Change of vergence after the Artisan phakic intraocular lens implantation

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Written by Ik Hee Ryu

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Abstract

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PURPOSE: To evaluate change of the vergence parameters after Artisan phakic intraocular lens (PIOL) implantation, an alternative to laser refractive surgery.

METHODS: Prospective study for the patients who received the Artisan PIOL implantation was performed. Before the surgery, routine ophthalmologic evaluations including refractive errors were performed. With rotary prism, convergence, divergence, and vertical vergence amplitudes were measured. The stimulus accommodative convergence to accommodation (AC/A) ratio was measured by the lens gradient method, and near point of convergence was measured, too. After the Artisan PIOL implantation, the identical evaluations including vergence amplitude were repeated at 1 week, 1 month and 3 months after the surgery.

RESULTS: A total of 21 patients (1 male: 20 female) enrolled the study. Mean age was 25.1±4.7 years old, and preoperative refractive error was -8.86±3.93 diopters (D). After the implantation, mean refractive errors significantly decreased to within ±1.00 D, and noticeable complications were not found.

Vergence amplitudes including convergence, divergence, vertical vergence, and near point of convergence did not change at any of follow-up periods significantly. But, stimulus AC/A ratio showed a statistical change from 4.39±0.79 △/D before the surgery to 3.79±0.47 △/D at 3 months after the surgery.

CONCLUSIONS: These results regarding implantation of the Artisan PIOL revealed nearly no effect on vergence amplitudes including convergence, divergence, vertical vergence and near point of convergence, except the stimulus AC/A ratio which decreased significantly.

Key words: AC/A ratio, Artisan PIOL, convergence, divergence, vergence

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I. INTRODUCTION

Various types of refractive surgery are becoming increasingly popular to those who seek an alternative to wearing spectacles. Besides excimer laser photorefractive keratectomy (PRK) and laser in-situ keratomileusis (LASIK), implanting an intraocular lens in phakic eyes became one of the most satisfactory surgical procedures for the correction of high myopia.[1] For severe myopia patients, the excimer laser technology may be considered unsuitable because of the anatomical structure incompatibility resulting the correction instability, haze, and corneal ectasia.[1] But, the phakic intraocular lens (PIOL) implantation opened an alternative way to correct the myopia without structural complications related to the excimer laser. In 1991, Artisan PIOL was introduced with a redesigned shape, and is now frequently encountered to those with high myopia.

Refractive surgery not only produces a positive benefit on the visual qualities, but also leads to some types of severe functional sequelae such as strabismus

and decompensation of binocularity besides its known complications.[2-7] These complications are usually manifested in early stage of postoperative period, but may became long-standing symptoms. Little has been known on causative mechanism of functional complications after refractive surgery, especially Artisan PIOL implantation. Moreover, to our knowledge, there has been no such a study concerning the changes of vergence amplitudes.

The purpose of this study was to evaluate the parameters of vergence such as convergence, divergence, accommodative convergence to accommodation ratio, and near point of convergence changes following the Artisan PIOL implantation, to identify the effect on the vergence amplitudes.

II. MATERIALS AND METHODS

1. Patients

The study included 21 patients (1 man and 20 women) who underwent implantation of an Artisan PIOL by same surgeon (J.K.K) at Kangnam Balgeunsaessang Laser Eye Clinic, Seoul, Korea from December 2006 to January 2007. Patients' age ranged from 19 to 34 years (mean: 25.1±4.7 years) and the preoperative refractive error ranged from -5.75 diopters (D) to -10.37 D (mean: -8.86±3.93 D) in spherical equivalent (SE). All of the patients wore contact lenses and spectacles as they preferred. Demographics of 21 patients are summarized in Table 1.

Preoperative best corrected visual acuity (BCVA) was >20/25 in all of 21

patients. Patients with systemic disease, previous corneal, intraocular, or extraocular surgery, anterior segment pathologic condition, glaucoma, and pre-existing macular degeneration or retinopathy were excluded.

Table 1. Demographics of patients who underwent the Artisan phakic intraocular lens implantation

Parameter	Value
Number of patients (male:female)	21 (1:20)
Mean age[1] (range) (y)	25.1±4.7 (19～34)
Mean refractive error[1] (range) (D)	-8.86±3.93 (-5.75～-10.37)
Best corrected visual acuity	>20/25

[1]Expressed in mean±standard deviation (SD)
y:years old, D:diopters

2. Preoperative examination

A. Artisan PIOL implantation

Preoperative examination included full ophthalmic evaluation including uncorrected visual acuity (UCVA) and BCVA with cycloplegic and manifest refraction, slit-lamp examination, tonometry, keratometry, pupil diameter, iris configuration, and full indirect ophthalmoscope examination. Complementary evaluations were followed: topography (Orbscan II, version 3.0), axial length and anterior chamber depth with ultrasound and central endothelial cell count (Konan SP8000, Hyogo, Japan).

