Multifocal vs Monovision - thru-luminance (scotopic-mesopic-photopic) comparison of two presbyopia correction ways

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Abstract

**Purposes:** a) comparison of two presbyopia correction methods – with multifocal and monovision contact lenses – by means of precise contrast sensitivity measuring under scotopic, mesopic and photopic conditions simultaneously; b) new computerized AltTechNV Thru-luminance CSF test trial operation.

**Methods:** contrast sensitivity of 14 initial presbyopes (40÷51 y.o., never wore contact lenses, used glasses for reading ≤+2.0D), and of 3 control presbyopes with anisometropia (ΔD: 1.0; 1.25; 2.0) of the same age group (43; 46; 47 y.o.) was measured binocularly in multifocal contact lenses and monovision ones of equal power, in arbitrary sequence.

We used computerized AltTechNV Thru-luminance CSF test, ver.4.05. Measurements were made under luminance levels of 0.34; 3.4; 10.0; 20.0; 34.0 and 100.0 Lux (controlled with luxmeter “Meterman LM631”, on the eyes level, in the monitor direction). Refractive errors were controlled using auto refractometer NIDEK AR-330A.

The measurement for each type of lenses was prolonged up to 24÷30 minutes, and we should secure the eyestrain control. For pupil size monitoring, the camcorder with infrared target light was used (built-in infrared filter was removed preliminary).

**Results:** the most evident difference of contrast sensitivities (up to 37%) was observed at low and medium spatial frequencies (2; 3; 5; 8 cpd) under scotopic (0.34 Lux) and mesopic (3.4; 10.0; 20.0 Lux) luminance conditions, in favor of multifocal lenses, as compared with monovision. There were no significant difference at high frequencies (12; 20 cpd) under light mesopic (34.0 Lux) and photopic (100.0 Lux) conditions. All of three anisometropes of control group showed no significant CSF difference between multifocal and monovision lenses – under all luminance levels.

**Conclusions:** visual quality of presbyopes who use multifocal and monovision lenses differs significantly. For presbyopes without anisometropia multifocal lenses provide significantly better visual quality under low luminance conditions, as compared with monovision lenses.

The special attention should be paid to the difference of contrast sensitivities at low frequencies, because this parameter indicates the reduced ability to detect the large moving objects. Ignoring this point may entail the increased danger, e.g. for night driving.

Interestingly, this difference could not be revealed with traditional vision testing tools. Contrast sensitivity at high spatial frequencies represents the visual acuity, and equality of CSF meanings at high frequencies explains why there were no significant divergence between the lenses of different design was found using both visual acuity tests (even low-contrast ones) and CSF photopic/mesopic tests, so far.

Introduction

Presbyopes are the most valuable part of humanity. In their 40’±50’Th, they are most educated, enough experienced and very capable at the same time. Strategically, presbyopes are the base society component for values produce. Evidently, presbyopes’ functionality should be the point of special attention and concern.

Presbyopia correction with multifocal (MF) and monovision (MV) contact lenses are the usual ways. Which way is preferable in individual cases? Is there an algorithm for the right correction prescription?

We have tried to find the answers in our comparative study, presenting the measurable difference between two methods. The most thorough new AltTechNV, Inc. test for thru-luminance vision quality evaluation was used.
Background

It is estimated that there were 1.04 billion people globally with presbyopia in 2005, 517 million of whom had no spectacles or inadequate spectacles. Of these, 410 million were prevented from performing near tasks in the way they required. Vision impairment from uncorrected presbyopia predominantly exists (94%) in the developing world. In view of the problem scale, the adequate algorithms for presbyopes’ right solutions finding are very important.

“Are you unhappy with your vision despite being told that you have “20/20” vision by your eye care practitioner?”

This question is the key one for understanding whether your patient’s visual system is really healthy. In-depth and thorough comparative studies of different methods of presbyopia correction may help to find the effective solutions.

Richdale et al reported that the majority of 38 patients preferred MFs to MVs, but no statistically significant difference was found measuring high- and low-contrast visual acuity at distance and near (Bailey-Lovie, logMAR).

