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CLINICAL STUDY

# Impact of laser refractive surgery on ocular alignment in myopic patients

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**Abstract**

*Purpose* **To evaluate the impact of myopic keratorefractive surgery on ocular alignment.**

*Methods* **This prospective study included 194 eyes of 97 myopic patients undergoing laser refractive surgery. All patients received a complete ophthalmic examination with particular attention to ocular alignment before and 3 months after surgery.**

*Results* **Patients with a mean age of 26.6 years and a mean refractive error of −4.83 diopters (D) myopia were treated. Asymptomatic ocular misalignment was present preoperatively in 46 (47%) patients: a small-angle heterophoria (1–8 prism diopters, PD) in 36%; and a large-angle heterophoria (>8 PD)/heterotropia in 11%. Postoperatively, the change in angles of 10 PD or greater occurred in 3% for distance and 6% for near fixation: in 7% of the patients with orthophoria, in 3% of those with a small-angle heterophoria, and in 18% of those with a large-angle heterophoria/heterotropia. No patient developed diplopia. The preoperative magnitude of myopia or postoperative refractive status was not related to the change in ocular alignment. The higher anisometropia was associated with a decrease in deviation ($P=0.041$ for distance and $P=0.002$ for near fixation), whereas the further near point of convergence tended to be related with an increase in near deviation ($P=0.055$).**

*Conclusions* **Myopic refractive surgery may cause a change in ocular alignment, especially in cases with a large-angle heterophoria/heterotropia. There is also a chance of improvement of misalignment in patients with anisometropia.**

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## Introduction

Laser refractive surgery has not only become a standard procedure to correct moderate myopia,[1] but also has emerged as a novel means of treatment for strabismus related to refractive error such as refractive accommodative esotropia.[2–6] In hypermetropic patients with accommodative strabismus, refractive surgery has the potential to eliminate both the dependence on corrective lenses and esotropia simultaneously.[2–6] Conversely, although 10-year follow-ups have demonstrated that the technique is safe and predictable,[1] refractive surgery can cause strabismus and binocular diplopia.[2,7–15] Patients with preexisting strabismus or anisometropia-causing aniseikonia, and those hoping to achieve monovision are at higher risk for postoperative strabismus and diplopia.[7] Therefore, refractive surgery might be a means of treatment for strabismus and a cause of strabismus.

Corneal refractive surgery is performed most commonly in myopic patients. Despite the high possibility of a coexistence of exodeviation in myopia and anisometropia,[2,16,17] there is, however, a paucity of data on the association between myopic refractive surgery and ocular misalignment. In small case series with constant exotropia exclusively or various myopic refractive surgeries including lens implantation extensively, exodeviation remained unchanged or improved postoperatively.[4,6,18,19] In contrast, there were some case reports with decompensation of exodeviation after laser surgery.[8,11,14,15]

To address this, we have performed a prospective study to determine whether myopic keratorefractive surgery affects ocular alignment.

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## Materials and methods

A prospective study was conducted in patients who had undergone laser refractive surgery for myopia at two centers in compliance with the tenets of the Declaration of Helsinki. The Institutional Review Board approved the study, and written informed consent was obtained from all patients. Inclusion criteria were myopic patients for laser refractive surgery, preoperative manifest refraction $< -9.00$ diopters (D), age $>18$ years, and stable refraction as documented by previous glasses. Patients with amblyopia, paralytic or restrictive strabismus were excluded. Patients with a history of ocular surgery or neurological disorders were also excluded.

