

# A Study Based on CASIA2: What the Subtle Changes Has Taken Place in the Shape of the Crystalline Lens After Cycloplegia?

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## Research article

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# Abstract

**Background:** To evaluate the shape of the crystalline lens biometry and the diopter before and after cycloplegia using the CASIA2 swept-source (SS) optical coherence tomography (OCT) system on the anterior segment.

**Methods:** This is a retrospective study. Children and adolescents (26 males and 29 females, aged 4–21 years) with simple ametropia were selected for optometry and CASIA2 imaging at 2 separate visits before and after cycloplegia. Diopter is derived from the spherical power (S) obtained by optometry. The Biometric parameters of the crystalline lens, including anterior chamber depth (ACD), anterior and posterior curvature of the lens (ACL and PCL), lens thickness (LTH), lens decentration(LD), lens tilt(LT), and the equivalent diameter of the lens (LED), were measured by CASIA2. The differences of these parameters before and after cycloplegia were compared, and the relationship between them was analyzed.

**Results:** Fifty-five participants (106 eyes) were initially enrolled. The differences were statistically significant( $P<0.05$ ) in S ( $t=-7.026$ ,  $P=0.000$ ), ACD ( $t=-8.796$ ,  $P=0.000$ ), ACL ( $t=-13.263$ ,  $P=0.000$ ) and LTH ( $t=7.363$ ,  $P=0.000$ ) before and after cycloplegia. The change of PCL ( $t=1.557$ ,  $P=0.122$ ), LD ( $t=0.876$ ,  $P=0.383$ ), LT ( $t=0.440$ ,  $P=0.661$ ) and LED( $t=-0.351$ ,  $P=0.726$ ) was not statistically significant ( $P>0.05$ ). There was a significant ( $P<0.05$ ) correlation between the change in S and ACL( $r=0.466$ ,  $P=0.000$ ),LTH ( $r=-0.592$ ,  $P=0.000$ ),and LED ( $r=0.223$ ,  $P=0.021$ ) but not between the PCL( $r=0.19$ ,  $P=0.051$ ), LD ( $r=-0.048$ ,  $P=0.0628$ ) and LT ( $r=-0.022$ ,  $P=0.822$ ). Furthermore, the change of ACD is closely related to the change of crystal morphology. However, in children and adolescents, we found that the change of crystal morphology will not have anything to do with age.

**Conclusion:** The morphological changes of the lens before and after cycloplegia are mainly the ACL and LTH, but there is no difference in the PCL, LD, LT, and LED. In the adolescent population, the change of S is related to the change of ACL, LED and LTH. However, age gets nothing to do with the shape of the crystalline lens. For different refractive states (myopia, hyperopia, emmetropia), whether groups of different ages can reach the same conclusion needs further research.

## Background

Children and adolescents have strong accommodation, cycloplegia must be performed in order to eliminate the interference of accommodation and obtain accurate diopter, so optometry after cycloplegia can be considered as the key point for refractive epidemiology research[1, 2].Pupil dilation is a side effect of cycloplegia[3],in clinical diagnosis and treatment and communication with patients, mydriasis tends to more intuitively express the process and function of cycloplegia. How does the crystal shape change after cycloplegia? Is this change related to age and diopter? Owing to the lack of equipment to directly measure crystal morphology, there are few related researches. CASIA2 is a new type of anterior segment scanner, it can produce reliable in vivo lens measurement regardless of the accommodation stress, and

the measurement of anterior segment parameters is not subject to pupil dilation, with good repeatability and reproducibility[4–6].Based on the application of CASIA2, the same pattern of examination before and after cycloplegia can help us to better observe and understand the physical changes of the lens parameters, and also provide reference for the research of myopia and accommodation.

## Materials And Methods

### Subjects

A retrospective analysis was made of 55 cases (106 eyes), 26 males and 29 females, with an average age of  $9 \pm 3.25$  years, of whom 43 cases (82 eyes) were aged 4–11 years, 9 cases (18 eyes) were aged 12–18 years, and 3 cases (6 eyes) were aged 19–21 years, who were admitted to the Department of Ophthalmology, Affiliated Hospital of North Sichuan Medical College from May to June 2020. All patients were simple ametropia, excluding patients with organic diseases such as ocular surface and fundus, and excluding patients who had undergone refractive, ocular surface and fundus related operations in the past.