Evans B noted that monovision method has received renewed interest with the increase in refractive surgery. Success rate of monovision in adapted contact lens wearers is 59-67%. Author highlights the need to take account of occupational factors. The main limitations are problems with suppressing the blurred image when driving at night.

Gupta et al in their comparative study showed that MVs provide better distance and near VA as compared with MF. At the same time, MFs provide better stereoacuity and near range of clear vision, whereas producing insignificant differences in the CSF at both distance and near (using Vision Contrast Test System 6500, Vistech Consultants).

Bausch & Lomb (both MV and MF producer) declare that the natural binocular vision provided by a multifocal lens is preferable to visual compromises inherent in a monovision correction. However, this suggestion is founded on patients’ subjective preferences only and is not sustained with experimental data.

Actually, there is no experimental conclusive evidence for the advantages or disadvantages MV as compared with MF or other correction methods. In this situation, there is real anxiety about the surgical implementation of monovision (or any other) method, without satisfactory arguments.

“More contact lens wearers prefer monovision than multifocal simultaneous-vision contact lenses because of the loss of contrast and dysphotopsia with multifocal contact lenses, and they are much more difficult to fit”, - Dr. Holladay said in his interview, and noted: “An advantage of monovision LASIK in comparison with monovision contact lenses is that the patient cannot compare monovision to stereo vision. When contact lens patients take out their lenses at night, they are reminded of the world of stereo vision, and for some patients the monovision modality suffers by comparison. Patients after bilateral LASIK or IOL implantation cannot make that comparison, and they finally adapt “with the tincture of time”.

We can only mention that patient cannot “take LASIK out” if it is not suitable for him, this advantage is questionable. By the way, many patients are able to adapt finally even to full blindness, if they have no choice. More correct approach to this problem is well known, we will remind to this approach below.

Thanks to previous studies, it could scarcely be expected the significant difference in visual acuities. However, visual acuity (VA) is not the exclusive basic parameter for visual quality assessment. VA has deficient functional sense in mesopic conditions, and has no sense under scotopic conditions. Contrast sensitivity function (CSF) – is not less important for vision characterizing, and it is functionally meaningful under mesopic and scotopic conditions, because CSF reflects the subjects’ ability to orientate themselves in the ambient space, to discern surrounding objects and relative motions, the relief specificities, etc. For example, scotopic and mesopic CSF find its meaningful expression in night and twilight driving.

Disposing the new thru-lumiance (scotopic-mesopic-photopic) simultaneous CSF measuring method, we submitted to this examination multifocal and monovision contact lenses efficacy.

Study objectives
- Multifocal and Monovision presbyopes’ correction effectiveness comparison by contrast sensitivity measuring under scotopic, mesopic and photopic conditions simultaneously;
- AltTechNV Thru-lumiance CSF test, ver.4.05 trial operation and verification.

Materials & Methods

14 presbyopes participated in the study (40±51 y.o., never wore contact lenses, used glasses for reading ≤+2.0D), and 3 control presbyopes with anisometropia (ΔD: 1.0; 1.25; 2.0) of the same age group. Scotopic, mesopic and photopic CSF was measured binocularly in multifocal contact lenses and monovision ones, in arbitrary sequence.
Lenses compared:

| Multifocal | PureVision™ Multi-Focal; BC 8.6; PWR 0.00; ADD Low (Bausch&Lomb®) |
| Monovision | PureVision™; BC 8.6; PWR +1.00 (Bausch&Lomb®) |

Measuring method:

Scotopic, mesopic and photopic CSF were defined using computerized AltTechNV Thru-luminance CSF test, ver.4.05

This test and accessory equipment are designed for stimuli threshold determination under raw of luminance levels: 0.34; 3.4; 10.0; 20.0; 34.0 and 100.0 Lux, providing the comparable measurement results.  
AltTechNV original stimuli are the four-choice pseudo-3D grates of sinusoidal brightness amplitude (SBA). SBA varies from 1% to 100% (HSB color space) of step 1%, for spatial frequencies – 2, 3, 5, 8, 12 and 20 cycles per degree (CPD). 
Refractive errors were measured with auto-refractometer.