B. Vergence amplitudes

Convergence, divergence, and vertical vergence were evaluated with rotary prism. Placing it before one eye with glasses on, the distant (6m) and near (33 cm) were both evaluated with speed of 4 prism/second. Convergence, vertical

vergence and divergence were measured in an order for the constancy, and target was fixed as a Snellen E chart, size of 20/30. The rotary prism was placed base-out for the convergence, base-in for the divergence, and base-up for the vertical vergence. As rotary prism increased in diopters, the instant which produces diplopia was defined as 'break point', and the instant immediate after the break point where diplopia diminishes was defined as 'recovery point'.

Stimulus accommodative convergence to accommodation (AC/A) ratio was measured using the lens gradient method. Through fully corrected spectacles, the baseline angle of ocular alignment for the accommodative target at 6 m was measured with the alternate prism cover test. Afterward, placing -3 D lens before the eye with full correction, deviated angle was measured. With the result from the procedure, stimulus AC/A ratio can be calculated using the following formula:

Stimulus AC/A ratio = (△1-△0)/D

where: △1 = deviation with -3 D lens in prism diopters

△0 = deviation in primary position in prism diopters

D = Diopters of lens placed over

The measurements were repeated three times, and the average of the measurements was considered to be the representative value.

By moving a dim light target at a speed of 2-3 cm/sec closer to a center of horizontal plane formed by both eyes, the near point of convergence (NPC)

was measured. As instructed to follow the target as it closes to the face, if target becomes duplicated, the point will be the NPC, the distance between lateral rim and the point.

3. Surgical procedure

Surgery was performed by the same surgeon (J.K.K.), and surgical protocol was identical in all cases. A week before the surgery, laser peripheral iridectomy was performed at 12 o'clock direction on a candidate eye for preventing pupillary block glaucoma. Antibiotics and fluorometholone eye drops were administered four times a day until the day before the surgery.

All procedures were performed under local anesthesia with peribulbar injection. With a main scleral tunnel incision at 12 o'clock and two lateral paracentesis at 10 and 2 o'clock made, lens was introduced into anterior chamber and enclavated to iris at 3 and 9 o'clock meridian. The viscoelastics were used to maintain the depth of the anterior chamber and removed just before wound tightening. The incision was closed with 10/0 nylon interrupted suture and postoperative medication including topical antibiotics and steroid was maintained over 4 weeks after the surgery.

4. Follow-up

All patients were examined on the first postoperative day, and 1, 2, 4 weeks after surgery. The following examination schedule proceeded with patient's convenience and condition. Visual acuity, tonometry, slit-lamp examination, endothelial specular microscopy, and indirect ophthalmoscopy were included on

routine examination on follow-up.

Refractive errors, postoperative UCVA, vergence amplitude, AC/A ratio, and NPC were checked as done in preoperative manner at 1 week, 1 month and 3 months after the surgery and compared with those of preoperative status.

5. Statistics

Statistical analysis was performed with the Kruskal-Wallis H test. A P value of less than 0.05 was considered significant. The SPSS program (Ver. 12.0; SPSS, Inc., Chicago, IL, USA) was used for all statistical calculations.

III. RESULTS

Pre- and postoperative refractive errors are shown in Figure 1. Comparing those of preoperative as -8.82±3.44 and -8.90±4.71 D in right and left eye, respectively, postoperative refractive errors showed statistically significant changes at 1 week, 1 and 3 months after the surgery ($p<0.05$). Refractive errors were -1.75±1.47 and -2.21±2.57, -0.75±0.15 and -0.64±0.51, and -0.50±0.30 and -0.52±1.33 D in right and left in an order of 1 week, 1 and 3 months after the surgery.

