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Influence of laser correction of presbyopia using the Presbyond® Laser Blended Vision (LBV) method on the contrast sensitivity

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HIGHLIGHTS

The studies published so far have shown that the use of the Presbyond® LBV method in the correction of all refractive errors does not reduce the contrast sensitivity.

ABSTRACT

Presbyond® Laser Blended Vision (LBV) method, based on the FemtoLASIK technique, is currently the most frequently performed laser refractive procedure to correct presbyopia. This method involves the non-linear aspheric ablation of the cornea with controlled induction of spherical aberrations in both eyes and the induction of micromonovision of -0.75 to -1.50 D in the non-dominant eye. The article presents the results of published studies analyzing the effect of laser correction of presbyopia using the Presbyond® LBV method on the contrast sensitivity. The studies published so far indicate that the Presbyond® LBV treatment does not significantly affect contrast sensitivity.

Key words: presbyopia, laser in situ keratomileusis, monovision, spherical aberration, contrast sensitivity

INTRODUCTION

Presbyond® Laser Blended Vision

Presbyopia is defined as the gradual, age-related loss of the eye's ability to accommodate and the increasing symptoms of asthenopia at near and intermediate distances. Presbyopia generally manifests itself from the age of 42–44 [1] and currently affects about 2.1 billion people worldwide [2]. Presbyopia can be corrected by conservative approaches (glasses, contact lenses), laser and surgical procedures. Due to increasing quality-of-life demands and longer professional activity of mature and elderly people, more invasive presbyopia treatment options are gaining popularity. Successful treatment of presbyopia, which is often accompanied by another refractive error, poses a challenge for the refractive surgeon. After refractive surgery, patients expect not only good vision at far, intermediate and near distances, but also good contrast and binocular vision. Furthermore, patients value comfort and high safety profile of the procedure, rapid visual rehabilitation, as well as the stability and possible reversibility of treatment effects. Existing laser treatments for presbyopia include monovision, multifocal ablation, and nonlinear aspheric ablation profiles combined with micro-monovision (Presbyond® Laser Blended Vision). In the standard monovision, the dominant eye is corrected for distant vision, and the non-dominant eye for near vision with induced myopia of -1.25 to -2.5 D, depending on the patient's age. Anisometropia induced by monovision is associated with compromising visual acuity at intermediate and far distances, reduced contrast sensitivity, and loss of stereopsis. Therefore, some patients report poorer treatment satisfaction scores [3–5].

Presbyond® LBV combines nonlinear aspheric corneal ablation and controlled induction of spherical aberrations in both eyes with micro-monovision of -1.50 D for the non-dominant eye. Presbyond®, based on the FemtoLASIK treatment, has been registered by the European Medicines Agency for adults above 40 years of age with myopia up to -8.0 D, emmetropia, hyperopia up to +4.0 D, astigmatism up to 2.5 D, and a positive cross-blur monovision tolerance test [6].

Spherical aberration is a naturally occurring higher order aberration in human eyes that disseminates the retinal focal point. Increased spherical aberration is a cause of twilight myopia and the halo effect and is associated with impaired vision and a reduced contrast sensitivity.

Rocha et al. [7] from the Cole Eye Institute in Cleveland, in a study using adaptive optics simulators, showed that a controlled increase in spherical aberration up to 0.56 μm in both eyes increased corneal power depth up to 1.5 D with possible filtering of image interference.

In Presbyond® LBV, the induction of aspherical aberration further improves visual acuity with accompanying defocus in the non-dominant eye, without compromising visual acuity at intermediate distances (blend zone). Moreover, Presbyond® procedure draws on the following mechanisms to increase depth of field: pupil constriction during accommodation, corneal epithelial remodeling, and the difference in refractive index between epithelium and stroma (1.401 vs. 1.377), and finally – binocular summation in the visual cortex after several months of neuroadaptation and preservation of binocular vision. The innovative nonlinear aspheric ablation profile considers the type and size of corrected refractive error, patient's age, and preoperative spherical aberration. Presbyond® LBV induces positive spherical aberration in myopes and negative spherical aberration in hyperopes. In patients with normal visual acuity, Presbyond® induces negative spherical aberrations to near and positive spherical aberrations to far. Presbyond® LBV extends the depth and the range of vision. Increased perception of depth and controlled induction of spherical aberrations levels below the threshold for vision impairment led to much better vision at far distances in the non-dominant eye than in standard monovision, without loss of contrast or abnormal retinal correspondence.

Contrast sensitivity test

Visual acuity and contrast sensitivity tests are crucial for assessing visual functions following corneal or lenticular presbyopia correction procedures. Contrast is the difference in luminance that makes an object (or an image) distinguishable, whereas contrast sensitivity determines the lowest contrast at which we can detect a given object.