Objective measuring value:

SBA Threshold (SBAT) – binocular measuring of minimal amplitude of SBA, which allows the patient to define the stimulus orientation certainly, for the corresponding spatial frequencies, under different luminance conditions.

Equipment:

<table>
<thead>
<tr>
<th>Auto Refractometer</th>
<th>NIDEK AR-330A</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>PC Intel P4 3.0 GHz</td>
</tr>
<tr>
<td>Video Card</td>
<td>NVIDIA GeForce 6600 256 Mb</td>
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<td>Monitor</td>
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<td>refresh rate</td>
<td>100 Hz</td>
</tr>
<tr>
<td>Luminance control</td>
<td>Luxmeter Meterman LM631</td>
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Study conditions:

| Luminance (measured on the eyes level) | 0.34; 3.4; 10.0; 20.0; 34.0 and 100.0 Lux |
| Distance “eye-monitor” | 4.6 meter |
| Background luminance | concordant to black map exposed on monitor |

Measuring procedure

Measuring procedure consisted in CSF measurement in MF and MV contact lenses under scotopic, mesopic and photopic luminance conditions.

Procedure steps:

1. Current vision acuity measuring
   The standard procedure of contact lenses prescription was applied.

2. Lenses wearing (1-st pair)
   Patient wore MF or MV – arbitrary, for the first testing round (the other lenses would be worn for the second round). 
   Researcher who would provide the test be not informed which one pair is applied (to exclude the unpremeditated influence on the results).

3. Preparations
   Each testing round was preceded by following steps:
   - Dark adaptation (DA) – in the full darkness, with closed eyes, during 15 minutes;
   - Patient instructing (during DA) of the continual vision relaxation necessity, divine attempts inadmissibility, etc.; brief describing of test procedure;
   - Trial testing under scotopic conditions – to familiarize the patient with the procedure and stimuli images.

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1 “Scotopic, mesopic and photopic contrast sensitivity precision measurement method and 3D stimuli sets”.  
EFS ID 4796474, App. No. 61152738, USPTO.

2 Accessory equipment for luminance levels evenness and controllability is currently in the process of patenting.  
The description will be available on the site: www.alttechnv.com - in Jan 2010.
4. **SBAT measuring (1-st round)**

SBAT was measured for the row of spatial frequencies (2, 3, 5, 8, 12 и 20 CPD) under luminance level 0.34 Lux. For each frequency, the SBA was increased from 1% up to the stimuli brightness amplitude value, on which patient could define the stimulus orientation certainly. This value is SBAT. Then these measurements were repeated for each of luminance levels: 3.4; 10.0; 20.0; 34 and 100 Lux. In order to prevent fatigability, patient’s eyestrain was controlled during all measurements by pupil size monitoring, as it is shown on the snapshots in Figure 1. Then lenses were worn off.

![Figure 1. Accommodative eyestrain control using pupil size monitoring in infrared light (snapshots).](image)

5. **Procedure break**

This break (15±20 minutes) is needed for tear film regeneration.

6. **Lenses wearing (2-nd pair)**

If the first pair of lenses was MF, they were changed for MV. If the first pair was MV, they were changed for MF.

7. **Preparations**

Dark adaptation during 15 minutes applied. Patient was reminded of the relaxation necessity.

8. **SBAT measuring (2-nd round)**

Procedure described above (p.4) was repeated.

9. **Feedback**

Patient was asked whether he/she had any subjective perceptions or any subjective lenses preferences, whether the testing procedure was too long/tiring/embarrassing etc.

10. **Data processing**

All SBAT data was inversed to Contrast Sensitivity: CS=1/ SBAT*100%.

