

Monovision with Laser in situ Keratomileusis

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Purpose: To investigate the postoperative outcomes of monovision correction by laser in situ keratomileusis (LASIK). **Methods:** In this retrospective study, 150 myopic patients, 40 years or older, who had LASIK with a follow-up of at least 3 months were examined. All monovision patients were divided into two groups: prepresbyopic group: 40 to 45 years, presbyopic group: 46 years and older. The following factors were evaluated: gender, level of anisometropia, uncorrected distance visual acuity (UDVA), need for glasses, and enhancement rate. **Results:** Eighty-seven patients (58%) chose to be corrected for monovision and 63 patients (42%) chose bilateral distance correction. Women selected monovision more often than men ($p = 0.002$). In monovision patients, the presbyopic group required a higher level of residual myopia in the near eye, and had a much lower rate of reaching J1 level ($p = 0.045$). Twenty-one patients (24%) required retreatment, only 4 patients (5%) chose to cancel monovision. However, 15 patients (17%) underwent subsequent enhancement of their distance vision eye. Monovision patients sought enhancement when UDVA in the distance eye was 20/30 or less ($p < 0.001$). **Conclusions:** The vision in the distance eye of monovision patients may have lower tolerance for residual refractive error and require perfect distance vision than bilateral distance correction.

Key Words: monovision, laser in situ keratomileusis (LASIK), presbyopia

Introduction

Patients in the presbyopic age range who undergo corneal refractive surgery want not only excellent distance vision but also functional near vision, preferably without glasses correction. Monovision contact lenses may be useful^{1~5)}, but most patients who have refractive surgery do not favor this approach. Many refractive surgery procedures have been forwarded to correct problems in the presbyopic age group, including monovision provided by laser in situ keratomileusis (LASIK) or photorefractive keratectomy (PRK)^{6~12)}, multifocal LASIK or PRK¹³⁾, holmium: yttrium aluminum garnet (Ho: YAG) laser thermal keratoplasty¹⁴⁾, radiofrequency¹⁵⁾, or diode laser thermal keratoplasty¹⁶⁾. Procedures that expand or relax the sclera¹⁷⁾, intracorneal implants¹⁸⁾, multifocal intra ocular lenses¹⁹⁾, accommodative intraocular lenses²⁰⁾, and anterior

chamber phakic multifocal intraocular lenses²¹⁾ are other approaches that have been used with varying degrees of success.

In monovision, the distance eye is targeted to plano refraction and the near eye is corrected to low myopia, typically in the range of -0.5 diopter (D) to -2.5 D. The dominant eye is usually corrected for distance vision and non-dominant eye corrected for near, although some patients prefer the opposite (i.e.; crossed monovision). We previously reported that most patients with monovision correction after photorefractive keratectomy (PRK) had good visual function, including good stereopsis at distance and near, with high satisfaction (90.5%)⁶⁾. Patient satisfaction with monovision refractive surgery reported in the literature has ranged from 88% to 97.6%^{7~12)}.

This study investigated the postoperative out-

comes of presbyopic and prepresbyopic patients selecting monovision correction by LASIK. We also evaluated the reasons why some patients had re-treatment with monovision refractive surgery.

Patients and Methods

This project was approved by the Institutional Review Board at the Cleveland Clinic and adhered to the tenets of the Declaration of Helsinki.

Medical records of 283 eyes of 150 consecutive patients who were treated with LASIK in one or both eyes at the Cole Eye Institute in the Cleveland Clinic were examined. Patients were followed up at least 3 months after surgery and were treated with Alcon LADARVision excimer laser (model 4000) (Alcon, Fort Worth, TX, USA) and created the flap by Moria M2 microkeratome (Moria, Paris, France) or IntraLase laser (Advanced Medical Optics, Santa Ana, CA, USA) by one surgeon (S.E.W.). Patients with hyperopia, amblyopia, ocular diseases and previous corneal surgery and/or intraocular lens implantation were excluded.

All patients older than 40 years received detailed explanations about presbyopia and chose between full distance correction in both eyes and monovision. Considerations in selecting monovision included occupation, sports, hobbies, and importance of preserving near vision. Contact lens trials for simulating monovision were provided prior to surgery, if the patients showing interest had no previous experience.

