

Photorefractive keratectomy influences the angle of ocular deviation in strabismus patients with hyperopia

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Abstract

Purpose To evaluate refractive, binocular vision and ocular alignment outcomes of photorefractive keratectomy (PRK) for the treatment of hyperopia in esotropic patients.

Methods Medical charts of hyperopic patients with full or partial accommodative esotropia (FAE or PAE) or consecutive exotropia (CE) undergone PRK from 2011 to 2014 were reviewed. The primary outcome was to assess the efficacy of PRK in improving ocular alignment. The secondary outcomes were the assessments of uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), spherical equivalent (SE) and stereoacuity.

Results Sixty-four eyes of 32 hyperopic patients were included. Three patients were affected by FAE, 24 by PAE and 5 by CE. All FAE patients and 4 PAE patients underwent only PRK; the remaining 25 patients underwent PRK plus strabismus surgery. After PRK, the mean corrected esodeviation decreased significantly in the overall esotropic population [7.15 ± 9.42 prism diopters (PD) vs. 5.04 ± 8.83 PD; $p = 0.03$] and in particular in the group with small-angle esodeviation (< 20 PD). Conversely, the only 2 patients with an angle of strabismus

≥ 20 PD as well as all CE patients did not show any postoperative variation of the deviation angle. Mean preoperative BCVA did not differ from postoperative UCVA ($p = 0.19$), while the mean postoperative SE decreased significantly after PRK ($p < 0.0001$).

Conclusions Our study confirmed that PRK eliminates the accommodative component of the deviation. In addition, this procedure seems to reduce or eliminate also the non-accommodative component of esodeviation (especially in small-angle deviation), thus suggesting to postpone strabismus surgery after PRK when esotropia and hyperopia coexist.

Keywords Photorefractive keratectomy · Refractive surgery · Strabismus · Esotropia · Hyperopia

Introduction

It is well established that uncorrected hypermetropia can cause esotropia since Donders' times [1]. In fact, hyperopic patients attempt to clear the image blur by increasing accommodative effort that, in turn, causes excessive accommodative convergence. Esotropia develops if fusional divergence is insufficient to compensate for this phenomenon. Two forms [namely, fully accommodative refractive esotropia (FAE) or partially refractive accommodative (PAE)] are distinguished according to the total or partial contribution of accommodative factors for the entire ocular deviation

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[2]. In fact, the correction of the refractive error by spectacles, contact lenses or refractive surgery completely eliminates the angle of deviation in FAE patients, while reduces the deviation correcting only the accommodative component in PAE ones. In the latter condition, strabismus surgery can be necessary to correct the non-accommodative component of the deviation. It can precede or follow refractive surgery according to the pathophysiology of the misalignment, the time of deviation onset and the steady or variable course of the deviation over time. Photorefractive keratectomy (PRK) represents one of the most common techniques used to correct refractive errors. Since the first report by Bilgihan and coworkers, several papers have been published about its successful use for the treatment of FAE and PAE [3–14]. Recently, PRK was demonstrated to be safe and effective also for the treatment of refractive errors in nystagmus patients [15, 16].

To date, no data are available in the literature about the possible effect of refractive surgery on the non-accommodative component of the ocular deviation in esotropic patients. This issue could be crucial for establishing the proper sequence and timing of strabismus and refractive surgeries. Therefore, the aim of the present study was to evaluate refractive, binocular vision and ocular alignment outcomes of PRK for the treatment of hyperopia in esotropic patients.

Patients and methods

We retrospectively reviewed the medical charts of patients who underwent PRK from January 2011 to December 2014 in our institution (Ophthalmology Unit Head Prof EC Campos, S.Orsola-Malpighi Teaching Hospital, University of Bologna, Italy). Inclusion criteria were hyperopia with a spherical equivalent (SE) up to 6.75 diopters (D), history of esotropia (FAE and PAE), age older than 15 years and stable refraction for at least 2 years. Exclusion criteria were history of previous refractive surgery procedures, pregnancy or lactation, systemic disease, nystagmus, ongoing therapies likely to affect wound healing, keratoconus or other active eye disease, pupil diameter of 8.0 mm or larger under mesopic conditions.

