

Original Article

Accommodation after an implantable collamer lens implantation in high myopia patients

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Abstract: Purpose: The purpose of the current study was to investigate the pathogenesis of visual fatigue in patients after implantable collamer lens (ICL) implantation based on an evaluation of accommodation function. Methods: Thirty patients (12 males and 18 females) with high myopia underwent a toric or non-toric ICL procedure. Accommodation function was tested pre-operatively and 1, 3, and 6 months post-operatively. Testing included amplitude of accommodation (AMP), accommodation facility (AF), accommodative response (AR), negative and positive relative accommodation (NRA/PRA), and ultrasound biomicroscopy (UBM) to analyze the relationship between the ICL loop and the ciliary body during accommodation. Results: After the ICL procedure, the AMP and PRA decreased, but the AF increased significantly compared to pre-operative values. The BCC and NRA were not significantly different before and after ICL plantation. Based on UBM, we surmised that when accommodation was relaxed, the partial foot loop of the artificial crystal contacted the ciliary body. When accommodation was tense, the ICL loop was in closer contact with the ciliary body, and even attached to the suspensory ligament. Conclusion: Contact between the ICL loop and ciliary body may affect ciliary muscle function, which resulted in a decrease in accommodation, and even visual fatigue while working at a near distance.

Keywords: Myopia, ICL, accommodation

Introduction

An implantable collamer lens (ICL) procedure, namely a posterior implantable collamer lens (PCIOL), is based on the idea of cornea and crystalline lens integrity reserves and has become the optimal procedure for patients with high myopia. At present, the criterion for success in many domestic and international studies has been based on improving monocular distance uncorrected visual acuity after ICL [1]; however, the post-operative patients continue to complain of visual fatigue to different degrees, especially while working at a near distance. Accommodation is thought to focus on these sporadic complaints. Jie et al. [2] reported that LASIK has no significant adverse effects on accommodation for high myopia; however, the ICL and corneal refractive procedures have different indications, operative methods, and operative parts. Kazutaka [3] reasoned that the amplitude of accommodation declined initially, then gradually recovered because of the

transient dysfunction of the ciliary muscles by ICL fixation, yet the working state of ciliary muscles during accommodation cannot be detected. An ICL implantation can remedy ametropia, but it is not clear how accommodation changes and what causes the changes. Thus far, there the literature is limited with respect to prospective evaluations of changes in accommodation after ICL. Considering that the haptics of an ICL need to be secured in the ciliary sulcus, it is possible that the ciliary muscles may be functionally affected by the ICL during the course of accommodation.

This study was designed to evaluate accommodation function, such as amplitude of accommodation (AMP), facility of accommodation (AF), accommodative response (AR), negative relative accommodation and positive relative accommodation (NRA/PRA), and ultrasound biomicroscopy (UBM), of patients with high myopia after ICL implantation, to analyze the

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relationship between the ICL loop and the ciliary body during accommodation.

Materials and methods

Materials

Thirty patients (12 males and 18 females) with high myopia who underwent a toric or non-toric ICL procedure between October 2014 and May 2015 by the same physician (Professor Jian Ye) were enrolled. The patients were between 20 and 35 years of age and had spherical powers from -10.00 D to -20.00 D and cylindrical powers from 0 to -5.00 D. The consent forms were signed before surgery. The patients complied with every follow-up examination within 6 months of the procedure. No patients were lost to follow-up. This study was approved by The Third Military Medical University Third Affiliated Hospital.

Methods

Pre-operative accommodation function measurements: In addition to the routine pre-operative examination of the ICL, accommodation function measurements were performed with the best distance spectacle correction in place. These tests included the AMP, AF, AR, and NRA/PRA.

The AMP was measured using the “minus-lens method”. A near target (one line of letters larger than the patient’s best spectacle corrected visual acuity [BSCVA]) at 40 cm was used as minus lenses were added in 0.25 increments until the subject could not distinguish the letter (sustained blur). The minus lenses plus the working distance (2.50 D) is the AMP.

