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# Optical quality of rotationally symmetrical contact lenses derived from their power profiles

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**Abstract**

Purpose: To present a methodology for evaluating the optical quality of rotationally symmetrical contact lenses (CLs) from a sole power profile.

Methods: Simulated rotationally symmetrical power profiles corresponding to different CLs designs (monofocal, two-zones center-near bifocal, and four-zones center-distance bifocal) were used to calculate the wavefront error profile by means of numerical integration. Then, each lens wavefront error profile was spun around the center to obtain the lens wavefront error surface. From the surface, monochromatic optical transfer functions (OTF), simulated images and the visual Strehl ratio based on the OTF (VSOTF) were obtained for different distances and pupil sizes (3 and 5.5 mm) after performing a through-focus.

Results: VSOTF variations, taking into account both vergence and pupil size, were presented for the three CLs designs. The monofocal design showed excellent optical quality only for far vision, whereas the bifocal designs exhibited good optical quality for far and near vision. Modulation transfer function (MTF) from each lens design, pupil size, and work distance and simulated images agreed with the previous results.

Conclusions: The methodology presented here allows for a rapid and thorough assessment of the optical quality of rotationally symmetrical CLs by means of optical quality metrics, with a special interest in simultaneous image contact lenses. This methodology may be useful for choosing the most suitable lens for each subject's visual demands.

**Keywords:** contact lens, simultaneous image contact lens, optical quality, power profiles

## Introduction

Simultaneous image contact lenses (CLs) are the most popular CLs for presbyopia compensation [1,2]. These lenses are based on the principle of simultaneous vision [1], where two or more images are formed simultaneously at the subject's retina. For this principle to work, the visual system must select the best focused image and supress the rest.

Currently, there is a fair amount of different simultaneous image CLs designs available in the market (e.g. center-near, center-distance designs) with different addition powers [1,2] and different number of zones or rings, and thus knowing their power distribution is essential. In the last years, several studies have evaluated the power distribution of simultaneous image CLs based on their power profiles [3–7]. A power profile shows how the refractive power provided by a lens varies with the radial distance. Typically, the power profiles analysed are from rotationally symmetric CLs, since in this case a sole power profile represents the refractive power distribution of the whole lens. If a CL does not present rotational symmetry (e.g. toric CL, angular patterns), then one power profile is not enough to know the refractive power distribution of the whole lens.

Power profiles, when interpreted correctly, offer useful information about the work distances that simultaneous image CLs can cover and about the effect of pupil size upon the power distribution [5,7]. However, power profiles cannot offer a thorough analysis regarding the optical quality of these lenses. For this reason, a methodology based on the vergence maps described by Nam et al. [8,9] was proposed. This methodology allows the assessment of the optical quality of rotationally symmetrical simultaneous image CLs by calculating the lens wavefront from a sole power profile.

## Methods

Contact lenses designs

Three simulated power profiles were considered in this study. All the power profiles corresponded to CLs that had a nominal power of 0 D and a spherical aberration of -0.075 D/mm$^2$. A negative value of spherical aberration is typically found in some CLs. The first power profile simulated a monofocal CL, the second a two-zone center-near [1,2] bifocal design with an addition power of 2 D, and the third a four-zone center-distance [1,2] bifocal design, also with an addition power of 2 D. The power profiles of these three CLs are shown in Figure 1.

Procedure

From now on it will be assumed that the power maps present radial symmetry, hence it is enough to work with half of a power profile, also known as half-chord.

A wavefront vergence map (V), which is equivalent to a refractive power map, can be derived from a wavefront error map (W) as follows [8–10]:

$$V(r,\theta) = n\frac{\delta W/\delta r}{r} \quad (1)$$

where r and θ are polar coordinates and n is the refractive index. The refractive index is already taken into account in the measured vergence map. Assuming that, as mentioned before, the refractive power map presents rotational symmetry, equation 1 transforms into

$$V(r) = \frac{\delta W/\delta r}{r} \quad (2)$$

From equation 2, the profile of the wavefront error map can be calculated by integrating the profile along the radial direction, as:

$$W(r) = \int V(r) r dr \quad (3)$$

Since the power map was considered to have rotational symmetry, the resultant wavefront error profile can be spun around the origin of the radial coordinates to obtain the wavefront error map, which will be also rotationally symmetric.

Once the lens wavefront was obtained, a computational through-focus [11,12] was performed by adding wavefronts with pure defocus to the lens wavefront. The range of the through-focus was from 0 to 4 D of vergence, in steps of a fourth of 0.125 D. At each step of the through-focus, the optical transfer function (OTF) was obtained for a wavelength of 550 nm. Then, the visual Strehl ratio based on the optical transfer function (VSOTF) was calculated and used as a quality metric [13,14]. For each amount of defocus, the VSOTF was computed using Fourier methods [13]. This metric was chosen because it is known to correlate well with subjective measures of visual performance [15]. This procedure was repeated for pupil diameters ranging from 0 to 6 mm, in 0.0625 mm steps.

