

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D.)

# **EXAMINATION OF ACCOMMODATION IN PSEUDOPHAKIC EYES**

by

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## **Introduction and literature review**

The essential function of human eye is to ensure sharp sight for far and for near objects. The process when the refractive status of the eye is changing called accommodation. During accommodation the eye will capable for sharp sight of near objects. The crystalline lens changes with age and loses its capacity for focusing to near objects. The amplitude of accommodation continuously decreasing and the near visual acuity is weakening without glass correction, so the eye became presbyopic.

In the course of cataract surgery the intraocular lens implanted to the place of the cataractous lens is monofocal lens without any accommodation capacity. After the procedure the far visual acuity is excellent without glass correction, but the near visual acuity uncommonly satisfying, so the patient need reading-glasses. So, the optical rehabilitation is only partially after a large number performed and expensive surgical procedure with standard intraocular lens. The largest challenge of today's ophthalmology is to substitute or restore accommodation after cataract surgery. There are a lot of possibility to solve this problem partially, but successful and complete restore of accommodation is not solved today.

Certain patients with monofocal intraocular lenses can achieve good visual acuity for distance and for near objects with distance correction. This phenomenon is previously known as apparent accommodation. There are two mechanisms in the background of apparent accommodation. The first is pseudophakic pseudoaccommodation, which is independent of contraction of the ciliary muscle and correlated with static optical features of eye like depth of focus, pupil diameter, higher degree of corneal astigmatism and motivation of the patients. During pseudoaccommodation the anatomical position of the intraocular lens so the anterior chamber depth (ACD) is not changing. During the other possible mechanism called pseudophakic accommodation, the monofocal intraocular lens is moving forward along the optical axis of the eye as a consequence of contraction of the ciliary muscle, and the refractive status of the eye is changing dynamically. In parallel with this process the distance between the cornea and the intraocular lens is decreasing, so the anterior chamber depth is decreasing. Thornton was the first to prove and represent the movement of certain intraocular lens along the axis of the eye during ciliary muscle activity with real-time A-scan ultrasonography in 1986. The quantity of the ACD shift is dependent on the fixating property

of the intraocular lens in the capsular bag, the characteristic of the haptic and the position of the haptic compare to the ciliary muscle. The different degrees of these factors explaining the different amplitude of accommodation with different intraocular lenses.

To differentiate pseudophakic accommodation from pseudophakic pseudoaccommodation is important to understand and to measure the optic action of intraocular lenses and can help to develop new types of multifocal or accommodating intraocular lenses.

So there can be a change in anterior chamber depth during changing of amplitude of accommodation. We can measure the amplitude of accommodation in pseudophakic eyes with different methods arranged in groups by Langenbucher. The most accurate methods to measure changes in the anterior chamber depth are static objective methods. We can use different devices using different physical basics to measure ACD: standard A-scan opththalmological ultrasound, ultrasound biomicroscopy, Scheimpflug imaging devices with better resolution, anterior segment optical coherence tomography and devices using partial coherence interferometry.

Measuring ACD is important to observe amplitude of accommodation in pseudophakic eyes and planning of intraocular diopter with new biometric formulas and accurate planning of gain-grounding phakic intraocular lenses.

In the case of any new device it is important to observe quality of comparison and identity of measured values with standard, widely used methods. It is essential to have good reproducibility, repeatability and high reliability of new methods. Besides new devices have to be a good correlations compared to standard and widely accepted methods.

## **Purpose**

We have the following purposes in our scientific works:

- I. To observe pseudophakic accommodation and pseudoaccommodation after cataract surgery in the case of two, different intraocular lenses with three different methods.
- II. To compare ACD with a new diagnostic device using Scheimpflug imaging (Pentacam®) and standard, contact ultrasonic methods in phakic and pseudophakic eyes.
- III. To observe anterior chamber depth measurement with a newly developed optical device, the anterior segment optical coherence tomograph (Visante® OCT) and study its repeatability, reproducibility and reliability compared to immersion ultrasonic methods in phakic eyes.

## **Patients and methods**

We had performed prospective, comparative studies at the Department of Ophthalmology in University of Debrecen. The study protocols were reviewed and approved by the Ethical Committee of Human Experiments of the Medical and Health Science Center, University of Debrecen, Hungary, in accordance with national laws, and were properly carried out in compliance with the University's Guidelines for Human Experimentation.