The following factors were evaluated: gender, preoperative refraction and spherical equivalent (SE), target for monovision correction decided by the patient after consultation with the doctor (-0.50 D to -2.5 D), postoperative SE, level of anisometropia, uncorrected distance visual acuity (UDVA) with both eyes and for each eye, need for glasses, and enhancement rate. The 87 monovision patients were divided into 2 subgroups: the prepresbyopic group including those with ages varying from 40 to 45 years (34 patients), and the presbyopic group including subjects above 46 years of age (53 patients). Moreover, data included results from 63 patients older than 40 years of age that had both full distance corrections.

The typical target for monovision correction depended on the patient's age according to our clinical nomogram derived from our first study⁶. In the prepresbyopic group, patients received between -0.75 and -1.0 D of myopia in the near eye; presbyopic patients received approximately -1.5 D to -2.0 D of myopia in the near eye.

Visual acuity for distance was measured with Snellen visual acuity charts at 20 feet. Near vision was measured with Jaeger table at 14 inches. All exams had similar lighting, equipment, and charts for distance and near measurements and took place between 3 and 9 months after surgery. The dominant eye for each patient was identified using the "pinhole test" whereby the patient, using both eyes simultaneously, lines up an object through a small hole. The eye that aligned through the hole with the viewing object was considered the dominant eye. We confirmed the dominance by asking the patient which eye he or she used to take a photograph or to shoot a gun.

Data is presented as the mean \pm standard deviation (SD) and were analyzed using statistical software (Stat view 4.5, Abacus Concepts, Berkeley, CA, USA). A p value less than 0.05 was considered to indicate a statistically significant difference.

Results

1. Who Chooses Monovision?

Of 150 consecutively treated myopic LASIK patients 40 years or older, 87 (58%) chose to be corrected for monovision and 63 (42%) chose bilateral distance correction. Monovision group had 87 patients: 38 subjects (43.7%) were men and 49 subjects (56.3%) were women. While in full distance correction group had 63 patients: 44 subjects (69.8%) were men and 19 subjects (30.2%) were women. Women preferred monovision to full distance correction ($p = 0.002$).

2. Postoperative anisometropia

In the monovision group, there were no significant differences related to preoperative SE in the distance eye, preoperative SE in the monovision eye, and postoperative SE in the distance eye between the 2 groups. The level of postoperative anisometropia was significantly different between the

Table 1 Comparison outcomes between prepresbyopic group and presbyopic group

	Prepresbyopic group (n = 34)	Presbyopic group (n = 53)	p value
Distance eye			
Preoperative SE	-4.78 ± 2.29 (D)	-4.12 ± 3.12 (D)	0.496 †
Postoperative SE	-0.2 ± 0.43 (D)	-0.14 ± 0.59 (D)	0.601 †
Near eye			
Preoperative SE	-4.42 ± 2.29 (D)	-4.20 ± 2.94 (D)	0.714 †
Postoperative SE	-0.97 ± 0.50 (D)	-1.43 ± 0.70 (D)	0.002 †
Anisometropia	-0.77 ± 0.59 (D)	-1.29 ± 0.88 (D)	0.003 †
Getting J1	28 (82.4%)	33 (62.3%)	0.046 ‡
Enhancement	5 (14.7%)	16 (30.2%)	0.127 ‡

SE: spherical equivalent, † By non-paired t-test, ‡ By Chi-square test.

The postoperative SE for near eye, the level of postoperative anisometropia and the rate of getting J1 level were significantly different between the pre-presbyopic group and presbyopic group.

Table 2 Enhancement rate related to UDVA for distance eye

UDVA for the distance eye		p value
20/15, 20, 25 (n = 71)	20/30 or worse (n = 16)	
7 (9.9%)	14 (87.5%)	p < 0.001

UDVA: uncorrected distance visual acuity, By Chi-square test.

The enhancement rate was significantly higher when UDVA was worse or equal to 20/30 in the distance eye.

prepresbyopic group and presbyopic group ($p = 0.003$). The rate of monovision patients reaching J1 level for reading was significantly higher in the prepresbyopic group than the presbyopic group (82.4% vs 62.3%, $p = 0.046$) (Table 1).

