Original Article

Nearwork-induced transient myopia and accommodation function before and after laser-assisted *in situ* keratomileusis surgery

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Purpose: To assess the change in Near Induced Transient Myopia (NITM) and other accommodation parameters, before and after undergoing LASIK surgery for myopia correction. **Methods:** Twenty-nine myopic subjects were recruited from a tertiary eye hospital in India. Age range was 21 to 35 years with an average age of 26.1 ± 3.5 years. Mean spherical equivalent was –3.86 D ± 1.50 D presurgery. NITM, lag of accommodation, near point of convergence (NPC), accommodative amplitude (AA), and binocular near accommodative facility (AF) were measured. All data were collected 21 days prior to and 30 days after LASIK surgery. **Results:** NITM, lag of accommodation and amplitude of accommodation were significantly lower (NITM -0.05 ± 0.15, Lag 0.38 ± 0.38, AA 10.27 ± 2.24) after surgery when compared to before (NITM 0.26 ± 0.12, Lag 0.77 ± 0.51, AA 12.18 ± 2.02; $P < 0.001$). Accommodative facility increased and near point of convergence was significantly more distal following surgery (AF 10.70 ± 2.29, NPC 7.96 ± 1.63) when compared to prior (AF 8.65 ± 2.74, NPC 5.62 ± 1.71; $P < 0.001$). **Conclusion:** Significant changes in NITM and accommodation function should be expected in the short term following LASIK surgery. This study supports the importance of evaluating accommodative parameters and patient counselling prior to and following refractive surgery.

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Laser-Assisted *in situ* Keratomileusis (LASIK) is acknowledged as a safe and effective mode of refractive correction[1] and works on the principle of modifying the optical properties of the cornea through laser ablation. The shift in refractive error from myopia towards emmetropia following LASIK is determined by the change in refraction brought about by the flattening of corneal curvature at the central optical zone.[2]

The success rates for LASIK have led to more people with myopia opting for this surgical mode of refractive correction.[3] A comprehensive literature review of patient satisfaction revealed 95% satisfaction with their visual outcome after LASIK.[4] With the introduction of new technology e.g., using a Femtosecond laser for flap, LASIK surgical outcomes and safety continue to improve.[1]

Nearwork-induced transient myopia (NITM) refers to the transient myopic shift in distance refraction following brief periods of near work.[5] This physiological shift in the refractive state is considered to be driven by the accommodative apparatus, and has been shown to have different magnitudes in different refractive error groups.[5-9] It has been well documented that accommodative responses are more variable and often reduced in myopes when compared to emmetropes,[10-15] especially when myopia is progressing.[13] This includes NITM magnitude which is increased in myopes when compared to emmetropes.[5,6]

Previously changes in lag of accommodation, AC/A ratio and vergence amplitude following LASIK for myopia have been reported,[16-18] however, the effect of LASIK on NITM has not been investigated. The effect of LASIK on multiple parameters of accommodation within one single cohort has yet to be presented – as most previous studies have compared a single variable of accommodative change pre and post LASIK.[19] As emmetropes experience less NITM than myopes it can be hypothesized that NITM will reduce post LASIK.

Multiple accommodation functions including NITM were measured prior to and following LASIK refractive surgery in young myopic adults to provide an intra-subject study on accommodation with modification of refractive error. Data were also examined to see if changes in near vision in the short-term post LASIK could be explained by changes in accommodation after surgery.

Methods

Twenty-nine subjects who visited a tertiary eye hospital, India, for refractive surgery were recruited between November 2015 to March 2016. Subjects had a mean age of 26.1 + 3.5 years (range from 21 to 35 years). Those with astigmatism greater than 1.00 DC, a manifest strabismus, amblyopia or any systemic

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condition that might affect visual function such as diabetes were excluded from the study. All subjects gave written informed consent for taking part in the study, which followed the tenets of the Declaration of Helsinki 1975, as revised in 2000. This study was approved by an institutional review board and ethics committee.

