Laser intrastromal keratomileusis for high myopia and myopic astigmatism

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Abstract

**Background**—Laser intrastromal keratomileusis (LASIK) is an evolving technique which enables high degrees of myopia (>8.0 dioptres) and myopic astigmatism to be corrected. This paper describes initial experience with this procedure. It also details the methodology, the results, the problems encountered, and discusses retreatment procedures.

**Methods**—51 eyes (43 primary cases and three retreatments) underwent LASIK for simple myopia or compound myopic astigmatism. After the keratotomy was fashioned with a Chiron corneal shaper, the ablation was performed with either a Summit or Meditec excimer laser. The actual preoperative astigmatism ranged from −0.5 D to −6.0 D (in the astigmatic myopic LASIK (AML) series), while the range of preoperative myopia in the combined myopic LASIK (ML) and AML series was −8.0 D to −37.0 D. Of the ML cases, group 1 (−8.0 to −15.0 D (dioptres)), group 2 (−15.0 to −20.0 D), and group 3 (−20.0 D) had mean preoperative myopia values (spherical equivalent) of −11.26 D, −16.84 D and −27.78 D. The same groupings (1, 2, and 3) for the AML cases had respective values of −9.702, −17.4, and −23.08. In the AML series the mean preoperative astigmatism was −2.109 D. Follow up ranged from 8 to 27 months (mean 15.8 months). Six of the cases required retreatment.

**Results**—There was a reduction in best corrected visual acuity (BCVA) (of 1 Snellen line) in seven of the primary cases (14.5 %) (three in the ML group and four in the AML group), and in one of the retreatment cases. The BCVA improved in 28 cases (58%) in the primary treatment group. The mean correction attempted (spherical equivalent) for the ML groups 1, 2, and 3 was 10.51 D, −14.5 D, and −27.78 D, versus a mean correction achieved of −9.445 D, −15.625 D, and −21.571 D. Similarly, for the AML groups, attempted correction values were −9.702 D, −17.4 D, and −23.08 D, while the values achieved were −6.95 D, −51.425 D, and −15.708 D. Regression was minimal and stabilisation of the refractive result was achieved in all groups, except group 3 of the ML series, by the 3 month examination period. The mean postoperative astigmatism in the AML series was −0.531 D. Vector analysis of the AML series showed that the mean surgically induced astigmatism was +0.93 D. The most common complication encountered was undercorrection, which occurred in 35 cases—23 cases in the ML group and 12 cases in the AML series. Twenty eight per cent of the ML cases, and 25% of the AML cases were within plus or minus 1.5 D of the attempted refraction.

**Conclusion**—For the correction of high myopia and myopic astigmatism, LASIK results in less postoperative pain and relatively little subepithelial haze compared with high myopic photorefractive keratectomy. Furthermore, a stable refraction and reasonably predictable outcome occurs much earlier. High myopia up to −37.0 D can be corrected, albeit with some limitations at the extremes of myopia—in terms of the amount of myopia correctable; this represents a limitation of the technique. Retreatment is a technically straightforward and effective way to treat undercorrection. Undercorrection, the main complication seen in our series, should become less common when the ablation algorithms are further refined.

When compared with the lower degrees of myopia, the correction of high myopia by photorefractive keratectomy (PRK) has been shown to produce a greater amount of corneal haze and regression. Attempts are being made to expand the range of myopia which can be corrected by PRK using multizone/multipass techniques, but to date, experience with these techniques is limited to the short term only. Following Buratto’s initial concept of intrastromal ablation of an excised corneal cap, with replacement of the cap and retention of Bowman’s membrane, and the possibility of intrastromal treatment in situ, Pallikaris et al introduced the concept of hinging the corneal cap, in order to minimise displacement and subsequent irregular astigmatism. By respecting Bowman’s membrane, it is generally felt that corneal haze and postoperative regression can be minimised. In the current literature several reports discuss this new technique, but only one describes the use of laser intrastromal keratomileusis (LASIK) to correct compound myopic astigmatism—that is, astigmatic myopic LASIK (AML). We discuss the results of treatment for simple myopia and compound myopic astigmatism, in a series with a mean follow up of 15.8 (SD 4.53) months, and in particular, the critical
criteria for treating extreme myopia (in the range −20.0 to −40.0 D).

Patients and methods

Patients with myopia greater than 8.0 D were considered as potential candidates for LASIK.

