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# Accommodative changes after SMILE for moderate to high myopia correction

Ke Zheng<sup>†</sup>, Tian Han<sup>†</sup> and Xingtao Zhou<sup>\*†</sup> 

## Abstract

**Background:** To investigate accommodative response and accommodative lag changes after femtosecond laser small incision lenticule extraction (SMILE) for moderate to high myopia correction.

**Methods:** A total of 32 eyes of 32 patients with no strabismus who underwent SMILE were enrolled in this prospective clinical study. The accommodative response was obtained viewing monocularly with spherical equivalent refractive error corrected, using an open-field autorefractor at different stimulus levels (2.00D, 2.50D, 3.00D, 4.00D and 5.00D) for the right eye before a standard SMILE surgery and at 1-month follow-up after surgery.

**Results:** The mean age of the patients were  $23.34 \pm 2.90$  years and the mean preoperative manifest refraction spherical equivalent was  $-5.74 \pm 1.98$  diopters. Significant differences were detected in both preoperative and postoperative accommodative responses to different stimulus levels ( $P < 0.001$ ). Multiple linear regression model analysis revealed preoperative manifest refractive spherical equivalent ( $P = 0.006$ ) and preoperative accommodative lag ( $P = 0.04$ ) showed a significant impact on postoperative accommodative lag.

**Conclusions:** This is the first report of accommodative changes after SMILE. Our preliminary results showed that a decrease in postoperative accommodative lag that might be related to the relief of the visual discomfort symptom.

**Keywords:** Small incision lenticule extraction (SMILE), Accommodative response, Accommodative lag, Visual discomfort symptom

## Background

Femtosecond laser small incision lenticule extraction (SMILE) was first introduced by Shah and Sekundo in 2011 and improved with continuous curvilinear lenticule extraction (CCL) technique by Zhou in 2015 [1–3]. SMILE is an effective and safe refractive surgery with a small incision and flapless feature [4]. Accommodation is an old theme in visual refraction. Accommodation is the ability to adjust the refractive power of the eye to bring the conjugate focus of the retina identical to an object. The accommodative lag refers to the insufficient accommodation and provides information about the accuracy of an individual's accommodative system handles increased demand. The accommodative lag has been investigated to have a positive correlation with the symptoms of near-related visual discomfort [5–7]. However, only few studies on accommodative changes after

refractive surgery have been published [8–10]. In addition, they mainly focused on accommodative amplitude and accommodative facility changes. Except for accommodative amplitude and accommodative facility, an alternative way to assess accommodation is to measure the stimulus response function [11]. By measuring the accommodative responses to different stimulus levels, we can get the information about accommodative lag that is associated with symptoms of near-related visual discomfort [5–7].

To date, the changes of accommodation in SMILE procedure has never been reported before. In this study, we studied the accommodative response and accommodative lag changes after SMILE for moderate to high myopia correction.

## Methods

### Subjects

In this prospective, non-randomized study, 32 patients (9 male and 23 female) who underwent SMILE between

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January and February 2015 at Refractive Surgery Center of the Department of Ophthalmology, Eye and ENT Hospital of Fudan University were enrolled. Inclusion criteria included ages 18–30, corrected distance visual acuity (CDVA) of 20/20 or better, stable refraction for 2 years. Old subjects may have difficulty in maintaining stable accommodation at large stimulus levels which maybe usually closer than their near point [12]. Therefore, patients older than 30 were excluded. Patients with strabismus were excluded as well and the near phoria (at 33 cm) was measured by modified thorington phoria test. Patients with systemic diseases known to affect accommodation such as multiple sclerosis, Graves disease, myasthenia gravis or Parkinson disease were also excluded.

This study followed the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Eye and ENT Hospital of Fudan University. Informed written consent was obtained from all participants.

### Surgical procedure

The VisuMax femtosecond laser system (Carl Zeiss Meditec, Jena, Germany) with a repetition rate of 500 kHz and pulse energy of 130 nJ was used to perform SMILE. Standard SMILE procedures were performed by the same surgeon (XTZ) for all the patients. Medication was received as follows: ophthalmic solution of levofloxacin, 0.1 % fluorometholone solution, and non-preserved artificial tear (carboxymethylcellulose sodium eye drops; Allergan, Inc., Irvine, CA).