3. Retreatment

Enhancement was performed in 21 (24.1%) of monovision patients. There was no statistically significant difference in enhancement rate between prepresbyopic and presbyopic group (14.7% vs 30.2%, $p = 0.127$) (Table 1). Only 4 patients (4.6%) chose to forego monovision and subsequently enhance the near eye to distance vision. The distance eye needed enhancement (71.4%) more commonly compared to the near eye (28.6%) to gain patient satisfaction with monovision. Patients with UDVA worse or equal to 20/30 in the distance eye had an enhancement rate of 87.5%, while patients with UDVA better than 20/30 had an enhancement rate

of 9.9% ($p < 0.001$) (Table 2). In the full distance correction group, the rate of enhancement was 28.6%. There were no statistically significant differences between the monovision group and full distance group ($p = 0.541$).

4. Need for glasses after LASIK

Finally, in the monovision group, 8 patients (9.2%) used glasses for night driving, and 10 patients (11.5%) used reading glasses at all times after re-treatment. In the full distance correction group, they were more likely to need reading glasses for most or all the time. With respect to distance glasses after LASIK, no patients required distance glasses at all times in both patients. There were no significant differences between the monovision group and the full distance group ($p = 0.193$). However, the monovision group was more likely to never need reading glasses after LASIK and less likely to need reading glasses at all times than the full distance correction group ($p < 0.001$) (Table 3).

Discussion

The findings of this study indicate that the visual results were excellent in both the monovision and full distance correction groups, and monovision with LASIK is a useful tool for patients with prepresbyopia and presbyopia who want to retain a combination of distance and near vision. If adequate patient selection is practiced, and good uncorrected vision is obtained in the distance eye, the success rate of this technique is high, reaching 72% to over

Table 3 Distance glasses and reading glasses after LASIK

Correction	Need for distance glasses			Need for reading glasses		
	Never	Night driving	Always	Never	Occasionally	All the time
Monovision	90.8%	9.2%	0%	77.0%	11.5%	11.5%
Full distance	96.8%	3.2%	0%	34.9%	23.8%	41.3%
p Value		0.193			<0.001	

By Chi-square test.

Monovision group was more likely to never need reading glasses after LASIK and less likely to need reading glasses at all times than the full distance correction group.

90% of the cases^{6)~12)}. The acceptance of monovision by our patients was 95.4%.

Goldberg⁸⁾ reported that women chose monovision 2: 1 over men, and male patients selected a significant preference for distance correction. Braun et al¹²⁾ reported women selected monovision slightly more often than men (66.9% vs 60.5%, $p = 0.14$). Our data also showed that women were more likely to prefer monovision to full distance correction.

There are several factors to consider when deciding on the level of anisometropia to target in a particular monovision patient. Jain et al²⁾ noted lower degrees of anisometropia facilitated intraocular blur suppression, stereo acuity, and contrast sensitivity. As a result, current studies^{6)7)10)~12)} limit the level of anisometropia to 1.5 to 2.0 D. However, the literature has not demonstrated clinical complaints of loss of depth perception with higher level of anisometropia, and the fact that loss of contrast sensitivity, which is most symptomatic with night driving, can be corrected with glasses for night driving. The advantage of a higher level of anisometropia is that it can prolong the duration of near reading without glasses. Goldberg⁸⁾⁹⁾ extended monovision to a correction of -2.5 D in the near eye for patients older than 65 years, while Greenbaum²²⁾ reported a high degree of success with -2.75 D of nearsightedness in the near eye in monovision resulting from pseudopakia after cataract surgery. In our study, we also targeted nearsightedness in the near eye at -2.0 D for patients older than 55 years, and achieved good results, but the ideal target for the near eye remains controversial.