Normal binocular single vision was diagnosed if normal sensory and motor fusion as well as stereopsis

were present. Fully accommodative esotropia was defined in the presence of esotropia without correction and orthophoria with normal binocular vision with full correction. Partially accommodative esotropia was defined in the presence of esotropia with and without correction (in the latter case the amount of deviation is higher), or even orthotropia with correction but without normal binocular vision. Detailed history of strabismus course over the time including previous medical and surgical treatment was collected. A complete ophthalmic examination was performed before the laser procedure. Briefly, uncorrected (UCVA) and corrected (BCVA) distance visual acuities, presence/absence of stereopsis (TNO test), angle of deviation (prism cover test), ocular motility, fusional amplitude, cycloplegic retinoscopy, slit lamp examination and a dilated fundus evaluation were performed. Subjective determination of manifest hyperopia was performed prior to cycloplegia. Total hyperopia (manifest and latent hyperopia) was determined by instilling two drops of cyclopentolate 1.0% 10 min apart and performing retinoscopy 30 min after instillation of the second instillation. The accommodative component of distance esotropia was designated as the amount of esotropia eliminated by the hyperopic correction (spectacles or contact lenses), while the patient fixed at distance. The remaining esotropia was designated as the non-accommodative component. Distance alignment measurements were obtained with correction preoperatively and without correction postoperatively. Refractive error was evaluated by the same diagnostic procedures used for routine refractive surgery. Briefly, corneal topography and thickness were measured using the Pentacam rotating Scheimpflug camera (Oculus Optikgeräte GmbH) and the Humphrey Atlas system (Carl Zeiss Meditec AG). Pupil size was measured in the dark using the Colvard pupillometer (Oasis Medical, Inc.). Contrast sensitivity testing was performed using the CSV-1000 chart (VectorVision) under controlled mesopic conditions (70 lx) at 3, 6, 12 and 18 cycles per degree. All eyes received 5 preoperative wavefront analyses using the Visx Customvue Wavescan aberrometer (version 3.62, Fourier) without pharmacologic intervention and under mesopic conditions with a minimum pupil diameter of 6.0 mm. In all cases, PRK was performed in both eyes under topical anesthesia by the same surgeon (EC Campos). Laser ablation was performed using the wavefront-guided

Visx Star S4 Customvue platform with Active-Track™ iris registration (Abbott Medical Optics, Inc.). The ablation profiles in this study included a treatment zone of 5.5–6.0 mm with a transition zone of up to 9.0 mm. Antibiotic and steroidal drops were prescribed for 14–28 days postoperatively. The use of unpreserved tear substitutes was recommended for at least 6 months after surgery. Patients were followed postoperatively at 1, 7 and 14 days; 1 and 3 months; and 1 year.

Statistical evaluation was performed by using MedCalc and SPSS 14 software and applying the two-tailed, paired Student's *t* test; values were considered statistically significant if *p* was less than 0.05. Snellen fraction was converted to logMAR equivalent for statistical analysis. Results were expressed in results section both in Snellen fraction and in logMAR as mean, minimum–maximum values and standard deviation (SD).

Outcomes

The primary outcome of the study was to assess the efficacy of PRK in improving ocular alignment in esotropic hyperopic patients. The secondary outcomes were the changes of UCVA, BCVA, spherical equivalent (SE) and stereoacuity before and after PRK.

Results

Sixty-four eyes of 32 hyperopic patients (22 females and 10 males) undergone PRK were included in the study. The mean patient age at the time of the PRK was 27.7 years (range 15–51; 9.82 SD). Three patients (9% of the total) were affected by FAE, 24 patients (75%) were affected by PAE, and 5 patients (16% of the total) were affected by consecutive postsurgical distance exotropia (CE). Four patients were affected by monocular amblyopia with a significant unilateral visual impairment. Two PAE patients wore successfully contact lenses before PRK.

All FAE patients and 4 PAE patients underwent PRK as the only procedure. Twenty PAE patients and all patients with consecutive exotropia underwent PRK plus strabismus surgery. In particular, 18 patients (16 with PAE and 2 with consecutive exotropia) underwent strabismus surgery only before PRK (mean interval time of 14.7 years), 2 patients with PAE

underwent strabismus surgery only after PRK (mean interval time of 1 year), and 5 patients (2 with PAE and 3 with consecutive exotropia) underwent strabismus surgery both before and after PRK (mean interval time pre-PRK of 20.6 years and post-PRK of 1.3 years) (Tables 1, 2).

