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Changes of the accommodative amplitude and the anterior chamber depth after implantation of an accommodative intraocular lens

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Abstract *Background:* Modern cataract surgery is interested in recovery of the accommodative power. This investigation aimed at determining pseudophakic accommodation in subjects implanted with the accommodative Human Optics 1 CU intraocular lens after drug-induced ciliary muscle stimulation by measuring the objective refraction and the changes in anterior chamber depth in comparison with a PMMA intraocular lens with rigid haptics. *Methods:* The studied sample involved 30 eyes of 30 patients undergoing cataract surgery due to age-related cataract. Patients were between 50 and 77 years of age (67.71±8.0). No randomization was performed. The 1 CU accommodative intraocular lens and the PMMA intraocular lens were implanted in 15 eyes of patients with an expected visual acuity of at least 0.7. Objective refraction under pilocarpine-stimulated ciliary muscle contraction was determined with a Hartinger coincidence refractometer. The anterior chamber depth was measured with Jäger's Haag–Streit slit-lamp attachment. The accommodative amplitude and the anterior chamber flattening were calculated from the measured values. *Results:* Twelve weeks after surgery the average accommodative amplitude in eyes with a 1 CU intraocular lens calculated from the refractive change under drug-induced stimulation was 0.48± 0.36 D (with a maximum of 1.25 D). The measured change of anterior chamber depth under drug-induced stimulation was 0.3±0.32 mm (at a maximum of 0.9 mm). In the reference group with PMMA lenses, the mean accommodative amplitude derived from the refractive changes under drug-induced stimulation was 0.34±0.27 D (at a maximum of 0.85 D). The measured change in anterior chamber depth under drug-induced stimulation was 0.18±0.09 mm (at a maximum of 0.31 mm). No statistically significant differences were found between the two groups of lenses concerning change in anterior chamber depth and accommodative amplitude. *Conclusions:* This investigations indicate a mean anterior 1 CU shift of only 0.32 mm and a maximum of 0.9 mm. The accommodative amplitudes measured with the Hartinger coincidence refractometer (mean value 0.47 D) correspond to these values. Similar conclusions may be drawn from existing investigative results of the reference group, which are on the same order of magnitude as those of the 1 CU group. Objective accommodation measurements are needed to evaluate commercially available accommodative intraocular lenses in a scientifically satisfactory manner. Objectively measurable parameters include changes of the anterior chamber depth as well as refraction, as determined for instance by coincidence refractometry and streak retinoscopy. Future studies should also consider the IOL properties, astigmatism, and pupillary diameter. This is the only way to identify pseudoaccommodation and a decisive factor for further development of accommodative artificial lenses.

Introduction

In recent years, modern cataract surgery has seen considerable improvement and change. For a long time presbyopia was considered to be an age-related, inevitable decline, but now research is interested in recovery of the accommodative power in conjunction with cataract surgery.

The term "accommodation" pertains to the eye's ability to adjust to an object at any given distance, projecting this object onto the retina where it creates a focused image. The refractive setting of the optical system of the eye is adjusted either by removing the projection plane further from the focal plane, or by changing the focal distance of the imaging system. Thus, on the one hand, the distance between the retina and the lens may change during accommodation. On the other hand, the focal distance may change with the radii of curvature or the refractive indices of the structures involved in imaging. In comparison, pseudoaccommodation is the phenomenon of exact perception of objects at varying distances without ocular focusing. Factors such as narrow pupils or simple myopic astigmatism play a role in this context. The phenomenon of pseudoaccommodation is observed in phakic, pseudophakic, and aphakic eyes [5, 14, 24, 38].

True pseudophakic accommodation is caused by ciliary muscle contraction.

The only currently available method of attaining pseudophakic accommodation involves effecting refractive changes by moving the optical system of the artificial lens along the optical axis, which is made possible by flexible haptics. Examples of accommodation mechanisms based on lens shifting are found among animals [9]. According to Gullstrand's eye model, a 1-mm shift of the artificial lens optics corresponds to a vertex refractive change of approximately 1.3 D [13]. So-called accommodative intraocular lenses are now commercially available from three manufacturers.