### Accommodative changes measurement

Open-field autorefactor was used to measure accommodative response and it is more objective compared with monocular estimate method (MEM) and Nott retinoscopy [13]. The accommodative response was obtained viewing monocularly with spherical equivalent refractive error corrected, using an open-field autorefractor (Grand Seiko WAM-5500, Japan) at different stimulus levels (2.00 diopters (D), 2.50D, 3.00D, 4.00D and 5.00D) for the right eyes before a standard SMILE surgery and at 1-month follow-up after surgery. Since there is no significant difference in accommodative lag between eyes [14, 15], the right eye was chosen as the previous studies [11, 13]. Subjects were instructed to keep looking attentively (blur-free) at a high contrast optotype (20/100 letters) at different viewing distances (50 cm, 40 cm, 33 cm, 25 cm, 20 cm, sequentially). The left eye was occluded and measurements were made with the room lights off. The patient's right eye viewed the target through the trial frame. The patient was instructed to look at the central letter and to keep it clear. Using the joystick to maintain focus of the corneal reflections on the monitor, the same examiner (KZ) took all the accommodation measurements. The sign of the spherical equivalent

accommodation reading was changed (plus to minus or minus to plus) to yield the accommodative response, which when subtracted from the accommodative demand yielded the accommodative lag if positive or the accommodative lead if negative. Five measurements were then taken by autorefraction.

### Data analysis

The accommodative lag/lead measurements used for analysis were the median value calculated from the five spherical equivalent measures of accommodative response by autorefraction. All statistical analysis was performed using the Statistical Package for Social Sciences (SPSS, Version 20) and reported as mean  $\pm$  standard deviation. The paired *t* test was used for comparisons between the preoperative and postoperative data. Multiple linear regression model was conducted to evaluate factors associated postoperative accommodative lag after SMILE with postoperative accommodative lag. For all tests, a  $P < 0.05$  was defined as statistically significant.

### Results

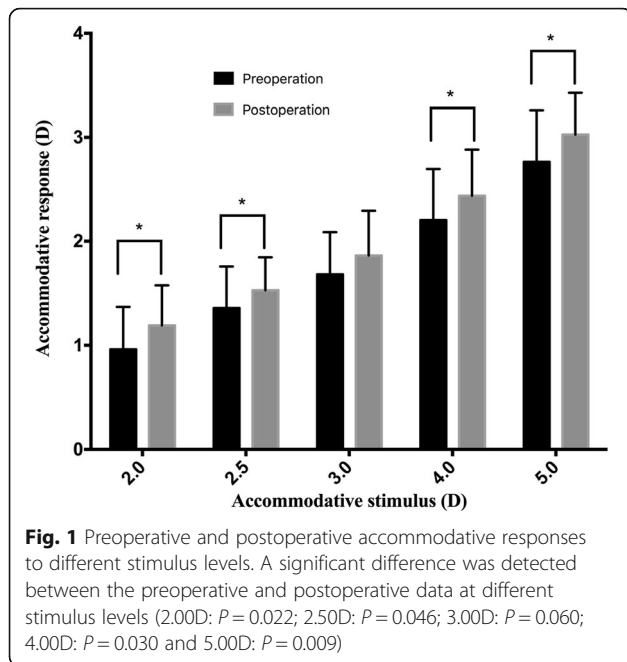
The mean age of the patients were  $23.34 \pm 2.90$  years and the mean preoperative manifest refraction spherical equivalent was  $-5.74 \pm 1.98$  diopters. At near (33 cm), esophoria  $> 1$  prism diopter (PD) was present in 6.24 % of patients, exophoria  $> 1$  PD in 59.38 %, and orthophoria in 34.38 %. The patient information and baseline data are shown in Table 1. The preoperative and postoperative uncorrected near visual acuity (UNVA) at 33 cm of all patients was 20/20 or better. No patient has complained of near-related visual discomfort in one-month post-operation.