The measurement of monocular AF was achieved using a near target with the letter size larger than the BSCVA at a distance of 40 cm using ± 2.00 flippers and occlusion of the non-viewing eye. We placed the +2.00 in front of the patient’s eye and asked the patient to try to see the letters clearly and singly as quickly as possible. When the letters were reported to be clear, the patient was instructed to press the flipper quickly to the minus side. Again, the patient was instructed to read the letters and report when the letters appeared clear or had disappeared. We recorded the cycles per minute.

The AR was measured by binocular crossed cylinders (BCCs) using a cross-target consisting of 4-5 vertical and horizontal lines presented to the subject at 40 cm. The cross-cylinder lenses (± 0.50 DC) were placed in front of the eyes (phoropter), and the patient was asked to indicate which group of lines was darker (vertical or horizontal). The end point of this test was that blackness or clarity of the horizontal and vertical lines was equal. To achieve this, we added minus lenses or plus lenses in 0.25 D increments until equality was reached.

NRA/PRA values were determined by adding lenses in front of the patients’ eyes (plus and minus lenses, respectively). The objective of the test was to keep the letters larger than the BSCVA at 40 cm as clear and single as possible, and to indicate when the letters were blurry or double. The NRA measurement was made before the PRA.

Surgical procedure: One week before surgery, the operative eye underwent two peripheral iridectomies. On the day of surgery, the patients were administered dilating and cycloplegic agents under topical anesthesia. A model V4 ICL was inserted through a 3-mm clear corneal incision with the use of an injector cartridge (STAAR Surgical) after placement of viscoelastic material into the anterior chamber. The ICL was placed in the posterior chamber. When the ICL spread slowly, the far side of the loop was pushed into the iris by the iris restorer. Then, using a special adjustable hook to bury the near side into the iris, the position of the ICL was adjusted to center. The remaining viscoelastic material was completely washed out of the anterior chamber with a balanced salt solution, and a myotic agent was instilled. All surgeries were uneventful and no intra-operative complications were observed.

Post-operative accommodation function measurements: In addition to the routine post-operative review (1, 3, and 6 months later), the AMP, AF, AR, and NRA/PRA measurements were reviewed. Six months after the ICL, the patients were examined by UBM to observe the relationship between the ICL loop and the ciliary body during relaxing and dynamic accommodation. During relaxing accommodation, the unchecked eye gazed at the right above. During dynamic

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Table 1. Changes of accommodative function in the parameters after I (ICL) operation on patients with high myopia (Mean \pm SD)

Time	AF (D)		AMP (D)		BCC (D)	NRA (D)	PRA (D)
	Right	Left	Right	Left			
Before the operation	4.20 \pm 2.09	4.58 \pm 2.43	7.22 \pm 1.75	7.35 \pm 1.71	0.04 \pm 0.30	2.05 \pm 0.23	-1.85 \pm 0.71
One month later	7.38 \pm 2.07	7.98 \pm 2.32	3.94 \pm 1.16	4.03 \pm 1.14	0.07 \pm 0.23	2.13 \pm 0.18	-1.23 \pm 0.58
Three months later	7.15 \pm 1.67	7.98 \pm 2.25	3.42 \pm 1.14	3.71 \pm 1.07	0.09 \pm 0.19	2.14 \pm 0.16	-1.31 \pm 0.44
Six months later	7.11 \pm 1.80	7.62 \pm 1.96	3.41 \pm 1.11	3.48 \pm 1.00	0.11 \pm 0.20	2.14 \pm 0.17	-1.26 \pm 0.42
F value	18.676	16.132	57.878	62.237	0.539	1.705	8.503
P value	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05

accommodation, the unchecked eye gazed at the visual card previous to the BCVA, slowly moving along the foresight from far-to-near to maintain a clear vision.

