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CONTRAST SENSITIVITY AND VISUAL ACUITY AFTER EXCIMER LASER TREATMENT FOR MYOPIA — PRELIMINARY FINDINGS ON 15 PATIENTS

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Abstract

This paper examines the preliminary effects of excimer laser treatment on visual function in 15 patients who had myopia ranging from −1.75 to −6.00 dioptres.
The use of the excimer laser to correct refractive error is discussed. Visual function was assessed using a Snellen's acuity test as well as the Vector Vision CSV 1000 contrast sensitivity test. All tests were performed without and then with additional glare using the Mentor Brightness Acuity Tester (BAT). Visual function was assessed prior to excimer treatment then post treatment at three months and the patients will be followed up again at six and 12 months. The visual function at three months post excimer is discussed in this paper.

Key words: *Excimer laser, photorefractive keratectomy (PTK), myopia, contrast sensitivity, Vector Vision CSV 1000, visual acuity.*

INTRODUCTION

In 1983 Trokel reported on the use of the Excimer laser for corneal surgery.[1] He showed that this ultraviolet laser allowed the precise removal of corneal tissue through an unusual laser/tissue interaction. The procedure, involving the use of the excimer laser to alter the refractive error of the eye is now known as photorefractive keratectomy[2] (PRK) as light energy (photo) is used to excise (ectomy) a portion of the cornea (kerato). (The therapeutic treatment of corneal opacities using the excimer laser is known as phototherapeutic keratectomy; PTK).

When performing PRK surgery the excimer laser actually ABLATES (or removes) a very thin layer of the central corneal stroma having the effect of flattening the central cornea thus reducing its refractive power. As a result, parallel rays of light are bent less and are able to come into focus on the fovea of the myopic eye. Initially, post excimer, the patient is made hypermetropic but this settles over time, resulting in a refractive error that is closer to (or at) emmetropia. As the excimer removes such a small depth of corneal tissue the structural integrity of the eye remains intact.

The name excimer is derived from the first two and last syllables of the term excited dimer.[3] An excited dimer is two atoms of inert gases, in this case argon and fluoride, which form a temporary and unstable molecule when forced together

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under extremely high pressure and high voltage. The unstable molecule (or the dimer) decays very readily giving off an emission of an individual photon of 193 nm far UV light. The particular properties of this wavelength of laser light make it suitable to use to decompose the cornea.

The emitted photons (or pulses) are of extremely short wavelength light thus they contain large amounts of energy. The photons are directed onto the cornea by a series of lenses and mirrors housed inside the laser.

Prior to commencement the epithelial layer of the cornea is marked then scraped away thus the photons ablate firstly the exposed Bowman's layer then corneal stroma. When a photon from the excimer laser hits the surface of the cornea the following occurs;

- the photon is absorbed by the corneal tissue it hits
- the energy from the photon (6.4 electron volts) exceeds the binding voltage of the corneal tissue carbon-carbon bonds thus the carbon molecule bonds breakdown removing the corneal tissue[4,5]
- the breaking of the molecular bonds occurs so quickly, (a few picoseconds; ie 1×10^{-12}), and