### *Assessment: preoperatively and postoperatively*

A thorough ophthalmologic evaluation was performed with particular attention to ocular alignment and sensory status. For the purpose of refractive surgery, the eye examination included visual acuity, manifest and cycloplegic refraction, anterior and posterior segment evaluation, intraocular pressure, corneal topography, pachymetry, and pupillometry. For the purpose of this current study, a complete orthoptic examination was performed before and 3 months after surgery. Visual acuity assessed with the conventional Snellen chart at 6 m was converted to a logarithmic scale (logMAR) for analyses. Ocular alignment was assessed in the primary position using the prism and alternate cover test, after fixating an accommodative target of 20/30 letter size that was positioned at distance (6 m) and near (1/3 m). The angle of deviation was used for analyses of actual change in ocular misalignment regardless of the type: positive values of change indicated an increase in deviation, whereas a negative value indicated a decrease in deviation. Alignment data were also divided into three alignment categories: orthophoria (0 prism diopters (PD)), a small-angle heterophoria (1–8 PD), or a large-angle heterophoria ($>8$ PD)/heterotropia. The sensory status was evaluated using the Titmus stereoacuity test and the Worth 4-dot test. A stereoacuity of 80 s of arc or better was defined as good.[20] All binocular vision tests were evaluated with optimal spectacle correction before refractive surgery and without correction postoperatively. All orthoptic findings were evaluated in each patient by the same examiner using the same technique. Near point of convergence (NPC), in centimeters, was measured three times using a push-up method before surgery, and the median value of the measurements was recorded. The main outcome measure was variable alignment defined as a change by 10 PD or greater between assessments before and after surgery, which are likely to indicate real change.[21]

### *Laser refractive surgery*

Corneal refractive surgery was performed by three surgeons. Laser *in situ* keratomileusis (LASIK), using either a femtosecond laser or an automated microkeratome, or laser epithelial keratomileusis (LASEK) was chosen according to the condition of the patient. Corneal refractive procedures were performed under topical anesthesia with proparacaine HCl (0.5%). Patients were fitted with hydrogel soft contact lens as a bandage immediately after surgery and received levofloxacin (0.5%) three times a day during the first 3–5 days postoperatively. This treatment was replaced by fluorometholone (0.1%) four times a day and tapered over the following 3 months. All eyes were targeted at emmetropia based on cycloplegic refraction. Patients underwent bilateral simultaneous procedures to minimize the disruption of binocularity and consolidate the recovery period.

### *Statistical analysis*

Data were analyzed using SPSS software version 15.0 (SPSS Inc., Chicago, IL, USA). Comparison of the angles of deviation before and 3 months after refractive surgery was performed using the paired *t*-test. The influence of preoperative variables on the changes in ocular alignment was examined using multiple linear regression analysis and chi-square test. *P*-values $<0.05$ were considered significant.

## Results

In total, 97 myopic patients (24 males and 73 females) with a mean age of 26.6 ± 5.8 years (range 19–37) were included in this study. Table 1 summarizes the refractive and orthoptic findings of the patients. Preoperative best spectacle-corrected visual acuity in each eye was better than or equal to 0.10 logMAR (Snellen 20/25). Myopia ranged from $-1.19$ to $-8.69$ D (mean, $-4.83 \pm 1.77$ D). Eleven patients with 1.50 D or greater of anisometropia were identified preoperatively. Refractive surgery was performed on 194 eyes from the 97 patients; LASIK was performed on 108 eyes and LASEK on 86 eyes. All patients underwent uneventful refractive surgery. No major postoperative complications were observed. In two patients corneal epithelialization was delayed, which required more intensive postoperative care. None of the eyes presented with postoperative topographic decentration of the dilated corneal zone and the flap, or with a shift in the axis of astigmatism, which can result in a tilting of the image. None of the patients lost any line of visual acuity after surgery. The refractive error improved in all patients. At 3-month follow-up, all eyes were within ±1.25 D of emmetropia.

### *Ocular alignment before and after surgery*

Preoperatively, 39 (40%) and 45 (46%) of the patients had asymptomatic ocular misalignment at distance and near fixation, respectively: 37 had a distant exodeviation, 42 had a near exodeviation, 2 had a distant esodeviation, and 3 had a near esodeviation. None had vertical deviation. Small-angle heterophoria was seen in 36% and large-angle heterophoria/heterotropia was in 11%. All heterotropia were intermittent exotropia of 8 PD or more. All patients had good stereoacuity.

Three months after refractive surgery, the change in angles of 10 PD or greater occurred in 3% for distance and 6% for near fixation: in 7% of the patients with orthophoria at baseline, in 3% of those with a small-angle heterophoria, and in 18% of those with a large-angle heterophoria/heterotropia (Table 2). Of the patients with exodeviation at baseline, more than half were measured to have an improvement (59% in distance and 56% in near fixation); 91% of these improvement occurred in those with a small-angle heterophoria at baseline. All three patients with esodeviation at baseline remained unchanged. For patients with orthophoria at baseline, three developed a new exodeviation >8 PD and five experienced a new small-angle exophoria (1–8 PD). None of the patients presented with postoperative diplopia or dominance problems such as fixation switch diplopia.[7] The mean amount of changes in distance deviation was $-1.60 \pm 3.34$ PD ($P<0.001$) and that in near deviation was $-0.29 \pm 5.12$ PD ($P=0.594$), which were clinically insignificant.