### *Ophthalmological devices used in our studies:*

*Ultrasonic devices* used in our studies (Ultrascan Imaging System, Alcon Laboratories, Forth Worth, TX, USA and Tomey AL-2000, Tomey, Erlangen, Germany) work with 10 Mhz acoustic wave. At the same time these are capable of measuring anterior chamber depth and axial length with contact method. Besides ultrasonic devices are suitable for measurements with non-contact immersion method, when there is a water bath between the ultrasound tip

and the top of the cornea. Avoiding direct corneal contact is important for eliminating damage of the cornea, preventing infections, and for measuring anterior chamber depth without shortening the axial length due to impressing of the corneal surface. The ultrasonic device defines anterior chamber depth as a distance between anterior corneal and anterior lens surface. Axial resolution of 10 Mhz ultrasound is 200-300  $\mu\text{m}$ .

The *ACMaster*<sup>®</sup> (Carl Zeiss Meditec, Jena, Germany) measures by optical method with 850 nm light, using the physical principle of partial coherence interferometry (PCI). The device can measure corneal thickness, anatomical depth of the anterior chamber and lens thickness like ultrasonic A-scan, using non-contact technique, with an axial resolution of 1  $\mu\text{m}$ . The built-in fixation point of the device is movable in a wide scale, so we can produce physiologically-like accommodative force. Other advantages of PCI technique is that the observed eye is to fixate so the device measures on the optical axis of the eye.

The *Pentacam*<sup>®</sup> (Oculus, Lynnwood, WA) uses 475 nm monochromatic blue light (LED) to produce 3D pictures from the anterior segment of the eye with a rotating camera using Scheimpflug imaging with non-contact technique. We can measure corneal thickness on the entire cornea, anterior chamber depth, topography of the anterior and posterior surface of the cornea and densitometry from the crystalline lens. The axial resolution is 18  $\mu\text{m}$ . *Pentacam*<sup>®</sup> defines anterior chamber depth as a distance between the anterior corneal surface and the anterior lens surface.

The *Visante*<sup>®</sup> *anterior segment optical coherence tomograph* (*Visante*<sup>®</sup> OCT, Carl Zeiss Meditec, Jena, Germany) is an optical, non-contact device using 1310 nm infrared light to measure. It works with low coherence interferometry method, the axial resolution of the device is 18  $\mu\text{m}$ . The device can measure corneal pachymetry, parameters of the anterior chamber and thickness of the lens under different accommodation conditions. All measurements are carried out in the axis of the eye with a fixation point in a movable scale of diopter. *Visante OCT*<sup>®</sup> measures the internal anterior chamber depth, so we have to add central corneal thickness to this data to get anatomical anterior chamber depth.

*Methods used in our studies:*

### **I. Measurements of accommodation with three methods in pseudophakic eyes.**

51 pseudophakic eyes of 44 patients (age:  $72.02 \pm 8.53$  years, range: 54-84 year) were studied prospectively. Exclusion criteria were more than 1.0 D of corneal astigmatism or any eye pathology affecting complete visual acuity. Standard phacoemulsifications were carried out after clear corneal incision. One of two different types of monofocal intraocular lenses were implanted in-the-bag. The one-piece Acrysof® SA60AT (Alcon Laboratories) has open loop design (group 1: N=21) without haptic angulation, the three-piece Acrysof® MA60AC (Alcon Laboratories) has haptic angulation of 10 degrees (group 2: N=30).

After a mean of  $13.85 \pm 7.35$  months of cataract operations (group 1:  $7.05 \pm 4.71$  months, group 2:  $17.01 \pm 6.44$  months) the amplitude of accommodation was observed with three methods masked to the results of other methods. The chronological order of the examinations was the following: 1. subjective defocusing technique 2. objective measurement of the anterior chamber depth with partial coherence interferometry under physiological conditions 3. measuring anterior chamber depth during near fixating and after blocking the ciliary muscle pharmacologically, so in maximal ciliary relaxation.

#### *Method 1: Subjective defocusing technique.*

Firstly, we observed the total amplitude of accommodation with defocusing technique. The patients were asked to look at the illuminated, distant visual acuity chart number of the 20/20 line of Snellen equivalent with the observed eye at a distance of 5 meters. With distance correction, minus diopter (D) lenses were added in front of the observed eye in 0.25 D steps. The patients reported when the 20/20 line could no longer be held in sharp focus. The maximum minus lens power added over the distance correction with which the patients can see the number in 20/20 line was recorded as the amplitude of accommodation.