### Methods

Before and after cycloplegia, the lens biometry measured according to the same experimenter. The instrument are listed: ARK-510A autorefractor (NIDEK,Co. Ltd., Gamagori, Japan) and DK-700 optometry (Topcon, Japan) to perform standardized optometry, and CASIA2( Tomey Corp., Nagoya, Japan). The S, ACD, ACL, PCL, LTH, LD, LT and the LED were recorded respectively. The cycloplegia drug is 0.5% tropicamide eye drops (Boshlen Frida Pharmaceutical Company), which are dropped once every 10 minutes for a total of three times, and relevant examinations after cycloplegia are carried out 30 minutes later. This is a retrospective study. According to the requirements of the Medical Ethics Committee of North Sichuan Medical College, this papers do not need ethics approval and consent to participate.

### Statistical Analysis

SPSS 25.0 statistical software was used for analysis. All the data were first tested by Kolmogorov-Smirnov (*K-S*) goodness of fit normality test, and compared before and after cycloplegia. The data before and after cycloplegia met the normal distribution using paired sample t test. If it not satisfied, non-parametric test is used for comparison. In the correlation analysis, the mean  $\pm$  standard deviation ( $X \pm S$ ) is used for those whose data conform to normal distribution, Pearson correlation analysis is used, and scatter plot is used to describe the correlation. If the data do not conform to the normal distribution, the median  $\pm$  quartile spacing ( $M \pm Q$ ) is used, and the Spearman correlation analysis is carried out. Multivariate linear regression analysis is performed on parameters with multiple correlations. The difference was statistically significant ( $P < 0.05$ ).

## Results

# Changes of parameters before and after cycloplegia

Based on CASIA2, the changes of the lens morphology before and after cycloplegia are shown in Fig. 1a.b. The distribution and comparison of eye biological parameters before and after cycloplegia are shown in Table 1. From the table, it can be observed that S, ACD and ACL and LTH after cycloplegia, with statistically significant difference ( $P < 0.05$ ). There was no significant differences in PCL, LT, LD and LED ( $P > 0.05$ ). Before and after cycloplegia, the change of PCL, LD and LED obey normal distribution, while the change of other parameters are skewed distribution, as showed in Table 2.

Table 1

The distribution and comparison of eye biological parameters before and after cycloplegia

	Before Cycloplegia		After Cycloplegia		<i>t/z</i> , <i>P</i>
	Distribution	Description	Distribution	Description	
S(D)	Skewed	$-1.25 \pm 2.00$	Normal	$-0.73 \pm 2.13$	-7.026,0.000*
ACD(mm)	Normal	$3.20 \pm 0.29$	Normal	$3.26 \pm 0.27$	-8.796,0.000*
ACL(mm)	Normal	$12.39 \pm 1.38$	Normal	$13.22 \pm 1.18$	-13.263,0.000*
PCL(mm)	Normal	$5.94 \pm 0.46$	Normal	$5.90 \pm 0.46$	1.557,0.122
LTH(mm)	Normal	$3.47 \pm 0.15$	Normal	$3.44 \pm 0.14$	7.363,0.000*
LT(°)	Normal	$4.80 \pm 1.23$	Normal	$4.77 \pm 1.22$	0.440,0.661
LD(mm)	Normal	$0.22 \pm 0.08$	Normal	$0.21 \pm 0.09$	0.876,0.383
LED(mm)	Normal	$9.56 \pm 0.35$	Normal	$9.57 \pm 0.34$	-0.351,0.726
*: It indicates that the comparison between the two is statistically significant.					

Table 2  
The description of the change of all eye biological parameters before and after cycloplegia

	Changes before and after Cycloplegia	
	Distribution	Description
S(D)	Skewed	0.25 ± 0.50
ACD(mm)	Skewed	0.045 ± 0.06
ACL(mm)	Skewed	0.69 ± 0.72
PCL(mm)	Normal	-0.04 ± 0.03
LTH(mm)	Skewed	-0.03 ± 0.04
LT(°)	Skewed	-0.007 ± 0.008
LD(mm)	Normal	0.1 ± 0.6
LED(mm)	Normal	0.006 ± 0.018