A threshold for acceptable vision was set at VSOTF = 0.12, which has been used previously [16,17]. This threshold corresponds to a 0.2 logMAR visual acuity [18] and it can be considered as the limit where half of the people show difficulty in reading [19]. Therefore, values greater or equal than the mentioned threshold are considered to provide acceptable vision. In addition, retinal images were calculated by convolving the point spread function (PSF) of each design for far and near distances for pupil diameters of 3 mm and 5.5 mm, with a chart composed of four letters that corresponded to a visual acuity of 0.2 logMAR. The modulation transfer function (MTF) for the cases described before was also calculated and shown. All the computations shown in this work were performed using MATLAB (MathWorks, Inc., Natic, MA, USA).

## Results

The VSOTF values for each design, with respect to the vergence and the pupil diameter can be seen in Figure 2. The white solid curves demarcate the zones where the VSOTF was equal or greater than 0.12. The upper panel corresponds to the VSOTF values obtained for the monofocal design, which presents only optimal VSOTF values at one vergence or working distance, in this case far. The peak got displaced to the right as the pupil diameter increased as a consequence of the negative spherical aberration [20]. The mid panel shows the VSOTF map for the center-near design. It is evident that for small pupils this design offered good optical quality only for near distances and the optical quality increased again for far when the pupil became larger than 3 mm in diameter. Lastly, the lower panel presents the VSOTF map for the center-distance design. This design showed opposite behaviour than the center-near design, and also slightly different optical quality distribution due to the complexity of the design.

Figure 3 shows how the optical quality changed with respect to the vergence. These curves correspond to horizontal cuts in the maps showed in Figure 2 for a 3 mm pupil size (left panel) and for a 5.5 mm pupil size (right panel). The solid gray curves stand for the monofocal design, while the black solid and dashed curves stand for the center-near and center-distance designs, respectively. The horizontal dotted black line indicates the 0.12 threshold, thus the lenses provide acceptable vision at the vergences where the curves are above this line.

Figure 4 shows the variation in the optical quality provided by each one of the lenses when the pupil size changes. The left panel corresponds to the far distance, whereas the right panel corresponds to the near distance. It should be noted that +0.25

D was the vergence selected for far vision, and −1.75 D the one selected for near vision, because of the small displacement in the peaks introduced by the negative spherical aberration [20], which was more noticeable at larger pupils.

From Figure 4, it can be seen how the monofocal design (gray solid curves) provides only good optical quality for the far distance, and it does not vary vastly as the pupil size increases. The center-near design (black solid curves) shows good optical quality outcomes for near distance with smaller pupils. This design starts showing acceptable values of optical quality for far distance when pupil size is larger than 3 mm. The behaviour of the center-distance (black dashed curves) design is opposite to the behaviour of the center-near design.

Figure 5 shows the MTF obtained for each design when the pupil diameter is 3 mm (upper row) and 5.5 mm (lower row), for both far (left column), and near distances (right column). The dotted black curves represent the diffraction-limited MTF in each case.

## Discussion

A methodology that allows for a rapid and thorough assessment of the optical quality of rotationally symmetrical CLs, based just on a power profile, has been presented. It can be particularly useful in optical quality evaluation of simultaneous image CLs [1,2] since the effect of the pupil size on these elements is paramount [21]. This methodology presents a series of advantages with regards to the direct evaluation of power profiles, since further information, other than power distribution, can be extracted. It can show also how an object would be seen through one of these lenses allowing for more representative comparisons between different designs. Another perk is the rapid evaluation of the optical quality at different work distances and for different pupil sizes, which is essential when compensating presbyopia [21].

As an example, Figure 6 shows simulated images of four letters that correspond to a visual acuity of 0.2 logMAR as they were seen through the different designs considered in this work, for both far and near distances, and for pupils of 3 mm and 5.5 mm. The monofocal design offers high quality vision for far whereas the bifocal designs offer good quality for far and adequate for near vision, depending on the aperture size.

Regarding the definition of acceptable vision adopted here, it should be noted that different thresholds could be selected for this purpose. First, it depends on the quality metric used to present the results. There are a wide variety of metrics [13] based on wavefront, PSF, OTF, or even based on the simulated images, like the cross-correlation [22]. The use of the VSOTF was justified here because of its better correlation with visual acuity than other metrics [18]. In addition, a 0.2 logMAR threshold was chosen [19], but another one could be selected with proper justification. For example, a threshold could be estimated by measuring subjective visual performance with different simultaneous image CLs and correlate it with objective results derived from this methodology.

One important limitation of this technique is the fact that the calculations were performed for monochromatic light, thus not considering the effects of chromatic aberration. Nevertheless, this can be partially solved by performing the same calculations for different wavelengths, or adding polychromatic light to the methodology [23]. Nevertheless, for adding the effect of polychromatic light to the methodology, measurements of the power profiles of the lenses at different wavelengths are required. Another limitation is that this methodology is valid only for rotationally symmetric CLs. However, it is still useful since the majority of simultaneous image CLs present rotational symmetry. Evaluating asymmetric CLs, such as toric CLs for compensating astigmatism, requires a more complex technique that would allow for the direct integration of the entire refractive power map.