Table 3 summarizes the orthoptic results of the patients whose deviation changed by 10 PD or greater and the patients with anisometropia at baseline. Of the three patients with a change in deviation of 10 PD or greater for both distance and near fixation, patients 2 and 4 showed a reduction in exodeviation, whereas patient 5 had deterioration of exodeviation. Eight (73%) of 11 patients with anisometropia showed a reduction in exodeviation, whereas none revealed a deterioration of deviation.

### *Factors influencing the change in ocular misalignment*

As shown in Table 4, there was no significant correlation between the magnitude of myopia and the change in ocular alignment ($P=0.534$ for distance and $P=0.668$ for near fixation). However, patients with a higher anisometropia showed a greater decrease in exodeviation ($P=0.041$ for distance and $P=0.002$ for near fixation), whereas patients with a less amplitude of convergence (further NPC) suffered a greater increase in near exodeviation ($P=0.055$). No difference was observed in the change in angles between the two modalities, LASEK and LASIK (independent *t*-test, $P=0.881$). When the patients whose postoperative refractive outcomes were outside ±0.50 D were analyzed as over/under-corrected,

**Table 1** Refractive and orthoptic findings of patients ($n=97$)

| *Characteristics* | *Value* |
|---|---|
| *Visual acuity (logMAR)* | |
| Preoperative (corrected) | 0.01 (0.00 to 0.10) |
| Postoperative (uncorrected) | −0.03 (−0.10 to 0.10) |
| *Refractive error (D; spherical equivalent)* | |
| Preoperative | −4.83 ± 1.77 (−8.69 to −1.19) |
| Postoperative | 0.08 ± 0.38 (−1.25 to 1.14) |
| *Ocular alignment (PD)* | |
| Preoperative | |
| Distance | 2.06 ± 2.76 (5 E to 12 X(T)) |
| Near | 3.12 ± 3.86 (6 E to 18 X(T)) |
| Postoperative | |
| Distance | 0.46 ± 2.01 (6 E to 15 X(T)) |
| Near | 2.83 ± 4.21 (6 E to 15 X(T)) |
| Preoperative stereoacuity (seconds of arc) | 45.3 ± 13.4 (80 to 40) |
| Preoperative near point of convergence (cm) | 8.1 ± 2.1 (5.5 to 12.5) |

Abbreviations: D, diopter; E, esophoria; PD, prism diopter; X(T), intermittent exotropia.
Data presented as mean ± SD (range).

**Table 2** Proportion of the patients whose deviation changed by ≥10 PD

| *Baseline alignment* | *Change in distant deviation* | | | *Change in near deviation* | | |
|---|---|---|---|---|---|---|
| | *No change* | *Decrease* | *Increase* | *No change* | *Decrease* | *Increase* |
| Orthophoria | 50 (98%) | 0 (0%) | 1 (2%) | 42 (93%) | 0 (0%) | 3 (7%) |
| Small phoria (1–8 PD) | 35 (100%)[a] | 0 (0%) | 0 (0%) | 36 (97%)[a] | 0 (0%) | 1 (3%) |
| Large phoria (>8 PD)/heterotropia | 9 (82%) | 2 (18%) | 0 (0%) | 13 (87%) | 2 (13%) | 0 (0%) |
| Total | 94 (97%) | 2 (2%) | 1 (1%) | 91 (94%) | 2 (2%) | 4 (4%) |

Abbreviation: PD, prism diopter.
Data presented as absolute numbers (% in each subgroup).
[a]All patients with esodeviation at baseline are included.

