Advantages of Laser-Blended Vision

This method of presbyopia correction does not compromise visual quality.

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Recent laser refractive surgery approaches for presbyopia correction focus on modifying the asphericity of the cornea,[1] which maintains more natural and continuous optics rather than inducing multiple images in each eye for the brain to interpret. The primary objective in the aspheric correction of presbyopia is to create an optical surface that modifies the optical properties of the entire eye, thus improving depth of field.[2,3]

Eight years ago, we began research in collaboration with Carl Zeiss Meditec (Jena, Germany), with the aim of improving the concept of simple asphericity or prolateness to develop more sophisticated nonlinear aspheric ablation profiles. We designed the nonlinear aspheric ablation profile to increase the prolate shape of the cornea; increasing the negative asphericity of the cornea increases the amount of negative spherical aberration (OSA notation). Hence, depth of field increases.

TAKE-HOME MESSAGE

- A nonlinear aspheric ablation profile increases the prolate shape of the cornea, which increases negative asphericity and the negative spherical aberration. This results in increased depth of focus.
- The major advantage of laser-blended vision is the creation of an intermediate and far-intermediate distance zone of fusion, which allows the brain to merge images from each eye.
- In contrast to traditional monovision, laser-blended vision results in an overlapping blend zone of vision in the intermediate range.

LASER-BLENDED VISION

We have observed that our nonlinear aspheric profiles increase depth of field, but not enough to provide clear vision at all distances, which would be the ideal solution. However, the fact that depth of field does increase means that good binocular near and distance vision are achievable with a lower degree of anisometropia than required by traditional monovision. We refer to this protocol as *micro-monovision*.

The dominant eye is targeted for exactly plano (mainly corrected for distance but also providing intermediate vision), and the nondominant eye is targeted for slight myopia (mainly corrected for near but also providing intermediate vision). The ideal target is -1.50 D, although this can be varied between -0.75 and -1.75 D depending on age, degree of presbyopia, and patient tolerance. The result is that the dominant eye is clearly focused for distance vision—but with reduced blur at near—and the nondominant eye is clearly focused for near vision—but with reduced blur at distance. The increase in depth of field is such that the ranges of clear vision achieved by the distance and near eyes overlap at intermediate distances, unlike the traditional monovision approach in which there is a gap in the range of clear vision. We refer to the combination of nonlinear aspheric profiles and micro-monovision as *laser-blended vision*.

METHODS

We have studied laser-blended vision using the MEL80 excimer laser system (Carl Zeiss Meditec) in patients with refractions ranging from +5.75 to -8.50 D, including emmetropic patients. Here, we present results of 366 consecutively treated patients, comprising of 136 myopes (maximum spherical equivalent [SE], -8.50 D), 111 hyperopes (maximum SE, +5.75 D), and 119 emmetropes (SE -0.50 to 0.75 D). The patients ranged in age from 43 to 71 years, and median age was 53 years. LASIK was performed in all eyes using the Hansatome zero-compression microkeratome (Bausch & Lomb, Rochester, New York) and the MEL80 excimer laser with the CRS-Master (Carl Zeiss Meditec). Results were analyzed based on 1-year data, with 90% follow-up; results included any enhancements.

RESULTS

In monocular visual acuity testing, with data pooled for all patients (+5.75 to -8.50 D), distance UCVA was 20/20 or better in 92% of distance eyes and 20/63 or better in 80% of near eyes. Binocular distance vision results demonstrated neural summation in all subgroups. A total of 98% of myopic patients, 95% of hyperopic patients, and 96% of emmetropic patients achieved 20/20 or better binocu-

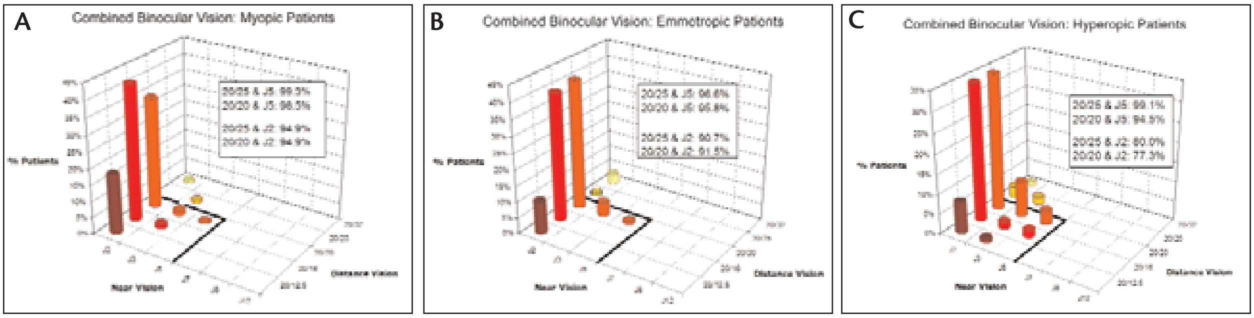

Figure 1. These 3-D graphs show the combined binocular UCVA outcomes of the (A) myopic, (B) hyperopic, and (C) emmetropic groups.

larly (Figure 1); 100% of patients achieved 20/32 or better. After surgery, UCVA was the equivalent to vision before surgery with glasses (ie, better than or no worse than one line less than the preoperative BCVA) in 94% of eyes, including data pooled for all patients.