This technique may be useful to evaluate the optical quality of CLs, in particular simultaneous image CLs, by means of optical and visual quality metrics. Coupling the wavefront of presbyopic eyes with the CL wavefront obtained as explained here could be used for predicting the visual quality of the subject with a particular CL design. To do so, a transfer of the lens wavefront from the lens plane to the pupil plane of the subject should be performed. Nevertheless, a direct sum of wavefronts could work as an approximation. This could help to choose the most suitable lens for each subject's visual needs. In addition, it could help to study the effect of residual astigmatism and higher-order aberrations (especially spherical aberration), since it plays a major role in the depth of focus of the eye [17,24,25], and on the visual quality of subjects wearing simultaneous image CLs. Moreover, this methodology could be of use in designing new simultaneous image CLs, aiming to improve patient satisfaction, by selecting the most suitable addition, design and spherical aberration that provides the subject with the best visual performance at the desired range of distances.

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## Figure legends

**Figure 1.** Power profiles of the three CLs designs considered in this study. Upper panel shows the power profile corresponding to the monofocal CL. Mid panel shows the power profiles corresponding to the two-zone center-near design. Lower panel shows the power profile corresponding to the four-zone center-distance design.

**Figure 2.** VSOTF maps with respect to the vergence (or work distance) and the pupil diameter for the monofocal (upper panel), the center-near (mid panel) and the center-distance (lower panel) designs. Black color indicates very poor optical quality, whereas white color indicates very good optical quality. The white curves surround the areas of acceptable vision (VSOTF ≥ 0.12).

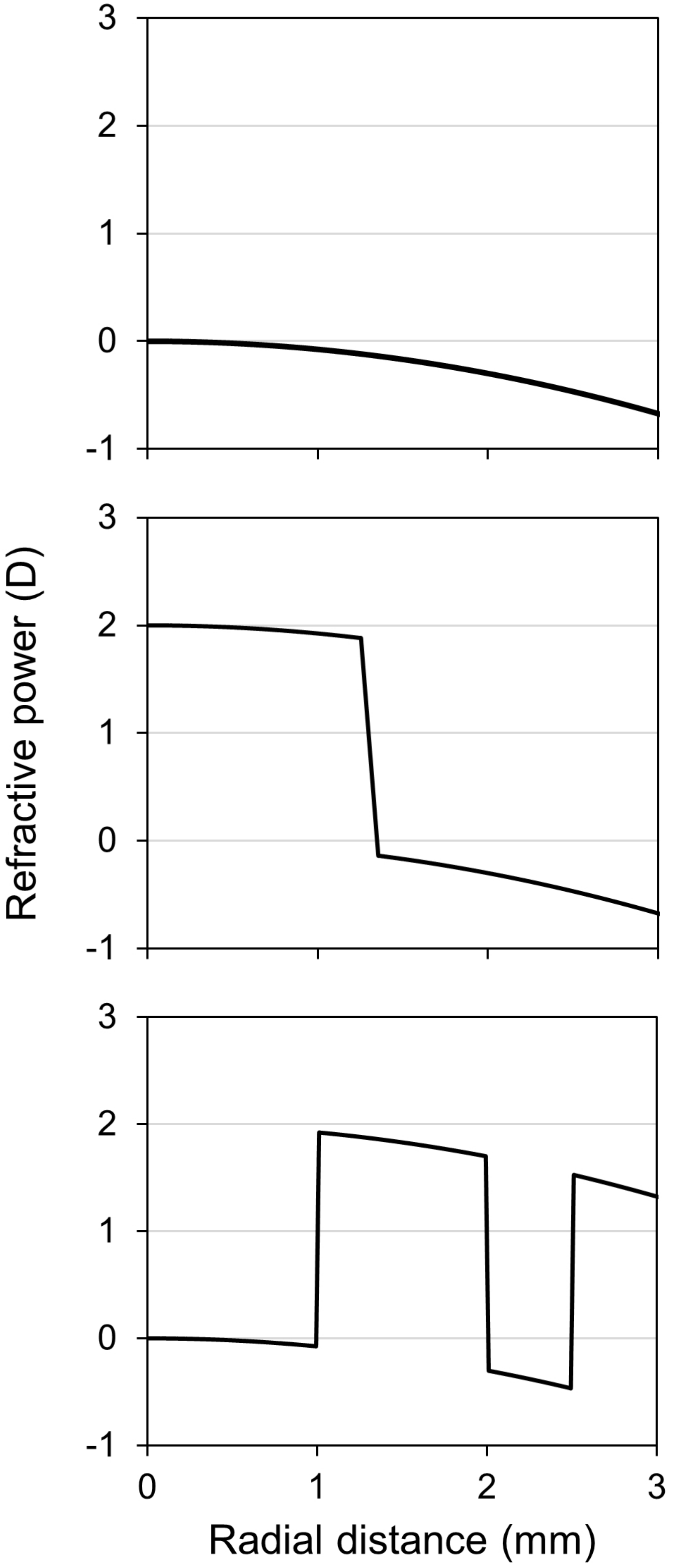
**Figure 3.** Variation of the optical quality (VSOTF) with respect to the vergence, or working distance, obtained for the different designs when the pupil size is 3 mm (right panel) and 5.5 mm (left panel). In both graphs the gray solid curves correspond to the monofocal design, the black solid curves stand for the center-near design, and the black dashed curves represent the center-far design. The dotted black line indicates the 0.12 threshold.

**Figure 4.** Variation of the optical quality (VSOTF) with respect to the pupil size, obtained for the different designs for far distance (right panel) and near distance (left panel). Other details as in Figure 3.