*Method 2: Measuring the anterior chamber depth with partial coherence interferometry.*

The ACD was measured with ACMaster® (Carl Zeiss Meditec) with built-in, movable target for physiological near and distance fixation. All of the patients were seated and were forced to fixate to the target at near and at distance too. The device measures the fixating eye so avoiding interference from convergence movement. A mean of five measurements were recorded with distance correction followed by minus 3.0 D added to distance correction for near fixating. The ACD shift was calculated subtracting of the two mean values.

*Method 3: ACD measuring in near fixation followed by pharmacologically induced maximal ciliary muscle relaxation.*

The anterior chamber depth (ACD) was measured during fixation with the contralateral eye at 30 cm and after instillation of 1 % cyclopentolate hydrochloride, administered 3 times at 15 minutes intervals. All patients were seated, with their heads and their eyes level vertical during the measurements to ensure that intraocular lens movements were only produced by ciliary muscle activity. ACD measurements were performed by contact A-scan (Ultrascan Imaging System). The average of 10-10 measurements was presented as the ACD value. ACD shifts were calculated by subtracting ACD under cyclopentolate from ACD during near fixation, corresponding to maximal ciliary relaxation and physiological ciliary contraction.

**II. Measuring anterior chamber depth with Pentacam® and A-scan contact ultrasonic device in phakic and pseudophakic eyes.**

42 phakic (age:  $65.12 \pm 14.27$  years) and 42 pseudophakic patients (age:  $70.62 \pm 10.97$  years) were enrolled to the study involving one eye of each patient. There was no significant difference between age of the patients ( $p=0.09$ ). The axial length was normal in the groups measured with contact A-scan technique. It was  $22.81 \pm 1.19$  mm in the phakic and  $22.99 \pm 1.23$  mm in the pseudophakic group ( $p=0.53$ ). In the pseudophakic group the measurements were performed  $35.03 \pm 16.67$  months after standard phacoemulsification and

in-the-bag implantation of AcrySof® SA60AT one-piece intraocular lens (Alcon, Texas, USA). ACD measurements were taken by one observer. All measurements were carried out without pupil dilatation, and the fixation point was in the far distance by both methods.

First, the central ACD was measured 3 times in each eye using the Pentacam® (Oculus) based on the Scheimpflug imaging technique. Three images were captured automatically with the rotating Scheimpflug camera and downloaded to a portable PC. With built-in image analysis software, the ACD was determined automatically. Subsequently, ultrasonic A-scan measurements were taken with AL-2000 (Tomey) by contact technique with local anaesthesia by tetracain hydrochloride eye-drop. Patients were placed in a sitting position and asked to fixate on a far target on the wall in order to exclude accommodation. The velocity of ultrasound was set to 1532 m/sec in aqueous. The mean of 3 values of the Pentacam® and ultrasonic data were used for statistical analysis.

### **III. Measuring anterior chamber depth with anterior segment OCT and A-scan ultrasound using immersion technique in phakic eyes.**

60 eyes of 41 phakic patients (age:  $59.95 \pm 16.39$  years) were enrolled to the study. Excluding criteria were any anterior segment abnormality, more than 3.0 D spheric, or more than 2.0 D cylindric refractive error, contact lens wearing or any ophthalmic surgical procedure in the anamnesis or known diagnosis of glaucoma.

Firstly, the central ACD was observed five times in five different images taken by an anterior segment optical coherence tomography (Visante® OCT). Measurements were made using a built-in software tool called „Chamber tool" (version 1.0), that has one line placed across the iris plane and a perpendicular projection that extends forward through the central cornea and calculates both an internal anterior chamber depth and a central corneal thickness. All measurements were done with manual controlling. The target refraction was set to the patients' far refraction diopter to reduce accommodation. Secondly, after topical anaesthesia with tetracain hydrochloride eye drops, an immersion shell filled with sterile water was attached to the surface of the volunteers' eye, and the ACD was measured five times with an ultrasonic A-scan using immersion technique (UltraScan Imaging System) All of



the measurements were done consecutively by two experienced ophthalmologists in each techniques, each masked to the other's results.

The anatomical anterior chamber depth is a distance between the anterior corneal and anterior lens surface, so we have to add central corneal thickness to the data of ACD derived from Visante<sup>®</sup> OCT measurements.