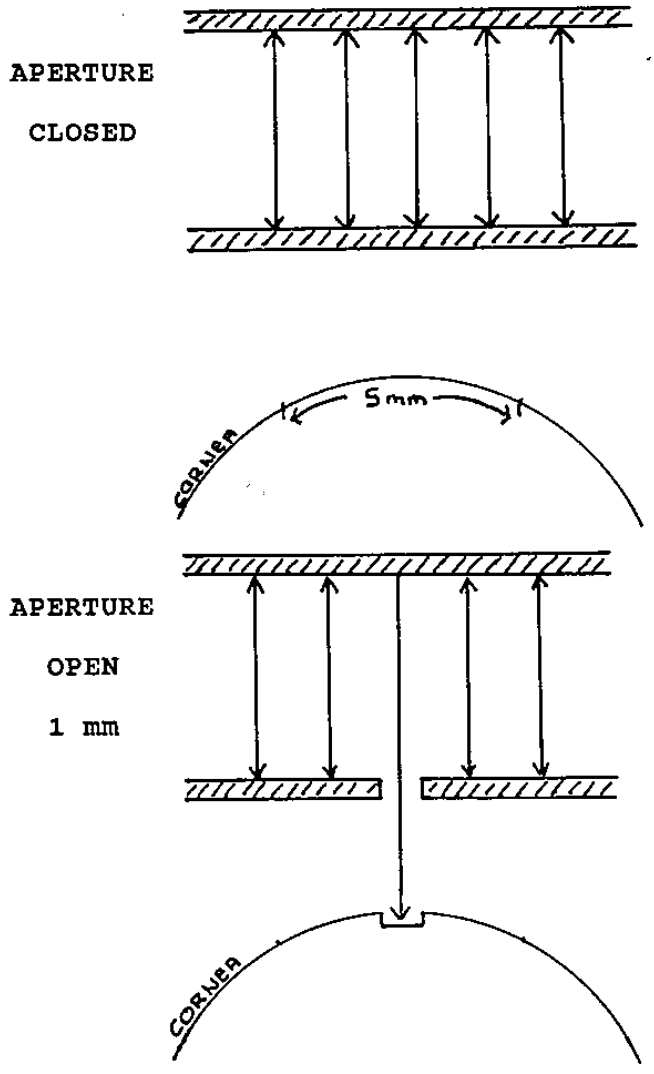

Figure 1: Excimer laser; aperture closed (top). Aperture open 1 mm allowing photons of 193 nm light to pass through onto the cornea ablating corneal stroma (bottom).

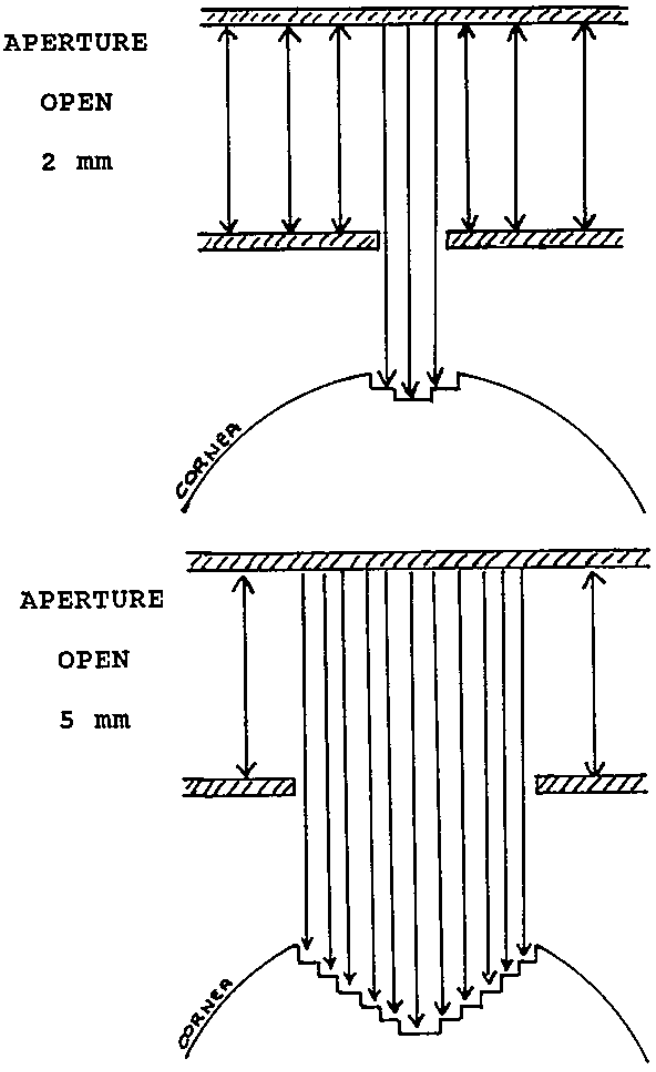

Figure 2: Excimer laser; aperture open 2 mm allowing more photons to pass onto the cornea creating a series of steps into the cornea (top). Aperture open 5 mm (maximum opening) allowing more photons to pass onto the cornea creating a deeper stepped ablation into the cornea (bottom).

