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# Correction of Presbyopia With Monovision

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Presbyopia is characterized by the gradual age-related loss of accommodative ability to the point where it becomes insufficient for near vision. Patients usually become symptomatic between the ages of 40 and 45 years. As our understanding of the pathophysiology of presbyopia has increased, so have the number of options to deal with failing or absent accommodation, including bifocal and multifocal spectacles, multifocal contact lenses, scleral relaxation, multifocal IOLs, and accommodative intraocular lenses.[1] However, for those patients seeking clear vision at multiple distances without the aid of spectacles, monovision has remained a popular refractive technique.

Monovision is a means of correcting presbyopia, whereby one eye is corrected for distance vision and the other corrected for near through creation of an acquired anisometropia. The literature on monovision cites excellent outcomes with anisometropia of 1.50 to 2.50 D.[2-5] The distance eye is corrected to move the far point to infinity (ie, target plano correction). Near vision can be specifically tailored to fit the patient's particular needs. Historically, the patient's dominant eye is corrected for distance and the nondominant eye for near. Crossed monovision occurs when the nondominant eye is corrected for distance, either intentionally or as a result of surgical error or unpredictability.

Contact lens-induced monovision (CLM) has been in use for 40 years, with a mean success rate of 73%[5] (see Chapter 14). Newer methods of providing monovision, such as refractive IOL exchange, photorefractive keratectomy (PRK), and laser-assisted in situ keratomileusis (LASIK), have been gaining popularity.[2] Corneal refractive surgery as a means of presbyopic correction is particularly attractive, as intraocular surgery is not required and recovery times are excellent. Patients dissatisfied with their surgery can have the near-sighted eye corrected for distance with minimal additional risk of adverse consequences.

This chapter will focus on the reported outcomes of refractive surgery in treating presbyopia through monovision. Numerous reports have been published since the publication of *Hyperopia and Presbyopia* in 2003,[1] and consolidation of this new information is necessary to help guide future research, as well as to maximize surgical efficiency and patient satisfaction.



Pallikaris IG, Plainis S, Charman WN.
*Presbyopia: Origins, Effects, and Treatment* (pp. 143-150).

# Goals of Monovision

Ideally, patients with monovision correction should be able to see clearly at most distances. The patient should experience continuous and smooth binocular depth of focus (DOF), and stereoacuity should not be significantly affected to the point that it interferes with daily activities. The loss of contrast sensitivity and binocular visual acuity should be minimal, allowing the patient to function adequately under most lighting conditions. Successful cases typically are associated with only a small amount of postoperative esophoric shift. Importantly, there should be proper blur suppression of the image from the unfocused eye, as problems with this ability uniformly result in an unsatisfying outcome.[6]

Before any reference to studies on the success of monovision in presbyopia, it should be noted that the definition of "success" is not standardized and is difficult to gauge scientifically. Some retrospective studies infer success if their patients did not reverse their monovision by the completion of their study, whereas others have more definitive criteria. In our analysis, we consider monovision successful if the patient can function happily without the assistance of spectacles 85% of the time.[7] Whatever the standard, an important factor to consider is patient satisfaction in the outcome and the ability for him or her to accomplish his or her goals with minimal dependence on spectacle or contact lens correction.

# Outcomes and Visual Performance in Monovision

## *Contact Lens Studies*

As the vast majority of publications on monovision have focused on CLM, a review of the pertinent findings is important prior to discussion of findings in refractive monovision (see Chapter 14).

### Binocular Depth of Focus

Patients with good monovision outcomes typically have continuous binocular DOF equivalent to the sum of the monocular depths of focus.[1] There is some evidence that this is most attainable with a near add below 1.50 D, as this decreases the range between the far points of each eye.[4] However, patients with very strong sighting preferences do not have the same capacity of binocular depth summation for moving objects[8];they experience blurring of the image as the object of regard moves into the range of the nondominant eye. This is likely explained by the inability of the visual system to switch focus from 1 eye to the other.[8]

