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Intraoperative Aberrometer Plus Image-guided System for Astigmatism Correction Compared to Standard Image-guided System for Significant Lens Opacity

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Abstract

Background/Aim: This study aimed to evaluate astigmatism after cataract surgery by comparing the use of an intraoperative aberrometer combined with an image-guided system (VLynk) *versus* an image-guided system alone (Verion) in patients with significant lens opacity.

Patients and Methods: The main outcomes included the corrected distance visual acuity (CDVA), astigmatism, spherical equivalent (SE) status, and the predicting factors for reduced astigmatism in the two groups.

Results: In this study, 73 patients were enrolled in the study group (VLynk); 76 individuals constituted the control group (Verion). Preoperative and postoperative CDVA between both groups were similar (all $p>0.05$). The postoperative cylinder power ($p=0.002$), postoperative SE ($p=0.004$), and the difference between real SE and estimated SE ($p=0.001$) were significantly lower in the VLynk group. Implantation of toric IOL was associated with less astigmatism in both groups (both $p<0.05$). Longer axial length ($p=0.013$) and higher central corneal power ($p=0.023$) were correlated with greater astigmatism in the Verion group.

Conclusion: VLynk is correlated with better postoperative astigmatism control and predictability compared to Verion in patients with significant lens opacity.

Keywords: VLynk, Verion, toric, astigmatism, cataract, lens opacity.

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Introduction

Cataract surgery can improve visual acuity not only by eradicating the turbid crystalline lens but also through reduction of astigmatism (1-3). In general, the effect of astigmatism on the impairment of vision is significant when the amount of astigmatism exceeds 1.00 diopter (D) (4). Recently, the introduction of toric intraocular lens (IOL) has allowed surgeons to choose the IOL with the appropriate cylinder power to eradicate corneal astigmatism and improve postoperative visual performance (5-7). However, the postoperative deviation in the axis of toric IOL can result in bothersome postoperative photopsia (8, 9). Thus, the calculation of proper refractive power and axis of toric IOL is vital, especially in those whose preoperative astigmatism is difficult to measure, such as patients with a dense cataract (10).

Traditionally, manual markings are drawn on the cornea to place the toric IOL in the proper axis (11). Recently, image-guided systems have been invented to allow more accurate placement of the toric IOL (12-14). The Verion system is an image-guided system that tracks the eye's position and projects the axis line on the corneal surface intraoperatively, according to the astigmatism data obtained preoperatively. This guides the surgeon in positioning the toric IOL accurately (15). In a previous study, the utilization of the Verion system significantly reduced IOL misalignment compared with manual marking in patients with astigmatism over 1.25 D (16). Similarly, cataract surgery with the use of the Verion system results in less postoperative residual refractive astigmatism and improved manifest refraction spherical equivalent (17).

For more precise refractive power calculation, the concept of measuring the manifest astigmatism after removal of opacified lens during cataract surgery was proposed. The first intraoperative aberrometer was introduced in the early 2010 (18). Optiwave Refractive Analysis (ORA) is an intraoperative aberrometer that measures the refractive status after cataract removal *via* a common IOL calculator programmed into the ORA device (19-24). The VLynk device, a combination of the Verion and ORA systems, has also been applied in clinical practice. In a preceding research, the combination of Femtosecond laser-assisted cataract surgery (FLACS), Verion image-guided system, and the intraoperative aberrometer did not significantly improve the outcome of astigmatism correction compared to traditional management (25). Nevertheless, only patients with bilateral uncomplicated cataract and without other major ocular disorders were enrolled in that study (25). Theoretically, VLynk is most useful for patients whose degree of astigmatism cannot be easily obtained and calculated preoperatively. Thus, further studies are needed to address these subjects.

The aim of the current research was to evaluate the effectiveness of the VLynk system and the Verion system in reducing astigmatism in patients whose lenticular astigmatism was difficult to measure due to significant lens opacity. In addition, the study also analyzed the impact of FLACS, implantation of toric IOL, and other ocular parameters on the outcome of astigmatism correction.