True pseudophakic accommodation (excluding pseudoaccommodative phenomena) may be quantified by measuring objective refractive changes as well as changes in anterior chamber depth during accommodation. Ciliary muscle contraction may be effected by near stimulation or by administering appropriate drugs.

This investigation aimed at determining pseudophakic accommodation in subjects implanted with the accommodative Human Optics 1 CU intraocular lens after drug-induced ciliary muscle stimulation by measuring the objective refraction and the changes in anterior chamber depth in comparison with a PMMA intraocular lens with rigid haptics.

Patients and method

The 1 CU study group

The studied sample involved 15 eyes of 15 patients undergoing surgery between May and September 2002 at Rostock University Eye Clinic due to age-related cataract. Patients were between 50 and 77 years of age (67.7±8.0). No randomization was performed. The 1 CU accommodative intraocular lens was implanted only in the eyes of patients with an expected visual acuity of at least 0.7 (retinometer vision). The refractive power of the implanted lenses was between +18.0 D and +24.0 D.

Patients more than 50 years of age and those with vision-impairing retinal or corneal diseases, optic neuropathies, preceding perforating injuries or intraocular surgery, chronic or relapsing uveitis, biomicroscopically detectable zonular defects were excluded, as were those who complied inadequately with subsequent check-ups.

After creation of a 5.0-mm capsulorrhexis and phakoemulsification of the lens via the corneoscleral tunnel, the accommodative artificial lens (Human Optics 1 CU) was implanted into the capsular bag. The corneoscleral incision size was 3 mm.

The reference group

The reference group included 15 eyes of 15 patients undergoing surgery between March and October 2002 at Rostock University Eye Clinic due to age-related cataract. Patients were aged between 64 and 89 years (78.1±7.3).

In this case, the inclusion and exclusion criteria were the same as those for the 1 CU group. The patients in the reference group, after phakoemulsification of the lens via a corneoscleral tunnel, received a PMMA intraocular lens (Bausch & Lomb 75 ST6) that was implanted into the capsular bag. The corneoscleral incision size was 6 mm. The refractive power of the implanted lenses was between +16.0 D and +26.0 D.

Postoperative investigations

The patients of the 1 CU group returned for check-ups at 6 and 12 weeks postoperatively, while the reference group was reexamined only once, 12 weeks after surgery.

At first, the objective refractometry was performed using an autorefractometer (Canon RK3). Distance visual acuity was determined using a standard Snellen projector system (Schwind Optostar IR-2000, Germany). Near reading vision was determined using Birkhäuser reading charts (Scalae Typographicae Birkhaeuseri, Birkhäuser Verlag) and an illumination of 70 Cd/m^2. After determination of the best-corrected and the uncorrected far vision, near vision was determined without additional near correction and with addition of +1.0, +2.0, +3.0, and +3.5 sph respectively. Visual acuity was expressed in decimal values and logMAR units. A slit-lamp examination was performed. Subsequently, two drops of cyclopentolate 1% were administered, one 5 min after the other. Thirty minutes later, objective refraction and anterior chamber depth were measured. On

the next day each patient received two drops of pilocarpine 2%, again at a 5-min interval. Approximately 30 min later, both the objective refraction and the anterior chamber depth were determined once more. The measurements obtained after pilocarpine administration were supposed to reveal a pupillary diameter between 2.0 and 2.5 mm. However, none of the patients attained this pupillary diameter during the 30-min waiting time. The waiting time was extended to a maximum of 45 min if after 30 min the pupil was still wider than 2.5 mm.

Objective refraction was determined with a Hartinger coincidence refractometer, which is based on Scheiner's principle of the coincidence of certain patterns of lines on the retina; the primary issue, therefore, is not the focusing on a test mark, but merely this coincidence of a pattern of lines. At a pupillary diameter of >2 mm, measurements performed with a Hartinger coincidence refractometer could be obtained in a measuring range between +15.5 and −28.5 D. In each case, three of the measuring results were averaged to yield a mean value.

