

Photorefractive Keratectomy for the Treatment of Compound Myopic Astigmatism Using the Ablatable Mask

W J Heng,**MBBS, M Med (Ophth), FRCS (Edin)*, W K Chan,***FAMS, M Med (Ophth), FRCOphth*, P Tseng.****FAMS, FRCOphth, FRCS (Edin)*,
V Balakrishnan,***M Med (Ophth), FRCOphth, FRCS (Edin)*, C H LOW ,*****FAMS, FRCOphth, FRCS (Edin)*

Abstract

Eight eyes of 8 patients with compound myopic astigmatism were treated with excimer laser photorefractive keratectomy (PRK) using a hand-held ablatable mask in conjunction with the Summit excimer laser. The attempted correction ranged from -1.25 to -4.00 dioptres (D) of astigmatism and 0 to -8.00 D of myopia. All eyes had attained at least 6 months of postoperative follow-up. Five of the 8 eyes achieved an unaided visual acuity of 6/12 or better. Postoperative refractions ranged from -0.50 to -3.50 D of refractive cylinder and from +0.50 to -3.75 D of spherical error. Decentration of the ablation zone was encountered in 3 eyes due to shifts in patients' fixation. Technical difficulty with the use of the hand-held ablatable mask limited the widespread application of this procedure and it has now been superseded by newer excimer laser systems which can correct astigmatism without having to employ a mask. Despite this, because of the theoretical ability of the mask to correct any form of refractive error, the concept of the mask shape transfer process will remain as a potential alternative in refractive surgery, especially for correction of hyperopia and hyperopic astigmatism.

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Introduction

The excimer laser is employed in refractive surgery because its photoablative property permits reshaping of the anterior surface of the cornea thus modifying its optical power. The use of the excimer laser for correction of myopia was first introduced by Trokel et al¹ in 1983. In 1984, Muller² proposed the concept of using an ablatable mask for performing photorefractive keratectomy (PRK). Thereafter, several preclinical trials have been performed on animal models. However, it was only until the last few years that clinical trials^{3,4} on human eyes were carried out. The technique of using PRK for the correction of myopia was first employed in Singapore in 1992 and since then, the predictability, stability, and safety of the procedure for correction of low to moderate myopia have been well shown.^{5,6} This paper reports the results of PRK using the hand-held ablatable mask technique for the correction of compound myopic astigmatism.

The concept of using the ablatable mask for PRK has been described in detail elsewhere³ and it will therefore only be reviewed briefly here. The ablatable mask con-

sists of a polymethylmethacrylate (PMMA) button. PMMA absorbs laser energy and is ablated at the same rate as corneal stroma. The energy delivered onto the cornea can be made asymmetrical at different axes by varying the thickness of the PMMA button at these axes. As the whole mask is ablated, the region of the cornea beneath the thinnest portion of the mask would be ablated most and that beneath the thickest portion of the mask would be ablated least (Fig. 1). This will produce a greater flattening along one axis and therefore corrects astigmatism. This also forms the basis of the mask shape transfer process.

Materials and Methods

This study was a prospective, non-randomized clinical trial approved by the Medical Board of the Singapore National Eye Centre. The laser system used was a 193 nm argon-fluoride excimer laser (ExciMed UV200LA, Summit Technology Inc, Waltham, MA, USA) with a fluence of 180 mJ/cm², ablation rate of 0.25 microns/pulse, and an ablation zone of 5 mm. The microscope used was a non-coaxial microscope.

* Registrar

Department of Ophthalmology
Tan Tock Seng Hospital

** Consultant

*** Senior Consultant and Head, Department A

**** Visiting Consultant

Singapore National Eye Centre

Address for Reprints: Dr Chan Wing Kwong, Singapore National Eye Centre, 11 Third Hospital Avenue, Singapore 168751.

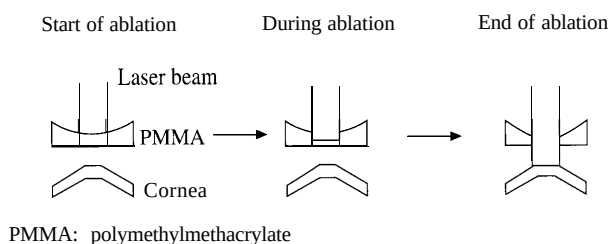


Fig. 1. Concept of photorefractive keratectomy with an ablatable mask

PRK was performed with the EmphasisTM ablatable mask (Summit Technology Inc, Waltham, MA, USA). The ablatable mask prescription was individualized for each eye's refractive error. This consisted of a PMMA button bonded to a quartz plate which is mounted in a hand-held plastic eyecup. On the PMMA button are a 2 mm diameter gold ring and a line indicating the axis of the mask prescription to facilitate alignment with the astigmatic axis of the eye. The eyecup is rested on the conjunctiva and keeps the PMMA disc 3.5 mm above the cornea. Three connectors to the cup provide humidified air, vacuum suction and fibreoptic illumination to the chamber between the cup and the cornea.