Patients and Methods

Data source. A retrospective cohort study was conducted in the First-Brightness Eye Clinic in Taiwan *via* a review of the medical records. Patients were enrolled in the VLynk group if they fulfilled the following criteria: 1) diagnosed with advanced nuclear sclerosis, cortical opacity, anterior subcapsular opacification or posterior subcapsular opacification, 2) received cataract surgery with the application of VLynk device (Alcon Laboratory Inc., Fort Worth, TX, USA), 3) were aged between 50 and 80 years old, and 4) had a follow up period of more than six months. We used the Lens Opacities Classification System III to evaluate the degree of lens opacity. Advanced cataract was defined as follows: nuclear sclerosis greater than NO5, cortical opacity greater than C4, posterior subcapsular opacification greater than P4, and a similar appearance to P4 for anterior subcapsular opacification. The exclusion criteria included: 1) initial corrected distance visual acuity

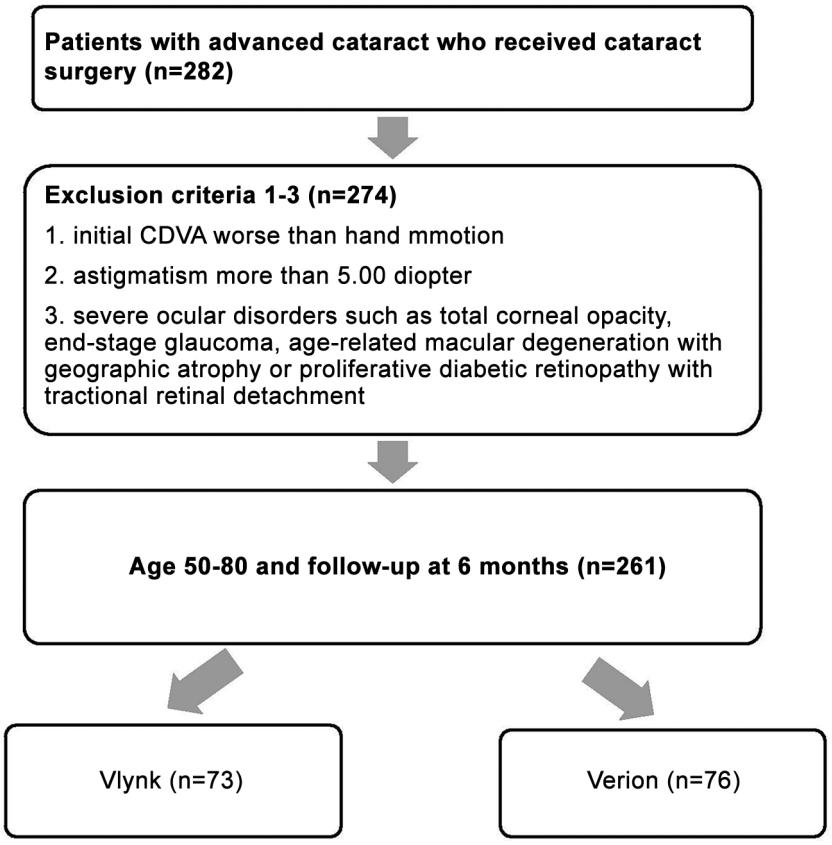

Figure 1. *Screening flowchart.*

(CDVA) worse than hand motion; 2) astigmatism greater than 5.00 D; and 3) extremely severe ocular disorders such as total corneal opacity, end-stage glaucoma, age-related macular degeneration with geographic atrophy or proliferative diabetic retinopathy with tractional retinal detachment. For comparison, a control group was formed from patients who met similar inclusion criteria but received surgery with the use of the Verion system (Alcon Laboratory Inc.) at the same institution and during the same period (Figure 1).

Surgical procedure. All cataract surgeries were performed by a single ophthalmologist (H.Y. Lin). Toric IOL implantation was considered in patients with astigmatism of more than 1.00 D. As a routine, details about Verion-assisted surgery were explained to all patients. Patients suitable for the VLynk application were informed about the course of surgery. First, routine preoperative examinations were arranged. Hill-RBF formula was applied as the primary preoperative prediction formula. Additional evaluation was performed by the Verion system (Alcon Laboratory Inc.), and the data were sent to the FLAC device (LenSx, Alcon Laboratory Inc.) and ORA system (Alcon Laboratory Inc.). The eye scheduled for operation was sterilized with povidone-iodine and then was draped aseptically. Topical Moxifloxacin eyedrops (Alcon Laboratory Inc.) were instilled just before the start of cataract surgery to avoid infection. The main corneal incision was positioned at 135 degrees. Phacoemulsification and lens cortical aspiration were performed using a single machine (Centurion, Alcon Laboratory Inc). After removal of the cataract, the residual astigmatism was calculated *via* the VLynk system, and the IOL power with the appropriate

degree was recommended by the VLynk. The IOL was then implanted, during which the proper axis for placement was guided by the Verion system in real time. The corneal wound was sealed by stromal hydration, and Moxifloxacin eyedrop was instilled again before the end of the surgery. Postoperatively, Tobradex ointment was applied four times per day for one week.