Table 2 shows the vergence amplitude of break point findings before and after the Artisan PIOL implantation. No significant changes of vergence parameter values were noticed. Among three parameters of vergence amplitudes, the convergence showed the highest value, divergence in second, and the vertical

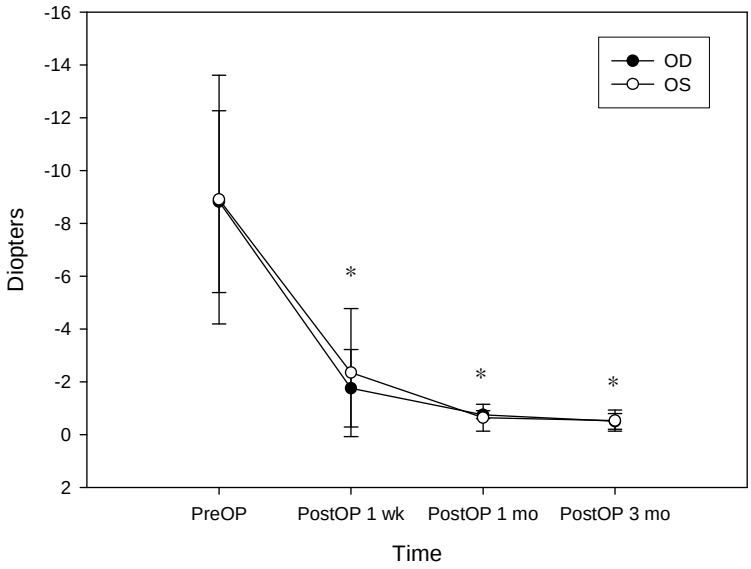

Figure 1. Refractive errors measured before and after the Artisan PIOL implantation. Significant decrease in refractive errors are observed at 1 week, 1 month, and 3 months after the surgery ($p<0.05$). There was no statistical difference between right and left eye at all follow-up period. Error bars show standard deviations, and asterisks show statistical significances.
PreOP: preoperative, PostOP: postoperative, wk: week, mo: month, OD: right eye, OS: left eye.

vergence showed the lowest value of all at before and 1 week, 1 month, and 3 months after the surgery. Amplitude of vergence was greater when induced by target distance than when induced by target near, after full correction of refractive errors.

Table 2. Break points of vergence parameters before and after the Artisan PIOL implantation

Break point[1]	PreOP		PostOP 1 wk		PostOP 1 mo		PostOP 3 mo	
	Near[2]	Distant[3]	Near	Distant	Near	Distant	Near	Distant
Convergence	25.17±3.92	18.83±5.81	24.87±2.15	18.81±4.25	26.11±3.54	18.97±5.12	26.45±3.17	19.01±4.35
Divergence	16.86±2.80	11.29±3.10	16.11±3.18	10.97±3.48	16.92±2.14	11.10±3.12	16.54±4.10	11.26±3.54
Vertical Vergence	8.00±1.15	7.71±2.14	7.85±1.51	7.55±1.59	8.12±1.55	7.58±2.65	8.05±1.15	7.45±2.25

[1]Prism diopters (PD) in scale, and expressed in mean±standard deviation.
[2]Values measured with near target of 33 cm.
[3]Values measured with distant target of 6 m.
PreOP: preoperative, PostOP: postoperative, wk: week, mo: months.

Recovery points of vergence parameters are shown in Table 3. Identical to the break points, the recovery point of convergence marked the highest value at all of follow-up periods. But, no significant changes were noted by the values of postoperative follow-up periods compared to preoperative values. In both break and recovery points of vergence, the amplitude of convergence tend to increase as follow-up period prolongs except at 1 week after the surgery.

Table 3. Recovery points of vergence parameters before and after the Artisan PIOL implantation

Recovery point[1]	PreOP		PostOP 1 wk		PostOP 1 mo		PostOP 3 mo	
	Near[2]	Distant[3]	Near	Distant	Near	Distant	Near	Distant
Convergence	17.33±4.32	12.17±4.83	16.97±3.54	12.05±4.21	17.58±4.35	12.24±5.11	17.84±3.65	12.41±4.12
Divergence	10.71±2.21	6.29±2.14	10.21±2.87	6.38±3.54	10.98±1.04	6.12±3.51	10.26±1.63	6.84±3.56
Vertical Vergence	3.43±0.79	4.00±1.00	3.00±0.89	3.89±0.76	3.15±0.88	3.87±1.12	3.58±0.57	4.02±1.10

[1]Prism diopters (PD) in scale, and expressed in mean±standard deviation.
[2]Values measured with near target of 33 cm.
[3]Values measured with distant target of 6 m.
PreOP: preoperative, PostOP: postoperative, wk: week, mo: months.

NPC slightly decreased as follow-up periods proceed as 3.79±1.82, 3.66±1.78, and 3.65±1.92 cm at 1 week, 1 and 3 months after surgery respectively compare with the preoperative value of 3.95±1.30 cm. But it was not enough for a statistical significance.