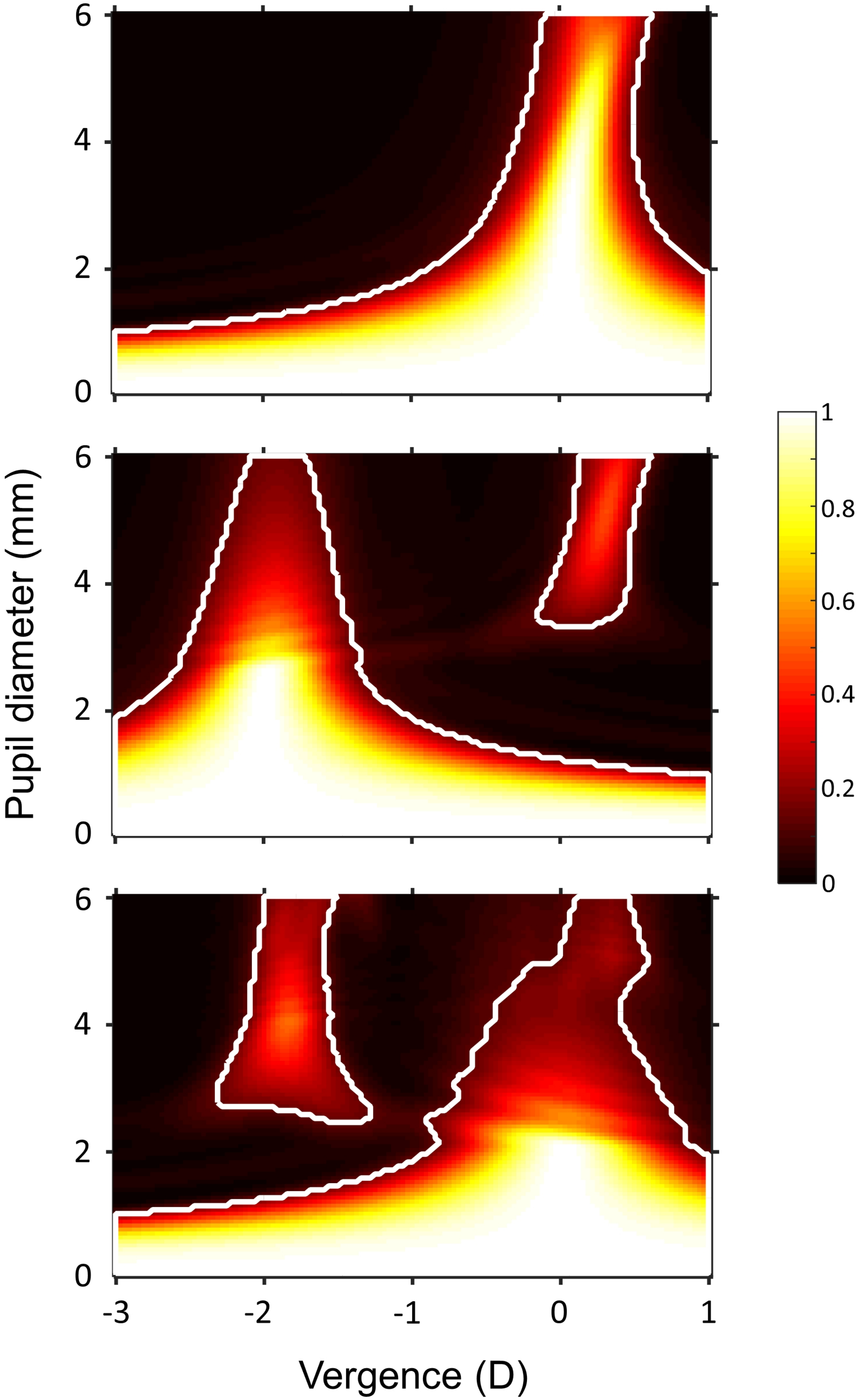
**Figure 5.** MTFs for the three different designs, plus the diffraction-limited MTF (black dotted curves). The upper left panel shows the MTFs for far distance and a pupil diameter of 3 mm; the upper left panel shows the same, but for near distance. Lower

row represents the same, but for a pupil diameter of 5.5 mm. Other details as in Figure 3.