the photon is so powerful that the corneal molecular fragments are ejected from the surface of the cornea at supersonic speed of 1000 to 3000 meters per second, carrying excess energy with them.[6]

- Each photon from the excimer removes between 0.1 and 0.5 micrometers or microns of tissue (1 micrometer = 1×10^{-6} meters) with no burning or cutting thus there is no adjacent tissue damage.[6] The tissue removal is precise to within 0.25 microns per pulse.

By the end of the procedure a 5 mm diameter of corneal tissue has been precisely removed by a series of photons passing through a gradually increasing aperture opening. The photons leave a series of steps in the cornea thus the section that is removed is deeper in the centre (see Figures 1 and 2). The steps are smoothed out by epithelial regrowth. (When the excimer laser is used for therapeutic purposes; PTK, the aperture remains fully open so that the tissue is removed evenly within the ablation zone). The excimer causes very little damage to the surronding tissue.

The ablation procedure is accompanied by a strong burning smell, similar to an intensive smell of burning hair. This is thought to be because the airborne particles ejected from the corneal surface are similar types of particles to those given off by thermally damaged biological tissue in the form of smoke but the excimer does NOT burn.[5]

The excimer laser thus differs from the other lasers commonly used in ophthalmology because its beams are absorbed by the cornea causing decomposition of a predetermined depth of corneal molecules without burning.

The aim of the current study was to examine the effect of excimer laser treatment for myopia on different aspects of visual function pre and post excimer treatment. This paper reports on the visual function of 15 patients three months post excimer. Visual function six and 12 months post excimer will be the subject of a later publication.

METHODS

A group of 15 patients ranging in age from 21 years to 57 years who had been followed up for three months post excimer treatment have been included in these preliminary results. All patients had myopia ranging from −1.75 to −6.00 dioptres (spherical equivalent) prior to being treated with the excimer (see Table 1).

Prior to treatment all patients had visual acuity (VA) assessed monocularly with a Snellen's chart at six meters, a logMAR chart at three meters and one third of a meter and an OPSM near vision chart. The distance vision tests were performed with and without optimal correction and with and without glare.

Contrast sensitivity function was assessed using the Vector Vision CSV 1000 at eight feet. The CSV 1000 chart is back lit for constant illumination. The illumination varied with ambient room light. This test was performed with and without optimal correction and with and without glare.

The CSV 1000 test consists of four different rows; each containing eight pairs of targets (numbered one to eight across the row). The targets decrease in contrast across the row. The spatial frequency of the pairs of targets in each row increases down the chart (that is, the stripes in each pair of targets become narrower). The spatial frequencies in each row are, row A = 3; row B = 6; row C = 12 and row D = 18 cpd.

Patients were instructed to tell the examiner whether the stripes appeared in the top target or the bottom target in each pair or if there were no stripes. For each eye the number of the target with the minimum contrast at which stripes were seen

TABLE 1
Refractive error; pre excimer and post excimer laser treatment

Case No	Age	Sex	Refractive error	
			Pre	Post
1	23	M	−2.50	+0.25
2	27	F	−3.25	+0.25
3	41	F	−3.75	+2.25
4	32	F	−6.00	+0.75
5	32	M	−3.50	+0.75
6	27	M	−1.75	+0.25
7	29	F	−2.75	+0.50
8	45	F	−4.75	+0.25
9	21	F	−4.75	−1.00
10	32	F	−5.25	−0.75
11	33	M	−4.25	+0.25
12	24	M	−3.00	+0.50
13	57	M	−3.75	+0.50
14	34	F	−6.00	+1.00
15	39	F	−1.75	−0.25

in each row was recorded. Thus contrast sensitivity was recorded as a number between one (maximum contrast; the worst score) and eight (minimum contrast; the best possible score) or zero was recorded if no stripes were seen on a given row.