### Blur Suppression

A good ability to suppress the blurred image from the nonfocusing eye is essential for the perception of sharp images, a phenomenon known as interocular blur suppression. Studies of blur suppression using the Anisometropic Blur Test by Schor et al[9] have revealed that, in patients with CLM, blur suppression of a bright target is most attenuated under low illumination and when the target is smaller. Given that the ability of a patient to suppress blurred images is highly variable, the amount of anisometropia that can be tolerated in a given individual also can vary widely. As a result, it has been proposed that blur suppression, not dominance, be used to determine which eye should be corrected for distance.[4]

### Binocular Acuity and Contrast Sensitivity

Decreased binocular acuity and contrast sensitivity with a CLM add of more than 1.50 D[8] are significant limiting factors for success. Evidence exists that this effect is exaggerated under low illumination conditions and for frequencies greater than 4 cycles per degree (cpd). Complaints from some patients experiencing glare and halos around pinpoint sources of light under low levels of illumination are common and may require spectacle correction (in the undercorrected eye) under certain conditions, such as driving at night.[8]

### The Role of Ocular Dominance

The practice of correcting the dominant eye for distance viewing is based on the assumption that it is easier for the nondominant eye to suppress blur. Thus, it would be reasonable to assume that determination of the dominant eye should help predict success in monovision. The literature, however, shows very little support for this idea. Numerous studies have shown either no connection or a very weak correlation between ocular dominance and blur suppression.[8] Schor et al[10] found that correcting either the dominant or nondominant eye for near did not significantly affect blur suppression ability. This may be because sighting dominance, as determined by asking a patient to line up the preferred eye with 2 objects at difference distances, is primarily a sensory dominance and is not a good measure of ocular dominance. Moreover, the literature seems to be replete with studies demonstrating the lack of agreement between the different tests of dominance. Robboy et al[11] found a relatively low proportion of patients exhibiting dominance in the same eye when tested for dominance using the hole-in-card method, mirror tests, and anisometropic blur suppression test. Those studies that do demonstrate difficulty with suppression in the dominant eye conclude that weak sighting dominance should be an advantage in monovision.

### Task Performance

Reduced visual acuity from monovision can have some real consequences, as shown in a study of task performance by Harris et al[12] in CLM versus reading glasses. They were able to demonstrate a 2% to 6% reduction in the performance of 3 near tasks independent of changes in stereo depth perception.[12] Another study by Collins et al[13] further elaborated on these results by reporting that the eye chosen to be defocused (dominant versus nondominant) did not influence outcomes. A significant decline in stereoacuity can also occur with monovision, as reported in numerous studies comparing CLM to bifocal correction.[4,8] The consensus among these studies was that stereoacuity declined significantly for anisometropia greater than +2.00 D.[8] This was later confirmed for PRK monovision by Wright et al[14] in 1999. Stereoacuity may have as decisive an effect as blur suppression in the acceptance of monovision, based on a study by Collins and Bruce[15] in 1994. They reported that decline in stereoacuity and near photopic visual acuity correlated with poor outcomes independent of blur suppression in patients with CLM.

### Visual Field

Monovision appears to have no appreciable effect on peripheral visual acuity or peripheral visual fields.[4]

## *Monovision in Refractive Surgery*

### Binocular Vision

Monovision success largely depends on the postoperative binocular distance and near acuity, which can be influenced by changes in contrast sensitivity or poor blur suppression.[4] Although success rates for monovision laser correction have been cited to be between 72% and 98%,[16] refractive monovision studies published to date largely report either residual refractive error[17] or excellent monocular near and distance acuities[16,18,19] as the final outcome without an assessment of those factors most critical to patient satisfaction. In one recent exception, Garcia-Gonzales et al[20] reported a small but statistically significant decline in binocular distance and near vision when compared to spectacle correction of the same patients. Despite this finding, none of the patients felt their distance vision was so poor as to require retreatment.