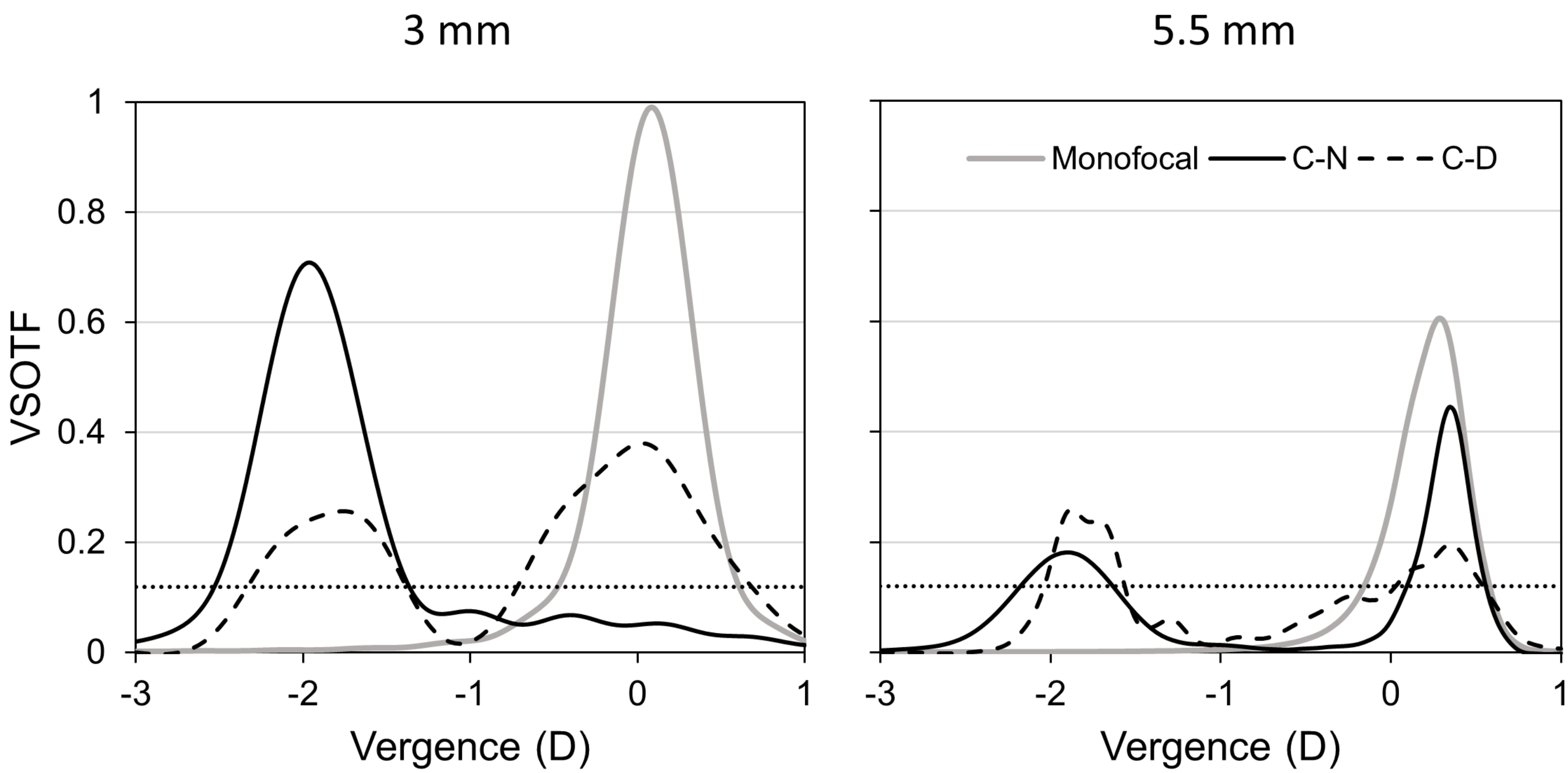
**Figure 6.** Simulation of images of a chart of letters corresponding to a 0.2 logMAR visual acuity as seen through a pupil of 3 mm (upper block) and 5.5 mm (lower block), for each design at both far and near distances.



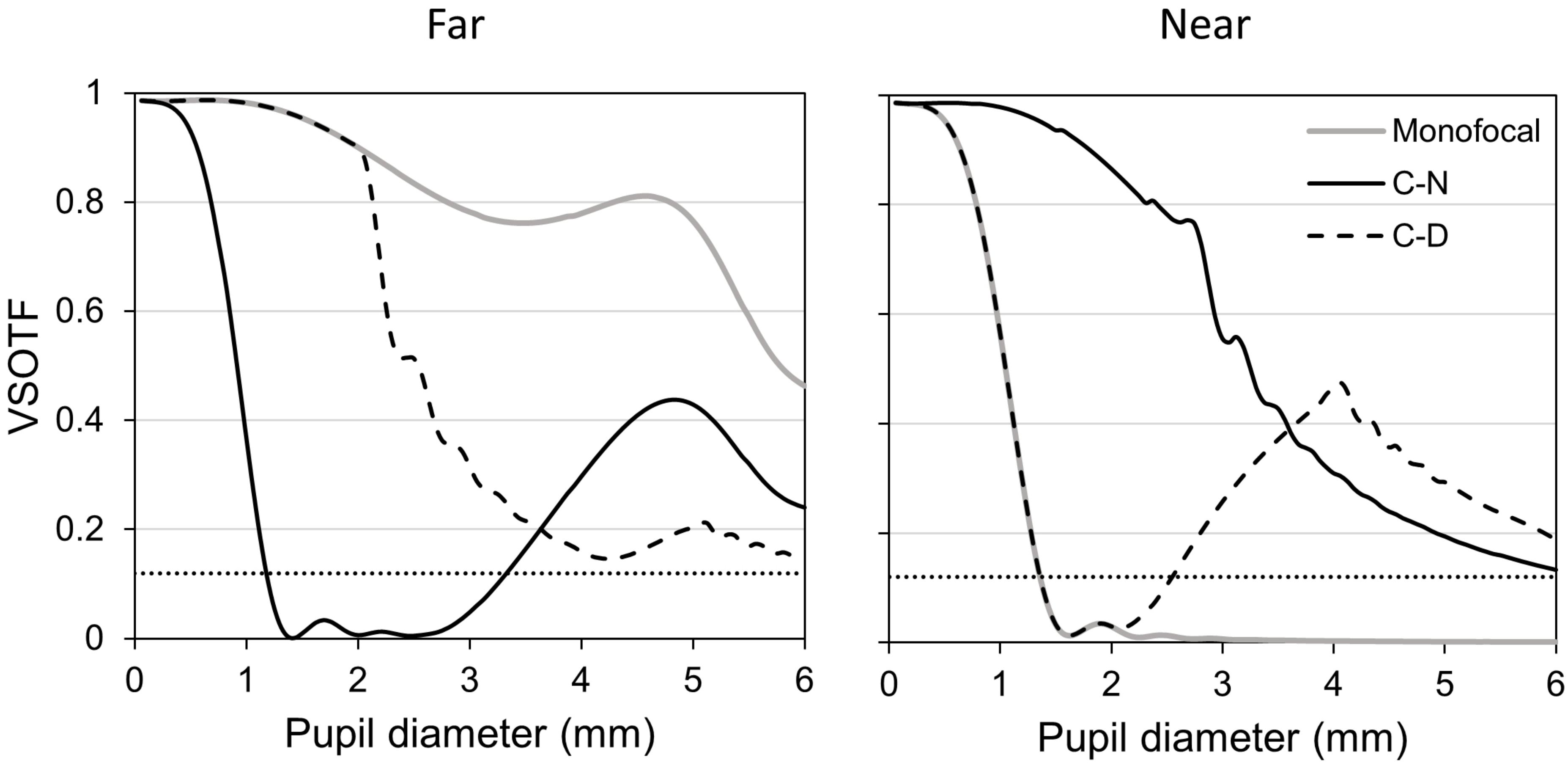
3
2
1
0
-1
Refractive power (D)
0
1
2
3
Radial distance (mm)