Exclusion criteria were evidence of corneal warpage from prolonged recent contact lens wear, tear film abnormality, corneal dystrophy, keratoconus, unstable myopia, patients with early cataracts, and eyes with pachymetry values less than 450 µm, diabetes mellitus, or collagen vascular disease. All patients were informed about the procedure, its risks, advantages, and disadvantages before surgery.

The preoperative examination consisted of a complete anterior and posterior segment examination, retinoscopy, videokeratography, and an endothelial cell count.

A cohort of 60 cases was assembled from a review of the hospital notes. Five cases were excluded from this study because of age (less than 18 years old). Three further cases were excluded from the study because the patients had previous corneal surgery (repair of a corneal perforation, failed Draeger’s and Schneider’s procedures—one case each). The remaining 52 cases included nine patients with amblyopia (either due to refractive and/or strabismic origin), and four patients who were retreated, together with one patient who was due to be retreated but the procedure was cancelled as the cornea was too thin to allow retreatment (see Table 1). The results from this latter group will not be included in the main body of the results. Cases were primarily classed as myopic LASIK (ML) 32 cases; AML 16; or retreatment three; and one cancellation.

They were then further subclassed as group 1 (−8 to −15 D), group 2 (−15.0 D to −20.0 D), or group 3 (−20.0 D), depending on their preoperative refraction (spherical equivalent).

Of the ML class the composition was as follows: group 1 (n = 16), group 2 (n = 8), and group 3 (n = 8), while for the AML class group 1 (n = 8), group 2 (n = 5), and group 3 (n = 3).

The age range was 18–56 years, the means (SD) for the ML groups were: 37.25 (10.45) years group 1; 30.625 (11.31) years group 2; and 34 (9.865) years group 3. For the AML series the values were: 33.125 (4.12) years group 1; 32.2 (9.066) years group 2; and 41.33 (11.59) years group 3.

Seventy per cent of the cases were female. Eight of the ML cases (25%) were treated using the Summit laser and the remainder with the Meditec laser. All the AML and retreatment groups were treated using the Meditec laser. The preoperative myopia for the modified cohort ranged from −8.0 to −37.0 D. In the ML groups, the mean (SD) preoperative refractions were as follows: group 1 −11.26 (2.564) D; group 2 −16.84 (0.825) D; and group 3 −27.781 (5.544) D. In the AML groups the preoperative refractions were group 1 −10.702 (1.786) D; group 2 −17.4 (2.553) D; and group 3 −23.083 (5.257) D. Six cases in our series had LASIK for myopia greater than −20.0 D (see Table 2). The range of preoperative astigmatism was from −0.5 to −6.0 D. The mean preoperative astigmatism was −2.35 (1.52) D.

Four cases were reoperated by lifting up the previously created corneal flap and retreatting in the previously ablated area (see Table 1). A further case is currently scheduled for retreatment for an undercorrection. In one −25.0 D eye (case 5), a decision to re-treat was cancelled because of an excessively thin residual cornea (of 120 µm) in the previously ablated area.

Whereas the majority of LASIK procedures were carried out under topical anaesthesia, a total of seven patients opted to have general anaesthesia. Topical anaesthesia consisted of 1.0% amethocaine, one drop every 3 minutes for the first 15 minutes, which was then followed by a mixture of 0.5 ml 4.0% Xylocaine (lignocaine) and 0.5 ml of 0.75% Marcaine (bupivacaine) with adrenaline, one drop per minute for 7 minutes. The eyes were draped using lint-free plastic sheeting: Steristrips and a Nevya speculum combined to give maximum exposure of the cornea and perilimbal sclera. Intraoperative pachymetry was performed using a Corneogage pachymeter (Sonogage).

Following patient fixation on the red HeNe laser beam, a Ruiz optical zone marking device dipped in gentian violet was used to make a pararadial 12 o’clock mark on the cornea (patients’ pupils were not constricted preoperatively with pilocarpine). This was followed by application of the 9 mm LASIK suction ring to the limbus; the increase in intraocular pressure is verified with a Barraquer appplanation tonometer on a dried corneal surface; just before the microkeratome (with preset hinge stop) is placed on the ring track. The microkeratome was then activated to pass across the cornea, and then reversed before releasing the vacuum. The flap was then reflected, and pachymetry used to measure the residual stroma and to verify the thickness of the corneal flap. Care was taken to avoid moisture from tears, or contaminants from the lids from impinging on the exposed stromal surface. Ablation of the underlying stroma was then carried out using the excimer laser.