### Poor Outcomes and Retreatment Rates

One of the early studies on refractive LASIK monovision found that, of the 391 patients assessed, a significantly higher number of monovision patients required retreatments compared with controls corrected binocularly for distance. Interestingly, the disparity seemed most profound in the hyperopic subgroup, where 24.7% of patients required retreatment compared with 14.7% of matched controls. Myopes with and without monovision had similar retreatment rates.[19] The causes of poor outcome in refractive monovision were assessed in a retrospective chart review of 82 patients by Reilly et al[18] in 2006. They found a 97.6% success rate with only 2 patients choosing monovision reversal. Success was defined as J2 near vision or better and the decision not to seek binocular distance correction. An interesting finding in this study was that the distance eye retreatment rate was 3 times higher than for the near eye. This is consistent with the results by Braun et al[16] who found that the retreatment rate was 27.9% for the distance eye compared with 9.9% for the near eye.[16] Twelve patients (7%) decided on monovision reversal. This finding emphasizes conclusions drawn from prior contact lens studies, as well as older refractive monovision studies,[19] that successful acceptance of monovision correlates with good binocular distance acuity. In our analysis, we did not observe a correlation between monovision rejection and either age or gender.

### Postoperative Anisometropia

The targeted degree of anisometropia is patient-dependent, with various factors such as age, native refractive error, occupational needs, and ocular dominance being taken into account. Goldberg's[19] study placed a ceiling of -2.50 D of anisometropia, whereas

Miranda and Krueger[21] had a maximum of -2.00 D, with increasing corrections based on age. In their study, the oldest group (57 ± 5.9 years), corrected between -1.50 D and -2.00 D, had a 94% success rate versus an 88.23% success rate in the younger group (43 ± 6.5 years) treated to a refractive correction between -0.50 D and -1.00 D. Mean postoperative spherical equivalent in the study by Reilly et al[18] was -1.24 D in near eyes, whereas in the study by Jain et al,[17] average near refractive correction was -1.95 D regardless of conventional versus crossed monovision. In the 2008 retrospective study by Braun et al[16] of 188 LASIK monovision patients, successful near eye correction was defined as a refractive correction of -1.00 D or more and a total anisometropia of greater than 1.00 D.[16] The degree of anisometropia did not correlate with rejection of monovision. Although not seen in the aforementioned studies, large postoperative anisometropia can potentially affect monovision outcomes by diminishing stereopsis.[14] In addition, prior studies have shown that binocular summation is greatest when the degree of anisometropia is less than +1.50 D.[5]

## Stereoacuity and Fusion

As noted previously, monovision patients exhibit an overall decrease in stereoacuity. Jain et al[5] reported a mean stereoacuity reduction of 50 to 62 seconds of arc in CLM patients. There is evidence that this effect is measurable in refractive monovision as well. Wright et al[14] corroborated these findings in their study of PRK-induced monovision, finding a slightly lower degree of stereoacuity relative to patients receiving PRK for bilateral distance correction; however, these results were not statistically significant. In a study of patients successfully adapted to LASIK or PRK monovision after 6 months, Fawcett et al[22] reported a median stereoacuity of 100 seconds of arc when anisometropia was less than 1.50 D, compared with 150 seconds of arc for patients with greater than 1.50 D of anisometropia. This was compared to control patients, who attained 40 seconds of arc. This study also demonstrated a persistent disruption of foveal fusion, even after balancing the binocular vision for distant and near. The patients with larger amounts of anisometropia were more likely to fail the Worth 4-dot test at 3 meters. In their series of 37 patients with LASIK monovision, Garcia-Gonzales et al[20] reported that 19% failed the Worth 4-dot test, all of whom had anisometropia of 1.25 D or greater.

## Contrast Sensitivity

The earliest study of contrast sensitivity in refractive monovision was by Wright et al[14] in patients undergoing PRK. They did not find a significant difference in contrast sensitivity when compared with those targeted for emmetropia.[14] A more recently published prospective observational study of LASIK monovision patients followed distance stereoacuity using the CSV-1000 ETDRS chart at different spatial frequencies.[21] These patients were measured at 3, 6, 12, and 18 cpd. The authors reported slightly decreased distance binocular contrast sensitivity compared with patients without monovision; however, the difference became statistically significant only at spatial frequencies 18 cpd and above. Near low-contrast acuity was measured with the 10% low-contrast ETDRS chart, and a statistically significant reduction was found compared with testing with bilateral near correction.[21] These findings validate the CLM studies describing reduced binocular contrast sensitivity in the middle to high spatial frequencies.[4] With increasing monocular defocus from higher degrees of anisometropia, the binocular contrast sensitivity reverts to monocular levels—a sign of suppression.[4]