**Table 3** Findings for patients whose deviation changed by ≥10 PD (numbers) and with anisometropia (letters)

| *Patient no.* | *Age/sex* | *Surgery* | *Preoperative* | | *Postoperative* | |
|---|---|---|---|---|---|---|
| | | | *Refractive error (D)* | *Ocular alignment (PD)* | *Refractive error (D)* | *Ocular alignment (PD)* |
| 1 | 26/F | LASEK | R: −4.75 −1.00×5<br>L: −4.37 −1.25×160 | Ortho at D, N | R: +0.25 −0.25×180<br>L: +0.75 −0.50×180 | Ortho at D<br>12X at N |
| 2, a | 32/F | LASEK | R: −5.00 −3.25 ×175<br>L: −3.50 −2.75×5 | 12X(T) at D<br>18X(T) at N | R: +0.25 −0.50×180<br>L: +0.75 −1.25×180 | Ortho at D<br>4X at N |
| 3 | 20/F | LASIK | R: −7.00 −0.75 ×75<br>L: −7.50 −0.75 ×110 | 4X at D, N | R: +0.75 −1.00×90<br>L: +0.50 −0.25×90 | Ortho at D<br>15X at N |
| 4, b | 22/M | LASIK | R: −5.50 −2.25×175<br>L: −4.00 −2.50×180 | 10X(T) at D<br>12X at N | R: +0.50 −0.25×180<br>L: +1.00 −0.50×180 | Ortho at D, N |
| 5 | 24/M | LASIK | R: −3.00 −0.75×180<br>L: −2.75 −1.00×180 | Ortho at D, N | R: −0.75 −0.75×180<br>L: −1.25 −0.25×180 | 15X at D, N |
| 6 | 25/F | LASIK | R: −3.00<br>L: −3.00 −0.25×130 | 4X at D<br>Ortho at N | R: +0.25 −0.50×90<br>L: +0.50 −0.25×90 | 6X at D<br>12X at N |
| c | 25/F | LASIK | R: −2.25 −2.50×175<br>L: −4.75 −1.25×175 | Ortho at D<br>10X at N | R: +0.25 −0.25×180<br>L: +0.75 −0.50×180 | Ortho at D, N |
| d | 27/F | LASIK | R: −6.00 −1.00 ×180<br>L: −8.00 | Ortho at D<br>4X at N | R: +0.25 −0.50×180<br>L: +0.75 −1.25×180 | Ortho at D<br>4X at N |
| e | 29/F | LASIK | R: −8.25 −0.25 ×180<br>L: −6.75 | 4X at D<br>8X(T) at N | R: +0.75 −1.00×180<br>L: +0.50 −0.25×180 | Ortho at D, N |
| f | 19/F | LASEK | R: −5.50 −0.25×120<br>L: −7.25 −0.25×90 | 6X at D, N | R: +0.50 −0.25×90<br>L: +1.00 −0.50×90 | Ortho at D<br>6X at N |
| g | 20/F | LASEK | R: −1.25 −2.50×165<br>L: −3.75 −1.50×10 | Ortho at D<br>6X at N | R: −0.75 −0.75×180<br>L: −1.25 −0.25×180 | Ortho at D, N |
| h | 19/F | LASEK | R: −2.50 −0.75×175<br>L: −4.50 −0.75×165 | 6X at D<br>8X(T) at N | R: +0.25 −0.50×180<br>L: +0.50 −0.25×180 | Ortho at D, N |
| i | 24/F | LASIK | R: −4.25 −0.50×160<br>L: −2.50 | 2X at D<br>8X at N | R: +0.75 −0.25×180<br>L: 0.00 | Ortho at D, N |
| j | 26/M | LASIK | R: −3.00 −1.00×175<br>L: −1.50 −1.00×180 | Ortho at D, N | R: 0.00 −0.25×180<br>L: 0.00 | Ortho at D<br>2X at N |
| k | 23/F | LASEK | R: −4.50 −1.25×165<br>L: −2.25 −1.25×170 | Ortho at D, N | R: +1.00 −1.00×180<br>L: 0.00 −0.75×180 | Ortho at D, N |

Abbreviations: D, diopter; PD, prism diopter; X, exophoria; X(T), intermittent exotropia.

**Table 4** Preoperative factors influencing the change in deviation

| *Variable* | *Change in distant deviation* | | *Change in near deviation* | |
|---|---|---|---|---|
| | β | P *Value*[a] | β | P *Value*[a] |
| Spherical equivalent | 0.124 | 0.534 | −0.129 | 0.668 |
| Anisometropia | −1.402 | 0.041 | −3.165 | 0.002 |
| NPC | 0.240 | 0.161 | 0.497 | 0.055 |
| | $R=0.281$ | 0.068 | $R=0.403$ | 0.002 |

Abbreviation: NPC, near point of convergence.
[a]Multiple linear regression analysis.

the alteration of ocular misalignment did not differ with respect to refractive outcomes. There was no difference in the change in angles among the 6 under-corrected (spherical equivalent (SE) <−0.50 D), the 82 full-corrected (SE ≤ ±0.50 D), and the 9 overcorrected patients (SE > +0.50 D) (chi-square test, $P=0.215$).