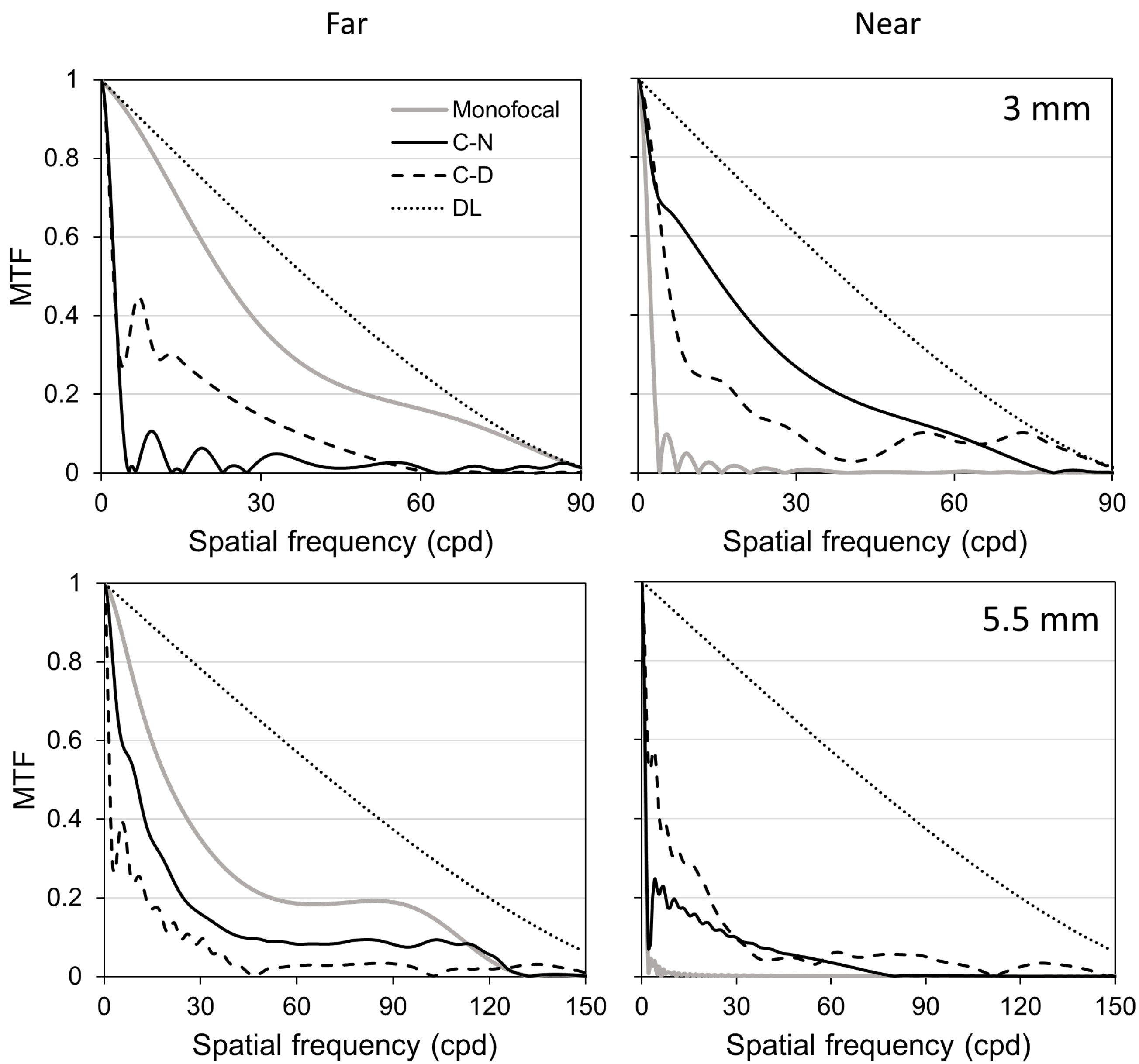
Pupil diameter (mm)
Vergence (D)
0
2
4
6
-3
-2
-1
0
1
0
0.2
0.4
0.6
0.8
1