PRK was performed in all patients without any intraoperative complication. Postoperative course was regular except for the onset of transient mild corneal haze in 23 eyes (36%) which resolved after few weeks of topical steroid treatment (mean interval time of 23 days). The median follow-up after PRK was 38 months (range 23–70; 15.52 SD).

Primary outcome

After PRK, the mean corrected distance esodeviation significantly decreased from 7.15 prism diopters (PD) (range from 0 to 40; 9.42 SD) to 5.04 PD (range from 0 to 40; 8.83 SD) in the overall esotropic population (*p* = 0.03). Conversely, the mean corrected distance consecutive exodeviation decreased from the preoperative value of – 22 PD (range from – 35 to – 10; 12.55 SD) to the postoperative value of – 20 PD (range from – 35 to – 10; 13.69 SD) with no statistical significance (*p* = 0.37) (Table 3).

Among PAE patient with small angle of deviation (< 20 PD), an improvement in the angle of strabismus was noticed after PRK in 7 patients (32% of the total). Conversely, the only 2 patients with an angle of strabismus ≥ 20 PD did not show any postoperative variation of the deviation angle. No change in the post-PRK angle of strabismus was noticed also in all the patients with CE. None case of worsened angle of deviation was recorded after PRK.

Secondary outcomes

The mean preoperative BCVA was 0.019 logMAR (range from 0 to 0.7; 0.093 SD). The mean preoperative SE was 4.28 (range from 0.25 to 7.5; 1.60 SD) diopters. One year after PRK, the mean postoperative BCVA was 0.013 logMAR (range from 0 to 0.3; 0.049 SD), the mean postoperative UCVA was 0.035 logMAR (range from 0 to 0.5; 0.090 SD), and the mean post-PRK SE was 0.025 (range from – 1.5 to 1.87; 0.46 SD) diopters.

There was no statistically significant change between the mean pre- and postoperative BCVA

Table 1 List of patients who underwent strabismus surgery before photorefractive keratectomy

No.	Patient initials	Surgery pre-PRK	Interval (years)
1	D.V.M.	BMR	18
2	B. I	BMR; BIOR; BLR	8
3	M.A.	MSOR; BMR; BIOR; MMR; MIOR	3
4	M.C.	BMR	43
5	S.E.	BMR; MLR; BMR	13
6	F.E.	BMR; BLR	27
7	M.V.	BMR; MIOR	1
8	P.F.	BMR; MIOR	11
9	D.C.M	BMR	11
10	M.F.	MMR; MMR	34
11	G.M.	BIOR; MMR; MMR; BLR	12
12	C.A.	BMR	16
13	V.A.	BMR	15
14	P.E.	BMR	15
15	B.J.	MMR	11
16	A.A.	BMR	10
17	C.C.	BMR	14
18	D.G.R.	BMR	31
19	M.F.	BMR	16
20	M.C.	BMR; MLRe; BMA	15
21	G.G	BMR	33
22	D.F.C.	BMR; BIOR	20
23	R.V.	BMR	9

BMR bilateral medial rectus muscle recession, *BIOR* bilateral inferior oblique muscle recession, *BLR* bilateral lateral muscle resection, *MSOR* monolateral superior oblique muscle recession, *MMR* monolateral medial rectus muscle recession, *MIOR* monolateral inferior oblique muscle recession, *MLR* monolateral lateral muscle resection, *MLRe* monolateral lateral rectus muscle recession, *BMA* bilateral medial rectus muscle advancement

Table 2 List of patients who underwent strabismus surgery after PRK

No.	Patient initials	Surgery post-PRK	Interval (years)
1	C.M.C.	BMR	1
2	D.F.C.	BMR	1
3	D.G.R.	BMR	2
4	M.F.	MMR	2
5	M.C.	MLRe; MMA	1
6	G.G	BMA	1
7	D.F.C.	MMA	1

BMR bilateral medial rectus muscle recession, *MMR* monolateral medial rectus muscle recession, *MLRe* monolateral lateral rectus muscle recession, *MMA* monolateral medial rectus muscle advancement, *BMA* bilateral medial rectus muscle advancement

($p = 0.45$). Furthermore, there was no statistically significant difference between the mean preoperative BCVA and the mean postoperative UCVA ($p = 0.19$) (Table 4).