Statistical analysis was performed using SPSS 11.0 and 13.0 software (SPSS Inc., Chicago, Illinois, USA), the data were described as mean±standard deviation (SD), at certain measurements, we had presented ranges. The differences in values between methods were recorded with the unpaired test of Wilcoxon. The association between values were described with Spearman's correlation of rho (r). A p value of 0.05 was considered as the level of significance. Repeatability was described with the intraobserver coefficients of variation (CV) and reproducibility was described with the interobserver CV. CV was defined as the ratio of the standard deviation to the mean in percentage. Reliability coefficients (the consistence of a set of measurements) calculation was based on analysis of variance and were calculated for AS-OCT and US measurements.

## **Results**

### **I. Measurements of amplitude of accommodation in pseudophakic eyes with three methods.**

Visual acuity was  $0.88 \pm 0.2$  in a decimal scale after phacoemulsification and implantation of intraocular lens. Correction was  $-0.92 \pm 0.91$  D,  $-0.93 \pm 0.99$  D in group 1 and  $-0.77 \pm 0.82$  D in group 2. ( $p=0.44$ ). Axial length was  $22.54 \pm 0.89$  mm,  $22.68 \pm 0.81$  mm in group 1 and  $22.46 \pm 0.96$  mm in group 2. ( $p=0.68$ ).

#### *1. Results with defocusing technique.*

The largest minus lens with which the 20/20 line was just readable by the patient was  $-0.83 \pm 0.63$  D. It was  $-0.95 \pm 0.67$  D (range:  $-2.5 - 0.0$  D) in the one-piece group and

-0.81±0.53 D (range: -2.0 – 0.0 D) in the three-piece group. The difference between the two groups was not significant (p=0.4).

## *2. Measurement of ACD with partial coherence interferometry.*

The ACD shift was -0.026±0.134 mm under physiological condition. It was -0.043±0.193 mm (range: -1.038–0.298 mm) in the single-piece group, and 0.014±0.079 mm (range: -1.063–0.385 mm) in the three-piece group. The difference was not significant (p=0.46).

## *3. Measurement of ACD with A-scan ultrasonography during near fixation, and after pharmacological blocking of ciliary muscle.*

The ACD shift was -0.18±0.28 mm. It was -0.16±0.3 mm (range: -0.51–0.2 mm) in the single-piece group, and -0.2±0.28 mm (range: -0.49–0.1 mm) in the three-piece group. The difference was not significant (p=0.68).

We did not find significant correlation between the ACD shift after pharmacological blocking of ciliary muscle and the diopter value of defocusing technique (Spearman's rho=0.16; p=0.37).

## **II. Measurement of anterior chamber depth with Pentacam® and contact ultrasonic device**

### *1. Phakic group.*

The anterior chamber depth was 2.87±0.4 mm measured with Pentacam®, and 2.89±0.49 mm with ultrasonic device (p=0.84). The correlation between devices was significant (r=0.547, p<0.001).

## *2. Pseudophakic group.*

The anterior chamber depth was  $3.41 \pm 0.28$  mm measured with Pentacam®, and  $3.97 \pm 0.45$  mm with ultrasonic device ( $p < 0.001$ ) The correlation between devices was significant ( $r = 0.404$ ,  $p < 0.01$ ).

### **III. Measurements of anterior chamber depth and its repeatability, reproducibility and reliability with anterior segment optical coherence tomograph and immersion ultrasonic device.**

#### *1. Measurements with anterior segment optical coherence tomograph.*

The ACD was  $3.12 \pm 0.33$  mm measured by observer 1 and  $3.11 \pm 0.33$  mm measured by observer 2 ( $p = 0.78$ ). The intraobserver coefficient of variation was  $0.8 \pm 0.4$  % by observer 1 and  $0.9 \pm 1.4$  % by observer 2. The difference in ACD between observers was  $0.007 \pm 0.041$  mm, corresponding to a coefficient of variation of 0.23 %. The reliability coefficient was 99.6 % in the case of anterior segment OCT.

#### *2. Measurements with immersion A-scan ultrasonic device.*

The ACD was  $2.98 \pm 0.33$  mm measured by observer 1 and  $2.95 \pm 0.34$  mm measured by observer 2 ( $p = 0.68$ ). The intraobserver coefficient of variation was  $6.4 \pm 3.8$  % by observer 1 and  $8.5 \pm 4.9$  % by observer 2. The difference in ACD between observers was  $0.026 \pm 0.231$  mm, corresponding to a coefficient of variation of 0.88 %. The reliability coefficient was 87.1 % in the case of ultrasonic device.