## The Relationship between the Change of the lens biometry and the Change of S

The S changes were -0.25 (4 eyes), 0 (33 eyes), 0.25 (32 eyes), 0.50 (15 eyes), 0.75 (11 eyes), 1.00 (5 eyes), 1.25 (1 eye), 1.50 (1 eye), 1.75 (1 eye), 2.00 (1 eye), 2.25 (1 eye), 3.00 (1 eye), totaling 106 eyes. The change of S is positively correlated with the change of ACL ( $r = 0.466$ ,  $P = 0.000$ ) and LED ( $r = 0.223$ ,  $P = 0.021$ ). There is a negative correlation with the change of LTH ( $r = -0.592$ ,  $P = 0.000$ ). It has nothing to do with the change of PCL ( $r = 0.19$ ,  $P = 0.051$ ), LD ( $r = -0.048$ ,  $P = 0.0628$ ) and LT ( $r = -0.022$ ,  $P = 0.822$ ).

## The Relationship between the Change of the lens biometry and the Change of ACD

The change of ACD is positively correlated with ACL ( $r = 0.584$ ,  $P = 0.000$ ) and negatively related to LTH ( $r = -0.587$ ,  $P = 0.000$ ). However, it has nothing to do with PCL ( $r = 0.035$ ,  $P = 0.725$ ), LD ( $r = 0.022$ ,  $P = 0.821$ ), LT ( $r = 0.018$ ,  $P = 0.858$ ) and the change of LED ( $r = 0.086$ ,  $P = 0.382$ ).

## The Relationship between the Change of the lens biometry and the Change of Age

Age was not linked to the change of ACD ( $r = 0.012$ ,  $P = 0.901$ ), the change of ACL ( $r = 0.067$ ,  $P = 0.496$ ), PCL ( $r = -0.052$ ,  $P = 0.595$ ), LTH ( $r = 0.04$ ,  $P = 0.685$ ), LD ( $r = -0.026$ ,  $P = 0.788$ ), LT ( $r = -0.132$ ,  $P = 0.178$ ), and LED ( $r = -0.029$ ,  $P = 0.77$ ).

## Discussion And Conclusion

Spherical equivalent refraction is given in the combined effect of several ocular components—specifically, axial length, corneal power, anterior chamber depth, and lens power[7]. There are limited studies on the observation of refractive power and morphology of the lens. In this paper, CASIA2 is used to compare the differences of refractive power and crystal morphology parameters before and after cycloplegia. It is well known that contraction of the ciliary muscle and relaxation of the suspension ligament will change the surface curvature of the lens, thus increasing the fundamental optical power of the lens[8]. However, cycloplegia resulted in hyperopia shift and astigmatism axis change, but astigmatism power was basically unchanged[9], the record of diopter change in this paper refers specifically to a spherical mirror. For the diopter changes before and after cycloplegia, 96.2% (102 eyes) of 106 eyes showed positive changes in different degrees, while the other 3.8% (4 eyes) showed changes of -0.25 D. Due to the relaxation of accommodation, the diopter changes in the direction of correction. The conclusion of this paper is compatible with previous studies and theories[10]. It has to be mentioned that there are also very few cases with a small amount (-0.25 D) of adverse deviation, which may be due to: (1) Significant changes in high-order aberrations of eyes after pupil dilation will affect the measurement of diopter to vary degrees[11, 12]. (2) Adolescents have extremely strong accommodation function, so the optometry results under the tiny pupil may not be reliable. (3) The possibility of measurement errors due to the cooperation degree of patients is not ruled out.

The change of crystal morphology before and after cycloplegia is mainly the ACL and LTH, but there is no obvious difference in PCL, LD, LT and LED. Schachar et al[13] reported that during the accommodation process, the anterior surface of the lens curvature (ACL) changes more than the posterior surface (PCL), while the lens itself has a accommodation range of about 7.8 D, and there is no movement or deviation during cycloplegia due to the lack of movement of the lens nucleus. Grzybowski et al[8] also found that the micro increase in lens thickness is related to the large change in accommodation amplitude, while the lens position has no obvious change. Changes in ocular biological parameters before and after cycloplegia have always been a hot topic in refractive research. Different mydriasis drops can relax dissimilar degrees of regulation by paralyzing ciliary muscle[14]. It can be seen that the changes of crystal morphology before and after cycloplegia are consistent with the changes of crystal morphology during dynamic accommodation of human eyes.