The Summit Technology laser used in our series was an ExciMed UV200LA argon fluoride laser, which produced pulsed laser radiation at a wavelength of 193 nm, and with a fluence of 180 mJ/cm² at the stromal surface. The Aesculap device was a Meditec Excimer laser (MEL 60), also producing laser radiation of wavelength 193 nm, but with a fluence of 200 mJ/cm² at the stromal surface. The algorithm for the Summit laser utilised the inbuilt MKM software program, the spherical equivalent corrected for back vertex distance being entered into the computer. In cases of astigmatism greater than 3.0 D, 70% instead of the usual 50% of minus cylinder was added to the spherical component. With the Meditec laser, where correction of astigmatism was possible, the policy was to fully correct all minus cylinder greater than −0.5 D. The ablation was
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After laser ablation, the flap was washed thoroughly with balanced salt solution (BSS) by irrigation directly through a lacrimal cannula, while simultaneously aspirating the excess fluid and conjunctival secretions with a standard suction handpiece, which was placed close to the flap in the conjunctival fornix. The flap was then rotated into its normal anatomic position overlying the stromal bed using a fine gauge Rycroft cannula attached to a syringe, which lifted the flap from the epithelial bed and moved it with its corneal base (Tables 1 and 2). The integrity of cap adherence checked under the microscope by asking the patient to blink. Two drops of Betadine (diluted 50%) and gentamicin were then instilled into the conjunctival fornix. The cornea was examined at the slit-lamp to detect microstriae, interface haze and debris, the centration of the ablation, and to verify the position of the cap on its corneal bed.

Retreatment was indicated in this series if (i) the sphere was undercorrected by −3.0 D or more; (ii) a central island was evident on topography, (iii) the patient was at least 9 months post treatment. For retreatment procedures (Table 1), following careful removal of the epithelium around the edge of the corneal flap using a Beaver 66 blade or a hockey knife blade, the edge of the flap is lifted gently using the fine blade edge, until an adequate amount of tissue is reflected, which will subsequently allow peeling backwards of the whole flap using a microforceps to grasp the edge without producing any damage to it. Pachymetry is immediately carried out to assess the residual stromal thickness, taking care to maintain complete dryness of the bed. Contraindication or limitation to the amount of repeated ablation depends on the amount of residual stroma. In this series, approximately 30% of the total corneal thickness was left intact beneath the ablated area in order to offset any subsequent danger of ectasia occurring. The corneal flap was then hydrated and replaced as in the primary procedure.

Table 1  Details of the cases requiring retreatment

<table>
<thead>
<tr>
<th>Case</th>
<th>Preoperative refraction</th>
<th>Postoperative refraction</th>
<th>Ablation</th>
<th>Correction attempted</th>
<th>Correction achieved</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>−28.5 D</td>
<td>−9.0 D</td>
<td>−19.0 D</td>
<td>−28.0 D</td>
<td>−19.0 D</td>
<td>Undercorrected</td>
</tr>
<tr>
<td>2</td>
<td>−9.0 D</td>
<td>−1.0 D</td>
<td>−9.0 D</td>
<td>−9.0 D</td>
<td>−8.0 D</td>
<td>Retreatment</td>
</tr>
<tr>
<td></td>
<td>−7.0 D</td>
<td>−4.5 D</td>
<td>−6.5 D</td>
<td>−6.5 D</td>
<td>−4.5 D</td>
<td>Undercorrected</td>
</tr>
<tr>
<td>3</td>
<td>−15.0 D</td>
<td>−0.75 D</td>
<td>−4.5 D</td>
<td>−4.5 D</td>
<td>−3.75 D</td>
<td>Retreatment</td>
</tr>
<tr>
<td></td>
<td>−7.0 × 1.0 × 10</td>
<td>−1.0 D</td>
<td>−7.0 × 1.0</td>
<td>−7.0 × 1.0</td>
<td>−6.5 D</td>
<td>Retreatment</td>
</tr>
<tr>
<td>4</td>
<td>−25.0 D</td>
<td>−9.0 D</td>
<td>−19.0 D</td>
<td>−19.0 D</td>
<td>−17.0 D</td>
<td>Central island</td>
</tr>
<tr>
<td>5</td>
<td>−9.0 D</td>
<td>−2.0 D</td>
<td>−7.0 D</td>
<td>−7.0 D</td>
<td>−7.0 D</td>
<td>Retreatment</td>
</tr>
<tr>
<td>6</td>
<td>−25.0 D</td>
<td>−6.0 D</td>
<td>−21.0 D</td>
<td>−25.0 D</td>
<td>−19.0 D</td>
<td>Undercorrected</td>
</tr>
<tr>
<td>7</td>
<td>−10.0 D</td>
<td>−3.25 D</td>
<td>−10.0 D</td>
<td>−10.0 D</td>
<td>−6.75 D</td>
<td>Undercorrected</td>
</tr>
</tbody>
</table>