The anterior chamber depth values was significantly different measured by observer 1 and 2 in the case of anterior segment OCT and ultrasonic measurements ( $p = 0.02$ ). There was a good correlation between the results of the the methods (observer 1:  $r = 0.732$ ;

$p < 0.0001$  and observer 2:  $r = 0.802$ ;  $p < 0.0001$ ). We observed negative correlation between the age of the patients and the ACD (anterior segment OCT:  $r = -0.411$ ;  $p = 0.001$ , ultrasonic device:  $r = -0.37$ ;  $p = 0.003$ ). There was no difference in reproducibility between AS-OCT and US ( $p = 0.54$ ).

## Discussion

The essential function of human eye is to ensure sharp sight for far and for near objects. The process when the refractive status of the eye is changing called accommodation. During accommodation the eye will be capable for sharp sight of near objects. Young eyes are capable of 14 diopter of accommodation, which represents a fixation from far to 7 cm near point.

With age unfavourable changes occur in the material and shape of the human lens, and the elasticity of the young crystalline lens is decreasing. The amplitude of accommodation continuously decreasing and the near visual acuity is worsening without near glass corrections. In the course of cataract surgery, cataractous lens without accommodation capacity is changed to intraocular lens. In the recent days implantations of monofocal intraocular lenses are common. After implantation of monofocal lens excellent distance visual acuity is achieved in the case of precise surgical technique and accurate planning of the diopter of the intraocular lens. However near visual acuity is weak without near correction, so there is a need for near glass correction to a distance of 33-40 cm.

The most widely investigated area in ophthalmology is to replace or restore accommodation after changing cataractous lens to intraocular lens. There are partially resolving techniques for restoring accommodation after cataract surgery: implantation of different types of multifocal or accommodative lenses with movable optic or using the „monovision“ technique. However, spreading widely of these techniques are blocked by unfavourable photopic phenomenon during application (halos, glare, flare) and potential decreasing of the quality of vision and contrast sensitivity.

Certain patients can achieve good near visual acuity with far correction after implantation of monofocal intraocular lenses. This phenomenon is called pseudoaccommodation. The quantity of this phenomenon differs from patient to patient and is derived from two factors. First, pseudophakic pseudoaccommodation determined by optical features of the pseudophakic eyes such as corneal multifocality, slight indirect myopic astigmatism, small pupil and increased depth of field. Pseudophakic pseudoaccommodation is independent of the ciliary muscle activity. The intraocular lens position so the depth of the anterior chamber is not changing during this process. The other process is pseudophakic

accommodation, which likes to the physiological accommodation caused by contraction of the ciliary muscle: the refraction of the eye changes because of movement of the optic of the intraocular lens along the axis of the eye. During this process, the depth of the anterior chamber is decreasing. Above mentioned two processes strengthen and increasing each other, but the differentiation is not so easy. It is important to understand and to measure these processes to develop new technique for restoring accommodation after cataract surgery or to develop new types of accommodating intraocular lenses.

We have numerous methods to measure the accommodation in pseudophakic eyes. Study of Langenbucher grouped these ones into dynamic or static and subjective or objective methods. The subjective, dynamic methods (subjective near point determination, defocusing technique) depends on patients motivation and cooperation, and are not suitable for differentiate pseudophakic accommodation from pseudophakic pseudoaccommodation.

Measuring change in anterior chamber depth is a static, objective method. We have different methods to observe ACD. The most common method is ultrasonic method, in addition to we can measure with devices using partial or low coherence interferometry, which have better resolution than ultrasound. The former, traditional method is to measure anterior chamber depth changes by pharmacologically influenced ciliary muscle (pilocarpine or cyclopentolate). These objective ACD measurement methods show a potential maximum of movement of the intraocular lens, so not the true, physiologically produced changing. Therefore we have to choose methods for measuring accommodation in pseudophakic eyes that can measure accurately movement of intraocular lenses under physiologically circumstances. Only optical and newly developed devices can measure that kind of changes in anterior chamber depth during accommodation process.

Our aim was to observe total amplitude of accommodation in pseudophakic eyes, to detect anterior chamber depth changes during accommodation with different methods and to compare results with each other. Besides we would like to study ACD with new devices and to compare the results to standard ultrasonographic data and to calculate repeatability, reproducibility and reliability of measurements.