The effect of glare on the vision tests and the contrast sensitivity test was assessed using the Mentor Brightness Acuity Tester (BAT) glare test at maximum power (400 foot lamberts).

The mean scores for VA and contrast sensitivity were calculated for all patients. Pre excimer VA and contrast sensitivity mean scores were then compared to post excimer scores using a *t* test to see it there was any significant difference in scores. When the *p* value was less than 0.01 the difference in scores was considered to be significant.

Immediately following the visual assessment the patients had excimer laser treatment (Summit Laser) to correct their myopia. Each patient was checked by their ophthalmologist two days after excimer treatment to ensure that the cornea had reepithelized. Patients were then seen weekly extending to monthly by their ophthalmologist. Subjective retinoscopies were conducted, the haze was graded and the IOP was measured.

All of the above mentioned visual function tests were repeated on all the patients after the excimer at six weeks, three and six months. They will also be tested at 12 and 24 months.

RESULTS

(i) REFRACTIVE ERROR: — Three months post excimer the refractive errors ranged from +2.25 to −1.00. Ten of the 15 patients were between +0.75 and +0.25. Twelve of the 15 were hypermetropic (see Table 1).

(ii) HAZE: — Post excimer all patients had corneal haze ranging from extremely mild to moderate. This suggested that all the corneas were still recovering.

All visual function results are stated as being either BEST CORRECTED (that is the scores with the full refractive correction) or UNCORRECTED (that is the scores without any correction). For statistical analysis Snellen's VA was divided into categories as follows; 6/5⁺, 6/5, 6/6⁺, 6/6, 6/9⁺, 6/9 and so on up to 1/60.

TABLE 2
Snellen's visual acuity; uncorrected pre excimer compared to post excimer and best corrected pre excimer compared to post excimer

Case No	Uncorrected VA		Best Corrected VA	
	Pre	Post	Pre	Post
1	3/60⁺	6/9⁺	6/6⁺	6/6
2	6/24	6/9	6/6	6/6
3	3/60	6/24⁺	6/9	6/9
4	2/60	6/12⁺	6/6⁺	6/5
5	3/60⁺	6/18	6/5	6/5
6	3/36	6/6⁺	6/5	6/5⁺
7	1/60	6/9	6/6⁺	6/6⁺
8	3/60⁺	6/9⁺	6/9⁺	6/9⁺
9	2/60	6/9	6/6	6/6⁺
10	6/60	6/9	6/6⁺	6/6
11	3/60	6/6⁺	6/5	6/6⁺
12	5/60	6/9⁺	6/5⁺	6/5
13	6/60	6/6	6/9	6/6
14	3/60⁺	6/9	6/6⁺	6/6
15	6/60	6/6⁺	6/9⁺	6/6
Mean	4/60	6/9⁺	6/6⁺	6/6⁺

(iii) VISUAL FUNCTION WITHOUT GLARE (pre excimer compared to post excimer).

(a) BEST CORRECTED: — The best corrected Snellen's VA pre excimer was 6/6 or better in all but four patients (who were all 6/9⁺ or 6/9; see Table 2. There was no significant difference in pre excimer compared to post excimer best corrected VA ($t = -1.11$, $p = 0.298$). All but two (Cases 3 and 8) were 6/6 or better post excimer. Both these cases had pre excimer VA of less than 6/6.

When the pre excimer best corrected contrast sensitivity scores were compared to post excimer best corrected scores the post excimer scores were all slightly reduced but there was no significant difference in scores (see Table 3).