Optical alignment of the laser-mask-eye complex was obtained as follows. The inferior edge of the gold ring was adjusted so that it passed through the centre of the pupil to compensate for the parallax error which resulted from the use of the non-coaxial microscope. The gold axis line was aligned with predetermined iris landmarks. The perpendicular orientation of the mask and the laser beam was achieved by means of 3 pairs of Helium-Neon laser aiming beams forming 3 sharply focused spots at the 10, 2, and 6 o'clock positions on a ring at the edge of the mask. With the help of these devices, the surgeon had to avoid translational movements of the eyecup along 2 axes on the horizontal plane as well as tilting movements with respect to the vertical axis. In addition, a green fixation light coaxial with the excimer laser beam was used for patient fixation. It can thus be seen that the whole process of alignment was complex and technically difficult to perform. This was the main risk factor for decentration.

Pilocarpine 1% was instilled half an hour before the operation to constrict the pupil to facilitate centration of the eye under the laser beam. The procedure was performed under topical anaesthesia with proparacaine 0.5% eyedrops. Under the microscope, iris landmarks coinciding with the axis of astigmatism were identified. The epithelium was manually removed prior to the actual procedure. The patient was asked to fixate on the fixation light. The eyecup was positioned over the eye and aligned as previously described. The manufacturer specified number of laser pulses were delivered. Postoperatively, the eye was patched with an antibiotic-steroid ointment (TobraDex, Alcon, Ft. Worth, USA) 5 times per day until the cornea was re-epithelialized. This was followed by a steroid eyedrop (fluoromethalone forte) 5 times per day for the first month and tailed down according to the refractive status and the amount of corneal scarring postoperatively.

Results

Eight eyes of 8 patients were operated on from October 1992 to July 1993. All patients had at least 6 months of follow-up (range 6 to 30 months). Their age ranged from 22 to 55 years. All were Chinese and there was an equal number of males and females. The inclusion criteria were: age of 21 years or older, myopia of more than 2 D, astigmatism of more than 1 D, best corrected visual acuity of 6/9 or better in both eyes, and a stable refraction for at least one year. Exclusion criteria included progressive myopia, active ocular diseases, glaucoma, irregular astigmatism, previous corneal surgery or trauma, and taking medication or having systemic diseases likely to affect wound healing.

Preoperatively, the mean astigmatic error was -2.5 D and the mean spherical error was -5.3 D. Postoperatively, the mean astigmatic error was -1.3 D and the mean spherical error was -1.2 D (Table I). Five of the 8 eyes had an unaided visual acuity of 6/12 or better (Table II). There was improvement in the unaided visual acuity after the procedure except in patients 5 and 6 where the unaided visual acuity remained unchanged (Fig. 2). One eye (patient no. 5) lost 2 lines of best corrected Snellen acuity (Fig. 3). Five of the 8 eyes were within ± 1.00 D of

