Effects of a change in the direction of view to near uncorrected visual acuity following implantation of monofocal intraocular lens

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Abstract. The objective of the present study was to evaluate the effect of the direction of view of the eye on the postoperative near visual acuity of patients with monofocal intraocular lens. A total of 121 eyes in which we performed conventional cataract surgery with implantation of a monofocal lens were included in the study group. The postoperative examination of near visual acuity was performed at two different positions of the eye at a constant distance from the reading table, with the assumption of improving visual acuity when looking perpendicularly to the plane of the floor. The mutual relation of the postoperative parameters central keratometry (K_c), keratometry in the visual axis (K_{VA}) and anterior chamber depth (ACD) for the single axial length ranges was determined using the correlation coefficients. In the case of vertical position of the eye (visual axis of the eye perpendicular to the floor), the uncorrected visual acuity following implantation of the monofocal lens was higher or equal compared to the horizontal position of the eye (visual axis of the eye parallel to the floor). The mean visual acuity at the horizontal position of the eye was 0.508 according to Jaeger's tables ($P<0.001$); at the vertical position, the mean value was 0.555 ($P<0.001$). Within the entire group, a weak association at best was observed between the postoperative parameters (K_c, K_{VA} and ACD) and subsequent near visual acuity. Different dependence was found after categorising the group according to the axial length of the eye. In conclusion, the near visual acuity in eyes with an implanted monofocal lens for emmetropy to distance reached higher values at the vertical vs. horizontal position of the eyes. However, neither of the observed parameters (K_C, K_{VA} or ACD) can be unambiguously determined as decisive for the assumption of the described feature.

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Abbreviations: ACD, anterior chamber depth; AL, axial length of the eye; IOL, intraocular lens; K_C, postoperative keratometry value-centre of the cornea; K_{VA}, postoperative keratometry value-visual axis of the cornea; UDVA, decimal value of uncorrected distance visual acuity; $UNVA_H$, decimal value of uncorrected near visual acuity in horizontal position; $UNVA_V$, decimal value of uncorrected near visual acuity in vertical position

Key words: near visual acuity, cataract surgery, post-cataract refraction, reading plane, monofocal intraocular lenses

Introduction

In the framework of cataract surgery, a comfortable postoperative uncorrected distance visual acuity (UDVA) may be successfully achieved due to the development of modern biometric methods and calculation formulas. However, patients also require to be able to see a normal reading text without further correction, which has led to the development of multifocal or accommodation intraocular lenses (IOLs). The challenge of these models is the number of contraindications, risk of asthenopic problems caused by higher-order aberrations, as well as the additional required payment by the patient.

For pseudophakic eyes, in addition to the optimal UDVA, the optimal uncorrected near visual acuity (UNVA) may also be seen, although a monofocal IOL has been implanted. In a previous study (1) it was proven that optimal near visual acuity may be achieved even without targeted postoperative myopisation in eyes with a short axial length (AL). For 30.33% of eyes with a UNVA of ≥0.6, the AL was ≤23.5 mm, whereas even for a UNVA of 0.8, the AL was up to 22.5 mm. Theoretically, a significant role of the postoperative pseudo-accommodation amplitude in such eyes may be expected, particularly the effect of an axial shift of the IOL causing a reduction of the anterior chamber depth (ACD), which occurs even when the direction of view of the eye is changed. It was proven that a change in the position of the eye affects the ACD, albeit to a lesser extent than predicted (2). The hydrodynamic status in the eye is practically indefinable with regard to several influencing factors. However, the validity of Pascal's law is hypothesised, and due to the hydrostatic pressure under the influence of a small gravitational force, the shift of the IOL causes a slight myopisation that likely confers an increase in near visual acuity.

The subject of the present study was a statistical evaluation of a change in the UNVA depending on the position of the text or a change of the direction of the eye, including an analysis of a mutual correlation of the individual eye parameters.

Table I. Input values and parameters of the study.