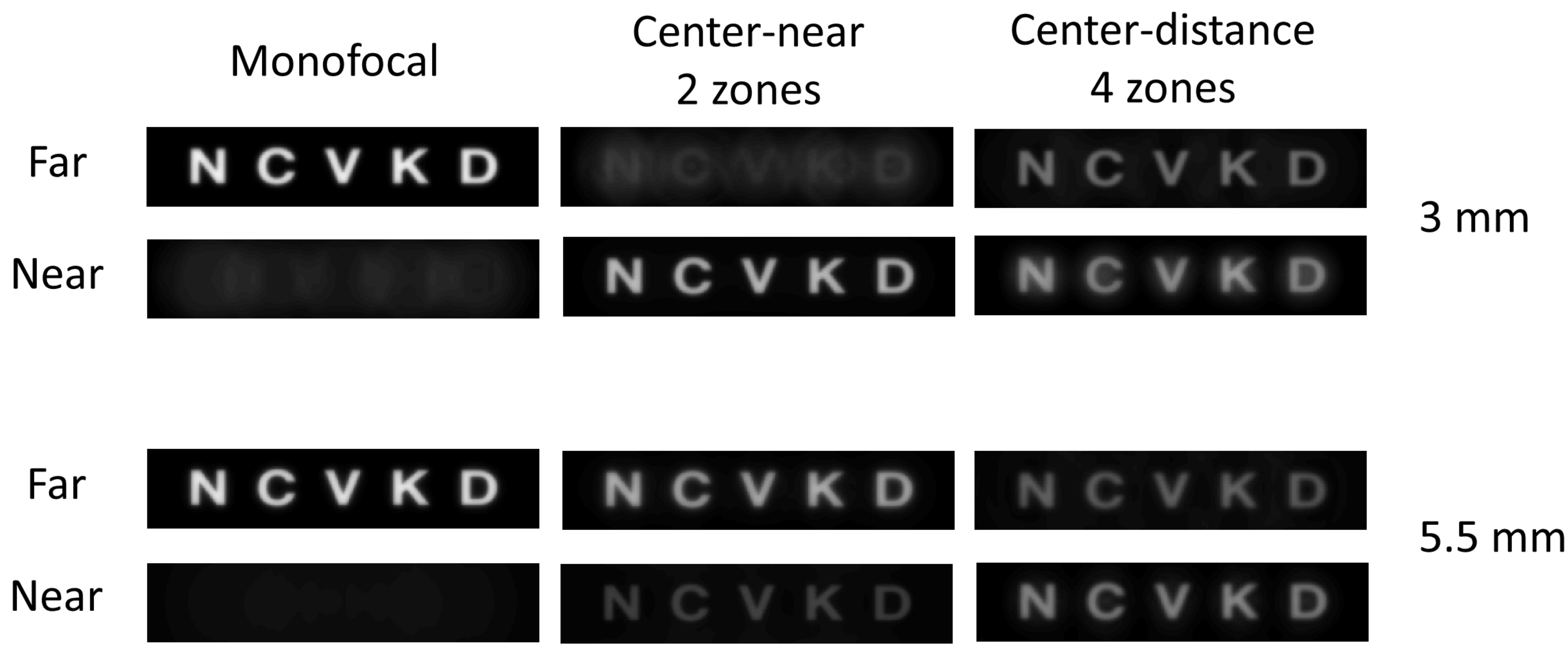
3 mm
5.5 mm
Monofocal
C-N
C-D
VSOTF
0
0.2
0.4
0.6
0.8
1
-3
-2
-1
0
1
Vergence (D)
Vergence (D)



Far
Near
VSOTF
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
Pupil diameter (mm)
Monofocal
C-N
C-D



Far
Near
Monofocal
C-N
C-D
DL
3 mm
5.5 mm
MTF
Spatial frequency (cpd)
1
0.8
0.6
0.4
0.2
0
30
60
90
120
150


Monofocal
Center-near
2 zones
Center-distance
4 zones
Far
Near
Far
Near
3 mm
5.5 mm
N C V K D

## Manuscript Details

| | |
|---|---|
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| **Article type** | *Short Communication* |


**Abstract**

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| | |
|---|---|
| **Keywords** | *contact lens; simultaneous image contact lens; optical quality; power profiles* |
| **Taxonomy** | *Contact Lenses, Presbyopia* |



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Dear Editor,

Please find enclosed a manuscript entitled “*Optical quality of rotationally symmetrical contact lenses derived from their power profiles*” for consideration for publication in Contact Lens and Anterior Eye as a *Short Communication*. We confirm that this work is original and has not been published elsewhere nor is it currently under consideration for publication elsewhere. The manuscript assesses computationally the optical quality of different theoretical simultaneous image contact lenses, providing a great deal of information from just a simple power profile. To our knowledge, such a computational study has not been previously conducted and it may be useful for improving simultaneous image contact lens fitting.