Power calculation

The sample size was calculated using: $n = (Z\alpha/2 + Z\beta)\ 2^*2\sigma2/d2$, where $Z\alpha/2$=Critical value of normal distribution at $\alpha/2$; $Z\beta$=Critical value of normal distribution at β; d = difference to detect; $\sigma2$ = population variance. Accommodation effect size was taken to be 0.34 D among refractive error group with standard deviation of 0.22 D from the study of Sivaraman *et al*. (2015),[12] this gave a sample size of 27 with $\alpha = 0.05$ and power of 90%.

Pre-LASIK surgery

Pre-LASIK, all the subjects underwent a detailed ocular examination including objective and subjective refraction, slit lamp examination, dry eye assessment, pupillary evaluation, pachymetry (Tomey-SP 3000), corneal topography (TMS-4 Tomey), and keratometry (KMS 6, Bausch and Lomb).

Accommodation measures

The following ocular accommodation parameters were measured 21 days (23.69 ± 2.01 days, range 21–29 days) prior to surgery with the patient wearing soft contact lenses (PureVision, Bausch and Lomb). Pre-operative readings were taken wearing contact lenses, to remove the impact of lens effectivity during accommodation measures. Measurements were repeated by the same examiner at least 30 days post-surgery (34.86 ± 6.43 mean days, range 30-65 days).

NITM

For NITM measurement, subjects sat in the dark for 5 min to dissipate any pre-existing transient accommodative effects.[11] Following this, they were asked to fixate a 6/9 Snellen equivalent and distance refraction readings were recorded continuously using a WAM-5500 open field auto-refractor for 1 minute for the right eye and averaged. The subjects then read N12 with 90% contrast for 5 minutes at 0.20 m. Immediately after this task NITM measurements were taken for 120 seconds. Continuous refractive data for each subject were divided into 10-s bins. The average difference between the pre-task and post-task distance refractive state in the first 10-s bin represented the initial NITM dioptric magnitude.

NPC

Near point of convergence in cm (NPC) was measured using an RAF rule, which was placed just above the nose at the brow between the two eyes. The target was moved toward the subjects at a rate of about 1 to 2 cm/s. Subjects were encouraged to try to keep the target single. The subject was asked to report the first doubling of the target that could not be fused when prompted. The subjective break value was recorded in centimetres.[20]

Amplitude of accommodation

Binocular amplitude of accommodation in diopters (AA) was determined with the subject viewing a row of letters one line larger than their near visual acuity. The subject was instructed to keep the letters clear. The chart was moved slowly towards the subject and was asked to report the point of first sustained blur. This distance was recorded in cm and converted into diopters.[21]

Near accommodative facility

Binocular near accommodative facility in cycles per minute (AF), was evaluated at 0.40 m using +2.00/–2.00 lens flippers to measure the subject's ability to make rapid and accurate accommodative changes under binocular conditions. The subjects were asked to hold the near vision card at 0.40 m and were asked to fixate a N6 target. They were instructed to hold the flipper close to the eyes (plus lens first) and flip the lens upon clearing the target. The numbers of flips made in 1 minute were noted. A full cycle consisted of clearing both plus and minus lenses.[22]

Lag of accommodation

Lag of accommodation in diopters was calculated from the subjects' accommodative response at 0.40 m using a WAM-5500 open field autorefractor. Subjects viewed the target at 0.40 m binocularly. A series of five readings were taken from the right eye and averaged. This value was then subtracted from the accommodative demand (2.50 D) to calculate the lag of accommodation.[10]

LASIK surgery

LASIK was performed under topical anaesthesia (Proparacaine 0.5%). A flap with a diameter of 9.00 mm and a thickness of 130 ± 20 μm was created with a superior hinge by means of the Supratome (Schwind, Kleinostheim, Germany). For the photoablation, a medical scanning spot excimer laser system (Allegretto, Wavelight, Erlangen, Germany) was used. This device includes a fast eye-tracking system (reaction time delay 6 ms), and a laser with a repetition frequency of 500 Hz and a Gaussian spot profile with an ablation diameter of 0.10 mm.[23] The ablation pattern had a circular full correction area with a diameter of 7.00 mm (ablation optical zone), surrounded by a transition zone of 1.00 mm. After photoablation, the flap was repositioned and the interface was rinsed with balanced salt solution; Vigamox, Lotepred and refresh tears were used postoperatively.[24]

The LASIK procedure was performed by specialized corneal refractive surgeons who had 5 years or more experience in performing the procedure.