A, AL <22.5 mm

Eye no.	AL (mm)	IOL	UDVA	ACD (mm)	K_C (D)	K_{VA} (D)	$UNVA_H$	$UNVA_V$
1	21.16	27.5 SA	0.80	3.90	44.68	44.95	0.40	0.50
2	21.28	26.5 SA	1.00	3.90	43.77	42.65	0.80	0.80
3	21.28	27.0 SA	1.00	4.00	46.05	45.33	0.50	0.60
4	21.43	23.0 SA	1.20	4.10	46.50	46.71	0.60	0.60
5	21.46	30.5 SA	1.00	3.40	42.15	41.68	0.80	0.80
6	21.47	23.0 SA	1.20	4.10	46.50	46.74	0.60	0.60
7	21.54	25.5 SA	1.20	3.80	44.86	45.46	1.00	1.00
8	21.64	24.5 SA	1.20	3.80	46.10	45.77	0.80	0.80
9	21.68	24.0 SA	1.20	3.80	46.10	45.84	0.80	0.80
10	21.75	26.0 SA	1.00	3.80	43.12	44.14	0.40	0.60
11	21.75	25.5 SA	1.00	3.80	42.00	43.00	0.40	0.60
12	21.80	24.5 SA	1.00	4.19	45.57	45.45	0.80	0.80
13	21.80	25.0 SA	1.00	4.19	44.67	45.06	0.80	0.80
14	21.80	27.0 SA	1.20	3.80	47.16	45.55	1.00	1.00
15	21.87	24.0 SA	1.20	3.50	45.20	45.67	0.50	0.50
16	21.87	24.5 SA	1.00	3.70	44.78	44.45	0.50	0.60
17	21.94	24.5 MA	1.00	3.30	45.91	44.76	0.30	0.40
18	21.95	24.0 SA	1.50	3.80	45.81	45.19	0.20	0.30
19	21.95	24.5 SA	1.00	3.50	45.00	44.81	0.40	0.40
20	21.96	24.0 SA	1.20	3.50	45.58	45.54	0.50	0.50
21	21.96	23.5 SA	1.50	3.90	45.64	45.93	0.20	0.30
22	21.99	25.0 SA	1.00	3.50	45.07	44.36	0.40	0.40
23	21.99	24.5 MA	1.00	3.50	45.70	44.47	0.30	0.40
24	22.12	26.5 SA	1.00	4.00	46.06	45.54	0.50	0.60
25	22.13	24.5 SA	1.00	3.50	44.84	44.53	0.50	0.60
26	22.14	22.0 SA	1.20	3.60	46.35	45.79	0.40	0.40
27	22.16	24.0 IQ	1.00	2.00	45.64	45.66	0.60	0.60
28	22.20	22.5 SA	1.20	3.80	45.93	46.25	0.50	0.60
29	22.22	25.0 IQ	1.20	4.20	44.00	44.01	0.30	0.30
30	22.28	22.0 SA	1.20	3.80	46.26	46.48	0.50	0.60
31	22.32	23.5 IQ	1.00	2.00	45.61	44.80	0.50	0.60
32	22.35	22.0 SA	1.00	3.60	45.94	46.52	0.60	0.60
33	22.38	24.5 SA	1.00	3.70	43.94	43.30	0.50	0.50
34	22.40	22.0 SA	1.00	3.70	45.28	45.11	0.60	0.60
35	22.42	24.5 IQ	1.20	3.60	44.27	44.38	0.30	0.30
36	22.46	24.0 SA	1.00	3.70	42.72	42.65	0.50	0.50
37	22.47	23.0 SA	1.20	4.20	44.45	44.80	0.30	0.40

B, AL 22.5-23.5 mm

Eye no.	AL (mm)	IOL	UDVA	ACD (mm)	K_C (D)	K_{VA} (D)	$UNVA_H$	$UNVA_V$
38	22.51	23.0 SA	1.20	4.30	44.46	44.42	0.30	0.40
39	22.56	23.0 SN	1.00	3.27	42.50	45.34	0.50	0.50
40	22.58	23.0 SA	1.20	3.70	46.47	44.55	0.40	0.40
41	22.58	23.0 SA	1.00	3.40	47.90	47.48	0.80	0.80
42	22.64	23.0 SA	1.00	3.97	43.62	43.96	0.40	0.50
43	22.66	23.0 SA	1.00	3.80	46.48	44.41	0.80	0.80
44	22.70	22.0 SA	1.20	3.70	46.50	45.44	0.80	0.80
45	22.73	21.0 SA	1.00	4.20	46.56	46.78	0.60	0.80

Table I. Continued.