TABLE I: PREOPERATIVE AND POSTOPERATIVE MANIFEST REFRACTION

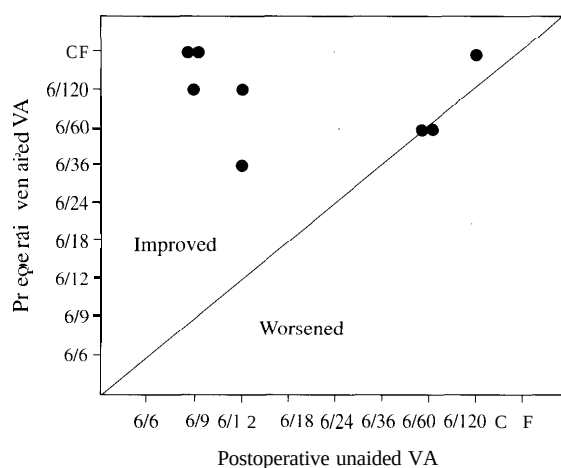
Patient	Preoperative Refraction	Attempted Correction	6 mo Refraction	1 y Refraction	Notes
1	-5.00-4.00 x 180	-5.00-4.00 x 180	-0.50-0.75 x 170	—	—
2	-6.75-2.25 x 170	-7.00-2.00 x 165	-2.75-1.25 x 145	-1.75-0.75 x 150	decentration
3	-8.00-1.50 x 180	-5.00-1.50 x 180	—	-3.00-0.75 x 180	intentional undercorrection
4	-6.25-1.25 x 175	-6.25-1.25 x 175	-0.50-0.50 x 165	-0.25-0.50 x 180	—
5	+1.50-4.00 x 180	plano-3.75 x 180	plano-4.50 x 10	plano-3.50 x 180	regression
6	-9.50-2.50 x 180	-8.00-2.50 x 180	-3.75-2.50 x 170	—	regression:retreated
7	-3.25-2.75 x 180	-3.25-3.00 x 180	—	+0.50-1.25 x 160	decentration
8	-5.50-2.00 x 180	-5.50-2.00 x 5	plano-2.25 x 50	-1.00-0.50 x 20	decentration

TABLE II: PREOPERATIVE AND POSTOPERATIVE VISUAL ACUITY

Patient	Preoperative UAVA	Preoperative BCVA	Postoperative UAVA	Postoperative BCVA	Notes
1	6/120	6/9	6/12	6/9	
2	6/30	6/6	6/12	6/6	decentration
3	CF	6/6	6/120	6/6	intentional undercorrection
4	CF	6/6	6/7.5	6/6	
5	6/60	6/6	6/60	6/12	regression
6	6/60	6/6	6/60	6/7.5	regression:retreated
7	6/120	6/7.5	6/7.5	6/6	decentration
8	CF	6/6	6/9	6/6	decentration

(postoperative visual acuities were at the last follow-up visit)

UAVA: unaided visual acuity; BCVA: best corrected visual acuity; CF: count fingers



VA: visual acuity; CF: count fingers

Fig. 2. Scatterplot of pre and postoperative unaided visual acuity. No eyes had worse unaided visual acuity after the procedure.

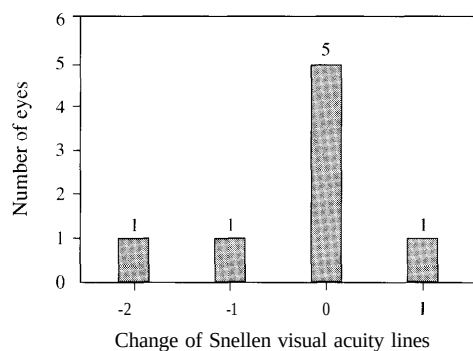


Fig. 3. Change of Snellen visual acuity lines after the procedure. Only 1 eye lost 2 lines of best spectacle corrected visual acuity. Change of ± 1 line is not considered significant.

the desired refraction 6 months postoperatively. Two of the 8 eyes showed regression at 6 months and 1 had to be retreated. Decentration was encountered in 3 of the 8 eyes with one patient complaining of monocular diplopia despite having a good unaided visual acuity of 6/9 (Figs. 4 & 5). None of the eyes developed significant corneal haze. There were also no other complications such as delayed corneal re-epithelialization, steroid-induced ocular hypertension, cataract or infective keratitis.

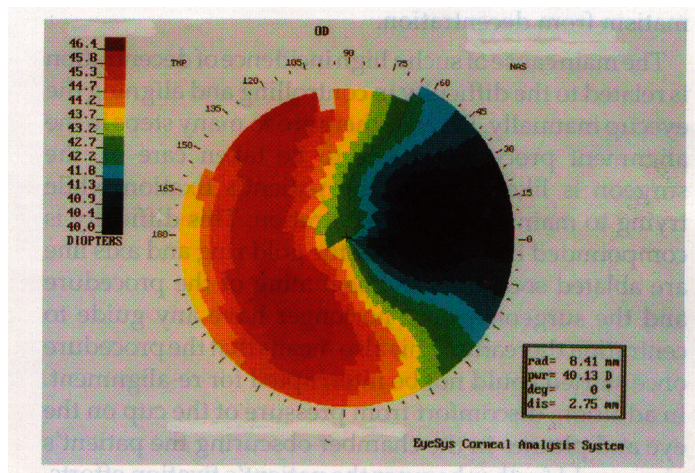


Fig. 4. Computerised corneal topographic map showing a well-centred ablation. The centre of the treatment zone coincides with the centre of the cornea.