Statistical analyses

Paired t-tests were used to evaluate changes in spherical equivalent refraction (SER), (calculated by combining sphere with half the cylindrical value), LogMAR visual acuity, corneal curvature, NITM magnitude, NPC, AA, AF and lag of accommodation.

Results

Results are presented for right eyes only. The following parameters were compared pre- and post-surgery. Paired sample t-tests are presented in Table 1.

Refractive error

Baseline preoperative SER was not correlated with age (r = -0.32, P = 0.09), unsurprising as these were stable myopes about to have refractive surgery. Cylindrical power preoperatively was -0.59 D ± 0.17 D (Range -0.50 D to -1.00 D) which was significantly reduced to 0.01 D ± 0.50 D (Range -0.50 to 0.87 D, $P < 0.01$).

Table 1: Mean and standard deviation of parameters pre and post LASIK refractive surgery

	Pre-Surgery	Post-Surgery	*P*
SER (D)	-3.86±1.57	0.01±0.50	0.00**
LogMAR Acuity	-0.05±0.07	-0.04±0.08	0.89
Corneal Curvature (D)	43.92±1.18	40.42±1.46	0.00**
NITM Magnitude (D)	0.26±0.12	-0.05*±0.15	0.00**
NPC (cm)	5.62±1.71	7.92±1.64	0.00**
Amplitude of Accommodation (D)	12.18±2.02	10.27±2.24	0.00**
Accommodative Facility (cpm)	8.66±2.74	10.71±2.29	0.00**
Lag of Accommodation (D)	0.75±0.51	0.38±0.38	0.00**

*A negative value of NITM indicates a hyperopic shift in refraction. **P<0.001 (difference between pre and post-surgery is significant at the 0.05 level, 2 tailed)

Visual acuity

Mean preoperative visual acuity was approximately 0.0 LogMAR. Vision was unchanged postoperatively when compared to pre-operative VA (P = 0.89).

Discussion

By investigating several accommodation parameters including NITM pre and post LASIK we have the unique opportunity to examine the effect of change in refractive error on accommodation in the same individuals. The results presented in this study also have implications for LASIK subjects in the short-term following surgery. LASIK subjects may experience changes in near vision post-refractive surgery[16] and should be counselled and reassured of changes to accommodation that can be expected shortly after LASIK. Post-surgery, the change from myopia to emmetropia results in a significantly more accurate accommodation response (demonstrated by a reduced lag of accommodation) compared to the eye preoperatively, albeit with lower accommodative capacity (demonstrated by a reduced AA).

Our results may be explained by considering depth of focus. Emmetropes are known to have a reduced depth of focus compared to myopes.[25,26] A smaller (narrower) depth of focus would also result in an improved accommodative accuracy (a decreased lag of accommodation).

NITM magnitude was significantly reduced following LASIK surgery, supporting our initial hypothesis. Previously reported NITM ranges between 0.21 D and 0.35 D.[11-14] Myopes have increased depth of focus resulting in increased blur tolerance and are also known to have increased NITM when compared to non-myopes.[11] As LASIK induces an emmetropic refraction the increased stimulus to accommodation post-surgery, a reduced depth of focus, could be the reason for the disappearance of NITM and changes in other measured parameters following the surgery. A reduced NITM may be beneficial for the patient as some individuals find NITM symptoms disruptive, experiencing distance blur when changing viewing from a near to distant object.

The accommodative system receives dual innervation, consisting of a parasympathetic (cholinergic) and a secondary sympathetic (adrenergic) component. An increase in parasympathetic stimulation results in an increase in accommodation. The sympathetic system is slower in onset (40 millisecs) and smaller in effect than the parasympathetic system.[27] A deficit in the sympathetic response has been proposed to result in increased NITM in myopes.[6] However, this study suggests that NITM can be reduced optically, rather than by alterations to the neural system.