B, AL 22.5-23.5 mm

Eye no.	AL (mm)	IOL	UDVA	ACD (mm)	K_C (D)	K_{VA} (D)	$UNVA_H$	$UNVA_V$
46	22.74	26.5 IQ	1.20	3.80	41.24	40.46	0.40	0.50
47	22.80	22.0 SN	1.20	3.28	44.50	44.24	0.50	0.50
48	22.80	21.5 SA	1.20	3.80	45.14	46.19	0.80	0.80
49	22.81	22.5 SA	1.50	3.96	45.15	45.16	0.60	0.60
50	22.81	22.0 SA	1.50	3.80	44.36	44.44	0.60	0.60
51	22.81	21.5 SA	1.50	3.90	43.93	43.74	0.50	0.60
52	22.85	22.0 SA	1.00	3.90	42.15	41.15	0.40	0.50
53	22.87	20.0 SA	1.00	4.20	47.18	46.32	0.60	0.80
54	22.87	22.0 SA	1.20	4.30	42.81	42.44	0.50	0.60
55	22.92	21.5 IQ	1.50	4.00	45.12	44.66	0.60	0.60
56	22.94	22.0 MA	0.80	3.60	44.10	45.59	0.40	0.50
57	22.95	22.0 MA	0.80	3.70	45.60	45.69	0.40	0.50
58	22.96	22.0 SA	1.00	2.20	43.73	43.50	0.50	0.50
59	22.96	22.5 SA	1.00	3.80	45.19	43.50	0.50	0.60
60	22.98	22.0 SA	1.00	3.80	42.37	43.06	0.50	0.60
61	22.99	22.0 SA	1.00	4.00	45.96	45.71	0.50	0.50
62	23.00	21.5 SA	1.00	3.60	43.93	44.73	0.60	0.60
63	23.10	20.5 SA	1.00	3.80	44.65	44.57	0.50	0.50
64	23.10	22.5 MA	1.50	4.10	42.48	43.13	0.40	0.50
65	23.12	24.0 SA	1.50	4.10	40.82	40.93	0.60	0.60
66	23.17	21.5 SA	1.00	4.20	42.78	41.76	0.50	0.50
67	23.24	24.5 IQ	1.20	3.80	40.20	41.07	0.40	0.40
68	23.26	21.0 MA	1.00	4.20	45.66	44.75	0.60	0.60
69	23.29	21.0 MA	1.00	4.20	44.32	45.19	0.60	0.60
70	23.30	23.0 IQ	1.20	3.60	42.09	42.12	0.50	0.60
71	23.31	21.0 SA	1.50	3.80	43.90	43.45	0.50	0.60
72	23.32	23.0 IQ	1.00	3.60	43.09	43.29	0.50	0.60
73	23.35	20.0 MA	1.20	3.60	45.36	45.26	0.60	0.60
74	23.37	20.5 SA	1.20	3.70	43.54	44.35	0.50	0.50
75	23.40	21.5 SA	1.00	3.60	44.26	44.94	0.60	0.60
76	23.40	24.5 SA	1.50	4.10	41.62	42.64	0.60	0.60
77	23.40	23.0 SA	1.20	4.20	41.88	42.71	0.40	0.50
78	23.41	20.0 MA	1.20	3.90	44.45	45.69	0.50	0.60
79	23.41	20.5 MA	1.20	3.80	44.79	45.02	0.50	0.50
80	23.41	21.5 MA	1.20	3.90	43.94	41.59	0.50	0.50
81	23.42	21.5 MA	1.20	3.80	42.43	43.26	0.60	0.80
82	23.42	22.0 MA	1.20	3.90	42.29	43.29	0.40	0.40
83	23.44	20.5 SA	1.20	3.90	44.15	44.36	0.50	0.50
84	23.44	21.0 MA	1.20	3.80	43.44	43.37	0.50	0.50
85	23.48	20.5 SN	1.20	4.30	43.22	44.76	0.50	0.50
86	23.50	20.0 SN	1.20	4.40	44.90	45.30	0.50	0.50
87	23.50	21.5 MA	1.20	3.60	45.65	44.57	0.60	0.60
88	23.50	20.0 SA	1.20	4.00	43.62	43.51	0.30	0.30
89	23.50	20.0 SA	1.50	3.70	43.83	45.61	0.20	0.30

C, AL >23.5 mm

Eye no.	AL (mm)	IOL	UDVA	ACD (mm)	K_C (D)	K_{VA} (D)	$UNVA_H$	$UNVA_V$
90	23.51	21.5 MA	1.20	3.80	41.93	42.99	0.40	0.40

Table I. Continued.