The contrast sensitivity test uses sinusoidal patterns that vary in luminance across a grating pattern. The number of cycles per degree is defined as the spatial frequency that corresponds to the thickness of lines or gaps in optotypes on a visual acuity test board.

The range of spatial frequencies varies from 0.5 cpd (visual acuity 6/320) to 30 cpd (visual acuity 6/6). Refractive errors have been shown to affect contrast sensitivity. Spherical aberrations can reduce contrast sensitivity proportionally to the size of the aberration – small aberrations reduce contrast sensitivity at high spatial frequencies, moderate aberrations at high and medium frequencies, and high aberrations at all frequencies. Astigmatism reduces contrast sensitivity at medium spatial frequencies. Some studies showed a transient reduction in contrast sensitivity at various spatial frequencies in patients after PRK and LASIK which improved 6 months postoperatively [8, 9]. Moreover, it has been confirmed that aging processes and aging degrade contrast sensitivity. With increasing age, contrast sensitivity reduction is brought by cumulative changes in the lens, retina, and neurons. In people over 50 years of age, contrast sensitivity declines at high and medium spatial frequencies, whereas in patients above 60 years – at all spatial frequencies [10, 11]. Visual acuity and contrast sensitivity

tests are complementary because full visual acuity assessed with high contrast optotypes (Snellen or a logMAR charts), does not rule out low-contrast visual acuity.

Contrastometry provides additional information regarding patient's quality of vision, which includes the perception of objects with different, even low, levels of contrast. Impaired recognition of low-contrast objects is associated with a subjective sense of impaired vision and poorer visual functioning in daily life, with problems recognizing faces and road signs, navigating at dusk, in the rain, or in fog. Contrast sensitivity has been confirmed to affect patients' ratings of visual satisfaction and quality of life [12].

LITERATURE REVIEW

Pubmed, Scopus and Web of Science databases were searched for prospective and retrospective studies evaluating the effect of Presbyond® LBV on contrast sensitivity. We used the following keywords: "presbyopia correction", "Presbyond®", "aspheric monovision LASIK", "laser blended vision", "contrast", "contrast sensitivity", which were combined with appropriate logical operators. Case reports, reviews, meta-analyses, systematic reviews, letters to the authors, congress reports, abstracts and papers published in languages other than English were excluded. We analyzed 8 articles, published between 2009 and 2023. The follow-up ranged from 3 to 12 months. In all studies, contrast sensitivity was measured using the CSV-1000 test (VectorVision, Inc.) at the distance of 2.5 m. The CSV-1000 test consists of 4 vertical sine-wave gratings at spatial frequencies of 3, 6, 12 and 18 cpd. The contrast sensitivity scale was expressed in numerical values from 0.10 to 1.70.

Reinstein et al. [6] analyzed the change in contrast sensitivity in 129 patients with hyperopic astigmatism and presbyopia. The median age of the study participants was 56 years (range: 44 to 66 years), and the mean preoperative spherical equivalent was +2.54 D (±1.16 D) (range: +0.25 to +5.75 D). The induced micro-monovision in the non-dominant eye ranged from -1.00 to -1.50 D. The mean follow-up was 12.5 months. The mean preoperative contrast sensitivity was 0.96 at 3 cpd, 0.94 at 6 cpd, 0.95 at 12 cpd, and 0.90 at 18 cpd, whereas postoperative contrast sensitivity was 0.99 at 3 cpd, 0.96 at 6 cpd, 0.97 at 12 cpd, and 0.92 at 18 cpd. A statistically significant increase was noted in postoperative contrast sensitivity at 3 cpd ($p = 0.008$) and 6 cpd ($p = 0.037$) compared to preoperative values, with no reduction at 12 cpd ($p = 0.181$) and 18 cpd ($p = 0.292$).

Another study by Reinstein et al. [13] included 155 patients with myopic astigmatism and presbyopia. Mean preoperative spherical equivalent (SE) correction was -3.59 (± 1.79) D, mean cylinder correction was 0.84 (± 0.63) D. Micro-monovision in the non-dominant eye ranged from -0.75 to -2.00 D, mean. -1.27 (± 0.31) D. Median follow-up was 12.5 months. Authors reported no difference between preoperative and postoperative contrast sensitivity at all spatial frequencies of 3 cpd, 6 cpd, 12 cpd and 18 cpd.

In another study, Reinstein et al. [14] included 148 patients with emmetropia. Preoperative SE refraction was ≥ -0.88 D, sphere ≤ +1.00 D, and postoperative micro-monovision in the non-dominant eye ranged from -1.00 to -1.88 D, mean. -1.52 (± 0.09) D. Authors noted a statistically significant increase in postoperative mesopic contrast sensitivity at 3 cpd compared to preoperative values and no change at 6, 12, or 18 cpd.