The near point of convergence became more distal from 5.62 ± 1.71 to 7.96 ± 1.63 (cm) after surgery in this study, which could be paired with reduced accommodative amplitude, as convergence increases with increased accommodative effort. Prakash, *et al*. (2007)[16] reported an initial decrease in AC/A ratio (deg/D) up to one post myopic LASIK surgery. After three months, it stabilized to near the pre-operative value. They suggested that this change in AC/A ratio at 1 was due to the increased accommodative effort of the eye in the emmetropic state, to produce the same amount of accommodative convergence. Our results are in accordance with this finding, as our subjects exhibited decreased convergence post-surgery with increased accommodative accuracy 30 days post-surgery. Our findings support the hypotheses of Li *et al*., (2016)[28] of reduced accommodative facility and increased accommodative recovery time (via increased NITM) in the myopic state.

Amplitude of accommodation was decreased at 1-post-surgery, a similar finding to that of Guo-Tao and Ya-Jie (2012)[17] who reported that accommodative amplitude decreased binocularly from 9.60 ± 0.37 D to 8.10 ± 0.54 D in the first week Post LASIK, yet had regained to 9.43 ± 0.38 D after one month. More recently this finding has been confirmed by Asyigah and Ismail (2020).[29]

The accommodative facility rate increased by approximately 2-3 cycles/minutes at the one-post-operative visit. Studies have shown reduced distance accommodative facility in myopes when compared to emmetropes.[10,23,30] This study showed that the dynamics of accommodation were improved in the emmetropic state. Another possible reason for the improvement in accommodative facility is that by simply measuring accommodative facility one is providing facility training,[31] hence the improvement in accommodation seen in this cohort could be due to either LASIK surgery or simply due to a training effect.

Lag of accommodation at near has been reported to be higher among myopes than emmetropes.[7] Post surgery the lag of accommodation was significantly lower than preoperatively. This suggests that lag of accommodation can be reduced optically and is a relationship between the depth of focus and refraction.

Despite the reduction in lag of accommodation post LASIK, there was a significant decrease in amplitude of

accommodation of 12.18 ± 2.02 to 10.27 ± 2.24 D. A reduced amplitude of accommodation post LASIK has also been reported by Li *et al*. (2016)[28] who suggested that by correcting refractive error to clear the retinal image, there is less accommodative demand, thereby reducing the accommodative amplitude. A decreased depth of focus in the emmetropic state could explain the reduction in amplitude of accommodation seen.

Our participants were young with a mean age of 26 years. The initial reduction in amplitude in accommodation post-surgery that could occur as suggested by the results in this study, even if temporary, should be raised with the pre presbyopic age groups pre-LASIK surgery.

There have been reports of subjects complaining of asthenopic symptoms post-surgery.[16] The current study suggests that reduced amplitude of accommodation does occur post LASIK and that subjects should be counselled of this potential eventuality when being assessed for surgery. However, our results also show an increase in accommodative accuracy and a reduction in transient myopia effects, which is an additional positive outcome.

In this study all subjects were stable myopes prior to the surgery. This result suggests that post-operative lag of accommodation may be a useful predictor for myopic regression post LASIK surgery. It would be prudent to follow subjects longitudinally after LASIK surgery to see if accommodation parameters could be predictive of later myopic regression.

Though the aim of the modern corneal laser surgery is to optimize the total wavefront aberrations of the eyes, studies have shown an increase in higher order aberrations following corneal laser surgery.[32-34] An internal process similar to emmetropisation could exist to compensate for the induced aberrations, resulting in maintenance of retinal image quality,[33] it is likely that this may have had some influence on accommodative changes seen in this study. A limitation of this study is that we were unable to analyse pre- and post-wavefront data and therefore are only able to speculate about the role of aberrations in this mechanism.

The above changes in accommodative parameters seen, could be due to the sudden change in refractive error and may revert to normal levels over time, as suggested by other post-operative accommodation results given above. Longitudinal studies investigating accommodative function post-LASIK surgery are ongoing. We can suggest that our results could be transferable to other photo ablation refractive surgeries.

Conclusion

To the best of our knowledge, this is the first study to report a range of accommodative and vergence parameters including NITM pre and post-LASIK surgery. The findings presented demonstrate that NITM and other accommodation parameters alter in individuals with a change in their refractive status. The finding of significant changes in accommodation in the short term after LASIK, supports the importance of evaluation of accommodation prior to and following refractive surgery, giving subjects appropriate pre- and post-operative advice.

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Conflicts of interest

There are no conflicts of interest.

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