After that, relationships Contrast Sensitivity (CS) - Spatial Frequency (SF) - Luminance (L) were processed by pairs (Multifocal and Monovision lenses data). For each patient:

- CS-SF graphs were plotted – for each of luminance levels, as it is shown in Figure 2 and Figure 3;
- CS-SF data for each L was transposed to CS-L - for each SF;
- Differences CS-L for each SF were calculated by pairs (Multifocal vs Monovision) and plotted for the next interpretation, as it is shown in Figure 4 (frequencies 2 and 20 are shown only, transitional graphs are hidden);
- Standard statistical treatment was performed for 14 patients (without anisometropia) using SPSS tools.

![Figure 2. Contrast sensitivities with MF lenses (example).](image)

![Figure 3. Contrast sensitivities with MV lenses (example)](image)

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Pupil size monitoring was performed using the camcorder (built-in infrared filter was removed preliminary), which transferred real-time image to control monitor by Firewire interface (IEEE 1394), and two infrared plate low-power light sources.
Luminance levels 3.4 and 34.0 Lux (Figures 2,3) were chosen for measurements as bounds: under 3.4 Lux only rods are workable (cones idle); above 34.0 Lux only cones are workable (rods idle). The area between these bounds is rods and cones joint operation zone. In our opinion, this area is the zone of special interest, and we will continue deep research in this direction. However, it is not the subject of this article, we just took transitional measuring (10.0 and 20.0 Lux) for differences evaluating under intermediate luminance levels.

**Results**

In whole, patients with multifocal lenses showed better contrast sensitivity results than with monovision ones. The most evident differences of contrast sensitivities were observed at low and medium spatial frequencies (2; 3; 5; 8 cpd) under scotopic (0.34 Lux) and mesopic (3.4; 10.0; 20.0 Lux) luminance conditions, in favor of MF lenses, as compared with MV.

There were no significant differences at high frequencies (12; 20 cpd) under light mesopic (34.0 Lux) and photopic (100.0 Lux) conditions.

Before presenting the statistically processed data, we invite you to become familiar with the raw individual measuring results of differences in thru-luminance CSF with multifocal and monovision corrections.

In the next figures CSF differences presented for frequencies 2 and 20 only (transitional graphs are hidden) for clear visualization of differences range.

**Figure 4. CS differences with MF & MV lenses (example).**

**Figure 5. Pat.# 1:**
female, 44 y.o.;
far: 20/20 (binocularly, photopic conditions);
near: OD+1.0; OS+0.75;
never used correction.

The most typical sample is shown in Figure 5. Red line represents the low-frequency (2 cpd) differences: \(D_{2} = CS_{MF} - CS_{MV}\). Blue line – high-frequency (20 cpd) differences: \(D_{20} = CS_{MF} - CS_{MV}\). Positive data signifies better CS in MF (i.e. MF advantage); negative – worse CS in MF (i.e. MV advantage). As we can see, there are no significant differences on frequency 20 cpd, with only scotopic (0.34 Lux) exception, neither MF nor MV has no considerable advantage. However, on frequency 2 cpd we observe significant differences under all luminance levels except photopic one (100 Lux). Relative difference varies from 11% (0.34 Lux) to 22% (20.0 Lux), 14% in the mean.
This patient (Figure 6) showed almost no CS high-frequency differences under all luminance conditions (blue line). On opposite, there are very considerable low-frequency differences under all luminance levels except light mesopic one (34 Lux). Very impressive looks scotopic (0.34 Lux) gap on frequency 2 cpd. Relative difference varies from 12% (34.0 Lux) to 37% (20.0 Lux), 23% in the mean.

One more typical sample is shown in Figure 7. There are no significant differences on frequency 20 cpd, except slight positive differences under scotopic (0.34 and 3.4 Lux) luminance. Again, low-frequency curve (red) demonstrate evident advantage of MF as compared with MV, especially under dark mesopic conditions. Relative difference varies from 9% (0.34 Lux) to 22% (10.0 Lux), 18% on average.
In all cases described above, we had the repetitive results in favor of MF. As far as the additional study objective was the new test adequacy verification, we undertook three peculiar experiments. We wore consequently the same lenses (MF: PWR 0.00 ADD Low, and MV PWR +1.0) on patient with anisometropia (OD+1.0; OS+3.0). The idea was that this prescription (incorrect on purpose) gave to MV the “handicap” on MF: MF of equal power could not work properly, and MV, on opposite, got the right correction (full or partial). As we expected, the balance moved to MV advantage, as it is shown in Figure 8, especially under dark mesopic conditions.