Statistical processing

Statistical analysis was performed using one-way ANOVA (SPSS, version 11.0; SPSS, Inc., Chicago, IL, USA). The Fisher least significant difference test was used between group comparisons. The results are expressed as the mean \pm SD, and a value of $P<0.05$ was considered statistically significant.

Results and discussion

All of the operated eyes showed uncorrected visual acuity of ≥ 0.6 post-operatively. The mean residual refractive error was -0.64 ± 0.51 D in spherical equivalents post-operatively.

The means of all the measured accommodative parameters were calculated for each period, and are shown in **Table 1**. By statistical variance analysis, the AF ($F=18.676$ in the right eye, $P<0.001$; $F=16.132$ in the left eye, $P<0.001$) increased in 1, 3, and 6 months post-operatively. The AMP ($F=57.878$ in the right eye, $P<0.001$; $F=62.237$ in the left eye, $P<0.001$) and PRA ($F=8.503$, $P<0.001$) decreased after ICL implantation; there were no statistically differences among the three post-operative periods. There were no significant differences in NRA ($F=1.705$, $P>0.05$) and BCC ($F=0.539$, $P>0.05$) pre- and post-operatively.

The variation trend of accommodation function is shown in **Figure 1**. The AMP was 7.22 ± 1.75 D pre-operatively, and 3.94 ± 1.16 D, 3.42 ± 1.14 D, and 3.41 ± 1.11 D post-operatively (1, 3, and 6 months, respectively). The variance of the

data was statistically significant ($P<0.001$) pre- and post-operatively (1, 3, and 6 months), but there were no significant differences between the three post-operative periods ($P>0.05$). The basis for this finding was likely because the ICL implantation procedure reduced the accommodation amplitude, which did not recover post-operatively. The BCC was not statistically different ($P>0.05$) before (0.04 ± 0.30 D) and after the OCL procedure (0.07 ± 0.23 D, 0.09 ± 0.19 D, and 0.11 ± 0.20 D [1, 3, and 6 months, respectively]). Thus, the procedure did not significantly change the accommodative response. The NRA was not significantly different ($P>0.05$) pre- (2.05 ± 0.23 D) and 1, 3, and 6 months post-operatively (2.13 ± 0.18 D, 2.14 ± 0.16 D, and 2.14 ± 0.17 D, respectively). Thus, we concluded that the ICL implantation did not influence relaxation of accommodation. The PRA (-1.85 ± 0.71 D pre-operatively) decreased significantly ($P<0.001$) 1, 3, and 6 months after the ICL procedure (-1.23 ± 0.57 , -1.31 ± 0.44 , and -1.25 ± 0.43 D, respectively) because the procedure reduced the accommodation tension function. Based on the test results, the AF increased 1, 3, and 6 months post-operatively (7.34 ± 2.08 , 7.15 ± 1.67 , and 7.12 ± 1.80 in the right eye; 7.98 ± 2.32 , 7.98 ± 2.25 , and 7.61 ± 1.96 in the left eye, respectively) compared to pre-operatively (4.20 ± 2.09 in the right eye; 4.58 ± 2.43 in the left eye). The results showed that accommodation facility increased post-operatively.

The results of this study demonstrated that the AMP decreased significantly following the ICL procedure. The AMP reflects the maximum capacity of human eye accommodation. Marran et al. [4] defined accommodative insufficiency as the AMP lower than at least 2 D than Hofstetter's age-based norms, which referred to the Daum study [5]. Previous studies proved