The anterior chamber depth was measured with Jäger's Haag–Streit slit-lamp attachment. In this case, doubling of the image is effected by shifting two glass plates in a plane-parallel configuration, so that equal parts protrude from above and from below into the path of the rays. The image-splitting eyepiece uses a prism effect to guide one half of these individual images into the upper half of the field of vision and the rest into the lower half. The measuring points lying in the optical split field are then brought into coincidence. A better depth of field of the slit image is attained by using a slit diaphragm, which makes it possible to select a wider slit illumination. The corneal epithelium and the anterior surface of the lens were designated as measuring points. Another slit-lamp attachment was used to measure the corneal thickness, which was then subtracted from the measured value. In each case, three measurements were obtained and averaged to yield a mean value. The accommodative amplitude and the anterior chamber flattening were calculated from the measured values.

Statistical analysis of the results was performed using MatLab 6.5 (The MatWorks, USA). Data are presented as mean±standard deviation. Differences between data were determined by the Wilcoxon rank sum test and p values less than 0.05 were considered statistically significant.

Results

In all cases, both the accommodative and the PMMA intraocular lenses were implanted into the capsular bags

Table 1 Results 6 weeks after implantation of an accommodative IOL (Human Optics 1 CU). *VF preOP* preoperative, best corrected far vision; *VF post sc* uncorrected postoperative far vision; *VF post cc* best-corrected postoperative far vision; *Refraction* spherical equivalent of the optimum postoperative distance correction in diopters; *VN post sc* postoperative near vision with distance correction; *VN post cc* best-corrected near vision in 35 cm; *Near addition* optimum near addition in diopters; *Accommodative amplitude* accommodative amplitude after drug-induced stimulation in diopters; *ACD change* change of the anterior chamber depth; *MW* mean value; *SD* standard deviation

	Age (years)	VF preOP (dec/logMAR)	VF post sc (dec/logMAR)	VF post cc (dec/logMAR)	Refraction	VNpost sc (dec/logMAR)	VNpost cc (dec/logMAR)	Near addition	Accommodative amplitude	ACD change
1	74	0.4/0.4	0.8/0.1	1.25/−0,1	−1	0.4/0.4	1.25/−0,1	2.5	0.75	0.56
2	71	0.2/0.7	0.5/0.3	1/0	0.5	0.2/0.7	1/0	3	0.5	0.1
3	58	0.5/0.3	0.9/0.05	1/0	−0.5	0.3/0.53	1/0	3	0.5	0.13
4	72	0.3/0.53	0.8/0.1	0.8/0.1	0	0.1/1.0	0.7/0.16	3.5	0	0.03
5	66	0.5/0,3	0.8/0.1	1/0	−0.75	0.3/0.53	1/0	3	0.25	0.2
6	75	0.4/0.4	0.4/0.4	0.8/0.1	−0.5	0.2/0.7	1/0	3	0.5	0.05
7	69	0.5/0.3	1/0	1/0	−0.5	0.2/0.7	0.8/0.1	3.5	0	0.08
8	55	0.7/0.16	1/0	1.25/−0,1	−0.25	0.3/0.53	0.8/0.1	3.5	1	0.9
9	66	0.6/0.22	0.8/0.1	0.9/0.05	−0.25	0.2/0.7	1/0	3	0.25	0.05
10	66	0.6/0.22	0.8/0.1	1.25/−0,1	−0.5	0.4/0.4	1.6/−0.2	2	0.25	0.12
11	71	0.7/0.16	0.7/0.16	0.9/0.05	−0.75	0.5/0.3	1/0	2	0.75	0.9
12	72	0.5/0.3	0.9/0.05	0.9/0.05	−1	0.4/0.4	1/0	2	1.25	0.7
13	72	0.4/0.4	0.7/0.16	1.25/−0,1	−0.75	0.3/0.53	1/0	3	0.25	0.1
14	77	0.4/0.3	0.9/0.05	1.25/−0,1	−0.5	0.4/0.4	1.25/−0.1	2	0.75	0.5
15	76	0.3/0.53	0.9/0.05	1/0	−0.5	0.3/0.53	1/0	3	0.25	0.1
MW	69.3	0.48/0.35	0.79/0.11	1.04/−0.01	−0.48	0.3/0.56	1.02/0	2.8	0.48	0.30
SD	6.28	0.15/0.15	0.17/0.10	0.17/0.07	0.38	0.11/0.17	0.19/0.01	0.56	0.36	0.32

without any complications. Recovery, too, was normal for all patients. Eccentricities or deformations, especially in the accommodative intraocular lenses, were not observed. At 12 weeks postoperatively, one patient in the 1 CU group and two patients in the reference group revealed a minor regenerative secondary cataract without objectifiable vision impairment (patient 5 in the 1 CU group and patients 4 and 7 in the reference group).