BCVA deteriorated by 1 Snellen line in seven (14.5 %) of the primary cases, three of these were in the ML group, and four were in the AML group. One of the retreatment cases also had a reduction in BCVA by 1 Snellen line. The BCVA increased in 28 (58%) cases postoperatively. Of the ML group 18 (56%) had a one line gain in Snellen acuity, two (6%) had a gain of 2 Snellen lines, and a further two (6%) had a gain of 3 Snellen lines. The AML group showed less benefit in terms of improved BCVA—five (31%) gaining 1 line, and one case (6%) gaining 3 lines. Two of the seven amblyopes who made up part of the ML series showed a gain in BCVA. Of the two amblyopes who were part of the AML series, only one showed a gain in BCVA. Group 3 (>−20.0 D) of the ML series had the highest percentage of cases (88%) with improved BCVA. Groups 2 and 3 (equally) had the highest incidence of decreased BCVA (12%). In the AML series also, group 3 had the highest percentage of cases showing increased BCVA—66%; while group 2 had the highest percentage of cases with a decrease in BCVA—40%.

The effect of ML and AML on refraction is dealt with below (see Table 2). The main information from this table is that ML would seem to be much more predictable than AML for any degree of myopia (groups 1, 2, or 3). The mean values for the correction attempted versus the correction achieved, and the values for the percentage correction attempted versus achieved seem respectable for both the ML and AML series, but examination of the percentage of cases obtaining within 1.5 D or −2.5 D of the attempted correction may be more informative and realistic.
Six eyes in our series had preoperative myopia of between −20.0 and −40.0 D. The maximal correction in these eyes was limited to the extent that 30% of the preoperative corneal thickness was left undisturbed beneath the ablated area in order to avoid a possible subsequent ectasia of the cornea. In these cases full correction was not possible and a deliberate undercorrection was achieved. Table 3 lists the pre- and postoperative characteristics of these cases. Astigmatism and myopia (compound myopic astigmatism) were corrected in 16 cases (that is, the AML group). The magnitude of the preoperative cylinder corrected (that is, attempted) was −0.5 to −6.0 D, with a mean of −2.109 (SD 1.855) D. Postoperatively, the cylindrical component range was reduced to between 0.0 D and −3.25 D, with a mean value of −0.531 (1.83) D. The correction achieved was −1.71 (2.39) D, giving a predictability (when expressed as a percentage of correction attempted) of 81%. Vector analysis using the Naylormethod,23 showed that the mean surgically induced refractive cylinder (of the AML series) was +0.93 (2.30) D, range 0 to 5.0 D.

Regression of the correction is a major obstacle to the final success of high myopic PRK.1–5 7 In this series of LASIK cases, we examined the refraction to ascertain the effect of regression at 1 month, 1–3 months, 3–6 months, and 1 year (Table 4).

A significant decentration of the ablation was seen in eight cases: seven of these (all in the ML groups) were performed using a Summit laser, but only one case (part of the AML group) was associated with the use of the Aesculap Meditec laser. Ablation decentration ranged from 0.5–1.60 mm, with a mean value of 1.20 mm and in four of these cases the eccentrication induced a degree of astigmatism.

Corneal complications occurred in 17 cases (see Table 5). Epithelial cell nests occurred in three patients but were not treated (see Fig 1). Active epithelial ingrowth appearing on slit-lamp examination as a focal cystic lesion originating from the extreme periphery of the flap–stromal bed interface, and actively progressing across the cornea, under the flap, occurred in two cases. This was accompanied by the development of increasing irregular asymmetric astigmatism, decreasing BCVA. In both cases, relifting of the flap and removal of the cells was required; this immediately resulted in restoration of the central ablation zone topography, and recovery of BCVA.