The change of diopter(S) before and after cycloplegia is highly related to the ACL, LTH and LED, but has nothing to do with the change of the PCL, LD and LT. Under the condition that the axial length and corneal refractive power are unvaried, the change of refractive power is mainly determined by the change of the lens refractive power. After cycloplegia, the ACL of the crystal increases and the thickness of the lens decreases. According to Lensmaker equation[15], both advancing the radius of curvature and reducing the thickness reduces the diopter of the crystal, which is corresponding with the change of diopter. The change of the diameter does not affect the change of the lens diopter, but it is related to the change of diopter. This may be that under the condition of ciliary muscle relaxation, the radius of curvature of the anterior surface of the lens increases, the thickness decreases, and the increase in diameter is an overall

change process. Amy et al[16] reported that the radius of curvature of the rear surface of the crystal changes significantly during the accommodation process. But we found that the change of PCL has nothing to do with the change of diopter, and the change of PCL before and after cycloplegia has no statistical significance. There may be for two reasons: One is the case that the PCL is small and the change value is not obvious when relaxing; Second, the circular fibers of cycloplegia and relaxation mainly act on the anterior surface of the lens and have little influence on the posterior surface. The change of human eye diopter is also related to the use of cycloplegia drugs, and the most suitable cycloplegia drugs should be comprehensively selected according to the patient's age, refractive state and other basic conditions[17, 18].

The change of ACD before and after cycloplegia is highly related to the ACL and LTH, but has nothing to do with the PCL, LD, LT and LED. Chen, Z et al[19] found that the lens became thinner and moved backward after cycloplegia. The increase of ACD was primarily due to the backward movement of the lens. These results are worthwhile to clarify the effect of the lens changes during accommodation.

The changes of various parameters of crystal morphology have nothing to do with age. Richdale et al's [20] quantitative accommodation study found that the change of the lens equatorial diameter and ciliary muscle thickness per diopter has nothing to do with the age of the subject, and even if the total accommodation amplitude decreases, ciliary muscle contraction per diopter has nothing to do with age. In addition, it is possible that the main object of this study is mainly concentrated in adolescent myopia patients, which have certain age limitations. For patients who have myopia, their accommodation is often lagging behind and insufficient[21], there is no difference in the changes of multiple lens parameters before and after cycloplegia.

CASIA2 can provide a preliminary measurement change of crystal biological parameters and can quantitatively and objectively evaluate relevant biological parameters[22], which can help us to better understand the physical changes of various anterior segment biological parameters such as lens biometry[23]. The change rule of crystal morphology is the basis for research on ametropia, regulation and other related aspects, providing reference for further research on myopia and regulation mechanism. Based on the comparison and analysis of diopter and crystal morphology before and after cycloplegia, it is found that for children and adolescents, the change of diopter after cycloplegia is highly correlated with the change of crystal morphology and age. Additional research is needed on whether the same conclusion can be reached for all age groups and different refractive states (myopia, hyperopia and emmetropia).

## Abbreviations

SS: swept-source; OCT: optical coherence tomography; S: the spherical power; ACD: anterior chamber depth; ACL: posterior curvature of the lens; PCL: posterior curvature of the lens; LTH: lens thickness; LD: lens decentration; LT: lens tilt; LED: equivalent diameter of the lens.

# Declarations

## Ethics approval and consent to participate

This is a retrospective study. According to the requirements of the Medical Ethics Committee of North Sichuan Medical College, this papers do not need ethics approval and consent to participate.

## Consent to publish

Not applicable for this study.

## Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.

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## Authors' Contributions

CD and ML were the major contributors to the experimental design and drafting of the manuscript. CD,ML and XL analyzed and interpreted collected data. BL contributed to the study concept and design. All authors reviewed and approved the final manuscript.