The Human Optics 1 CU group

After 6 weeks, the best-corrected far vision was −0.01 logMAR (1.04±0.17 in decimal values) at a remaining refraction of −1.0 to +0.5 D (−0.48±0.38). Near vision without additional near correction was 0.56 logMAR (0.3± 0.11 in decimal values); the value with optimum near correction was 0 logMAR (1.02±0.19 in decimal values). An average near correction of +2.8±0.56 D was obtained subjectively.

The average accommodative amplitude calculated from the refractive change under drug-induced stimulation was 0.48±0.36 D (with a maximum of 1.25 D). The measured change of anterior chamber depth under drug-induced stimulation was 0.3±0.32 mm (at a maximum of 0.9 mm).

The values 12 weeks postoperatively largely corresponded with those of the 6-week check-up. The parameters of the individual patients are shown in Tables 1 and 2.

The reference group

In the reference group, the best-corrected far visual acuity 12 weeks postoperatively was also 0.01 logMAR (0.99± 0.15 in decimal values) at a remaining refraction of −0.75 to +0.75 D (−0.12±0.49). Near vision without additional near correction was 0.44 logMAR (0.39±0.12 in decimal values); while with optimum near correction it was 0.03 logMAR (0.95±0.15 in decimal values). Subjectively, an average near correction of +2.67±0.56 D was obtained.

The mean accommodative amplitude derived from the refractive changes under drug-induced stimulation was 0.34±0.27 D (at a maximum of 0.85 D). The measured change of anterior chamber depth under drug-induced stimulation was 0.18±0.09 mm (at a maximum of 0.31 mm).

The parameters of the individual patients are listed in Table 3. Using Wilcoxon rank sum test the medians in refraction power of the two IOL groups are not significantly different (p=0.83). No statistically significant differences have been found between the 1-CU and the control group concerning the change in anterior chamber depth (p=0.07) and accommodative amplitude (p=0.17) under pharmacological stimulation. There has not been found any correlation between the refraction power of the used 1 CU IOLs and their accommodative effect, based on the of a linear correlation (R^2=0.005, linear model).

Table 2 Results 12 weeks after implantation of an accommodative IOL (Human Optics 1 CU). For explanation of abbreviations see Table 1