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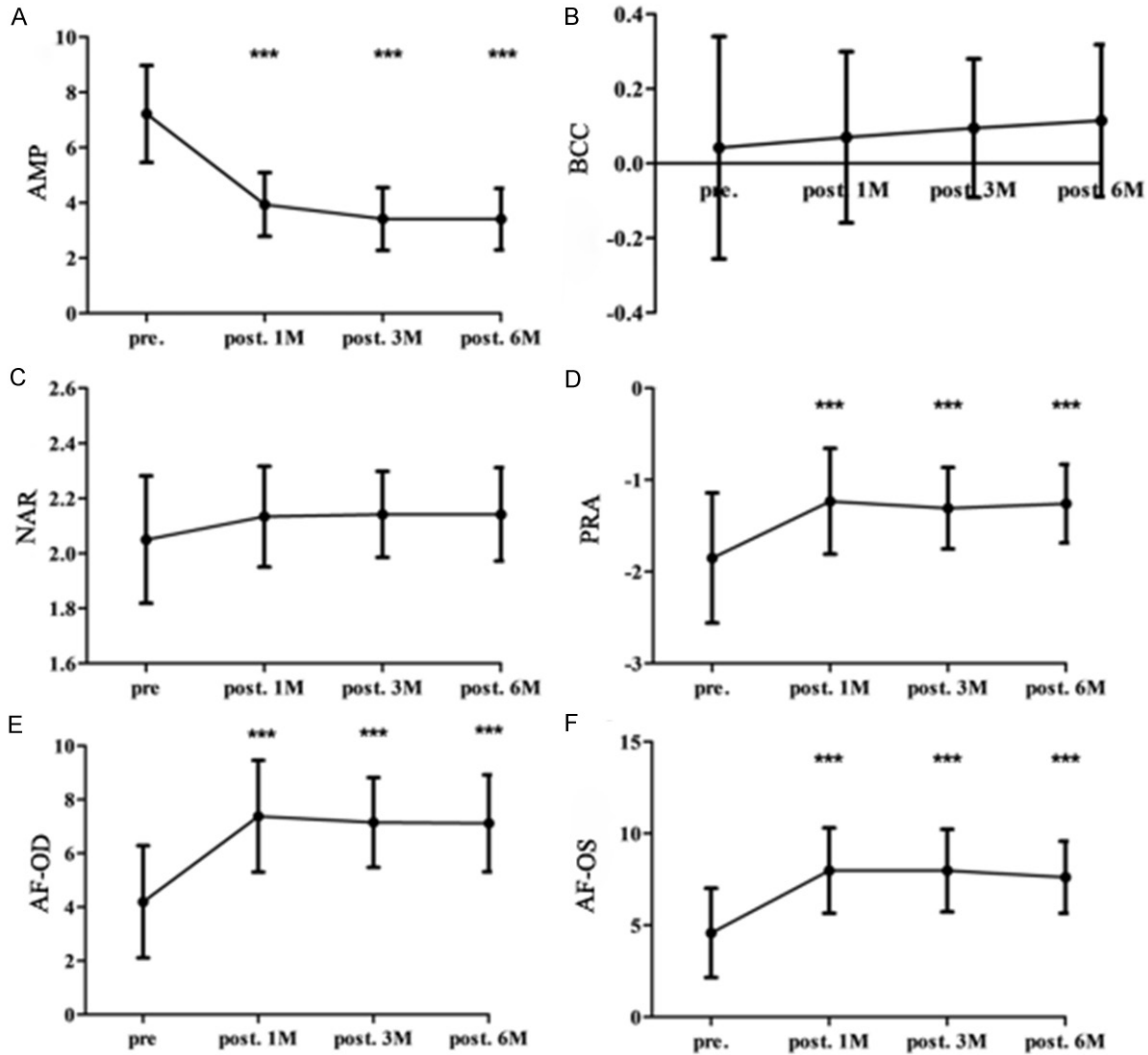


Figure 1. Accommodation function pre ICL, 1 month, 3 months and 6 months after the ICL procedure. A. The measurement of AMP; B. The measurement of BCC; C. The measurement of NRA; D. The measurement of PRA; E. The measurement of AF-OD; F. The measurement of AF-OS. * $P < 0.05$ compared with pre-operatively; *** $P < 0.001$ compared with pre-operatively.