TABLE 3
Effect of excimer laser on best corrected contrast sensitivity scores. Pre excimer compared to post excimer; (mean scores, standard deviations, *t* and *p* values)

Row	Contrast sensitivity score				*t* value	*p* value
	Pre excimer		Post excimer			
	Mean	SD	Mean	SD		
A	4.7	(1.418)	4.5	(1.269)	0.43	0.678
B	5.3	(0.949)	4.7	(1.494)	1.41	0.193
C	5.1	(0.876)	4.7	(1.494)	0.60	0.565
D	5.7	(1.337)	4.4	(2.171)	1.49	0.169

(b) UNCORRECTED: — The pre excimer uncorrected VA ranged from 1/60 to 6/24 with only four patients having 6/60 or better. (The mean uncorrected VA was 4/60; see Table 1).

The uncorrected VA at the three months post excimer visit was significantly improved in all cases (mean VA 6/9$^+$; $t=16.51$, $p=0.0001$). Scores were as follows; seven of the 15 patients had 6/9$^+$ or better, six of the 15 patients had 6/12$^+$ or 6/9, (Cases 2, 4, 7, 9, 10, 14) and two of the 15 patients had 6/18 or less, (Cases 3 and 5; see Table 2).

At the time of writing this paper the six month data was available on four of the six patients with 6/12$^+$ or 6/9, (Cases 2, 4, 7, 9). All four had improved to 6/6 or better by six months. Six month data was also available on both of the cases who had VA of 6/18 or less at three months. One had improved to 6/5 (no refractive error; Case 5). The other patient (Case 3; who had a best corrected VA of 6/9 pre excimer) still had 6/18 vision.

Pre excimer contrast sensitivity was not assessed without correction as most patients could not see the contrast sensitivity chart without their correction.

(c) BEST CORRECTED PRE EXCIMER COMPARED TO UNCORRECTED POST EXCIMER VISUAL FUNCTION: — As the aim of excimer treatment is to enable the patient to see and function normally without the aid of glasses or contact lenses the results of the pre excimer visual function with best correction were compared to the post excimer uncorrected visual function.

There was a minimal decrease in scores from pre excimer best corrected VA (mean 6/6$^+$, SD 6/9$^+$ to 6/5) to post excimer uncorrected VA (mean 6/9$^+$, SD 6/6$^+$ to 6/12) at three months (see Table 2). This decrease was NOT significant ($t=-3.12$, $p=0.008$).

Statistical analysis of pre excimer best corrected contrast sensitivity compared with post excimer uncorrected contrast sensitivity revealed that contrast sensitivity was significantly worse post excimer in rows C and D (high spatial frequencies) at three months post excimer (see Table 4). As this finding must be reflecting the residual refractive error present in all patients three months post excimer no meaningful conclusions can be drawn at this stage.

TABLE 4
Effect of excimer laser on contrast sensitivity scores. Pre excimer best corrected scores compared to post excimer uncorrected scores; (mean scores, standard deviations t and p values)

Row	Contrast sensitivity score (Best corrected) (Pre excimer		(Uncorrected) Post excimer		t value	p value
	Mean	SD	Mean	SD		
A	4.6	(1.183)	4.1	(1.710)	1.17	0.262
B	5.1	(0.915)	3.9	(1.981)	2.50	0.025
C	5.0	(1.069)	3.5	(1.885)	3.15	0.007
D	5.4	(1.454)	3.6	(2.230)	3.11	0.008

(iv) VISUAL FUNCTION WITH GLARE

(a) GLARE EFFECT ON BEST CORRECTED SCORES: — When comparing results pre excimer without glare to pre excimer with glare VA scores remained at a mean of 6/6$^+$ with and without glare ($t=-0.72$, $p=0.486$) thus glare had no effect on VA. Contrast sensitivity showed that scores without glare were significantly reduced in all rows; (see Table 5).