	Age (years)	VF preOP (dec/logMAR)	VF post sc (dec/logMAR)	VF post cc (dec/logMAR)	Refraction	VN post sc (dec/logMAR)	VN post cc (dec/logMAR)	Near addition	Accommodative amplitude	ACD change
1	74	0.4/0.4	0.8/0.1	1.25/−0.1	−1	0.4/0.4	1.25/−0.1	2.5	0.75	0.7
2	71	0.2/0.7	0.5/0.3	0.9/0.05	0.5	0.2/0.7	0.9/0.05	3	0.75	0.4
3	58	0.5/0.3	0.9/0.05	1/0	−0.5	0.3/0.53	1/0	3	0.5	0.13
4	72	0.3/0.53	0.9/0.05	1/0	0	0.1/1.0	1/0	3.5	0	0.03
5	66	0.5/0.3	1.25/−0.1	1.25/−0.1	−0.75	0.3/0.53	1.25/−0.1	3	0.5	0.2
6	75	0.4/0.4	0.5/0.3	0.7/0.16	−0.5	0.2/0.7	0.7/0.16	3	0.38	0.1
7	69	0.5/0.3	1/0	1/0	−0.5	0.2/0.7	0.8/0.1	3.5	0	0.08
8	55	0.7/0.16	1/0	1.25/−0.1	−0.25	0.3/0.53	0.8/0.1	2.5	0.75	0.7
9	66	0.6/0.22	0.8/0.1	0.9/0.05	−0.25	0.2/0.7	0.9/0.05	3	0.5	0.25
10	66	0.6/0.22	0.8/0.1	1.25/−0.1	−0.5	0.4/0.4	1.6/−0.2	2	0.25	0.12
11	71	0.7/0.16	0.7/0.16	0.9/0.05	−0.75	0.5/0.3	1/0	2	0.75	0.7
12	72	0.5/0.3	0.9/0.05	0.9/0.05	−1	0.4/0.4	1/0	2	1	0.7
13	72	0.4/0.4	0.6/0.22	1.25/−0.1	−0.75	0.3/0.53	1/0	3	0.25	0.1
14	77	0.6/0.22	0.9/0.05	1.25/−0.1	−0.5	0.4/0.4	1.25/−0.1	2	0.75	0.55
15	76	0.3/0.53	0.9/0.05	1/0	−0.5	0.3/0.53	1/0	3	0.25	0.1
MW	69.3	0.48/0.35	0.83/0.1	1.05/−0.02	−0.48	0.3/0.56	1.02/−0.04	2.73	0.47	0.32
SD	6.28	0.15/0.15	0.2/0.11	0.18/0.08	0.38	0.11/0.18	0.21/0.08	0.53	0.30	0.27

Table 3 Results at 12 weeks after implantation of a PMMA posterior chamber lens (Bausch & Lomb 75 ST 6). For explanation of abbreviations see Table 1

	Age (years)	VF preOP Dec/logMAR	VF post sc dec/logMAR	VF post cc dec/logMAR	Refraction	VN post sc dec/logMAR	VN post cc dec/logMAR	Near addition	Accommodative amplitude	ACD change
1	84	0.2/0.7	0.7/0.16	0.9/0.05	−0.5	0.6/0.22	0.9/0.05	2	0.85	0.31
2	73	0.5/0.3	0.9/0.05	1.25/−0.1	0.5	0.4/0.4	1.25/−0.1	2.5	0.5	0.28
3	87	0.5/0.3	0.8/0.1	0.8/0.1	0	0.2/0.7	0.8/0.1	3	0.25	0.15
4	87	0.6/0.22	0.7/0.16	1/0	−0.75	0.3/0.53	1/0	3	0.25	0.3
5	64	0.4/0.4	1.25/−0.1	1.25/−0.1	0	0.4/0.4	1.25/−0.1	3	0	0.1
6	74	0.3/0.53	0.8/0.1	1/0	−0.5	0.5/0.3	1/0	2.5	0.25	0.1
7	67	0.4/0.4	1/0	1/0	0	0.5/0.3	1/0	2.5	0.2	0.11
8	77	0.7/0.16	0.7/0.16	1/0	0.5	0.3/0.53	0.9/0.05	3	0	0.06
9	83	0.5/0.3	0.8/0.1	0.9/0.05	−0.5	0.4/0.4	0.8/0.1	2.5	0.5	0.2
10	75	0.3/0.53	1/0	1.25/−0.1	0.25	0.5/0.3	1/0	2.5	0.5	0.23
11	77	0.6/0.22	0.7/0.16	0.9/0.05	−0.75	0.4/0.4	0.9/0.05	2.5	0.5	0.2
12	83	0.5/0.3	0.6/0.22	0.8/0.1	0.75	0.2/0.7	0.8/0.1	3	0.25	0.15
13	78	0.6/0.22	0.8/0.1	1/0	−0.75	0.5/0.3	0.8/0.1	2	0.85	0.3
14	74	0.3/0.53	1/0	1/0	0	0.4/0.4	1/0	3	0	0.06
15	89	0.2/0.7	0.8/0.1	0.8/0.1	0	0.2/0.7	0.8/0.1	3	0.25	0.13
MW	78.13	0.44/0.39	0.84/0.09	0.99/0.01	−0.12	0.39/0.44	0.95/0.03	2.67	0.34	0.18
SD	7.34	0.15/0.17	0.17/0.08	0.15/0.06	0.49	0.12/0.16	0.15/0.07	0.35	0.27	0.09