There are a lot of studies observing subjective and objective amplitude of accommodation in pseudophakic eyes. In majority of these studies the ACD shift was observed after stimulating the ciliary muscle with pilocarpine or blocking the ciliary muscle

with cyclopentolate. Conclusions were made from these data in the case of monofocal or accommodative intraocular lenses. Under accommodative conditions, the intraocular lenses mostly moving forward along the axis of the eye.

In our study we had chosen a dynamic, subjective method, the defocusing method and two static, objective, indirect methods: measuring ACD with A-scan ultrasonic device and with ACMaster<sup>®</sup> under desaccommodative and accommodative conditions with and without blocking the ciliary muscle. The amplitude of accommodation was significantly different with our three methods. We did not observe significant movement of the intraocular lenses under physiological conditions measured with PCI technique. Our two intraocular lenses have different shapes: Alcon Acrysof<sup>®</sup> MA60AC is a three-piece lens with an angulation of 10 degree, the Alcon Acrysof<sup>®</sup> SA60AT is a single-piece lens without angulation. The fixation of these two intraocular lenses are different in the capsular bag. Despite this fact, we did not observe any difference in amplitude of accommodation or movement of the intraocular lens with any of our methods.

We had measured a mean of 0.2 mm of ACD shift before and after cycloplegia, so with pharmacological influencing of the ciliary muscle. This result is similar to that of in the literature in the case of monofocal intraocular lenses. According to Nawa a movement of intraocular lens such as ours means approximately 0.3-0.35 diopter pseudophakic accommodation at an average axial length. We have measured significant, 1.0 D subjective total amplitude of accommodation after implantation of both intraocular lenses. However we can not verify significant correlation between total amplitude and physiological or forced ACD changes. Intraocular lens movement during pharmacological influenced ciliary muscle accounts for only one third of total subjective amplitude measured with defocusing technique, so we have verified other factors besides ACD shift. Corneal multifocality, against-the-rule myopic astigmatism, smaller pupil than the average, increased depth of focus, and patients motivation can increase and multiply the true, objective measured amplitude of accommodation in pseudophakic eyes.

Measuring amplitude of accommodation with different methods shows significantly different results. Defocusing technique measures the total amplitude of accommodation, PCI technique measures physiologically induced movement of intraocular lens, blocking of the ciliary muscle with cyclopentolate shows maximal potential of ACD shift – three components of a complex process. Besides this components there are other influencing factors in

accommodation observed in pseudophakic eyes. Above mentioned methods uses different physiological principle, so data are not comparable with each other and the assessment of data are not simple.

Measuring anterior chamber depth became important not to observe accommodation, but to planning of intraocular lens with new generation biometric formulas using preoperative value of ACD (Haigis, Holladay II) and planing of phakic intraocular lenses. An error of 0.1 mm in anterior chamber depth causes 0.1 D error in postoperative refraction after cataract surgery at average axial length. Most of the explantation of intraocular lenses in todays cataract surgery is performed because of unacceptable refraction error by unaccurate biometry. Measuring ACD and its change is important to measure the potential intraocular lens movement during accommodation. There are different ways to detect ACD: ophthalmological A-scan ultrasound biometry, ultrasound biomicroscopy, Scheimpflug imaging (Pentacam<sup>®</sup>), anterior segment optical coherence tomography, or partial coherence interferometry.

Ultrasonic A-scan method is the common for measuring ACD. Disadvantages of contact method are possibilty of corneal abrasion or infection, and chance for off-axis measurement. In addition, impressing the cornea can cause shorter anterior chamber depth as the real one. Axial length measurements show 0.3 mm difference between contact and immersion method, because of impressing the cornea and the anterior chamber during contact method. So the axial length of the eye is smaller with contact ultrasound than immersion method, although there are contrary studies. To eliminate such an error, we have to use immersion technique during ultrasonic measurements. Int he case of immersion method there is a water bath supported by the limbus between the ultrasonic tip and the corneal surface, so measurements are done without direct corneal contact. A little bit difficult, time consuming and uncomfortable for the patients to measure with ultrasonic immersion technique. Therefore, there is increasing demand for more comfortable and faster non-contact methods.

Hoffer had measured a mean of 3.24 mm anterior chamber depth in 6950 phakic, cataractous eyes, which is a little bit larger than our data (2,89 mm) with contact ultrasonography. The background of this difference can be the fact, that Hoffer measures with slit-lamp pachymeter in 60 % and A-scan ultrasound only in 40 % in the same age group (72 years). Another study with large number of eyes measures an anterior chamber



depth of 2.96 mm with immersion method, similar to our data. According to our observation in phakic, emmetropic eyes A-scan ultrasound and Pentacam<sup>®</sup> measures the same ACD, but in pseudophakic eyes ultrasonic data are larger than with optical device. Central depth of the anterior chamber was measured larger with an optical device (Visante<sup>®</sup> OCT) than ultrasound. So measuring anterior chamber depth are dependent on the measuring method strengthen by other studies.