Main outcome measurement. The primary outcome was set as the amount of residual astigmatism in the VLynk and Verion group according to the medical documents. The differences between the estimated residual astigmatism and the real residual astigmatism between the two groups were analyzed. Besides astigmatism, the visual acuity, including the preoperative CDVA one week before the surgery, postoperative CDVA one month and six months after the cataract surgery were collected from the medical documents. Other ocular parameters including axial length (AL), anterior chamber depth (ACD), central corneal power, lens thickness (LT), and corneal diameter (CD) were collected *via* the optical biometry (IOL master 500, Zeiss, Oberkochen, Germany) and the Verion system. The above data were included in the statistical analysis. Possible complications including elevated intraocular pressure, persistent corneal edema, would dehiscence, wound rupture, persistent corneal epithelial defect, uveitis, cystoid macular edema, retinal detachment, infectious keratitis, and postoperative endophthalmitis were also recorded. Postoperative photic phenomena, including halo and glare, were also documented if they persisted for more than six months.

Statistical analysis. All statistical analyses were conducted using the SPSS 20 version (SPSS Inc. Chicago, IL, USA). Descriptive analysis was used to present the mean and standard deviation (SD) of the astigmatism and other parameters; the Chi-Square test was applied to evaluate the ordinary parameters, and independent *T*-test was used to compare the numerical parameters. The preoperative and postoperative visual acuity, the preoperative and postoperative cylinder power, the preoperative and postoperative spherical equivalent (SE), the estimated postoperative SE, and the difference between real postoperative SE and estimated postoperative SE were analyzed using the application of generalized estimated equation (GEE), which considers the effect of all parameters in the analysis model and yielded the adjusted odds ratio (aOR) and corresponded 95% confidence interval (CI). In addition, the influence of each parameter on the refractive outcome of both the VLynk and Verion groups were analyzed using the GEE model separately. A *p*-value less than 0.05 was regarded as statistically significant.

Results

A total of 73 and 76 individuals were enrolled in the VLynk and Verion groups, respectively. The mean age in the VLynk group was 65.73 years old, and in the Verion group, it was 67.08 years old, without a significant difference between the groups (p=0.235). There were 29 men and 44 women in the VLynk group, while another 33 male and 43 female were enrolled in the Verion group; the male-to-female ratio was similar between the two groups (p=0.404). The distribution of systemic disease was similar between the two groups (p=0.128); however, the Verion group showed a higher rate of retinal disease than the VLynk group (p=0.013). No significant difference was observed in the ocular parameters, numbers of FLAC application, and numbers of toric IOL implantations between the two groups (all p>0.05) (Table I).

The preoperative UDVA, postoperative 1-month UDVA, and postoperative 6-month UDVA in the VLynk group were 0.71±0.38, 0.17±0.20, and 0.07±0.18, respectively. The corresponding UDVA in the Verion group were 0.65±0.49, 0.27±0.26, and 0.15±0.23, respectively. The preoperative CDVA, postoperative 1-month CDVA, and postoperative 6-month CDVA in the VLynk group were 0.60±0.33, 0.16±0.18, and 0.07±0.15, respectively. The corresponding CDVA in the Verion group were 0.59±0.44, 0.20±0.28, and 0.10±0.21, respectively. The CDVA between both groups were similar throughout the study interval (all p>0.05) (Table II). The preoperative cylinder power (–1.66±2.53