Figures 1 and 2 show the preoperative and postoperative accommodative responses and lags to different stimulus levels (2.00D, 2.50D, 3.00D, 4.00D and 5.00D). The accommodative lag for each target stimulus except for 3.00D was significantly smaller in the postoperative group compared with preoperative group. The average of accommodative lags in postoperative group ( $1.29 \pm 0.58$ ) was significantly lower than in the preoperative group ( $1.51 \pm 0.63$ ) ( $P < 0.001$ ). Significant differences were detected both preoperative and postoperative accommodative responses and lags to different stimulus levels (responses: preoperative group:  $F = 88.90$ ,  $P < 0.001$ , postoperative

**Table 1** Demographic data

Variables	Mean	SD	Range
Age (y)	23.34	2.90	18 to 29
Preoperative MRSE (D)	-5.74	1.98	-10.50 to -3.00
MRSE changes (D)	-5.77	1.85	-10.25 to -2.88
Postoperative MRSE (D)	-0.03	0.30	-0.63 to +0.63

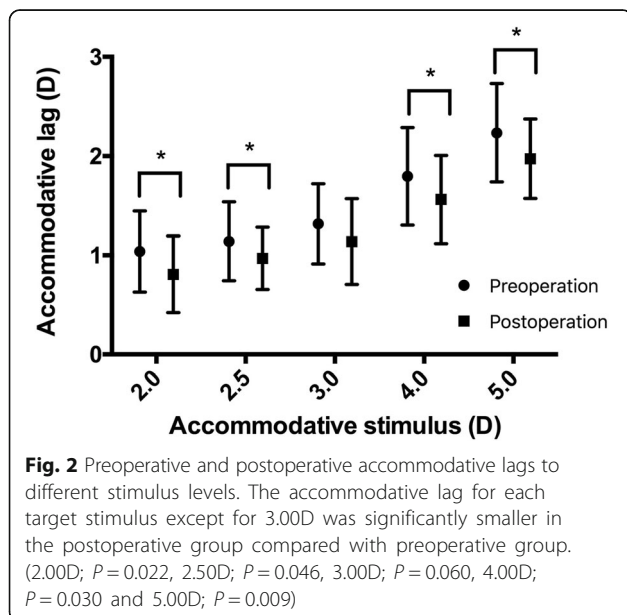
y years, MRSE manifest refractive spherical equivalent, D diopters



**Fig. 1** Preoperative and postoperative accommodative responses to different stimulus levels. A significant difference was detected between the preoperative and postoperative data at different stimulus levels (2.00D:  $P = 0.022$ ; 2.50D:  $P = 0.046$ ; 3.00D:  $P = 0.060$ ; 4.00D:  $P = 0.030$  and 5.00D:  $P = 0.009$ )

group:  $F = 107.82$ ,  $P < 0.001$ ; lags: preoperative group:  $F = 41.10$ ,  $P < 0.001$ , postoperative group:  $F = 45.38$ ,  $P < 0.001$ ). Both accommodative response and lag became significantly larger at larger stimulus.

Multiple linear regression model analysis in Table 2 reveals that postoperative accommodative lag after SMILE increased as preoperative manifest refractive spherical equivalent increased ( $P = 0.006$ ) and preoperative accommodative lag increased ( $P = 0.04$ ).



**Fig. 2** Preoperative and postoperative accommodative lags to different stimulus levels. The accommodative lag for each target stimulus except for 3.00D was significantly smaller in the postoperative group compared with preoperative group. (2.00D:  $P = 0.022$ , 2.50D:  $P = 0.046$ , 3.00D:  $P = 0.060$ , 4.00D:  $P = 0.030$  and 5.00D:  $P = 0.009$ )

**Table 2** Factors associated with postoperative accommodative lag after smile in multiple regression analysis

Variables	b	P
Preoperative MRSE (D)	0.41	0.006
Preoperative AL (D)	0.29	0.04

b regression coefficient, MSRE manifest refractive spherical equivalent, AL accommodative lag, D diopters

**Discussion**

Under viewing conditions at near distances with a steady near point stimulus, a small accommodative lag will be present [16]. Accommodative lag is quite common. Most individuals fail to bring the target into complete focus on the retina due to accommodative lag [17]. It is believed that some discrepancy between accommodative demand and accommodative response is normal though no criteria has been made yet.