There are a lot of possible factors in the background of different ACD data measured with different methods in pseudophakic eyes. The refractive properties can widely differs from crystalline lens. The material of intraocular lenses have high refractive index, or any interference can be presented in the case of partial coherence interferometry measurements and with Scheimpflug imaging, too.

The reproducibility of ACD measurements with ultrasonic methods are relatively worse, because of the resolution of 200-300  $\mu\text{m}$ . Our data showed better reproducibility with immersion ultrasonic method ( $<1\%$ ), equal with data from anterior segment OCT measurements. Data derived from optical devices are much more independent of the observer. We observed  $<1\%$  reproducibility and repeatability in the case of anterior segment OCT. We observed high repeatability, reproducibility and reliability of ACD measurements with manually controlled Visante<sup>®</sup> OCT measurements. The ACD was different measured by anterior segment OCT and immersion ultrasound, but data are well correlated.

In conclusion, measuring amplitude of accommodation is a difficult task and not able to differentiate accommodation and pseudoaccommodation from each other. Only parts of this complex process can be measured. Besides, there are a lot of poorly measured factors to help accommodating with pseudophakic eyes. ACD measurements dependent on the observer. The ACD values are significantly different with non-contact optical devices than standard ultrasonic devices. Further studies necessary to detect accuracy and validity of ACD measurements with different methods.

## **Summary of new results**

I. We had measured pseudophakic accommodation and pseudoaccommodation in pseudophakic eyes with three different methods described in the literature. With defocusing technique we had proved approximately 0.8-0.9 D total amplitude of accommodation. With partial coherence interferometry method, the mean shift of the intraocular lens was minimal under physiological accommodation condition. After pharmacological blocking of the ciliary muscle the intraocular lens shift was a mean of 0.2 mm, with no difference between our two types of monofocal intraocular lenses.

II. We had proved that there is a difference in anterior chamber depth values in phakic and pseudophakic eyes measured by a newly developed diagnostic tool using Scheimpflug imaging and a standard ultrasonic device. In phakic eyes the results are the same, but in the case of pseudophakic eyes the Pentacam<sup>®</sup> measures significantly smaller anterior chamber depth.

III. The anterior chamber depth was larger measured with newly developed anterior segment optical coherence tomograph (Visante<sup>®</sup> OCT) than ultrasonic device using immersion technique in phakic eyes. The repeatability, reproducibility and reliability of measurements of anterior chamber depth was much better with optical device.

## **Publications**

*This thesis is built upon the following publications:*

1. Nemeth G, Vajas A, Kolozsvari B, Berta A, Modis L Jr: Anterior chamber depth measurements in phakic and pseudophakic eyes: Pentacam versus ultrasound device. J Cataract Refract Surg 2006; 32:1331-1335 (IF:2.285)
2. Nemeth G, Vajas A, Tsorbatzoglou A, Kolozsvari B, Modis L Jr, Berta A: Assessment of anterior chamber depth and its reproducibility with an anterior segment optical coherence tomography compared to immersion ultrasonic method. J Cataract Refract Surg 2007; 33:443–447 (IF:2.285)
3. Nemeth G, Tsorbatzoglou A, Vamosi P, Sohajda Z, Berta A: A comparison of accommodation amplitudes in pseudophakic eyes measured with three different methods. Eye 2008; 22:65-69 (IF:2.084)

*Other publications:*

1. Nemeth G, Tsorbatzoglou A, Kertesz K, Vajas A, Berta A, Modis L Jr: Comparison of central corneal thickness measurements with a new optical device and a standard ultrasonic pachymeter. J Cataract Refract Surg 2006; 32:460–463 (IF:2.285)
2. Vamosi P, Nemeth G, Berta A: Pseudophakic accommodation with 2 models of foldable intraocular lenses. J Cataract Refract Surg 2006; 32:221-226 (IF:2.285)
3. Tsorbatzoglou A, Nemeth G, Math J, Berta A: Pseudophakic accommodation and pseudoaccommodation under physiological conditions measured with partial coherence interferometry. J Cataract Refract Surg 2006; 32:1345-1350 (IF:2.285)