Discussion

Currently available surgical techniques of presbyopia treatment are either of questionable value, as are the so-called sclera-expanding surgical techniques [4, 23], or they are still facing unsolved problems, like other attempts at presbyopia treatment by photorefractive keratectomy [39], eccentric LASIK [3], or implantation of corneal rings [16]. None of these approaches has been able to attain actual accommodation; at best, multifocal intraocular lenses [1, 10, 27, 36] allow improved uncorrected near vision to the detriment of contrast vision [36], which limits their broad use in daily clinical practice even in the elderly.

All attempts at developing accommodative artificial lenses rely on the fact that the ciliary muscle, even at advanced age, is still able to contract. This was confirmed by various studies involving impedance cyclography [37] and ultrasound biomicroscopy [2, 33–35]. Thus, presbyopia should be expected to largely result from increasing loss of lens elasticity due to sclerogenesis [40]. This suggests that it ought to be useful to utilize the remaining contractive power of the ciliary muscle even in human beings of advanced age.

The ideal accommodative artificial lens should completely fill the capsular bag and exhibit the same optical and biomechanical properties as those of natural lenses in young eyes. This concept of microsurgical recovery of the accommodative power involves removal of the lens substance through a narrow opening and refilling of the capsular bag with flexible materials, the so-called phakoersatz. For several years, various groups have made renewed attempts to develop such an artificial lens [11, 17, 25, 26, 29, 31]. Flexible silicone polymers and hydrogels are being tested as potentially suitable materials for capsular bag filling. Surgical techniques are being optimized in animal experiments, and investigations regarding the biocompatibility of the used materials are being performed. The concept of injectable lenses appears to be the most promising option in terms of recovery of the accommodative power in conjunction with cataract surgery. Even though initial surgical results involving primate eyes yielded promising results, with accommodative amplitudes of up to 8 D [11, 26], this method has, as yet, been limited to animal experiments.

Other efforts are relying on mechanical concepts based on the assumption that the continued functional ability of the ciliary muscle and of the zonular fibers allows movement of artificial lenses with flexible haptics along the optical axis inside the intact capsular bag. Such acrylic artificial lenses are commercially available today; the list includes the BioComFold 43A (Morcher), the AT-45 Crystalens (C&C Vision) and the 1 CU (Human Optics). According to Holladay, an accommodative amplitude of 2.9 D, which is equivalent to reading ability at a distance of

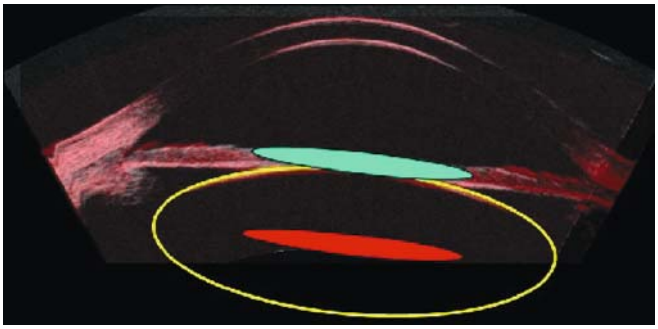

Fig. 1 Diagram showing the inevitable positional change of accommodative artificial lenses inside the capsular bag of the human eye (VHF Ultrasound Arcscan Systems Artemis 2; human eye, 36 years of age). To attain a refractive power change of 2.9 D, a 20-D artificial lens would have to undergo a 2.2-mm anterior shift. The *red* artificial lens schematically indicates the normal position inside the capsular bag. At a shift of 2.2 mm, it would assume the position of the *green* artificial lens, ending up in front of the pupillary plane.

35 cm, would necessitate a forward displacement of 2.2 mm inside the eye of an artificial lens with a refractive power of 20 D [13]. This indicates the limits of such mechanical concepts of presbyopia, since such a shift would cause a displacement of the iris diaphragm—which, in turn, would considerably impair the control of physiological processes in the anterior portion of the eye (Fig. 1).