Interface haze was graded as 0 to 2. Nine patients demonstrated this complication, eight patients had grade 1 haze which was not associated with any subjective visual disability. One patient with grade 2 haze had severe difficulty driving at night. Despite meticulous

Table 2 Refractive variables for this series

<table>
<thead>
<tr>
<th>Group</th>
<th>Refraction (mean (SD))</th>
<th>Correction (mean (SD))</th>
<th>% of correction attempted</th>
<th>% within −1.5 D or −2.5 D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preop</td>
<td>Postop</td>
<td>Attempted</td>
<td>Achieved</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−1.5 D</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−2.5 D</td>
</tr>
<tr>
<td>Myopic LASIK series:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>−11.26 (2.564)</td>
<td>−1.74 (2.285)</td>
<td>−10.51 (2.224)</td>
<td>−9.445 (3.67)</td>
</tr>
<tr>
<td>2</td>
<td>−16.84 (0.825)</td>
<td>−0.843 (3.285)</td>
<td>−14.5 (1.309)</td>
<td>−15.625 (3.67)</td>
</tr>
<tr>
<td>3</td>
<td>−27.78 (5.544)</td>
<td>−4.781 (5.957)</td>
<td>−21 (4.123)</td>
<td>−21.571 (4.032)</td>
</tr>
<tr>
<td>Astigmatic myopic LASIK series:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>−9.702 (1.786)</td>
<td>−2.75 (3.638)</td>
<td>−9.671 (1.792)</td>
<td>−6.952 (3.165)</td>
</tr>
<tr>
<td>2</td>
<td>−17.4 (2.553)</td>
<td>−1.925 (1.35)</td>
<td>−17.1 (2.625)</td>
<td>−15.42 (3.53)</td>
</tr>
<tr>
<td>3</td>
<td>−23.083 (3.257)</td>
<td>−7.078 (2.194)</td>
<td>−19.583 (2.919)</td>
<td>−15.708 (4.66)</td>
</tr>
</tbody>
</table>

All cases were deliberately undercorrected.

Table 3 LASIK for the extremes of myopia (−20.0 to −40.0 D)

<table>
<thead>
<tr>
<th>Preoperative refraction</th>
<th>Postoperative refraction</th>
<th>Preoperative Flap</th>
<th>Residual</th>
<th>(% of original thickness)</th>
</tr>
</thead>
<tbody>
<tr>
<td>−22.0 D</td>
<td>−4.0/+3.0 × 180</td>
<td>50</td>
<td>186</td>
<td>164 (29.8%)</td>
</tr>
<tr>
<td>−23.0 D</td>
<td>−1.0 D</td>
<td>500</td>
<td>108</td>
<td>186 (37%)</td>
</tr>
<tr>
<td>−24.0 D</td>
<td>−5.0/+6.0 × 30</td>
<td>550</td>
<td>110</td>
<td>273 (49%)</td>
</tr>
<tr>
<td>−26.0/+6.0 × 30</td>
<td>−8.0/+1.0 × 40</td>
<td>540</td>
<td>135</td>
<td>230 (42%)</td>
</tr>
<tr>
<td>−30.0 D</td>
<td>−3.0</td>
<td>580</td>
<td>120</td>
<td>230 (39.6%)</td>
</tr>
<tr>
<td>−37.0 D</td>
<td>−10.0</td>
<td>520</td>
<td>60</td>
<td>165 (31%)</td>
</tr>
</tbody>
</table>

Figure 1 Epithelial ingrowth occurring after LASIK.

Six eyes in our series had preoperative myopia of between −20.0 and −40.0 D. The maximal correction in these eyes was limited to the extent that 30% of the preoperative corneal thickness was left undisturbed beneath the ablated area in order to avoid a possible subsequent ectasia of the cornea. In these cases full correction was not possible and a deliberate undercorrection was achieved. Table 3 lists the pre- and postoperative characteristics of these cases. Astigmatism and myopia (compound myopic astigmatism) were corrected in 16 cases (that is, the AML group). The magnitude of the preoperative cylinder corrected (that is, attempted) was −0.5 to −6.0 D, with a mean of −2.109 (SD 1.855) D. Postoperatively, the cylindrical component range was reduced to between 0.0 D and −3.25 D, with a mean value of −0.531 (1.83) D. The correction achieved was −1.71 (2.39) D, giving a predictability (when expressed as a percentage of correction attempted) of 81%. Vector analysis using the Naylormethod,23 showed that the mean surgically induced refractive cylinder (of the AML series) was +0.93 (2.30) D, range 0 to 5.0 D.