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1. Németh G, Vámosi P, Berta A: Measuring pseudoaccommodation with different types of intraocular lenses. 2002.04.12. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely

2. Németh G, Vámosi P, Berta A, Módis L: Long term following of pseudoaccommodation measured with Pentacam<sup>®</sup>. 2004.04.02. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
3. Németh G, Berta A: Morphological changes in ciliary muscle during accommodation (ultrahang biomicroscopic study). 2005.03.31-04.02. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
4. Németh G, Berta A, Módis L: A comparison of contact ultrasonographic (A-scan) and non-contact optical (Pentacam<sup>®</sup>) techniques for anterior chamber depth measurement of pseudophakic patients. 2005.09.25-29. Societas Ophtalmologica Europæa kongressusa (SOE), Berlin
5. Németh G, Berta A, Módis L: Possible role of anterior chamber depth in biometry. 2006.03.31. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
6. Tsorbatzoglou A, Németh G, Máth J, Berta A: Pseudophakic accommodation and pseudoaccommodation under physiological conditions. 2006. Congress of Hungarian Ophthalmological Society, Sopron

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1. Németh G, Vámosi P: Retinopathy induced by interferon-alfa. 2002.08.31. Congress of Hungarian Ophthalmological Society, Retina section; Miskolc
2. Németh G, Vámosi P, Berta A: Results in biometry with eyes of different axial length. 2003.03.28. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
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5. Németh G: Microincisional cataract surgery: advantages, disadvantages, the present and the future. 2007.06.21. Congress of Hungarian Ophthalmological Society, Live Surgery, Debrecen
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7. Németh G, Berta A: Cataract and refractive Surgery in Hungary, Statistics, Centers and Research Activities. 2004.10.08-09. „Bridges in Life Sciences”: US-CEE Research Networking Meeting on Invasive Cardiac Procedures and Corneal Diseases
8. Németh G, Berta A, Módos L: Long-term changes in corneal endothelium after perforating keratoplasty. 2005.03.31. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
9. Németh G, Tsorbatzoglou A, Berta A: Examination of contrast sensitivity with different types of intraocular lenses. 2006.06.15. Congress of Hungarian Ophthalmological Society, Sopron
10. Németh G, Zajác M, Berta A: A rare case of megalocornea. 2005.06.09.-11. Congress of Hungarian Ophthalmological Society, Szeged
11. Tsorbatzoglou A, Módos L, Kertész K, Németh G, Berta A: Divide and conquer és chop techniques in the course of Aqualase phacoemulsification. 2006.03.31. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
12. Tsorbatzoglou A, Németh G, Berta A: Our experiences with Acrysof SA60D3 (ReSTOR) intraocular lens. 2006.03.31. Congress of Hungarian Society of Cataract and Refractive Surgeons (SHIOL), Keszthely
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*Posters:*

1. Vamosi P, Nemeth G, Berta A: Pseudoaccommodation with different intraocular lenses. 2003.09.06-10. European Society Of Cataract and Refractive Surgeons, München
2. Nemeth G, Vajas A, Kolozsvari B, Berta A, Modis L Jr: Comparison of anterior chamber depth measurements with Pentacam® and with ultrasound device in phakic and pseudophakic eyes. 2006.09.09-13. European Society Of Cataract and Refractive Surgeons, London
3. Tsorbatzoglou A, Nemeth G, Math J, Berta A: Pseudophakic accommodation and pseudoaccommodation under physiological conditions. 2006.09.09-13. European Society Of Cataract and Refractive Surgeons, London
4. Nemeth G, Tsorbatzoglou A, Berta A: Vector analysis of corneal astigmatism induction with two different sizes of corneal incision. 2007.09.08-12. European Society Of Cataract and Refractive Surgeons, Stockholm
5. Tsorbatzoglou A, Németh G, Széll N, Biró Zs, Berta A: Anterior segment changes with age and during accommodation measured with partial coherence interferometry. 2007.09.08-12. European Society Of Cataract and Refractive Surgeons, Stockholm

*Citable abstract in relation to the theses:*

1. Németh G, Tsorbatzoglou A, Berta A: Examination of contrast sensitivity with different types of intraocular lenses. Hungarian Ophthalmology 2006; 143(S):83
2. Tsorbatzoglou A, Németh G, Máth J, Berta A: Pseudophakic accommodation and pseudoaccommodation under physiological conditions. Hungarian Ophthalmology 2006; 143(S):119

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