Post excimer 10 cases were tested with best correction and glare (Cases 2, 7-15). When comparing the results post excimer without glare to post excimer with glare VA, scores were

TABLE 5
Effect of glare on contrast sensitivity scores. Best corrected pre excimer and post excimer scores; (mean scores, standard deviations t and p values)

Row	Contrast sensitivity score Without glare		With glare		t value	p value
	Mean	SD	Mean	SD		
Pre excimer						
A	4.6	(1.183)	2.8	(1.781)	3.02	0.009
B	5.1	(0.915)	2.9	(1.685)	4.08	0.001
C	5.0	(1.069)	2.7	(1.944)	4.28	0.001
D	5.4	(1.454)	2.5	(2.134)	4.56	0.001
Post excimer						
A	4.5	(1.269)	3.4	(0.843)	3.16	0.012
B	4.7	(1.494)	3.9	(1.524)	2.45	0.037
C	4.7	(1.494)	3.0	(1.700)	5.67	0.001
D	4.4	(2.171)	2.7	(1.418)	2.68	0.025

marginally improved with glare but this improvement was NOT significant (mean with 6/6⁺ and without glare 6/6; $t = -1.35$, $p = 0.209$) for these 10 cases. Contrast sensitivity scores were significantly reduced in rows A and C. In rows B and D the scores were almost significant. As there were only 10 cases it is possible that, with more cases, the reductions will become significant (see Table 5).

(b) GLARE EFFECT ON BEST CORRECTED PRE EXCIMER COMPARED TO POST EXCIMER SCORES: — VA was not significantly altered by glare when pre excimer VA with glare (mean 6/6, SD 6/5 to 6/9⁺) was compared to post excimer VA with glare (mean 6/6, SD 6/6⁺ to 6/9; $t = -1.11$, $p = 0.298$).

Contrast sensitivity scores pre excimer with best correction and glare were slightly lower than the post excimer scores with best correction and glare. This was not significant in any rows, however, in rows A and B it was almost significant. Once again the small population may be affecting the figures (see Table 6).

(c) GLARE EFFECT ON UNCORRECTED PRE EXCIMER COMPARED TO POST EXCIMER SCORES: — Uncorrected VA and contrast sensitivity scores using the glare test were not statistically analysed as the addition of glare created a pinhole effect overcoming the refractive error.

(iv) LogMAR RESULTS: — LogMAR results have not been analysed for this study.

(v) NEAR VISUAL ACUITY: — The results of near VA were unaffected by excimer laser treatment with all the patients achieving exactly the same near VA post excimer as pre excimer. However, patients frequently took a long time to focus on the N5 chart.

TABLE 6
Effect of glare on contrast sensitivity. Best corrected contrast sensitivity; (mean scores, standard deviations t and p values). Pre excimer compared to post excimer

Row	Contrast sensitivity score				t value	p value
	Pre excimer		Post excimer			
	Mean	SD	Mean	SD		
A	4.7	(1.418)	4.5	(1.269)	0.43	0.678
B	5.3	(0.949)	4.7	(1.494)	1.41	0.193
C	5.1	(0.876)	4.7	(1.494)	0.60	0.565
D	5.7	(1.337)	4.4	(2.171)	1.49	0.169

DISCUSSION

During the first three months post excimer laser a corneal haze was apparent in all cases. This was thought to be reflecting corneal stroma recovery. Currently the corneal haze is being monitored to ascertain whether or not the amount of haze will prove to be a useful indicator of the rate of regression towards emmetropia; the greater the haze the more the regression.

It is usual for patients to have some degree of hypermetropia in the first few weeks post excimer which regresses with time. The majority of the patients in this study were slightly hypermetropic in the first few weeks. The regression process naturally steepened the patient's cornea taking the eyes back towards emmetropia or even myopia in some cases after three months. No patients in this study were emmetropic at three months post excimer.