The Human Optics 1 CU investigated in this study, according to the technical data supplied by the manufacturer, may shift up to 1 mm inside the eye, corresponding to an eyeglass correction change of 1.3 D (Fig. 2). In fact, the investigations discussed in this context indicate a mean anterior 1 CU shift of only 0.32 mm and a maximum of 0.9 mm. The accommodative amplitudes measured with the Hartinger coincidence refractometer (mean value 0.47 D) correspond to these values. Findl et al. arrived at the same results when investigating the mean anterior displacement of accommodative intraocular lenses (Morcher BioComFold and Human Optics 1 CU) by partial coherence interferometry. Based on these results they calculated the resulting accommodative amplitudes. The maximum accommodative amplitude attained by the two patient populations was 1 D (mean value 0.5 D). Thus, these results were very similar to those shown by reference groups implanted with conventional intraocular lenses [6–8]. Similar conclusions may be drawn from the results in the reference group, which are at least on the same order of magnitude as those of the 1 CU group. The variable forward shift of capsular bag-supported PMMA lenses and foldable lenses after pilocarpine administration has been confirmed by other authors [21].

Kammann, too, who investigated patients with accommodative intraocular lenses (C&C Vision AT 45), found unsatisfactory results, since all patients required additional correction for near tasks [15]. Our own investigations confirmed that all patients, after being implanted with a 1 CU intraocular lens, required additional near correction of 2.8 D on average, with a minimum of 2 D.

Küchle et al. [19] and Langenbucher et al. [20], when examining patients with accommodative intraocular lenses (Human Optics 1 CU), found mean accommodative amplitudes of 1.2 D and a greater change in anterior chamber depth than in the reference group. Küchle et al. and Langenbucher et al. measured the anterior chamber depth with an IOL Master, which, however, precludes measurement of pseudophakic eyes [18]. In conjunction with the present investigations, a Haag–Streit slit-lamp attachment according to Jäger was used to perform anterior chamber depth measurements. Compared to automated measurements with an IOL Master, this has the advantage that the position of the anterior lens surface under optical control, despite differences in reflectivity of the artificial lens, may be precisely determined in relation to the natural lens. However, even the accommodative amplitudes attained after implantation of a Human Optics 1 CU, as determined by Küchle et al. and Langenbucher et al., can only reduce but not eliminate the dependency on eyeglasses.

Objective accommodation measurements are needed to evaluate commercially available accommodative intraocular lenses in a scientifically satisfactory manner. Available methods, especially for measuring near vision, tend to depend on subjective patient information and a variety of influences that are difficult to objectify, such as the type of eyeglass correction, illumination, distance, and the type of reading test. Objectively measurable parameters include

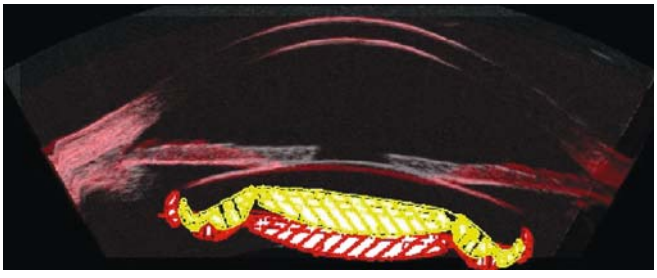

Fig. 2 An accommodative intraocular lens (Human Optics 1 CU according to Hanna) and a schematic representation of its positional change inside the capsular bag (*red* lens). In view of the technical conditions, this lens might possibly undergo a maximum shift of 1 mm at 30° haptic angulation (*yellow* lens). This corresponds to a vertex refractive change of 1.3 D.

changes of the anterior chamber depth (which, however, should be obtained by suitable methods, such as those published by Findl et al. [6–8]) as well as objective measurements of refraction, for instance by coincidence refractometry according to Scheiner's principle (Hartinger coincidence refractometer), and streak retinoscopy. Future studies regarding accommodative lenses should also consider the IOL properties, astigmatism, and pupillary diameter. This is the only way to identify pseudoaccommodation. Although possibly of secondary importance to the patient, it is a decisive factor for further development of accommodative artificial lenses.

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