Table I. *Clinical characteristics of the study population.*

Characteristics	VLynk (n=73)	Verion (n=76)	*p*-Value
Age	65.73±9.52	67.08±9.82	0.235
Sex (M:F)	29:44	33:43	0.404
Systemic diseases			0.128
HTN	19	14	
DM	18	15	
CAD	10	5	
Others	7	0	
Cataract grade			0.215
NO5 or more	73	76	
C4 or more	14	13	
P4 or more	19	25	
Ocular diseases			0.013*
Retinal disease	3	13	
Myopia	13	9	
Dry eye	0	2	
Glaucoma	1	4	
Ocular parameters			
AL	23.56±1.84	23.79±1.63	0.352
ACD	3.35±0.93	3.30±0.74	0.660
Central corneal power	44.62±3.05	45.31±2.94	0.121
LT	4.46±1.57	4.20±1.62	0.747
CD	12.44±0.77	12.56±0.85	0.829
Use of FLAC	47	50	0.941
Use of toric IOL	32	30	0.776

HTN: Hypertension; DM: diabetes mellitus; CAD: coronary arterial disease; AL: axial length; ACD: anterior chamber depth; LT: lens thickness; CD: corneal diameter; FLAC: Femtosecond laser-assisted cataract surgery; IOL: intraocular lens. *Significant difference between the two groups.

Table II. *Preoperative and postoperative uncorrected and corrected distance visual acuity between the two groups.*

	VLynk	Verion	*p*-Value
UDVA			
Preoperative	0.71±0.38	0.65±0.49	0.408
1 month postoperative	0.17±0.20	0.27±0.26	0.010*
6 months postoperative	0.07±0.18	0.15±0.23	0.018*
CDVA			
Preoperative	0.60±0.33	0.59±0.44	0.658
1 month postoperative	0.16±0.18	0.20±0.28	0.106
6 months postoperative	0.07±0.15	0.10±0.21	0.075

UDVA: Corrected distance visual acuity; CDVA: corrected distance visual acuity. *Significant difference between the two groups.

Table III. *Refractive status between the two groups before and after cataract surgery.*

Refraction	VLynk	Verion	*p*-Value
Preoperative cylinder power	−1.66±2.53	–1.97±3.11	0.262
Postoperative cylinder power	–0.28±0.15	–0.96±0.88	0.002*
Preoperative SE	–2.08±9.06	–3.03±5.76	0.455
Estimate postoperative SE	–0.15±0.24	–0.16±0.45	0.903
Real postoperative SE	–0.18±0.41	–0.57±0.74	0.004*
Estimate-real difference of SE	–0.03±0.21	–0.41±0.58	0.001*
Angle of alignment error	0.76±2.48	2.89±8.37	0.038

SE: Spherical equivalent. *Significant difference between the two groups.

versus –1.97±3.11, *p*=0.262), preoperative SE (–2.08±9.06 *versus* –3.03±5.76, *p*=0.455), and estimated SE (–0.15±0.24 *versus* –0.16±0.45, *p*=0.903) were similar between the VLynk and Verion groups. However, both the postoperative cylinder power (–0.28±0.15 *versus* –0.96±0.88, *p*=0.002) as well as the postoperative SE (–0.18±0.41 *versus* –0.57±0.74, *p*=0.004) were significantly lower in the VLynk group compared to the Verion group. Furthermore, the difference between the real SE and estimated SE was also significantly lower in the VLynk group compared to the Verion group (–0.03±0.21 *versus* –0.41±0.58, *p*=0.001). The angle of alignment error was 0.76±2.48 and 2.89±8.37 in the VLynk and Verion group, respectively (*p*=0.038) (Table III).

The predictive factor for a lesser refractive error in the VLynk and Verion groups was the implantation of a toric IOL, which was significantly associated with less SE (aOR=2.04, 95%CI=1.05-4.41, *p*=0.004) in the VLynk group. However, other parameters including the application of Femtosecond laser-assisted device, axial length, anterior chamber depth, central corneal power, lens thickness, and corneal diameter did not significantly alter the refractive outcome of VLynk-assisted cataract surgery (all *p*>0.05) (Table IV). However, toric IOL implantation was still significantly associated with less SE in the Verion group, although the aOR was numerically lower than that of the VLynk group (aOR=1.22, 95%CI=1.01-1.74, *p*=0.038). Moreover, longer axial length (aOR=0.58, 95%CI=0.10-0.92, *p*=0.013) and higher central corneal power (aOR=0.44, 95%CI=0.05-0.61, *p*=0.023) were correlated with a higher SE in the Verion group. Other parameters including the application of Femtosecond laser-assisted device, anterior chamber depth, lens thickness, and corneal diameter did