## Discussion

Myopia is commonly associated with exodeviation.[2,16,17] In our series, up to 42 (43%) of the 97 myopic patients had asymptomatic exodeviation. Despite the high prevalence of exodeviation in the myopic population and refractive surgery becoming increasingly popular, the incidence of ocular misalignment related to myopic refractive surgery has not been reported. Some studies have described cases with postoperative diplopia retrospectively, or included a pre-selected population with various manifest strabismus.[7–15,18] Moreover, the impact of myopic refractive surgery on exodeviation has been reported to vary among reports.[2,4,6,18]

We identified that corneal refractive surgery for low to moderate myopia in general did not appear to have an impact on ocular alignment. This was attributed to several factors. First, our patients were deemed to be at low risk of postoperative decompensation of strabismus and diplopia, as recommended by Kushner and Kowal.[7] They stratified patients into low, medium, and high risk for postrefractive surgery diplopia. To be considered low risk, the following criteria must be met: myopia, $<4.00$ D of anisometropia, no history of strabismus or diplopia, no prisms in glasses, and at most a minimal phoria on the alternate prism cover testing. Current spectacles, manifest refraction, and cycloplegic refraction should all be within 0.50 D of each other. As most of the patients met this condition, the change in ocular alignment after surgery might be insignificant in our series. Second, the mean refractive error of our patients was $-4.83$ D myopia. The concave lens of $>5.00$ D could serve as a base-in prism, and might have partially corrected the preexisting exotropia.[7,22] After refractive surgery, the removal of the prismatic correction might have increased the exodeviation, leading to a deterioration of deviation.[7,15,22] This prismatic effect of high myopia might not affect the majority of our patients because they had low to moderate myopia. In addition, we found that the magnitude of myopia was not related to the change in deviation despite the expectation that higher myopia might increase the variability of measurements. Furthermore, one patient (patient 5 in Table 3) who showed a deterioration of exophoria $>10$ PD had moderate myopia of $-3.25$ D, which is not high. Third, there was no notable difference between the habitual glasses and the actual refraction/interpupillary distance in all patients. Thus, the induced prismatic effect of glasses using an off-axis method or overcorrecting minus lens therapy for intermittent exotropia did not affect our patients.[23,24] Fourth, there was no significant over/undercorrection that might affect the postoperative alignment, especially in cases with the accommodative component.[15] None of the patients lost any line of visual acuity. Thus, these refractive conditions helped to prevent a deterioration of preoperative misalignment or a development of new misalignment.

However, some patients were measured to have a change in their angles. Although Godts *et al*[18] reported that ocular alignment and binocular function remained unchanged postoperatively even in patients with manifest deviation, we found the change in angles of 10 PD or greater occurred more frequently in patients with a large-angle heterophoria/heterotropia and in near deviation. All these patients had exophoria or intermittent exotropia. The improvement of exodeviation, especially in near fixation might be owing to the additional need for accommodation and convergence after becoming emmetropic in previously myopic patients.[19]

In addition, myopic patients with anisometropia at baseline were likely to have a reduction of exodeviation postoperatively in concordance with previous reports.[6,18] When anisometropia is corrected with spectacle, vertex distance might cause aniseikonia and anisophoria. Jampolsky *et al*[25] suggested unequal clarity retinal images due to anisometropia present an obstacle to fusion that may facilitate suppression and contribute to the pathogenesis of exotropia. Therefore, cancellation of the vertex distance by refractive surgery might help to improve the fusion.[15]

Conversely, the patients with a further NPC appeared to have deteriorated near exodeviation. Convergence is mostly attributed to accommodative convergence and fusional convergence. Myopic adults and children have an elevated accommodative lag.[26] Thus, the low ability of accommodation seen in some myopic patients could result in decompensation of near exodeviation. In addition, Rajavi *et al*[19] and Hashemi *et al*[27] reported a significant reduction in convergence and divergence amplitudes, and a significant increase in NPC after photorefractive keratectomy, which might aggravate near exodeviation after surgery.