However, the mean postoperative SE was significantly lower compared to preoperative values ($p < 0.0001$).

The three patients with FAE had stereoacuity evidenced by TNO stereoacuity test both before and after PRK. Of the remaining twenty-nine patients without stereopsis before PRK, twenty-seven had no change in stereoacuity after the procedure, while two patients acquired stereopsis post-PRK.

Discussion

It is well known that refractive surgery is efficacy for correcting ocular alignment in accommodative strabismus. This procedure corrects the entire amount of the deviation in FAE patients; conversely, strabismus surgery, before or after refractive surgery according to the strabismus pathophysiology and history, is needed in partially accommodative esotropic patients.

Table 3 Variation of the angle of deviation before and after PRK

No.	Patient initials	Deviation before PRK (PD)	Deviation post-PRK (PD)	Δ deviation (PD)
1	D.V.M.	1	1	0
2	B.I.	10	8	2
3	M.A.	8	8	0
4	M.C.	17	10	7
5	R.V.	– 20	– 10	10
6	S.E.	– 10	– 10	0
7	F.E.	6	1	5
8	M.V.	2	2	0
9	P.F.	10	8	2
10	D.C.M.	5	5	0
11	M.F.	19	1	18
12	G.M.	1	1	0
13	C.A.	5	5	0
14	V.A.	0	0	0
15	P.E.	16	0	16
16	B.J.	0	0	0
17	A.A.	0	0	0
18	C.C.	0	0	0
18	C.G.	1	1	0
20	S.F.	8	1	7
21	S.M.	0	0	0
22	R.S.	0	0	0
23	P.E.	0	0	0
24	M.M.	0	0	0
25	Q.I.	0	0	0
26	C.M.C.	40	40	0
27	D.F.C.	20	20	0
28	D.G.R.	6	6	0
29	M.F.	18	18	0
30	M.C.	– 35	– 35	0
31	G.G.	– 35	– 35	0
32	D.F.C.	– 10	– 10	0

PRK photorefractive keratectomy, PD prism diopters

In our study, PRK was performed in young adult patients older than 15 years. Indeed, even if hyperopia usually stabilizes approximately at 12 years, we consider appropriate to perform refractive surgery later because symptomatic esophoria could develop between 12 and 15 years [2]. Furthermore, patients' compliance, mandatory to perform surgery under topical anesthesia, is usually present only after this

age threshold; otherwise, we consider safer to postpone surgery.

Our study confirmed that PRK eliminates the accommodative portion of the deviation, improving postoperative UCVA up to preoperative BCVA. Furthermore, neither residual refractive errors nor regression over 0.75 diopters after hyperopic treatments was noticed within the follow-up period.

Table 4 Refractive and visual outcomes of PRK

No.	Patient initials	EYE	BCVA pre-PRK (logMAR)	UCVA post-PRK (logMAR)	SE pre-PRK	SE post-PRK
1	D.V.M.	OD	0	0	4.5	0
		OS	0	0	5.5	0
2	B.I.	OD	0	0	4.37	0
		OS	0	0	4.75	0
3	M.A.	OD	0	0	3.75	0
		OS	0	0	1.75	0
4	M.C.	OD	0	0	3.75	0
		OS(A)	0	0.1	7	1.25
5	R.V.	OD	0	0	3.75	0
		OS	0	0	3.75	0
6	S.E.	OD	0	0	3.25	0
		OS	0	0	0.25	0
7	F.E.	OD	0	0	6.75	0
		OS	0	0	7.5	0
8	M.V.	OD	0	0	1.875	0
		OS	0	0	2	0
9	P.F.	OD	0	0	2	0
		OS(A)	0	0.2	3	0
10	D.C.M.	OD	0	0.1	3.125	− 1.25
		OS	0	0	2.875	− 0.375
11	M.F.	OD	0	0	5.5	0
		OS	0	0	5.25	0
12	G.M.	OD	0.1	0.1	6.5	− 1.25
		OS	0	0.2	6.5	− 0.75
13	C.A.	OD	0	0	2.5	0
		OS	0	0	1.625	0
14	V.A.	OD	0	0	5	0
		OS	0	0	5.5	0
15	P.E.	OD	0	0	5.625	0
		OS	0	0.2	6	1
16	B.J.	OD	0	0	5.25	0
		OS(A)	0.7	0.3	5.5	0
17	A.A.	OD	0	0	5.875	0
		OS	0	0	5.75	0
18	C.C.	OD	0	0	6	0
		OS	0	0	5.5	0
19	C.G.	OD	0	0	4.12	0
		OS	0	0	3.62	0
20	S.F.	OD	0	0	3.5	0
		OS	0	0	3	0
21	S.M.	OD	0	0	4	0
		OS	0	0	4.25	0