In this study, we found that at closer viewing distances, accommodative lags and response became larger. Accommodative response and lag typically increased with increasing demand. It matched the accommodative classical model which was also reported by others [13, 18, 19].

Our results indicated that the accommodative changes after SMILE was apparent ( $P < 0.001$ ). The accommodative response increased and accommodative lag decreased after SMILE ( $P < 0.001$ ). Previous studies concerning other parameters to measure accommodation also reported that accommodation after refractive surgery was improved obviously compared with preoperative accommodation. Karimian et al. determined that accommodative facility increased in myopic patients 1 month after photorefractive keratectomy (PRK) [8]. Moreover, Liu et al. and Fu et al. observed an increase of accommodative amplitude and accommodative facility 1 month after implantation of iris-fixated phakic intraocular lens respectively [9, 10]. The lower accommodative lag that was found after SMILE could be an early sign of an addition in the accommodation amplitude [20]. Thus, our results are in accordance with previous studies.

Multiple linear regression model analysis revealed that preoperative manifest refractive spherical equivalent ( $P = 0.006$ ) and preoperative accommodative lag ( $P = 0.04$ ) showed a significant impact on postoperative accommodative lag. The findings suggested that patients with higher preoperative manifest refractive spherical equivalent, higher preoperative accommodative lag tended to have higher postoperative lag. Karimian et al. also reported in PRK that preoperative accommodative amplitude and accommodative facility had a significant effect on 3-months postoperative accommodative amplitude and accommodative facility, respectively [8].

Previous studies showed that accommodative lag played an important role in visual discomfort symptom [5–7]. Visual discomfort describes adverse symptoms

associated with reading and close work, containing headaches, asthenopia, diplopia, light sensitivity, blurred text, moving letters and other unpleasant somatic symptoms and perceptual distortions [21]. The incidence of visual discomfort symptom is very high. Borsting et al. found that 60 % of surveyed college students with moderate to severe symptoms [22]. Many studies confirmed that an increase in accommodative lag was found in the high visual discomfort patients, whereas the low discomfort group had a stable response [5–7]. Accommodative lag accounts for a proportion of symptom variance, while accommodative amplitude is a poor predictor of visual discomfort [5, 23]. Chase et al. concluded that the increase of accommodative lag developing at a viewing distance of 20 cm was better at predicting visual discomfort symptoms than clinical testing [5]. In this study, postoperative UNVA at 33 cm of all patients was 20/20 or better and no patient has complained of near-related visual discomfort in one-month post-operation. We hypothesize that the decrease in accommodative lag after SMILE procedure might relieve the visual discomfort symptom, which might contribute to patients' satisfaction of SMILE.

There are some limitations in this study. The follow-up period of the study was not long enough to judge about the course of accommodative response and accommodative lag changes after surgery. In addition, we did not objectively evaluate frequency and severity of visual discomfort symptom using a survey in the patients. Near-related visual discomfort might be negligible to some patients. It would be better if visual discomfort was evaluated with a survey developed by Convergence Insufficiency Treatment Trial Group and the other developed by Conlon et al. [24].

## Conclusions

In conclusion, this is the first report of accommodative response and accommodative lag changes after SMILE. Our preliminary results suggested that a decrease in postoperative accommodative lag might be related to the relief of the visual discomfort symptom. It might help refractive surgeon to provide the possible guidance for postoperative consult in clinical practice.

## Abbreviations

CCL: Continuous curvilinear lenticulerrhexis; CDVA: Corrected distance visual acuity; D: Diopters; MEM: Monocular estimate method; PD: Prism diopter; PRK: Photorefractive keratectomy; SMILE: Small incision lenticule extraction; SPSS: Statistical package for social sciences

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## Availability of data and materials

Available upon request from the first author; Dr. Ke Zheng.

## Authors' contributions

Study concept and design (KZ, TH, XZ); data collection (KZ); analysis and interpretation of data (TH); drafting of the manuscript (KZ, TH); critical revision of the manuscript (XZ); supervision (XZ). All authors read and approved the final manuscript.

## Competing interests

The authors declare that they have no competing interests.

## Consent for publication

Not applicable.

## Ethics approval and consent to participate

This study followed the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Eye and ENT Hospital of Fudan University. Informed written consent was obtained from all participants.

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