C, AL >23.5 mm

Eye no.	AL (mm)	IOL	UDVA	ACD (mm)	K_C (D)	K_{VA} (D)	$UNVA_H$	$UNVA_V$
91	23.53	19.5 IQ	1.00	3.70	44.56	44.47	0.50	0.50
92	23.54	23.5 SA	1.20	3.70	40.92	41.41	0.60	0.80
93	23.55	21.5 SA	1.00	4.20	43.05	43.81	0.60	0.60
94	23.57	20.0 MA	1.20	3.90	44.22	44.57	0.50	0.50
95	23.58	20.5 SN	1.00	3.96	46.21	44.91	0.50	0.50
96	23.60	21.5 IQ	1.50	4.10	45.90	45.86	0.60	0.60
97	23.61	19.5 MA	1.00	4.10	45.13	45.66	0.20	0.30
98	23.63	18.5 IQ	1.00	3.80	45.43	45.99	0.50	0.50
99	23.66	20.0 MA	1.00	4.20	45.81	46.16	0.20	0.30
100	23.67	19.5 SN	1.00	4.00	43.54	44.85	0.50	0.50
101	23.69	18.5 MA	1.20	4.20	45.96	44.33	0.50	0.60
102	23.73	22.5 SA	1.20	3.80	42.53	42.05	0.60	0.80
103	23.74	21.0 MA	1.20	4.10	43.57	42.96	0.30	0.30
104	23.78	21.0 SA	1.00	4.20	41.24	44.98	0.50	0.60
105	23.81	20.5 MA	1.20	4.10	42.83	44.14	0.30	0.30
106	23.85	20.5 MA	1.20	3.80	43.19	43.56	0.60	0.80
107	23.88	22.5 SA	1.20	4.20	41.28	41.42	0.50	0.50
108	23.90	20.0 SA	1.00	3.90	46.56	45.50	0.50	0.60
109	23.90	20.0 SA	1.00	3.90	45.81	43.06	0.50	0.60
110	23.92	22.5 SA	1.20	4.10	41.04	41.07	0.50	0.50
111	23.97	22.0 SA	1.00	4.00	40.43	40.80	0.50	0.50
112	24.12	21.5 IQ	1.20	3.90	41.40	41.60	0.20	0.30
113	24.13	21.5 IQ	1.20	3.80	41.50	41.97	0.20	0.30
114	24.27	21.5 SA	1.00	3.90	40.68	41.15	0.50	0.50
115	24.35	17.5 MA	1.00	3.90	44.72	44.94	0.50	0.60
116	24.46	17.0 MA	1.50	3.90	44.84	44.91	0.60	0.80
117	24.65	22.0 MA	1.00	4.10	41.66	41.68	0.50	0.50
118	24.75	18.5 IQ	1.50	4.20	42.74	42.50	0.50	0.50
119	24.76	18.5 IQ	1.50	4.40	42.85	42.80	0.50	0.50
120	24.81	15.5 MA	1.20	4.00	44.71	45.81	0.60	0.60
121	24.83	22.0 MA	1.00	4.10	41.26	41.15	0.50	0.50

AL, axial length of eye; IOL, intraocular lens-power and model (SA=SA60AT, MA=MA50BM, IQ=SN60WF IQ); UDVA, decimal value of uncorrected distance visual acuity; ACD, anterior chamber depth; K_C postoperative keratometry value-centre of the cornea; K_{VA}, postoperative keratometry value-visual axis of the cornea; $UNVA_H$, decimal value of uncorrected near visual acuity in the horizontal position; $UNVA_V$, decimal value of uncorrected near visual acuity in the vertical position.

Materials and methods

Study parameters. In total, 121 eyes were evaluated following surgery in 65 patients. Patients who underwent cataract surgery with implantation of a monofocal IOL were included in the study. The patient selection was performed randomly, depending on the time the patients came for the check-up examinations between January and March 2017. The surgery was performed by a single surgeon using an identical technique (phacoemulsification using the initial incision of 2.2 mm), and the relation SRK/T was used to calculate the optical power of the IOL for emmetropy; the evaluation period was at least 1 month post-surgery. The following models of IOL were implanted: MA50BM (58.68%

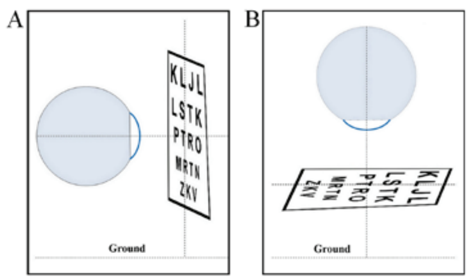

Figure 1. Demonstration of the position of the mutual axes. (A) The viewing axis of the eye is parallel with the ground-$UNVA_H$; (B) the viewing axis of the eye is pointing towards the ground-$UNVA_V$. $UNVA_H$, decimal value of uncorrected near visual acuity in the horizontal position; $UNVA_V$, decimal value of uncorrected near visual acuity in the vertical position.