With the use of topical corticosteroid eye drops the different rate of regression that occurred from patient to patient was compensated for. Thus if a patient was regressing too quickly (i.e. was rapidly approaching emmetropia or had returned to myopia) steroid drops were used to slow the regression rate. Alternately if a patient was remaining at a constant level of hypermetropia which was too high they were taken off steroids to allow for more regression.

In all cases three months after treatment the patient's myopia had been reduced to a significant degree. After six months most were progressing towards emmetropia (these findings will be the subject of a later publication).

A recent Multicentre study[7] reported that, in all 31 patients, best corrected VA scores were within one line of their pre excimer best corrected VA scores three months post excimer treatment. However no statistical analysis was given. The findings from the present study demonstrated statistically that there was no difference in the best corrected VA scores pre excimer compared to post excimer. Even the slight decrease in the mean VA

when post excimer uncorrected VA scores were compared to pre excimer best corrected scores was not significant.

The introduction of glare pre excimer and post excimer did not significantly affect VA scores in this study. Even when comparing the pre excimer scores with glare, to the post excimer scores with glare there was no significant difference on VA scores. Thus in this study VA assessment using the Snellen chart, even with additional glare, proved to be too gross an assessment to detect the effects of excimer treatment on visual function.

The Multicentre study[7,8] also reported on contrast sensitivity scores using the Pelli-Robson test and the Vistech MCTS test. (Pelli-Robson results cannot be compared to the results of this current study as the Pelli-Robson test was designed to detect peak contrast while being relatively insensitive to defocus. The MCTS test, like the Vector CSV 1000 tests contrast sensitivity function at high spatial frequencies thus is very sensitive to defocus).[9] The results of the Multicentre study[7] and a subsequent letter to the editor of Archives of Ophthalmology[8] stated that no significant difference was found between contrast sensitivity with the BAT glare test set at maximum illumination three months after excimer treatment. They did not state whether contrast sensitivity was tested with or without correction thus it is not possible to make a comparison between the results of their study and the results of the present study.

In the present study, three months after excimer treatment there was a slight decrease in best corrected contrast sensitivity scores when comparing pre excimer scores to post excimer scores. This finding was not significant.

Contrast sensitivity scores were reduced with the introduction of glare pre excimer (that is, glare reduced the performance on contrast sensitivity BEFORE excimer treatment was carried out) thus contrast sensitivity scores were reduced with glare irrespective of excimer treatment. The same finding occurred post excimer. As a result, contrast sensitivity scores with glare post excimer compared to those without glare were not useful in terms of monitoring recovery of visual function. The analysis of pre excimer compared to post excimer best corrected contrast sensitivity scores was also not conclusive. These findings conflict with those reported by Hogan et al.[10] who demonstrated that 17 patients tested with the Vistech MCTS contrast sensitivity test had decreased scores when tested with glare post excimer laser.

In discussion of the Multicentre study,[7] Adamsons[8] commented that the contrast sensitivity results reported were not detailed enough. She went on to state that " . . . it is imperative that its (*excimer laser's*) effect on visual function be evaluated as rigourously as possible. This evaluation should include not only contrast sensitivity and glare testing, but also subjective evaluation by the patient of his or her visual function using a standardised questionnaire".[8] It is hoped that the present study will fulfil these goals after twelve months.

Subjective comments from patients in the present study revealed they were not at all worried about the post excimer haze or small degrees of residual refractive error. The fact that they could see without glasses was overwhelming in terms of patient satisfaction with the procedure. The only complaint made by some of the patients was discomfort experienced from the glare from oncoming headlights when driving at night. Most felt that this was "a small price to pay" in return for not having to wear glasses. Seiler[11] also reported that many of the 255 patients in his study complained of post operative glare which did not interfere with their activities in the long term.

CONCLUSIONS

As stromal recovery is reported to occur for up to two years it is difficult to draw any meaningful conclusions from the present study at this early stage. By following the patients for 12 months (or 24 months if necessary) it is hoped this study will document any subtle effects on visual function.

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