Table IV. *The predicting factor for less astigmatism in the VLynk group.*

Predicting factor	aHR (95%CI)	*p*-Value
FLAC	3.54 (0.91-6.87)	0.331
Toric IOL	2.04 (1.05-4.41)*	0.004*
AL	0.98 (0.67-4.88)	0.659
ACD	1.32 (0.45-2.37)	0.442
Central corneal power	2.13 (0.72-6.39)	0.186
LT	1.02 (0.89-1.50)	0.972
CD	1.24 (0.68-1.31)	0.705

aHR: Adjusted hazard ratio; CI: confidence interval; FLAC: Femtosecond laser-assisted cataract surgery; IOL: intraocular lens; AL: axial length; ACD: anterior chamber depth; LT: lens thickness; CD: corneal diameter. *Significantly and positively correlated with a less refractive error.

Table V. *The predicting factor for less astigmatism in the Verion group.*

Predicting factor	aHR (95%CI)	*p*-Value
FLAC	1.35 (0.62-3.45)	0.517
Toric IOL	1.22 (1.01-1.74)*	0.038*
AL	0.58 (0.10-0.92)*	0.013*
ACD	0.95 (0.36-1.67)	0.876
Central corneal power	0.44 (0.05-0.61)*	0.023*
LT	1.31 (0.73-4.82)	0.894
CD	1.09 (0.47-1.23)	0.827

aHR: Adjusted hazard ratio; CI: confidence interval; FLAC: Femtosecond laser-assisted cataract surgery; IOL: intraocular lens; AL: axial length; ACD: anterior chamber depth; LT: lens thickness; CD: corneal diameter. *Significantly correlated with a less refractive error.

not significantly influence the refractive outcome of individuals who underwent cataract surgery with the application of the Verion system (all $p>0.05$) (Table V).

In regards to postoperative complications, no severe postoperative complications including persistent corneal edema, wound dehiscence, wound rupture, persistent corneal epithelial defect, uveitis, cystoid macular edema, retinal detachment, infectious keratitis, and postoperative endophthalmitis were recorded in the two groups.

Sixteen patients in the VLynk group and 14 patients in the Verion group reported mild postoperative pain, which subsided within one week with the use of analgesics. Seven patients reported persistent postoperative photic phenomena in the Verion group and one patient experienced similar symptoms in the VLynk group, with no significant difference between the two groups ($p=0.107$).

Discussion

The current study showed lower postoperative astigmatism in the VLynk group compared to the Verion group, along with greater accuracy in the estimated postoperative astigmatism. Moreover, the implantation of toric IOL can contribute to a better postoperative refraction status in both the VLynk and Verion groups. On the other hand, longer AL and higher central corneal power were associated with more residual astigmatism in the population receiving cataract surgery with Verion assistance.

The current study demonstrated more effective astigmatism retardation in the VLynk group compared to the Verion group. In a previous study, the application of VLynk did not result in less residual astigmatism compared to the traditional marking method for toric IOL placement (25). However, the patients recruited in that study were diagnosed with uncomplicated cataract, while the participants included in our study were those with dense nuclear sclerosis cataract or nuclear sclerosis with other lens opacities, such as posterior subcapsular opacity or anterior subcapsular opacity (25). To our knowledge, there are limited studies demonstrating the effect of astigmatism reduction using the VLynk system in patients with advanced cataract. Moreover, the control group in our current study included patients that received cataract surgery with the Verion system, which can guide the positioning of astigmatism axis intraoperatively and enable more precise axis placement compared to the traditional marking technique during toric IOL implantation (26). However, in the current study, both the residual astigmatism and the difference between the estimated residual SE and real residual SE were higher in the Verion group compared to the VLynk group. This finding may indicate the importance of intraoperative refractive measurement in patients whose precise preoperative astigmatism cannot be obtained due to marked lens opacity. However, whether the refractive measurements of the VLynk system are affected by

corneal disorders, such as corneal opacity or ectasic condition, needs further evaluation.