Another important issue was the need for enhancements after monovision with LASIK. Monovi-

sion enhancement rates in literature vary from 1.8%⁷⁾ to 27.9%¹²⁾. Goldberg⁸⁾ shows that a higher rate of enhancement is necessary to achieve success with LASIK monovision. He also reported monovision patients are more likely to require enhancements than full distance correction patients. However, our study represents that there were no statistically significant differences between the monovision group and full distance group. Furthermore, we confirmed that the distance eye needed enhancement more frequently compared with the near eye. Some previous studies¹¹⁾¹²⁾ reported that enhancement rate in the distance eye was statistically higher. Thus, good uncorrected visual acuity in the distance eye is paramount for patient satisfaction with monovision and patients with monovision tend to seek enhancement when the distance eye has a vision equivalent to 20/30 or less. The vision in the distance eye in the monovision patient may have lower tolerance for residual refractive error and require perfect distance vision than a bilateral distance correction. The 4 dropouts failed to tolerate monovision because of a higher level of anisometropia than they expected. They also had insufficient contact lens trial for CL intolerance. Given these findings, a contact lens trial should be required, especially in patients who have never experienced contact lens monovision. Prior use or trial of contact lens monovision is important for the key to success with monovision LASIK. Overall patient acceptance with monovision was 95.4% in this study after enhancement was performed, which is similar to previous studies^{6)~12)}.

As expected, patients who chose full distance correction were more likely to wear reading glasses

and patients who chose monovision were more likely to need distance glasses occasionally. Our results suggest that monovision with LASIK may not be suitable for patients in whom night driving and/or reading are an essential part of their lives.

Several other surgical procedures that aim to correct presbyopia^{13)~21)} have been reported to have varying results. Some of these procedures, including multifocal excimer laser ablations and multifocal phakic intraocular lenses are being actively investigated and appear promising, but others are controversial and have questionable efficacy and/or safety. Therefore, at present, monovision corrections with either LASIK or PRK remain the most common options to treat presbyopic and prepresbyopic patients who are considering refractive surgery in order to decrease dependency on both near and distance glasses.

In summary, the most adequate candidates for monovision with LASIK would be women who have experienced contact lens monovision. This study demonstrates that retreatment is commonly needed when the vision in the distance eye is equivalent to 20/30 or less in monovision with LASIK. The vision in the distance eye in the monovision patient may have lower tolerance for residual refractive error and require the perfect distance vision than a bilateral distance correction. Patients require 20/30 or better uncorrected distance vision and J2 or better near vision to be satisfied.

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老視患者におけるモノビジョン LASIK

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〔目的〕モノビジョンとは、優位眼を遠方視に、非優位眼を近方視に用いる老視矯正法である。古くからコンタクトレンズによるモノビジョン法は普及していたが、近年 laser in situ keratomileusis (LASIK) においても、老視患者に対してモノビジョン LASIK が行われるようになってきている。モノビジョン LASIK の術後成績から、患者満足度の高いモノビジョン LASIK の要因を知ることを目的とした。〔対象と方法〕対象は 40 歳以上の近視矯正 LASIK を受けて 3 ヶ月以上経過観察可能であった 150 名である。モノビジョン LASIK を希望した群 87 名 (58%) と両眼遠方矯正を希望した群 63 名 (42%) との比較、さらにモノビジョン群は年齢で 40~45 歳の老視前段階群と 46 歳以上の老視群に分けて、性別、モノビジョンのための不同視量、裸眼視力、追加矯正手術率とその理由、眼鏡使用率を検討した。〔結果〕モノビジョン希望者は女性のほうが有意に多かった ($p=0.002$)。老視群では、近方視用の屈折値は老視前段階群よりも強い近視を残す必要があり、近方視の良好条件を満たす率も有意に低かった ($p=0.045$)。追加矯正の再手術は 21 名 (24%) に必要としたが、そのうちの 4 名 (5%) はモノビジョンの見え方に適応できないため、近視を残してある近方視眼を遠方視用に矯正し直し、両眼遠方視とした。一方 15 名 (17%) は、遠方視眼の追加矯正を要した。とくに遠方視眼の裸眼視力が 20/30 (小数視力 0.67 相当) より悪い場合、良好な遠方視眼を得ている症例よりも有意に追加矯正を希望した ($p<0.001$)。モノビジョン群では、両眼遠方矯正群と比べ、遠用眼鏡使用率は有意差がないものの、近用眼鏡使用率が有意に少なかった ($p<0.001$)。〔結論〕本研究から、モノビジョン LASIK を受けた患者は遠方視眼の視力が 20/30 以下であると追加矯正を強く必要とすることが明らかになった。遠方視眼が片眼のみであるモノビジョン患者は残余屈折誤差に対する認容が低く、両眼遠方矯正患者よりも完全な遠方視眼を要求する。