Table II. Mean parameters of the input group following categorization into the groups.

Parameters	Values of the whole group	Values based on the AL groups		
		<22.5	≤22.5-23.5≥	>23.5
Count (eyes)	121	37	52	32
AL (mm)	22.96±0.85	21.93±0.36	23.09±0.31	23.96±0.43
ACD (mm)	3.83±0.37	3.68±0.47	3.84±0.35	3.68±0.47
K_C (D)	44.19±1.73	45.11±1.21	44.04±1.65	43.36±1.91
K_{VA} (D)	44.21±1.58	44.96±1.17	44.10±1.55	43.53±1.73

Values are presented as mean ± standard deviation. AL, axial length of eye; ACD, anterior chamber depth; K_C, postoperative keratometry value-centre of the cornea; K_{VA}, postoperative keratometry value-visual axis of the cornea.

Table III. Mean values of $UNVA_H$ and $UNVA_V$.

Category	Mean (mm)	SD	t	P-value
All AL				
$UNVA_H$	0.51	0.15	-8.18	<0.001
$UNVA_V$	0.56	0.15		
$AL_{<22.5}$				
$UNVA_H$	0.53	0.20	-4.62	<0.001
$UNVA_V$	0.58	0.18		
$AL_{22.5\text{-}23.5}$				
$UNVA_H$	0.52	0.12	-5.25	<0.001
$UNVA_V$	0.56	0.12		
$AL_{>23.5}$				
$UNVA_H$	0.47	0.13	-4.19	<0.001
$UNVA_V$	0.52	0.16		

AL, axial length of eye (different groups); $UNVA_H$, decimal value of uncorrected near visual acuity in the horizontal position; $UNVA_V$, decimal value of uncorrected near visual acuity in the vertical position; SD, standard deviation.

Table IV. Correlation coefficients for the whole group and different ALs.

AL (mm)	Variables			
	ACD	K_C	K_{VA}	AL
Whole group				
$UNVA_H$	-0.06	0.24	0.18	-0.21
$UNVA_V$	-0.04	0.22	0.17	-0.22
<22.5				
$UNVA_H$	0.06	0.11	0.06	-0.39
$UNVA_V$	0.07	0.06	0.04	-0.45
22.5-23.5				
$UNVA_H$	-0.09	0.45	0.34	-0.21
$UNVA_V$	0.01	0.42	0.33	-0.29
>23.5				
$UNVA_H$	-0.11	0.03	-0.01	0.12
$UNVA_V$	-0.28	0.07	0.02	0.05

AL, axial length of eye; ACD, anterior chamber depth; K_C, postoperative keratometry value-centre of the cornea; K_{VA}, postoperative keratometry value-visual axis of the cornea; $UNVA_H$, decimal value of uncorrected near visual acuity in the horizontal position; $UNVA_V$, decimal value of uncorrected near visual acuity in the vertical position.

of eyes), SA60AT (23.14%), SN60WF (13.22%) and SN6ATx (4.96%). Only the postoperatively emmetropic eyes among the eyes examined were included, with 97.52% of the eyes achieving a vision of 1.0 or better (the remaining 2.48% of the eyes achieved a vision of 0.8, whereas no correction improved the vision). Input data for the study are summarised in Table I.

The evaluated postoperative parameters included the typography values (Anterior Segment Analyser Orbscan II) for optical power in the central part of the cornea (KC), as well as in the visual axis (KVA), anterior chamber depth (ACD; OcuScan biometer) and eye axial length (AL; OcuScan biometer).

To determine the near vision values, each eye was examined separately using the Jäeger table ZEISS at a distance of 40 cm and its perpendicular position relative to the eye viewing axis. First, the value of the least read text was recorded at the horizontal position of the eye ($UNVA_H$, viewing axis of the eye parallel with the floor) and subsequently at the vertical position ($UNVA_V$, viewing axis of the eye perpendicular to the floor). Demonstration of the position of the mutual axes is shown on Fig. 1. The observed parameters were evaluated for the whole group of patients, but also following categorisation of the group into three cohorts according to the AL: The group of short eyes ($AL_{<22.5}$) included eyes up to 22.5 mm, AL 22.5-23.5 mm was identified as the group of normal eyes ($AL_{22.5\text{-}23.5}$) and the cohort of long eyes had an AL >23.5 mm ($AL_{>23.5}$).

