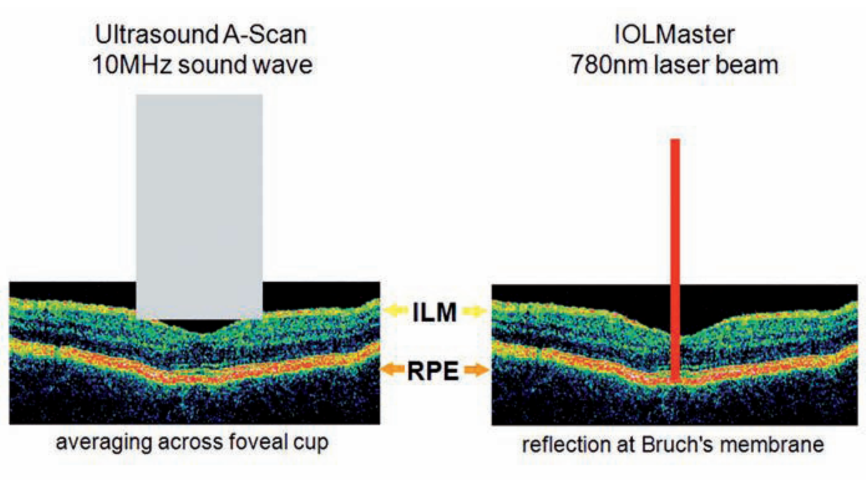


Fig. 3 Various points of reflection of optical and ultrasound signal from structures of retina (from illustrative materials of Zeiss company).

Also of interest is a comparison of the frequency of "large" deviations (above 1.0 D and above 2.0 D) recorded in both methods. From the results it is evident that a statistically significantly higher number of large deviations is demonstrated by measurement of AL by ultrasound. This analysis is very probably a certain expression of the quantity of the number of subjective errors which occur primarily upon examination using UB biometry. Despite the fact that the examination is performed in our centre by a carefully trained and highly dextrous technician, in the population 25% of the measurements we recorded by UB biometry recorded a deviation from the optimised value of dioptric power of the IOL higher than 1.0 D. Subjective factors which influence the precision of measurement by ultrasound probe represent both a qualitatively (height of deviation) and quantitatively (25% of measurements) significant disadvantage of the UB method in comparison with the optical method. We identified analogous conclusions in studies conducted by a range of other authors (4, 7, 8, 9, 16, 17, 18, 19, 24, 25, 27).

On the basis of our own seven-year experience with using of optical biometry, in our case with the IOL-Master appliance, we take the liberty of stating that for us in BOC, this has been the method of choice practically since its introduction. Examination using an IOL-Master is substantially quicker and far more comfortable for the patient and for the examiner (3). Today we conduct an examination of the length of the eye by ultrasound only in the case that the method of optical biometry cannot be used for the above-stated reasons, and exceptionally for re-measurement of the eye in the case of "suspect" values of measurement by OB. In recent years a similar procedure has factually been applied at all workplaces which have both measurement technologies available (16, 17, 18, 22, 27).

CONCLUSION

Cataract surgery poses stringent claims in terms of precision, speed and comfort of the preoperative examination. As a result, in recent years optical biometry has been the gold standard of eye surgery facilities. This is a noncontact method, which is more pleasant for the patient. Training of the examiner is fundamentally shorter than in the case of the ultrasound technique. A fundamental advantage of the optical method is the fact that it measures the axial length of the eye precisely according to the angle of vision. Thanks to the principle of optical technology, subjective factors of measurement which can be observed in ultrasound biometry, and which can have a significantly negative influence on the result of measurement, are eliminated. Their elimination is dependent on the skill and experience of the examiner.

Upon correct measurement by an ultrasound probe, the results of both methods correlate to a large extent and are therefore mutually interchangeable. In the above-mentioned cases optical biometry cannot be used, and as a result it is still essential to have an ultrasound instrument available in surgical centres. Unfortunately, the current relatively low frequency of use of the ultrasound method, in comparison with the time when it was the only possible alternative, increases the probability of an imprecise measurement of AL with all the negative refractive consequences ensuing from this. As a result, today it is all the more necessary to lay stress on maximum precision of performance of ultrasound measurement.

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