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Table 4 Refraction (SD) at various postoperative intervals

<table>
<thead>
<tr>
<th>Group</th>
<th>1st Postop day</th>
<th>1 Month</th>
<th>3 Months</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopic LASIK series:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>−0.859 (2.473)</td>
<td>−1.138 (2.09)</td>
<td>−1.86 (2.266)</td>
<td>−1.861 (2.675)</td>
<td>−1.93 (2.064)</td>
</tr>
<tr>
<td>2</td>
<td>−0.833 (3.055)</td>
<td>−2.25 (0.933)</td>
<td>−2.56 (3.163)</td>
<td>−2.687 (3.977)</td>
<td>−2.697 (2.12)</td>
</tr>
<tr>
<td>3</td>
<td>−4.1 (7.162)</td>
<td>−4.291 (3.241)</td>
<td>−4.25 (6.717)</td>
<td>−6.166 (5.636)</td>
<td>−6.241 (3.729)</td>
</tr>
<tr>
<td>Astigmatic myopic LASIK series:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0 (1.732)</td>
<td>−1.25 (0.787)</td>
<td>−1.75 (1.433)</td>
<td>−1.75 (1.658)</td>
<td>−1.85 (1.666)</td>
</tr>
<tr>
<td>2</td>
<td>−1.0416 (2.796)</td>
<td>−1.25 (2.327)</td>
<td>−1.975 (2.242)</td>
<td>−1.989 (2.242)</td>
<td>−1.999 (2.222)</td>
</tr>
<tr>
<td>3</td>
<td>−3.14 (5.142)</td>
<td>−3.673 (4.131)</td>
<td>−4.0 (4.1)</td>
<td>−4.114 (4.179)</td>
<td>−4.2 (3.907)</td>
</tr>
</tbody>
</table>
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Table 5 Complications of LASIK

| Undercorrection greater than −1.5 D | 35 cases |
| Retreatment required * | 6 cases |
| Corneal haze | 9 cases |
| Decentred ablation | 8 cases |
| Epithelial ingrowth | 3 cases |
| Interface debris | 3 cases |
| Cap stress lines | 2 cases |

*One retreatment is scheduled, and one case could not be retreated as the residual cornea was too thin.

Discussion

Currently, four procedures are in widespread use for the correction of myopia—radial keratotomy, clear lens exchange, PRK, and LASIK. For the correction of the lower degrees of myopia (up to −6.0 D) PRK gives a predictable outcome. However, for higher degrees of myopia (greater than −8.0 D) PRK is associated with an unacceptable degree of regression and subepithelial haze.1–7 To overcome these drawbacks, new techniques for delivering the ablation in high myopia are being investigated—for example, multizone/multimode procedures, and one recent study with a short term follow up suggests that it may be possible to expand the range of myopia correctable by PRK, thus overcoming the previous problems of regression and subepithelial haze. Laserablation using a corneal flap technique was shown to be possible by Pallikaris et al.10 There are several variations of the technique to create the LASIK flap—manual dissection15 of the flap, use of a Draeger keratome,12 or use of a Chiron microkeratome, as we describe. The ablation may be to the underside of the cap, the so called Buratto technique,14 now abandoned by its creator owing to the possibility of traumatising Bowman’s membrane,15,16 or to the stromal bed as described by Pallikaris et al. The reason for creating a flap, and for ablating the stromal bed rather than the cap, is that preservation of Bowman’s membrane has been shown to be associated with a reduction in the amount of regression and haze induced.17

The potential disadvantages for high myopes treated by PRK include corneal haze,2–5 and a variable but significant amount of regression.1–6 Nine patients in our LASIK series demonstrated interface haze, but this was only subjectively visually debilitating in one case. Of course, contrast sensitivity testing would perhaps uncover others who are asymptomatic, but to date, contrast sensitivity has not been examined in LASIK patients. Regression associated with high myopic PRK may be somewhat ameliorated by utilising a multizone technique4,15 or tapered transition zones,15,17 but further research in these areas is warranted. Regression after LASIK is not a significant problem—we found that while the mean amount of regression peaked at the 1–3 month period for all groups except group 3 of the ML series, the amount is insignificant, especially for this latter group, if one considers the range of myopia corrected. Compare this with the findings of Epstein et al.20 who showed that stabilisation of refraction does not occur until 18–24 months after PRK (for myopia up to −7.5 D). The refraction in the postoperative period extending from 12 months on (up to a maximum of 27 months) continued to be stable, but the number of patients having such extensive follow up was not deemed sufficient to include them in Table 4.