In this study, the main predictive factor for astigmatism reduction in patients who received VLynk- or Verion-assisted cataract surgery was the implantation of a toric IOL, which resulted in more effective control of postoperative astigmatism and a higher aOR. This result is reasonable, as toric IOL has been an effective method used for astigmatism reduction in cataract surgery for decades (6, 7, 27, 28). In general, implantation of toric IOL was not considered when the amount of preoperative astigmatism was not prominent, which included patients with less than 1 D, both in our clinic and in previous studies (28). Nevertheless, the current study revealed that the patients who received toric IOL implantation had less postoperative astigmatism compared to those who did not receive a toric IOL, in both the VLynk and Verion groups. This outcome may suggest widening the threshold for toric IOL implantation if advanced guiding systems are available. Additionally, longer AL and higher central corneal power resulted in higher residual astigmatism in the Verion group but not in the VLynk group. Although both the mean AL and mean central corneal power in the Verion group were numerically higher than those in the VLynk group, there was little evidence to suggest that the use of intraoperative aberrometry would benefit this population. We speculate that the multiple measurements procured in the VLynk group contributed to a more precise astigmatism prediction. Furthermore, the effect of significant lens opacity may lead to increased preoperative measurement error due to low biometry accuracy. Consequently, multiple measurements, whether with or without the application of VLynk system, are suggested in individuals with higher AL or central corneal power.

Regarding the CDVA, both the VLynk and Verion group reached a mean CDVA non-inferior to 0.8 four weeks after the cataract surgery. The CDVA for both groups in the current study is comparable to those in previous studies (29, 30). The Verion group showed a numerically lower CDVA compared to the VLynk group, which may be related to the higher ratio of retinal disease in the Verion group. For the patients with retinal disease, approximately half were diagnosed with non-proliferative diabetic retinopathy, while branch retinal venous occlusion and epiretinal membrane comprised the rest. In addition, the rate of glaucoma was also numerically higher in the Verion group compared to the VLynk group. The presence of retinal and glaucomatous disorders may influence the postoperative CDVA to some extent, although it was not statistically significant.

As for the postoperative visual disturbance and complications, seven patients in the Verion group reported persistent postoperative photic phenomena compared to only one patient in the VLynk group. These differences were not statistically significant, but imply that patient with Verion assistance may be under a higher risk for developing postoperative visual symptom compared to individuals receiving VLynk assistance. Because postoperative photic phenomena may significantly influence the quality of life in patients who receive multifocal or multifocal-toric IOL implantation (31, 32), the VLynk device may be recommended for those with significant lens opacity requiring astigmatism correction. As expected, no severe postoperative complications were observed in both groups. Although we did not perform intracameral cefuroxime injection, as suggested in a previous study (33), the performance of povidone iodine swab and perioperative moxifloxacin utilization may also effectively reduce the possibility of postoperative infection.

Study limitations. The small study population with a total of 149 participants diminishes the statistical power of our study. Additionally, the amount of preoperative astigmatism in the Verion group was numerically higher than that in the VLynk group. Although the difference was not statistically significant, it may render some bias to the analysis of residual postoperative astigmatism and the predictive factor for postoperative astigmatism. Furthermore, we did not collect the data for those who received the traditional marking technique as another control group for comparison, since this method has been

seldom used in our institution for years. Moreover, higher order aberration should be measured in all participants, as it can also influence patients' visual satisfaction after cataract surgery (34); only less than half of our patients received such exam due to the retrospective design of our study. However, since higher order aberration does not significantly influence astigmatism calculation, the analyses of astigmatism in the current study may not be substantially influenced by this oversight.

Conclusion

The application of the VLynk system can contribute to lower postoperative astigmatism and more accuracy in astigmatism prediction compared to Verion assisted cataract surgery in individuals with significant lens opacity. Implantation of toric IOL is effective for reducing astigmatism with both devices; however, astigmatism correction is less effective with the Verion system in patients with longer AL and higher central corneal power. Consequently, the VLynk system could be recommended for those with obvious lens opacities and astigmatism for better control of postoperative refractive error. Further large scale studies may be warranted to investigate whether the VLynk system can provide good refractive predictions in patients with intraoperative complications, such as posterior capsular rupture.

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Conflicts of Interest

The Authors declare no competing interests in relation to this study.

Authors' Contributions

MCC, CYL, YHC, and HYL conducted the analysis and drafted the article. They also contributed to data interpretation. MCC, CYL, SFY, and HYL contributed to writing the manuscript. All Authors critically reviewed and approved the final version.

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