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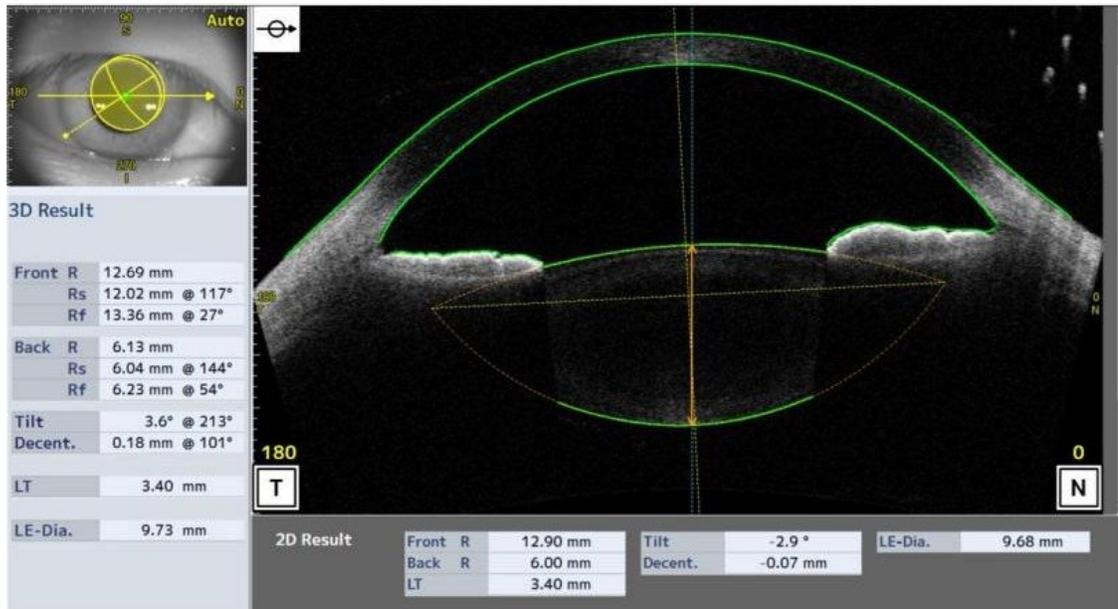
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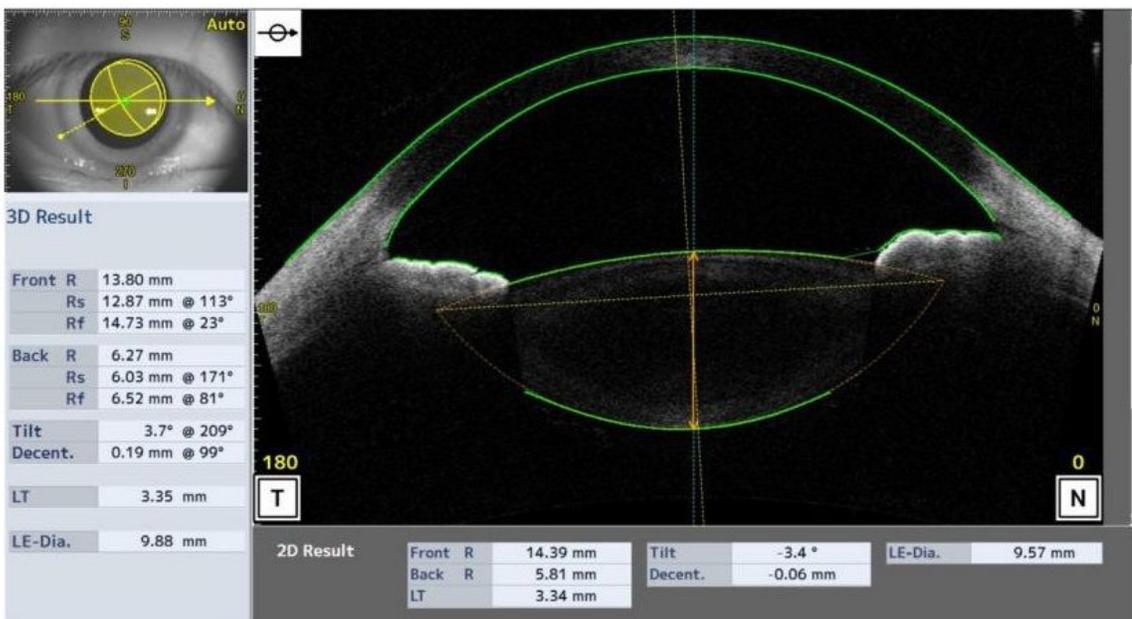
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## Figures



a



b

Figure 1

The changes of lens morphology before and after cycloplegia a: before; b: after