One more example is given in Figure 9. In this case anisometropia was 1.25D (OD+0.75; OS+2.0), and we can observe no significant differences between MF and MV, in spite of MV priority in advance.

Third patient with anisometropia showed the similar results. Thereby, we were convinced of the test adequacy.

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**Figure 8.** Pat.# 4: female, 43 y.o.;
far: 20/20 (binocularly, photopic conditions);
near: OD+1.0; OS+3.0;
anisometropia ΔD=2.0;
never used correction.

![Figure 8](image)

**Figure 9.** Pat.# 5:
male, 48 y.o.;
far: 20/20 (binocularly, photopic conditions);
near: OD+0.75; OS+2.0;
anisometropia ΔD=1.25;
never used correction.

![Figure 9](image)
Figure 10. Central tendencies of CS differences with MF & MV lenses for low (2 cpd, red) and high (20 cpd, blue) frequencies – under scotopic, mesopic and photopic conditions.

Analysis

Efficacy of presbyopia correction with multifocal contact lenses is higher than with monovision ones. Efficacy difference depends on both luminance level and spatial frequency. There is no considerable difference of high-frequency (20 cpd) contrast sensitivity with MF and MV lenses. These results are consistent with previous comparative studies\(^4\) of MF and MV that found no significant difference in high and low contrast distant visual acuity.\(^5\)

However, low-frequency (2 cpd) contrast sensitivity in MF and MV differs very noticeable, especially under scotopic (0.34 Lux), dark-mesopic (3.4; 10.0 Lux) and light-mesopic (20.0; 34.0 Lux) luminance conditions. Relative degradation of scotopic and mesopic contrast sensitivity function may achieve 30% and higher. It means that in spite of traditional testing methods cannot provide possibility to reveal the difference between MF and MV, this difference exists indeed. In practical application, use of MV draws the significant night vision degradation, as compared with MF.

Low- and medium-frequency scotopic and mesopic CSF reflects the subjects’ ability to orientate themselves in the ambient space, to discern large- and medium-scale objects and relative motions, the relief specificities. Therefore, relative degradation is very meaningful for night driving, cycling and walking, as well as for any other activities under poor illumination, and may be the source of increased danger. This risk should be taken into consideration while monovision correction is prescribed for presbyopes.

We should touch upon the issue of considering a monovision refractive surgery. There is no reliable approaching to making the right decision whether monovision surgery is the acceptable comparing with the other techniques. The surgeon often recommends monovision operation relying on their own experience and intuition, because the existing tests do not reveal the advantage of certain method.

But more acceptable way is the advanced (to trial prescriptions, including adaptability checking, etc.) study in order to get choice of available correction methods and their comparative efficacy, along with the adaptability prognosis – before any refractive surgery, in order to exclude the unpremeditated mistakes. This way could help to prevent many justified claims.

\(^{iv}\) Snellen acuity of 20/20 is defined as the ability to resolve letters of 1° visual angle. This value corresponds to high-frequency (20 cpd) contrast sensitivity.
Conclusions

- Visual quality of presbyopes who use multifocal and monovision lenses differs significantly. For presbyopes without anisometropia multifocal lenses provide significantly better visual quality under low luminance conditions and at low and medium spatial frequencies, as compared with monovision lenses. The special attention should be paid to the CSF differences at low and medium spatial frequencies;
- Monovision lenses application draws significant night vision degradation, as compared with multifocal ones. This fact should be taken into consideration for monovision correction prescription of any type: glasses, contact lenses or refractive surgery;
- The comprehensive description of vision quality in whole could not be revealed with traditional vision testing tools. Visual Acuity (whether low- or high-contrast) is only subcase of Contrast Sensitivity Function at high spatial frequencies under the corresponding luminance levels.

References