## Crossed Versus Conventional Monovision

The conventional wisdom is that patients who want monovision surgery should consider having their dominant eyes corrected for distance. However, there are conflicting reports in the CLM literature, with some suggesting crossed monovision decreases blur suppression in the defocused eye, whereas others report no such change. A number of refractive monovision studies have attempted to determine whether conventional monovision truly has better acceptance rates. In the study by Jain et al,[17] 43% of patients were corrected with crossed monovision, and though this type of monovision was due to unintentional undercorrection of the dominant eye in 31% of patients, patient satisfaction did not differ significantly from the control group receiving conventional monovision. Of 82 patients in the study by Reilly et al,[18] 5 had crossed monovision, and none elected reversal. Although most of the literature supports a high success rate for crossed monovision, comparable to conventional treatment, there have been exceptions. In the study by Braun et al,[16] 12 (7%) patients had crossed monovision, with 50% requiring retreatment compared with 34% of the conventional group. Both distance vision and near vision success rates (50% and 56%, respectively) were lower compared with the conventional group (68% and 70%, respectively) at 1 month.[16]

## Patient-Specific Variables to Consider in Maximizing Outcomes

### Age

Patients over the age of 40 years who are losing their accommodative ability are the most suitable candidates for monovision with refractive surgery. Although it makes sense that older patients with their increased loss of accommodative ability would do better with monovision, the literature does not support an association between age and success.[16,17]

### Gender

Women make up a greater percentage of patients seeking monovision.[14,16,17] In Goldberg's[19] study comparing myopes and hyperopes seeking monovision, 20% of men chose monovision versus 50% of women, a proportion of which held true even when accounting for baseline refractive state. In the study by Braun et al,[16] women were half as likely as men to reject monovision. A review of the literature, however, does not support gender-dependent differences in monovision success.

### Determining the Distance Eye

Different approaches have been used for selecting the distance eye. Among these are (1) using handedness to determine the distance eye, (2) assigning the eye with a closer near point of convergence as the near eye, and (3) using the "swinging plus test," whereby a +1.50-D lens is placed first over one eye, then over the other, with the most comfortable spectacle-corrected eye serving as the near eye.[1]

To date, ocular dominance is the most commonly used marker in selection of the eye to be corrected for distance. Most of the research reviewed classifies ocular dominance based on the eye used to view a distant target through an aperture made with the hands. Putting aside the inadequacy of current methods of determining ocular dominance (which is better referred to as sighting dominance), the results of conventional versus crossed monovision, as summarized in the previous sections, essentially demonstrate equivalent success rates.

We conclude that ocular dominance likely plays a significant role in surgical outcomes in eyes with a high degree of dominance, as this tends to lead to reduced blur suppression. These patients have problems with blurring, particularly as the object of regard moves from the monocular clear range of the dominant eye to the range of the nondominant eye. It is especially important in these patients to attempt a contact lens trial. If patients undergoing a monovision contact lens trial prefer to have their nondominant eye corrected for distance, this should not pose a significant problem.

### Monovision Trials

A number of the refractive monovision studies incorporated contact lens or spectacle trials to determine whether acceptance could predict surgical outcomes. In a recent study of 188 patients undergoing LASIK monovision, 46% chose monovision after a contact lens trial, whereas 22% chose monovision after spectacle lens trials. Twenty percent of the monovision LASIK patients were already using monovision, either with contact lenses or spectacles, with every monovision contact lens wearer choosing LASIK monovision over bilateral distance vision. Patients in the study who had a successful trial with monovision contact lenses were more likely than those tested with spectacles to have monovision refractive surgery. In another retrospective chart review of LASIK monovision, 37% of the monovision cohort underwent a contact lens trial, and of these 30 patients, none elected reversal. Several other studies corroborate these findings.[7,18]

Based on the data reviewed, we conclude that monovision contact lens trials can be a useful and accurate way to determine which patients can tolerate surgical monovision. It should be noted that at least 3 weeks may be needed for proper climatization before deciding whether a patient is intolerant. Contact lens fit should be assessed, and residual astigmatism should be corrected via spherocylindrical over-refraction. Adjustments to the near eye add can be made during the contact lens trial to help refine the degree of anisometropia preferred by the patient.