Table 4 continued

No.	Patient initials	EYE	BCVA pre-PRK (logMAR)	UCVA post-PRK (logMAR)	SE pre-PRK	SE post-PRK
22	R.S.	OD	0.2	0.2	5.75	1.875
		OS	0	0	6	0.75
23	P.E.	OD	0	0.2	6.75	1
		OS	0	0	6.75	0
24	M.M.	OD	0	0	2.5	0
		OS	0	0	2.5	0
25	Q.I.	OD	0	0	5	0
		OS	0	0	5	0
26	C.M.C.	OD	0	0	2.875	0
		OS	0	0.5	3.375	– 1.5
27	D.F.C.	OD(A)	0.2	0.1	5	0
		OS	0	0	4.125	0
28	D.G.R.	OD	0	0	5.25	0
		OS	0	0	3.875	0
29	M.F.	OD	0	0	4.625	0
		OS	0	0	3.75	0
30	M.C.	OD	0	0	2.625	0
		OS	0	0	2.75	0
31	G.G.	OD	0	0	4.25	0
		OS	0	0	1.5	0
32	D.F.C.	OD	0	0	3.25	0
		OS	0	0	3.375	0

PRK photorefractive keratectomy, BCVA best-corrected visual acuity, UCVA uncorrected visual acuity, SE spherical equivalent, A amblyope

Surprisingly, we noted that PRK could allow to reduce or eliminate also the non-accommodative amount of deviation in partially accommodative esotropic patients presenting small angle of deviation (< 20 PD) before PRK. On the contrary, this phenomenon was not demonstrated for PAE esotropic patients with large angle of deviation (≥ 20 PD) and patients with consecutive exotropia. As a consequence, we consider more appropriate to firstly perform PRK and then strabismus surgery only if a clinically significant angle of deviation persists. This approach seems to be particularly crucial in the presence of small esodeviation that could be reduced, or even fully eliminated, only by PRK, avoiding subsequent surgery on extraocular muscles. One hypothesis could be related to the possible influence of the type of optical correction (spectacles or contact lenses) while measuring the corrected distance angle of deviation. In our routinely practice, we measure the angle of deviation with the preferred correction used

by the patient. However, we hypothesize that the corrected angle of deviation could be differently influenced by spectacles or contact lenses. In particular, accommodation and vergence demands have been demonstrated to be different in patients wearing contact lenses and spectacles. In fact, myopes are required to exert more accommodation and vergence when wearing contact lenses compared to spectacles, and conversely hypermetropes are required to exert less accommodation and vergence when wearing contact lenses compared to spectacles. This phenomenon could be particularly crucial in strabismus patients. Although the type of optical correction more predictive of the influence of PRK in modifying postoperative ocular alignment is not known, it should be highlighted that in our study only two patients wore contact lenses, while the remaining wore spectacles, which could have affected the measurement of the corrected distance angle of deviation [17–20].

Although this study represents one of the largest case series in this field, its major limitation concerns the retrospective design, and larger prospective studies are desirable to confirm and better explain these data.

In conclusion, this study highlighted the influence of PRK in modifying ocular alignment in hyperopic strabismus patients. Despite several previous studies reported the efficacy of the procedure on the accommodative component of strabismus, the correct timing between strabismus and refractive surgeries and the influence of PRK upon the non-accommodative component are here demonstrated for the first time. This finding could influence patient's surgical management when esotropia and hypermetropia coexist. It appears that refractive surgery should always precede strabismus surgery, when the latter is needed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethical standard All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (place name of institute/committee) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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