Through all of the vergence parameters, stimulus AC/A ratio was a sole factor that showed a statistically significant change, and shown in Figure 2. Comparison of stimulus AC/A ratio before and after the surgery showed an improvement of AC/A ratio, decrease in numeric expression. Before the surgery, the stimulus AC/A ratio was 4.39±0.79 △/D, and changes occurred as 4.41±1.49,

4.12±0.59, and 3.79±0.47 △/D at 1 week, 1 and 3 months after the surgery, respectively ($p<0.05$).

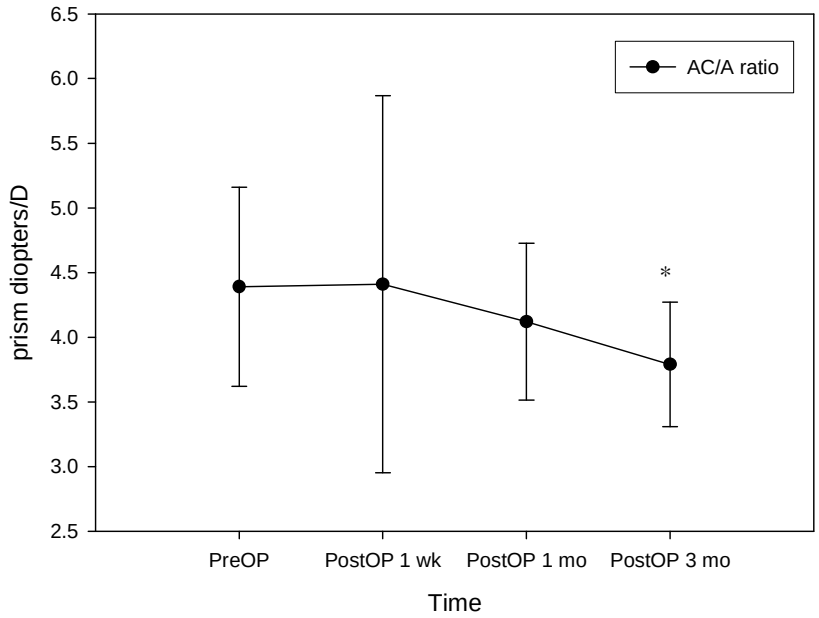

Figure 2. Change of stimulus AC/A ratio after the Artisan PIOL implantation. After slight increase at 1 week after the surgery, AC/A ratio decreased afterward, resulting a statistical significance at 3 months after the surgery compared to preoperative value ($p<0.05$). Error bars show standard deviations, and the asterisk shows a statistical significance.
PreOP: preoperative, PostOP: postoperative, wk: week, mo: month.

IV. DISCUSSION

The effect on the vergence parameters by the implantation of the Artisan PIOL was not found except on stimulus AC/A ratio, which significantly decreased 3 months after the implantation. The convergence after the surgery slightly increased as follow-up periods proceeded, but not enough for a statistical significance.

Relation of AC/A ratio to refractive errors had been reported in numerous reports in past, revealing general increase in myopes. Rosenfield and Gilmartin[8] reported greater accommodative convergence and stimulus AC/A ratios in myopes than in emmetropes. In younger population, myopic children had been found to have reduced accommodation, whether measured in the laboratory[9,10] or clinically,[11,12] which result in increase of AC/A ratio. Additionally, the significantly higher AC/A ratios in the children who became myopic are known to be a result of significantly reduced accommodation.[13] Manas[14] reported the mean stimulus AC/A ratio of 5.1 △/D(SD=2.1) in myopes, higher than the emmetropes' average as 3.4 △/D(SD=2.2). In present study, enrolled patients' mean stimulus AC/A ratio was 4.39±0.79 △/D, slightly higher than that of emmetropes known as 3.7-4.2 △/D,[15] which corresponds to previous reports.

Change of the stimulus AC/A ratio after the refractive surgery was seldomly discussed before. After LASIK, no significant change of response AC/A ratio between the group wearing glasses before surgery and naked after surgery had been reported,[16] but none associated with the Artisan PIOL implantation, and none associated with stimulus AC/A ratio. In the present study, the stimulus AC/A ratio decreased 3 months after the surgery significantly. The cause of the decrease can be speculated as a decrease in accommodative convergence or an elevation in accommodation or combination of both. Because myopes are being accustomed to less accommodation and less convergence per unit distance due to the prismatic effect of spectacles,[17] when placed in the optically equivalent contact lens correction, nearly identical to the Artisan PIOL, they require more of both to accomplish the same visual tasks. So as adaptation period prolongs

after the implantation, the patients are adapted to accommodate and convergent more to acquire the same visual tasks as before, resulting the decrease in AC/A ratio. This phenomenon may expressed in clinical symptoms such as diplopia, where patient's not fully adapted to naked eyes at immediate postoperative period with AC/A ratio remaining. But, as adaptation periods proceed with more convergence and accommodation equipped, symptoms would subside. But, the exact extent of the mechanism concerning the changes in AC/A ratio would be evaluated in further investigations.