Binocular near vision results were equally impressive in all subgroups, with 96% of myopic patients, 81% of hyperopic patients, and 95% of emmetropic patients achieving J2 near vision. All patients achieved J5 (ie, reading newsprint) or better near vision.

Combined binocular vision of 20/20 at distance and J2 at near was achieved in 94% of myopic patients, 77% of hyperopic patients, and 91% of emmetropic patients. Good functional combined binocular vision (ie, 20/25 at distance and J5 at near) was achieved in 99% of myopic patients, 99% of hyperopic patients, and 97% of emmetropic patients.

The safety of the procedure was also excellent. No eye lost two or more lines of BCVA; however, 8% of myopic eyes, 17% of hyperopic eyes, and 13% emmetropic eyes lost one line of BCVA. Paired t-tests showed that contrast sensitivity was either unchanged from the preoperative level or statistically significantly increased at some spatial frequencies for each subgroup.

ADVANTAGES OF LASER-BLENDED VISION

The major advantage of laser-blended vision is the creation of an intermediate and far-intermediate distance zone of fusion—allowing the brain to merge images from each eye. Therefore, less suppression is required, and there is no dissociation between eyes. Even with the addition of considerably blurrier distance vision in the near eye, binocular distance UCVA improved compared with the vision in the distance eye alone, demonstrating neural binocular summation of the images from the two eyes.[4]

Further, due to increased depth of field in both eyes, the distance vision of the near eyes and the near vision of the distance eyes were better than anticipated for the degree of targeted myopia.[4] For example, the near eyes in the hyperopic subgroup had a mean refraction of -1.32 ±0.61 D, but the mean distance UCVA was 20/44 (45% achieved 20/40 or better and 80% achieved 20/63 or better). For a typical eye, 0.25 D of myopic defocus results in the loss of one logMAR line of UCVA.[5] Therefore, an untreated eye with myopia of -1.32 D should only achieve a distance UCVA of 20/70. At near, a 55-year-old would be expected to need a near addition in the range of +1.50 to +2.25 D.[6] The mean patient age in the hyperopic subgroup was 56 years, and the mean achieved spherical equivalent in the nondominant eye was only -1.32 ±0.61 D. This still enabled 100% of patients to read newsprint and 81% to read J2.[4]

In an ongoing prospective study, we are investigating stereoacuity before and after laser-blended vision in patients with and without correction. We have been surprised by our preliminary findings: Although uncorrected near stereoacuity is slightly reduced, it is still present despite the discrepancy between the UCVA of the two eyes.

The nonlinear aspheric ablation profile results in a form of hyperprolatization of the cornea that does not reduce contrast sensitivity or produce multiple images in the eye. Some effects are due to increased negative fourth-order spherical aberration, which conveniently counterbalances the age-related increase in positive spherical aberration of the crystalline lens. It essentially places an on-visual–axis reduction in spherical aberration of the crystalline lens, which may explain why it improves contrast sensitivity. It also may account for the increase in depth of field, which distinguishes this procedure from other forms of presbyLASIK and multifocal IOLs that can lead to image quality loss and a decrease in contrast sensitivity (most likely due to the induction of multiple images within the same eye).[7-9] Instead, it takes advantage of the innate binocular neural adaptation system in which neuronal gates, when presented with two visual fields from fellow eyes, instantaneously select the better image, or elements of each, to obtain the most effective single percept.

In contrast to traditional monovision, laser-blended vision results in an overlapping blend zone of vision in the intermediate range. Both eyes have similar visual acuity that can be fused by the brain. With laser-blended vision, there is no dissociation between the eyes, and much less suppression is required by the brain.

The overlapping blend zone of clear vision and smaller amount of anisometropia distinguish this micro-monovision approach from traditional monovision, in which the depth of field is small, a significant amount of myopia is needed in the nondominant eye, and the patient ends up with a middle blur zone. This results in a significant difference in tolerability. According to published reports, between 45% and 60% of patients can tolerate traditional contact lens monovision because of the significant anisometropia.[10] In contrast, we found a tolerance rate of 97% for our micro-monovision laser-blended vision protocol in preoperative screening.

CONCLUSION

The ultimate goal of presbyopia correction is to refine the ablation profile to increase the depth of field enough in both eyes so that each eye achieves clear vision at all distances. The current ablation is based on nonlinear aspheric profiles that, although they effectively increase depth of field, do not provide clear vision at all distances. We are not sure that this is achievable without compromising visual quality. In the meantime, based on these features and the outcomes we have achieved, almost all presbyopes who come into our clinic who are candidates for laser vision correction now receive laser-blended vision. ■

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