Pallikaris and Siganos12 in their study of patients up to 1 year postoperatively, found a mean regression of less than −1.50 D, with refraction tending to be stable after 1 month. The PRK group of Pallikaris and Siganos,12 however, showed extreme regression over a 1 year period, from +1.29 D (at 1 month postoperatively) to −7.42 D (at 12 months postoperatively). This large amount of regression associated with high myopic PRK is mirrored by other series in the literature.1–5

Of the 48 cases in our modified series, seven (14%) showed a drop in visual acuity postoperatively of one Snellen line. In Pallikaris and colleagues’ recent report,18 they described two cases (20%) of reduced visual acuity which were due to interface abnormalities. We attribute six cases (of reduced visual acuity) to the same abnormality, as no obvious problems were detected on slit-lamp examination or videokeratography. The other case associated with a drop in visual acuity was in a patient with a central island—later successfully retreated (with a restoration of BCVA). One further case was associated with a retreatment procedure, which, of course, increases the risk of having interface abnormalities. In our series,
The major complications seen with the current LASIK technique are undercorrection and decentration. Undercorrection (greater than \(-1.5\) D) was the most frequent complication seen in our series, and 35 cases were undercorrected in total. This is a serious problem, but it is a problem attributable to the laser’s inbuilt ablation algorithm rather than the procedure (LASIK) itself. In our series undercorrection was more than twice as common with the Meditec laser as with the Summit laser. Five patients required retreatment procedures to reduce undercorrection. Other centres have found predictability values (that is, the percentage of cases obtaining \(1.0\) D of the attempted correction) of \(66\%\) (Pallikaris et al) to \(74\%\) (Kremer et al); compared with our findings of \(28\%\) of the ML group, and \(25\%\) of the AML group being within \(1.5\) D of the attempted correction. Our results may have been adversely influenced by the fact that two different lasers were used. This prevented us from developing long-term experience with one device, which in turn would have allowed us to overcompensate for the laser’s undercorrection. Piander and Tayfour experienced a tendency towards overcorrection in their series. Our incidence of overcorrection was \(20\%\) for the combined ML and AML series. Overcorrection was less common in the AML series as the Meditec laser was tending to undercorrect, in comparison with the Summit laser—the AML series were all treated with the Meditec.

In our series eight cases demonstrated ‘significant’ decentration of the ablation zone. We defined ‘significant’ decentration as ablation decentration of \(0.5\) mm or more from the centre of the entrance pupil; the work of Cavanagh et al suggests that (for PRK) only decentration greater than \(0.5\) mm may be clinically significant. Of these cases, only one patient had postoperative monocular diplopia—so, subjectively, decentration seems to be well tolerated by LASIK patients. Our centre has compared the centration in myopic PRK and myopic LASIK groups; we found centration to be worse in the LASIK group—the magnitude of the displacement being almost twice as high in the LASIK group. This we attribute to three factors. Firstly, the majority of cases (\(87\%\)) in which decentration occurred were performed with the Summit laser, which depends very much on patient cooperation for optimal centration. The Meditec laser was associated with more accurate centration. This we believe to be a function of the better centration mechanism of this machine—that is, the suction mask, which places control of centration into the operator’s hands. The second reason, is that the stromal bed is much more difficult to mark with landmarks for ablation, as gentian violet cannot of course be applied to the interface. This is in contrast with high myopic PRK, where the optic zone is easily determined after marking with gentian violet. The third factor is that very much higher corrections are attempted with LASIK, so the procedural duration is longer (therefore giving more time in which decentration can occur), and these very
high myopic LASIK patients have poor (un-
helped) visual acuity—which makes visualisa-
tion of the fixation target difficult. In their 
series, Bas and Omnis3 found three cases of 
decentration (greater than 1.0 mm), while 
Fiander and Tayfour14 found five cases of ‘mild’ 
decentration associated with induced regular 
astigmatism (both used Summit lasers). Pal-
likaris and Siganos12 found that centration in 
their PRK and LASIK groups were compara-
tible; their cases were all performed with an 
Aesculap Meditec device which would, for 
previously mentioned reasons, seem to 
improve centration.

Corneal problems occurred in 17 cases 
(35%). Among these were cap stress lines, epi-
thelial ingrowth, interface debris, and interface 
haze (see Table 5 for a complete list of corneal 
complications).