that the mean AMP was related to the degree of ametropia---the higher the degree of myopia, the smaller the AMP [6-8]. This study confirmed the conclusion. Before the ICL procedure, the AMP of 21 patients (70%) with high myopia was lower at least 2.00 D than the peers' minimum. After the ICL procedure, all of the AMP measurements (100%) decreased further and had accommodative insufficiency. There were only 2 patients (32 years of age [patient A] and 28 years of age [patient B]) with high myopia in whom the AMP was normal before surgery. One month later, however, the AMP decreased to >5.00 D, and 3 and 6 months after the ICL the AMP further declined at different levels. Both

patients reported blurred vision, ocular pain, ocular acidity, and easy weariness during near distance work. The symptoms of fatigue are closely related to accommodation ability and demand [9-11]. The smaller the AMP, the more obvious the near visual fatigue symptoms. The findings were consistent with the decreased AMP in the results of this study.

Kazutaka et al. [3] reported AMP decreased 1, 3, and 6 months after ICL implantation, which was in good agreement with our findings. Kazutaka et al. [3] also showed that the AMP nearly returned to baseline 1 year after ICL implantation. In our study, we did not have

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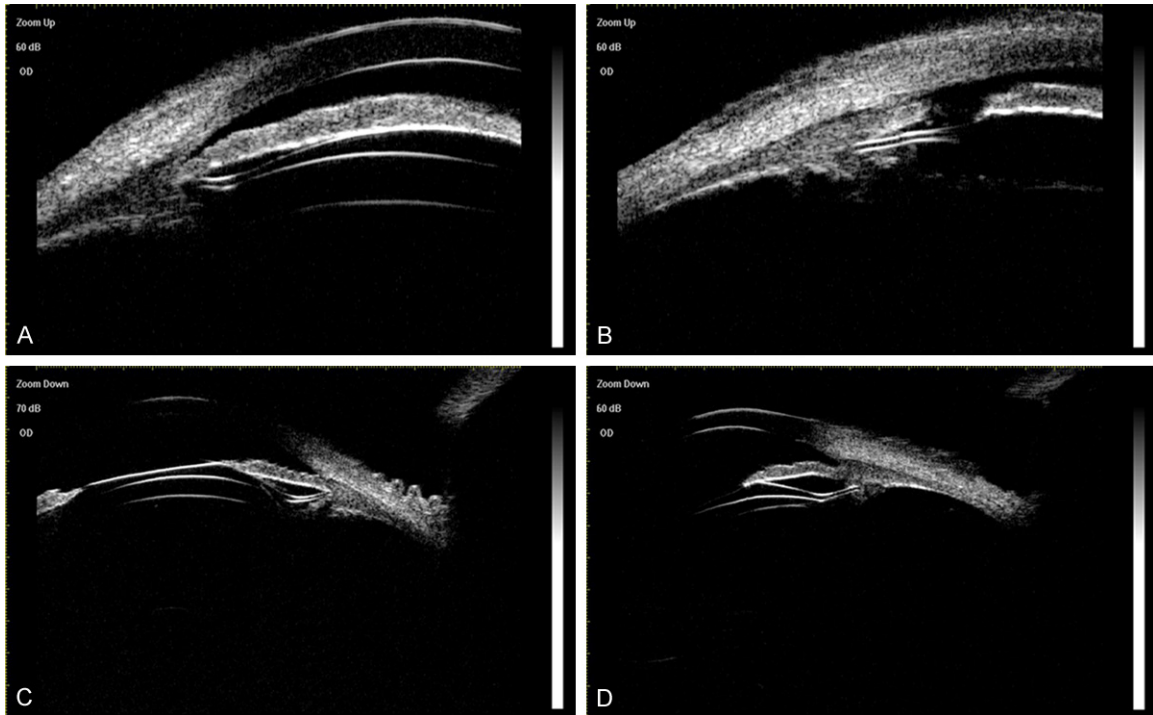