In extension of a same line, convergence power, which showed a slight decrease 1 week after, but a pattern of increase afterward, may related to the change of the stimulus AC/A ratio. As accommodative convergence recovers after the implantation, the convergence power would recover simultaneously, resulting in an increase in convergence power. If this speculation stands correctly, the convergence change might turn out to be statistically significant with the further study with long-period of follow-up.

In current study, the mean refractive error 1 week after the implantation makes a gap compared with those of 1 month and 3 months. Because several sutures on main scleral tunnel incision induced the astigmatism, elevated spherical equivalent diopters would be resulted. But after suture removal around 1 month after the implantation, the induced astigmatism would resolve without any complications which can explain the significant difference between 1 week and 1 month after the implantation.

This prospective study shows a decrease in the stimulus AC/A ratio with unchanged vergence parameters such as convergence, divergence, and vertical

vergence after the Artisan PIOL implantation. Because of limited cases and time, further follow-up with more number of cases is necessary to confirm these data and to long-term effect of the Artisan PIOL implantation on vergence parameters.

V. CONCLUSION

The current study aims at the change of vergence parameters: convergence, divergence, vertical vergence, near point of convergence and AC/A ratio after the Artisan PIOL implantation, an alternative to those who are not suitable for the laser refractive surgery because of anatomical structures. The result revealed no such effect of the surgery on vergence amplitudes except the stimulus AC/A ratio which decreased significantly 3 months after the surgery. Recovery of AC/A might predict and explain the functional subjective symptoms of individuals related to the Artisan PIOL. The future study would investigate further to evaluate the long-term effect of the Artisan PIOL on vergence parameters.

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ABSTRACT (IN KOREAN)

Artisan phakic intraocular lens 삽입술 후 이향운동력의 변화

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목적: 고도근시 환자에게 시행되는 Artisan phakic intraocular lens (PIOL) 삽입술 후 이향운동력의 변화를 알아보고자 하였다.

방법: Artisan PIOL 삽입술을 시행 받은 환자를 대상으로 전향적 연구가 진행되었다. 수술 전, 굴절이상측정 등의 전반적인 안과검사를 시행하였다. Rotary prism을 이용하여 눈모음, 눈벌림, 수직융합력을 측정하였으며, 눈모임근점 역시 측정되었다. 렌즈차 이용법을 통해 조절모임 대 조절 (AC/A) 비를 측정하였다. Artisan PIOL 삽입술 후, 이향움직임 항목들을 포함한 동일한 검사가 수술 1주 후, 1개월 후, 그리고 3개월 후에 반복되었으며, 이를 통해 수술 전 결과와 비교하였다.

결과: 총 21명 (남자 1명, 여자 20명)의 환자가 본 연구에 참여하였다. 평균 연령은 25.1±4.7 세이였으며, 수술 전 굴절이상은 -8.86±3.93 디옵터(D) 이었다. 수술 후, 평균굴절이상은 ±1.00 D 이내로 감소되어 통계학적으로 유의한 변화가 관찰되었으며, 수술과 연관된 합병증은 관찰되지 않았다. 눈모음, 눈벌림, 수직이향력 및 눈모임근점 등의 이향운동력은 수술 후 유의하게 변하지 않았지만, AC/A 비는 수술 전 4.39±0.79 △/D 와 비교하여 수술 후 3개월째 3.79±0.47 △/D 로 확인되어 통계학적으로 유의한 변화를 관찰할 수 있었다.

결론: Artisan PIOL 삽입술은 눈모임, 눈벌림, 수직이향력 및 눈모임근점에 통계학

적으로 유의한 영향을 발생 시키지 않았다. 그러나, AC/A 비는 수술 후 3개월에 통계학적으로 유의한 감소를 보였으며, 이는 수술 초기에 발생하는 복시 등의 주관적인 기능적 불편감을 일부분 설명할 수 있을 것으로 사료된다.

핵심되는 말: Artisan PIOL, 눈모임, 눈벌림, AC/A 비, 이향운동