Cap stress lines occurred in two patients, but 
both showed no reduction in visual acuity. 
These stress lines are felt to be at the level of 
Bowman’s membrane, and are probably due to 
undetectable intraoperative misalignment of 
the corneal cap on the stromal bed. Epithelial 
ingrowth and interface debris are really varia-
tions of the same problem—contamination of 
the interface. Epithelial cells from the conjunc-
tiva or lid margins may be swept onto the inter-
face by excessive irrigation, or excessive patient 
tearing. Epithelial ingrowth can be removed 
relatively easily, as was done in our retreatment 
cases. Interface debris may arise from the ker-
atectomy incision itself, the instruments, or from 
the swabs used to clean the interface. We are 
currently using Merocel sponges (Merocel 
Corp, Mystic, USA), which seem to shed less 
corneal debris than other varieties. We also use gentle 
aspiration on the interface to minimize spong-
ing. Unfortunately, there is the risk of tearing 
the hinge if the flap is engaged, therefore a 
reflux facility is necessary on the aspiration 
unit. The problems arising from interface haze 
(nine cases), were examined subjectively—that 
is, only in terms of the presence or absence of 
glare and halo phenomenon. Of these nine 
cases, only one patient with grade 2 haze had 
visual problems (night driving di
cases, only one patient with grade 2 haze had 

haze and halo phenomenon. Of these nine 
cases, only in terms of the presence or absence of 
glare and halo phenomenon. Of these nine 
cases, only one patient with grade 2 haze had 
visual problems (night driving difficult). 
Unfortunately, contrast sensitivity testing was 
not examined in our series, nor has it been 
examined in any other reported LASIK series. 
This is an important quality control test of the 
technique, as other refractive procedures—for 
example, epikeratophakia and PRK, are associ-
ated with drastic reductions in contrast sensi-
tivity.

Retreatment procedures for the treatment of 
undercorrection, central islands, or epithelial 
ingrowth combined with undercorrection (as 
was seen in two cases in this series) proved sat-
isfactory and technically simple. Although predict-
ability was good (see Table 1), two of the 
cases retreated lost 1 Snellen line, presumably 
due to undetectable interface abnormalities. 
The actual technique for performing a retreat-
ment is relatively straightforward, as the flap 
has already been created during the original 
procedure; however, the critical point to bear 
in mind is that the residual corneal thickness 
will determine how much more cornea can be 
ablated. Part of the versatility of LASIK lies in 
the fact that, by relifting the flap, complications 
with the original procedure can be corrected at 
a second setting. We feel that retreatment 
should be delayed till at least 9 months postop-
eratively when the refraction will be stable. 
in group 3 ML patients it might be preferable to 
wait until 1 year, so that the full amount of 
regression can be determined.

In conclusion, LASIK is an exciting new 
technique which currently offers the surgeon a 
one step extracocular procedure for the treat-
ment of high myopia. Its advantages are 
little/no postoperative pain and haze and a 
simple postoperative regime, which requires 
only a Cartella shield (for a few days), no pad, 
and a short 4 to 5 day course of postoperative 
antibiotics, topical steroids being unnecessary. 
LASIK is, however, no panacea. The disadvan-
tages include the need for a fully functioning 
theatre suite and the purchase of an expensive 
microkeratome. The actual surgical procedure 
is technically difficult, and it should only be 
performed by an experienced ophthalmic 
surgeon. Furthermore, because of the creation 
of a flap, the risk of infection is theoretically 
greater, and because the intraocular pressure 
must be elevated so high (65 mm Hg) during 
the keratotomy, there is, therefore, some 
concern about the possibility of inducing 
macular damage in these high myopes.

Corneal (extracocular) procedures, while 
attractive as regards safety, unfortunately lack 
the predictability of their alternatives (in-
traocular procedures such as clear lens ex-
change). There is still a long way to go with this 
technique, in particular improving the micro-
keratome, making it safer and more user 
friendly. More accurate nomograms need to be 
developed in order to improve the predictabil-
ity of the procedure, and with the combined 
use of LASIK and multizone or multipass 
strategies some of the problems detailed above 
can be overcome. These steps will significantly 
advance this technique, and perhaps even allow 
it to compete with PRK as a treatment for low 
myopia. At our unit we are currently evaluating 
the technique to include the treatment of 
hyperopia. This is an exciting new develop-
ment in the field of refractive surgery.

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Laser intrastromal keratomileusis for high myopia and myopic astigmatism

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