Figure 2. The position relationship between the artificial lens and ciliary body during relaxing and dynamic accommodation. A. In the nasal field of the right eye, the ICL loop was at different level with the ciliary body and was in the zonule. B. In the nasal field of the right eye, the ICL loop attached to the ciliary body was in the zonule. C. As the patient's accommodation relaxed, in the temporal field of the right eye, the ICL loop was close to ciliary body, but not projecting into the ciliary body, and was in the zonule. D. As the patient's accommodation became tense, in the temporal field of the right eye, the ICL loop was buried in the ciliary body and was under the zonule.

exam results after 6 months post-operatively. After the ICL procedure, the AMP also returned gradually. Kazutaka et al. [3] assumed that the fixation of the ICL to the sulcus resulted in transient dysfunction of the ciliary muscles, but that was not verified.

In the current study, UBM was used to detect the anatomic relationship between the ICL loop and the ciliary body during accommodation (**Figure 2**). When accommodation was relaxed, partial foot loop of the artificial crystal contacted the ciliary body. When the patients were watching at a near distance, accommodation was tense. The pupil contracted and the ICL was pushed back by the iris as the ciliary body contracted and the lens protruded. These changes resulted in closer contact of the ICL loop to the ciliary body, with attachment to the suspensory ligament. For the ideal ICL location, the artificial crystal is set between the back of the iris and the front of the personal lens. The foot loops are buried in the ciliary sulcus of the iris adjacent to the ciliary body and suspensory

ligament. Placement of the foot loop is completed by special hooks that bury the foot loop in the iris. The process is not orthophoria. Sheng et al. [12] reported that 46.3% of high myopia patients who underwent ICL operation had a foot loop in the ciliary sulcus and 53.7% had a foot loop under the ciliary sulcus. Bacskulin [13] found with accommodation the processus ciliares shifted forward and were displaced inward [13]. Du and his colleagues [14] found that the ICL and iris are in contact. These founding was consistent with the observed phenomena of our study. Thus we conjecture the contact between ICL loop and ciliary body may affect the function of the ciliary muscle, resulting in a decrease in AMP.

Dong et al. [15] reported that 3 months after an iris-fixated intraocular lens implantation, the AMP was higher than pre-operatively. Hongm et al. [16] also considered that fixed iris refractive intraocular lens implantation in patients with high myopia did not affect accommodation function. Chen et al. [17] found that AMP

increased after LASIK. The ICL procedure is different from the corneal refractive procedure and iris-fixated intraocular lens implantation with respect to the principles and operative parts. Thus, these differences may account for this discrepancy in AMP measurements.

Chen [17] reported that after a LASIK operation, the PRA increased significantly. In contrast to Chen [17], the PRA decreased in this study after the ICL procedure, suggesting that the accommodation ability was also damaged in keeping the fusion condition. The reason may be the same reason the AMP decreased, and the contact between the ICL lens loop and the ciliary body also led to a decrease in the PRA. Karimian [18] reported that 2 weeks after the PRK operation, AF decreased slightly, but significantly increased 1 month post-operatively. Our study showed that AF increased significantly after the ICL procedure, which was in contrast to the Karimian study [18]. The reason for the decline in AF early after PRK, we identified the point of view of Karimian [18], may be associated with a decline in early visual function after PRK, especially the contrast sensitivity function [19]. After the ICL operation, the contrast sensitivity increased [20]. Good imaging quality leads to strong visual signals, resulting in an increase in the AF, which was consistent with the results of Fu [21].

Conclusion

ICL implantation can improve visual acuity; however, the relationship between the ICL loop and the ciliary body may affect accommodation. Within 6 months post-operatively, accommodation function decreased, which resulted in visual fatigue when working at a near distance.

Disclosure of conflict of interest

None.

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