This study has several limitations. First, we measured the deviation at different conditions: with optimal spectacle correction before refractive surgery and without correction postoperatively. Therefore, the inherent effect of the base-in prism of minus lens spectacles and the enlarged image due to the cancellation of the vertex distance might have affected the measurement before and after surgery, respectively.[15] As the condition after refractive surgery is similar to that with contact lens correction,[15] preoperative orthoptic evaluation wearing contact lenses might be useful for identifying this issue. Second, our findings have limited generalizability because of the selected healthy patient population with low to moderate myopia. We conducted the study with patients who are commonly indicated for laser refractive surgery, which is similar to clinical practice. Although in our series the magnitude of myopia was not related to the change in angles, it is well known that patients with high myopia are at higher risk of ocular misalignment.[15] Further study in patients with high myopia who implant phakic intraocular lens can be meaningful. In addition, all patients in our series had normal visual acuity for each eye and were asymptomatic regarding the orthoptic findings. Therefore, our findings cannot be applied to a population with manifest strabismus or with amblyopia. Third, we did not measure motor fusion status such as a prism fusion range and postoperative sensory status. They might provide a possible explanation for the change in deviation after refractive surgery in some patients. Further study regarding the change in motor and sensory status after refractive surgery is needed. Finally, a 3-month follow-up might be relatively short for identifying the association between the stability of ocular alignment and myopic regression. Although myopic regression occurs more frequently in the early postoperative period, slowing down with time, it stabilizes between 2 to 5 years after LASIK for moderate myopia.[28] Therefore, our results should be applied with caution.

In conclusion, patients with low to moderate myopia should be informed that corneal refractive surgery may also cause a change in ocular alignment, especially in cases with a large-angle heterophoria or heterotropia. We consider it advisable to perform an adequate orthoptic examination before and after refractive surgery even in patients with low to moderate myopia.

## Summary

**What was known before**

- Although laser refractive surgery for myopia is considered as a safe and predictable technique, some authors have reported cases with postoperative diplopia and strabismus.

**What this study adds**

- We found that the laser refractive surgery for moderate myopia may also cause a change in ocular alignment, especially in cases with a large-angle heterophoria/heterotropia.
- There was a chance of improvement of deviation in patients with anisometropia at baseline, but a chance of deterioration of near deviation in patient with less amplitude of convergence at baseline.

## Conflict of interest

The authors declare no conflict of interest.

## Author contributions

Study concept and design (SAC); data collection (SAC, WKK, HY, and JKK); analysis and interpretation of the data (SAC, JWM); drafting of the manuscript (SAC, JWM, and SBL); critical revision of the manuscript (SAC, WKK, HY, JKK, SBL, and JBL); statistical expertise (SAC); supervision (JBL).