In a study on the functional outcomes of Presbyond® LBV in commercial and military pilots, Reinstein et al. [15] evaluated quality of vision parameters, including mesopic contrast sensitivity. The study included 23 presbyopic pilots. Median age was 55.0 years (range: 42 to 68 years) and a mean preoperative SE of -0.54 (± 2.55) D (range -6.50 to +4.88 D). The non-dominant eye was targeted for monovision (-1.50 D), and, if necessary, this range was lowered to be acceptable by the pilot. The median follow-up was 12 months. There was a statistically significant increase in postoperative contrast sensitivity at 3 cpd (+0.09), 6 cpd (+0.11), 12 cpd (+0.10), and 18 cpd (+0.12) compared to that measured preoperatively.

Lim et al. [16] enrolled 27 patients with a mean age of 50.2 years (± 7.5) and a mean preoperative SE of -2.14 (± 2.91) D (range -7.50 to +3.25 D) undergoing Presbyond® LBV. The induced micro-monovision in the non-dominant eye ranged from -1.00 to -1.50 D, mean -1.44 (± 0.21) D. The mean follow-up was 22 months. There were no statistically significant changes in distance contrast sensitivity at spatial frequencies of 3 cpd, 6 cpd, 12 cpd and 18 cpd. However, a statistically significant increase in postoperative near contrast sensitivity was reported at spatial frequencies of 12 cpd and 18 cpd. The mean preoperative near contrast sensitivity was 1.601 at 3 cpd, 1.567 at 6 cpd, 1.116 at 12 cpd and 0.337 at 18 cpd. Postoperative contrast sensitivity changed to 1.647 at 3 cpd, 1.697 at 6 cpd, 1.313 at 12 cpd ($p = 0.002$) and 0.729 at 18 cpd ($p = 0.008$).

Zhang et al. [17] conducted a prospective analysis of the functional outcomes of myopic astigmatism and presbyopia correction with Presbyond® LBV. Forty patients with a mean age of 43.4 (± 4.9) years (range: 38 to 63 years) and a mean preoperative spherical equivalent refraction of -5.68 (± 1.98) D (range -1.25 to -11.13 D) were enrolled in the study. Micro-monovision in the non-dominant eye ranged from -0.75 to -2.25 D, mean -1.41 (± 0.28) D. Patients were monitored for 3 months after surgery. No significant changes were noted in distance contrast sensitivity at spatial frequencies of 3 cpd, 6 cpd, 12 cpd and 18 cpd in mesopic (AULSF [the area under the log contrast sensitivity function] 1.38 vs 1.41, $p > 0.05$) and photopic (AULSF 1.42 vs 1.43; $p > 0.05$) conditions.

In a study on the functional outcomes following Presbyond® LBV, Brar et al. [18] assessed visual quality parameters, including contrast sensitivity and reading speeds. Thirty patients were enrolled in the study, including 18 patients with hyperopia (mean SE +1.28 [± 1.38] D) and 12 patients with myopia (mean SE -2.84 [± 1.86] D). The observation time was 6 months. The mean postoperative SE in the dominant eye was -0.03 [± 0.29] D, and in the non-dominant eye -1.26 [± 0.40] D. No statistically significant changes were reported in distance contrast sensitivity at spatial frequencies of 3 cpd, 6 cpd, 12 cpd and 18 cpd.

Romero et al. [19] enrolled 50 patients with presbyopia, mean age 46.8 years (± 4.2), and assigned them into 3 study groups based on the preoperative spherical equivalent. Group 1 included patients with hyperopia (mean SE +1.71 [± 0.62] D, range +0.50 to +3.0 D). Group 2 included patients with myopia and SE lower than -3.0 D (mean. SE -2.11 [± 0.85] D, range -1.0 to -3.0 D). Group 3 included patients with myopia and SE greater than -3.0 D (mean SE -3.93 [± 0.87] D, range -3.0 to -6.0 D). All patients underwent Presbyond® LBV. Micro-monovision of -0.75 to -1.50 D was induced in the non-dominant eye. The follow-up lasted 6 months. Authors reported a statistically significant improvement in contrast sensitivity in the myopic group down to -3.0 D at a spatial frequency of 18 cpd ($p = 0.021$); however, in other groups no change was reported for contrast sensitivity.

CONCLUSIONS

Most studies published to date have shown that Presbyond® LBV presbyopia correction does not significantly affect contrast sensitivity. Few clinical trials have shown that Presbyond® procedure may improve contrast sensitivity compared to preoperative values. However, to verify these results, there is a need to conduct further research with standardized study groups, research methods and observation period.

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