## Myopia Versus Hyperopia

Farid and Steinert[6] observed that the percentage of hyperopic candidates for refractive surgery tends to be lower than that for myopic candidates, due to lower predictability at higher powers of hyperopia, greater rates of amblyopia, strabismus, and strong sighting preference in hyperopia. Braun et al[16] reported that of 22 hyperopic patients treated, only 2 decided to have their near eye corrected for distance later. Both of the individuals in this group treated with crossed monovision adapted successfully. Mean rates of acceptance did not differ from acceptance rates in myopes (90.9% versus 93.3%). Interestingly, all patients selected the more hyperopic eye for near vision, suggesting a preference for distance vision with the less hyperopic eye.[16] This preference likely contributes to better interocular blur suppression. Final distance visual acuity after monovision in myopes was found to be statistically better compared with hyperopes, which may help explain why this group complains more of glare, halos, and difficulty with dim light.

Our analysis suggests that, although LASIK monovision seems to be a reasonable approach in hyperopes seeking relief from presbyopia, a preoperative trial of monovision contact lenses is valuable. It also seems, based on the few published studies, the more hyperopic eye would be better suited for near correction.[16,19]

## Patient Expectations

Careful assessment of patient expectations is important prior to any refractive surgical treatment, and this is especially true in individuals opting for monovision. Often, patients arrive to the clinic with unrealistic expectations regarding the quality of their potential postoperative vision. As noted in the previous sections, monovision can lead to slightly diminished binocular acuity, decreased scotopic contrast sensitivity, diminished stereoacuity, and complaints of glare and halos at night. These issues may require use of spectacles or contact lenses under certain conditions, such as driving at night or with fine acuity tasks at near.[16] Patients not informed of these potential issues prior to the procedure, unaware of the possibility of needing multiple retreatments, and not reminded of the need for a period of adaptation after the surgery may end up frustrated and unhappy.

The patient's occupation and lifestyle are critical to take under consideration. In 2000, a report was published of an aircraft accident in which the pilot's monovision was partially implicated.[4] However, pilots are not the only patients who make poor candidates. Patients needing smooth binocular DOF and sharp stereopsis, such as baseball players tracking a fast-moving ball, are also likely not good candidates for the procedure. In addition, patients who drive professionally or who drive frequently at night may not be satisfied with monovision and should be counseled accordingly.[19] The possible medicolegal liability in overlooking the patient's particular visual needs should be obvious.

In the study by Braun et al,[16] 20% of monovision LASIK patients were already using monovision with spectacles or contact lenses, and of those wearing contact lenses, all chose monovision over bilateral distance correction. The retrospective study by Jain et al[17] also noted that all 10 patients, who had a preoperative trial of monovision, requested the monovision procedure, with 80% satisfaction postoperatively. This suggests that monovision trials help patients develop a better understanding of the postoperative outcome of the surgery, which in turn leads to more realistic expectations that work to filter poor candidates. It is important to note to all patients that, should monovision not succeed, the near eye can always be corrected for distance.

## Summary

Monovision is an attractive and safe option in patients considering treatment for presbyopia that can reduce dependence on spectacles or contact lenses. Several surgical modalities could create the needed anisometropia, but currently the safety profile, reliability, reproducibility, and efficacy of laser refractive surgery seems higher than alternative surgical procedures. Monovision is associated with some compromise in visual function, including decreased stereopsis, contrast sensitivity, and binocular visual acuity. These problems may be especially exacerbated in individuals with strong sighting dominance. Most patients do not have strong dominance, and for these patients, conventional and crossed monovision are both viable and equally successful. Giving patients an idea as to how their vision will change with surgery, by attempting a CLM trial, can be extremely helpful in identifying proper candidates for the procedure. Patients also need to be screened according to their expectations and informed that it may still be necessary to use near spectacles for reading extremely fine print or distance spectacles for driving, especially at night.

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