Results

Mean parameters of the input group following categorization. The mean age of the group was 71 years. The mean parameter values of the eyes included in the study are presented in Table II.

Mean values of $UNVA_H$ and $UNVA_V$. The paired t-test was used to compare visual acuity at the horizontal and vertical position of the eye for the whole group of patients. The results revealed that, in the case of $UNVA_H$ for the horizontal position of the eye, the values were lower compared with $UNVA_V$ for the vertical position of the eye (mean 0.51 vs. 0.56, respectively; $P<0.001$). A higher or identical $UNVA_V$ value compared with $UNVA_H$ was always achieved in all groups based on the AL. Visual improvement in $UNVA_V$ was observed in 40.2% of the eyes. The lowest mean value for the $UNVA_H$ was recorded in eyes with an AL >23.5 mm. The highest mean value for the $UNVA_V$ was achieved in short eyes (mean 0.58; $P<0.001$). The complete values are summarised in Table III.

Correlation coefficients. Evaluation of the association of the eye parameters for $UNVA_H$ and $UNVA_H$ was performed using correlation coefficients (Table IV). We did not identify a more significant than weak correlation value for the whole group. For the $AL_{<22.5}$ group, we observed a weak negative correlation of the $UNVA_H$ with AL (-0.39), but a moderate negative correlation was observed for AL and $UNVA_V$ (-0.45). In the $AL_{22.5\text{-}23.5}$ group of eyes, the positive correlation of the $UNVA_H$ with K_C (0.45) and K_{VA} (0.34), and of $UNVA_V$ with K_C (0.42) and K_{VA} (0.33), was found to be more significant. For eyes with an AL >23.5 mm there was only a weak negative correlation of $UNVA_V$ with ACD (-0.28).

Discussion

During the postoperative evaluation of patients with implanted monofocal IOL following standard cataract surgery, an unexpectedly high postoperative near visual acuity was observed. To predict this effect, scientific studies have gradually attempted to identify a correlation between eye parameters and this phenomenon. The pupil size and AL were not conclusively found to be correlated with near vision in 84 patients. However, a pupil diameter <2.6 mm along with AL <23 mm demonstrated better near visual acuity (3). Our previous study partially supports these conclusions, as our data revealed a moderate negative correlation of the postoperative UNVA with a decreasing AL (<22.5 mm) (1).

Association of age with UNVA was not proven in the present study, whereas Hayashi *et al* (4) confirmed that patient age is a negative factor affecting the postoperative amplitude of pseudo-accommodation (correlation coefficient of -0.49); however, that study also included patients aged <40 years, while only 3 patients were <60 years of age in the present study. A relevant assessment of the dependence on age would require a higher age range. According to Nanavaty *et al* (5), corneal astigmatism (against the rule) is a significant factor that increases the possibility of pseudo-accommodation up to 10-fold.

A more statistically significant dependence on preoperative ACD, K_C or K_{VA} for the whole group of patients was not observed. When comparing different positions of the read text and the position of the eyes, there was a probability of increasing the value of the near vision for the vertical position ($UNVA_V$). The mean values show an increase of near visual acuity in all patients, particularly those with an AL <22.5 mm. It is believed that, in short eyes with an implanted IOL of higher optical power, the same value of its displacement towards the cornea will cause a higher myopia compared with an IOL that of lower optical power.

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Availability of data and materials

The input data for the study are summarised in Table I and do not include any direct or indirect identifiers. The datasets generated and analysed in the present study are available from the corresponding author on reasonable request.

Authors' contributions

MZ conceived, designed and performed the data analysis of this study. MF and JL coordinated preoperative and postoperative examinations of the eyes and made general revisions. SP performed cataract surgery in all the patients and made general revisions of study. All the authors have read and approved the final version of this manuscript for publication.

Ethics approval and consent to participate

All patients included in the present study provided written informed to participate, and the study protocol conformed to the principles outlined in the Declaration of Helsinki under approval from the ethic committee of JL Clinic FBME CTU in Prague.

Patient consent to publication

All patients consented to disclose their postoperative condition, visual acuity and eye parameters to be published in the present study.

Competing interests

The authors state that there are no conflicts of interest regarding the publication of this article.

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