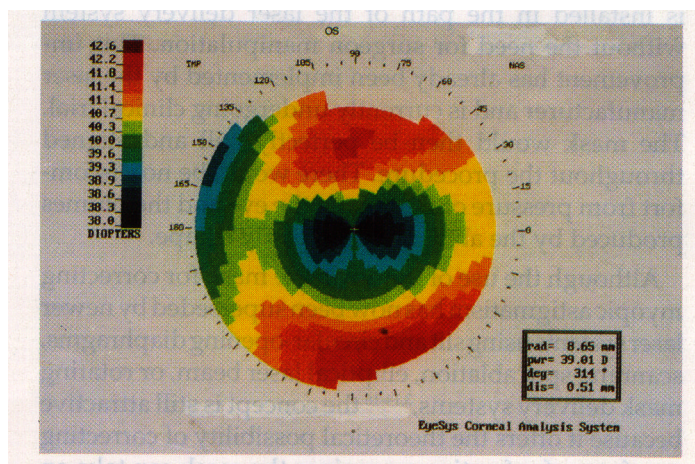


Fig. 5. Computerised corneal topographic map showing a decentred ablation. The centre of the flattened ablation zone has been shifted away from the centre of the cornea.

Discussion

In this study, decentration of the ablation zone was the main problem. Although the number of eyes studied was too small for any statistical inference, this finding is similar to the frequency of decentration reported by Gobbi et al⁷ (2 out of 5 cases), Hersh and Patel⁸ (32%) and Brancato et al⁹ (2 out of 5 eyes). As a result of this problem, the predictability of this procedure (measured

in terms of percentage of eyes within ± 1 D of desired correction) was lower compared to the PRK (without the ablatable mask) results for low to moderate myopia which was reported as 92% by Lavery,¹⁰ 84% by Salz et al,¹¹ 91% by Kim et al¹² and 81% by Ficker et al¹³ after 6 months. Similarly, although this procedure was effective in reducing the amount of astigmatic and spherical errors, not as many patients see as well compared to PRK for low to moderate myopia. Salz et al¹¹ reported 91% and Balakrishnan et al¹⁵ reported 94% of their patients seeing 6/12 or better (unaided) after PRK. In this study, only one eye lost 2 lines of best corrected visual acuity. This was due to induced irregular astigmatism from decentration.

The main cause of such a high incidence of decentration is related to the difficulty in controlling and aligning the eyecup manually. Because there are so many steps in the alignment process that has to be taken care of, the surgeon is likely to lose the patient's fixation while trying to maintain eyecup centration. This difficulty is compounded by the fact that the gold ring and axis line are ablated soon after the beginning of the procedure and the surgeon would no longer have any guide to centration thereafter. This also means that the procedure once started could not be interrupted for re-alignment. In addition, discomfort from pressure of the cup on the eye and plumes in the chamber obscuring the patient's view could further hamper the patient's fixation efforts.

Most of these problems could be bypassed if the mask is installed in the path of the laser delivery system without the need for surgeon manipulation. This improvement has already been implemented by the laser manufacturer and is currently undergoing clinical trial. The mask would then be perfectly still and aligned throughout the procedure. There would be no discomfort from pressure of the cup on the eye and the plumes produced by the ablation could easily escape.

Although the use of the ablatable mask for correcting myopic astigmatism has now been superseded by newer laser systems using slit and circular-opening diaphragms, scanning spot ablation, elliptical laser beam, or rotating mask delivery systems,^{3,14-16} the concept is still attractive because it offers the theoretical possibility of correcting any form of refractive error since the mask can take on any shape. So long as a negative image of the curvature of the cornea can be transferred onto the mask, it can be used to correct even irregular astigmatism, hyperopia, and hyperopic astigmatism. A further advantage is that the mask produces a smoother ablation compared to the conventional opening-diaphragm technique which tends to produce microsteps within the ablation zone due to diaphragm movement.¹⁷ This has been postulated as a possible reason for the lower incidence of corneal scarring and persistent epithelial defects following PRK

with the ablatable mask.^{18,19} It therefore remains for us to find a way of feeding the corneal topography of the patient's eye to a computerised lathe and then instructing it to shape an appropriate mask to achieve the desired refraction. In this respect, the ablatable mask technique still remains as a potential tool in refractive surgery.

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