## References

1 Alió JL, Muftuoglu O, Ortiz D, Artola A, Pérez-Santonja JJ, de Luna GC *et al.* Ten-year follow-up of photorefractive keratectomy for myopia of less than -6 diopters. *Am J Ophthalmol* 2008; **145**: 29–36.
2 Minnal VR, Rosenberg JB. Refractive surgery: a treatment for and a cause of strabismus. *Curr Opin Ophthalmol* 2011; **22**: 222–225.
3 Hutchinson AK, Serafino M, Nucci P. Photorefractive keratectomy for the treatment of purely refractive accommodative esotropia: 6 years' experience. *Br J Ophthalmol* 2010; **94**: 236–240.
4 Kirwan C, O'Keefe M, O'Mullane GM, Sheehan C. Refractive surgery in patients with accommodative and non-accommodative strabismus: 1-year prospective follow-up. *Br J Ophthalmol* 2010; **94**: 898–902.
5 Stidham DB, Borissova O, Borrissov V, Prager TC. Effect of hyperopic laser in situ keratomileusis on ocular alignment and stereopsis in patients with accommodative esotropia. *Ophthalmology* 2002; **109**: 1148–1153.
6 Nemet P, Levinger S, Nemet A. Refractive surgery for refractive errors which cause strabismus. *Binocul Vis Strabismus Q* 2002; **17**: 187–190.
7 Kushner BJ, Kowal L. Diplopia after refractive surgery. *Arch Ophthalmol* 2003; **121**: 315–321.
8 Mandava N, Donnenfeld ED, Owens PL, Kelly SE, Haight DH. Ocular deviation following excimer laser photorefractive keratectomy. *J Cataract Refract Surg* 1996; **22**: 504–505.
9 Schuler E, Silverberg M, Beade P, Moadel K. Decompensated strabismus after laser in situ keratomileusis. *J Cataract Refract Surg* 1999; **25**: 1552–1553.
10 Holland D, Amm M, de Decker W. Persisting diplopia after bilateral laser in situ keratomileusis. *J Cataract Refract Surg* 2000; **26**: 1556–1557.
11 Yap EY, Kowal L. Diplopia as a complication of laser in situ keratomileusis surgery. *Clin Exp Ophthalmol* 2001; **29**: 268–271.
12 Godts D, Tassignon MJ, Gobin L. Binocular vision impairment after refractive surgery. *J Cataract Refract Surg* 2004; **30**: 101–109.
13 Kowal L, Battu R, Kushner B. Refractive surgery and strabismus. *Clin Exp Ophthalmol* 2005; **33**: 90–96.
14 Yildirim R, Oral Y, Uzun A. Exodeviation following monocular myopic regression after laser in situ keratomileusis. *J Cataract Refract Surg* 2003; **29**: 1031–1033.
15 Snir M, Kremer I, Weinberger D, Sherf I, Axer-Siegel R. Decompensation of exodeviation after corneal refractive surgery for moderate to high myopia. *Ophthalmic Surg Lasers Imaging* 2003; **34**: 363–370.
16 Ekdawi NS, Nusz KJ, Diehl NN, Mohney BG. The development of myopia among children with intermittent exotropia. *Am J Ophthalmol* 2010; **149**: 503–507.
17 Yekta A, Fotouhi A, Hashemi H, Dehghani C, Ostadimoghaddam H, Heravian J *et al.* The prevalence of anisometropia, amblyopia and strabismus in schoolchildren of Shiraz, Iran. *Strabismus* 2010; **18**: 104–110.
18 Godts D, Trau R, Tassignon MJ. Effect of refractive surgery on binocular vision and ocular alignment in patients with manifest or intermittent strabismus. *Br J Ophthalmol* 2006; **90**: 1410–1413.
19 Rajavi Z, Nassiri N, Azizzadeh M, Ramezani A, Yaseri M. Orthoptic Changes following Photorefractive Keratectomy. *J Ophthalmic Vis Res* 2011; **6**: 92–100.
20 Holmes JM, Leske DA, Hatt SR, Brodsky MC, Mohney BG. Stability of near stereoacuity in childhood intermittent exotropia. *J AAPOS* 2011; **15**: 462–467.
21 Holmes JM, Leske DA, Hohberger GG. Defining real change in prism-cover test measurements. *Am J Ophthalmol* 2008; **145**: 381–385.
22 Scattergood KD, Brown MH, Guyton DL. Artifacts introduced by spectacle lenses in the measurement of strabismus deviations. *Am J Ophthalmol* 1983; **96**: 439–448.
23 Remole A. Determining exact prismatic deviations in spectacle corrections. *Optom Vis Sci* 1999; **76**: 783–795.

24 Caltrider N, Jampolsky A. Overcorrecting minus lens therapy for treatment of intermittent exotropia. *Ophthalmology* 1983; **90**: 1160–1165.
25 Jampolsky A, Flom BC, Weymouth FS, Moster LE. Unequal corrected visual acuity as related to anisometropia. *Arch Ophthalmol* 1955; **54**: 893–905.
26 Abbott ML, Schmid KL, Strang NC. Differences in the accommodation stimulus response curves of adult myopes and emmetropes. *Ophthalmic Physiol Opt* 1998; **18**: 13–20.
27 Hashemi H, Samet B, Mirzajani A, Khabazkhoob M, Rezvan B, Jafarzadehpur E. Near Point of Accommodation and Convergence after Photorefractive Keratectomy (PRK) for Myopia. *Binocul Vis Strabolog Q Simms Romano* 2013; **28**: 29–35.
28 Alió JL, Muftuoglu O, Ortiz D, Pérez-Santonja JJ, Artola A, Ayala MJ *et al*. Ten-year follow-up of laser in situ keratomileusis for myopia of up to −10 diopters. *Am J Ophthalmol* 2008; **145**: 46–54.