Thank you for your consideration of this manuscript.

Sincerely yours,
Antonio J. Del Águila-Carrasco.

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## Introduction

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Currently, there is a fair amount of different simultaneous image CLs designs available in the market (e.g. having different number of zones or rings, center-near, center-distance designs) with different addition powers [1,2], and thus knowing their power distribution is essential. In the last years, several studies have evaluated the power distribution of simultaneous image CLs based on their power profiles [3–7]. A power profile shows how the refractive power provided by a lens varies with the radial distance. Typically, the power profiles analysed are from rotationally symmetric CLs, since in this case a sole power profile represents the refractive power distribution of the whole lens. If a CL does not present rotational symmetry (e.g. toric CL, angular patterns), then one power profile is not enough to know the refractive power distribution of the whole lens.

Power profiles, when interpreted correctly, offer useful information about the work distances that simultaneous image CLs can cover and about the effect of pupil size upon the power distribution [5,7]. However, power profiles cannot offer a thorough analysis regarding the optical quality of these lenses. For this reason, a methodology based on the vergence maps described by Nam et al. [8,9] was proposed. This methodology allows the assessment of the optical quality of rotationally symmetrical simultaneous image CLs by calculating the lens wavefront from a sole power profile.

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Procedure

From now on it will be assumed that the power maps present radial symmetry, hence it is enough to work with half of a power profile, also known as half-chord.

A wavefront vergence map (V), which is equivalent to a refractive power map, can be derived from a wavefront error map (W) as follows [8–10]:

$$V(r,\theta) = n\frac{\delta W/\delta r}{r} \quad (1)$$

where r and θ are polar coordinates and n is the refractive index. Assuming that the refractive index is 1, and, as mentioned above, that the refractive power map presents rotational symmetry, equation 1 transforms into:

$$V(r) = \frac{\delta W/\delta r}{r} \qquad (2)$$

From equation 2, the profile of the wavefront error map can be calculated by integrating the profile along the radial direction, as:

$$W(r) = \int V(r) r dr \qquad (3)$$

Since the power map was considered to have rotational symmetry, the resultant wavefront error profile can be spun around the origin of the radial coordinates to obtain the wavefront error map, which will be also rotationally symmetric.

Once the lens wavefront was obtained, a computational through-focus was performed by adding wavefronts with pure defocus to the lens wavefront. The range of the through-focus was from 0 to 4 D of vergence, in steps of a fourth of 0.125 D. At each step of the through-focus, the optical transfer function (OTF) was obtained for a wavelength of 550 nm. Then, the visual Strehl ratio based on the optical transfer function (VSOTF) was calculated and used as a quality metric [11,12]. For each amount of defocus, the VSOTF was computed using Fourier methods [11]. This metric was chosen because it is known to correlate well with subjective measures of visual performance [13]. This procedure was repeated for pupil diameters ranging from 0 to 6 mm, in 0.0625 mm steps.

A threshold for acceptable vision was set at VSOTF = 0.12, which has been used previously [14,15]. This threshold corresponds to a 0.2 logMAR VA [16] and it can be considered as the limit where half of the people show difficulty in reading [17]. Therefore, values greater or equal than the mentioned threshold are considered to provide acceptable vision. In addition, retinal images were calculated by convolving the point spread function (PSF) of each design for far and near distances for pupil diameters of 3 mm and 5.5 mm, with a chart composed of four letters that corresponded to a visual acuity of 0.2 logMAR. The modulation transfer function (MTF) for the cases described before was also calculated and shown.

## Results

The VSOTF values for each design, with respect to the vergence and the pupil diameter can be seen in Figure 2. The white solid curves demarcate the zones where the VSOTF was equal or greater than 0.12. The upper panel corresponds to the VSOTF values obtained for the monofocal design, which presents only optimal VSOTF values at one vergence or working distance, in this case far. The peak got displaced to the right as the pupil diameter increased as a consequence of the negative spherical aberration [18]. The mid panel shows the VSOTF map for the center-near design. It is evident that for small pupils this design offered good optical quality only for near distances and the optical quality increased again for far when the pupil became larger than 3 mm in diameter. Lastly, the lower panel presents the VSOTF map for the center-distance design. This design showed opposite behaviour than the center-near design, and also slightly different optical quality distribution due to the complexity of the design.

Figure 3 shows how the optical quality varies in a through-focus. These curves correspond to horizontal cuts in the maps showed in Figure 2 for a 3 mm pupil size (left panel) and for a 5.5 mm pupil size (right panel). The solid gray curves stand for the monofocal design, while the black solid and dashed curves stand for the center-near and center-distance designs, respectively. The horizontal dotted black line indicates the 0.12 threshold, thus the lenses provide acceptable vision at the vergences where the curves are above this line.

Figure 4 shows the variation in the optical quality provided by each one of the lenses when the pupil size changes. The left panel corresponds to the far distance, whereas the right panel corresponds to the near distance. It should be noted that +0.25

D was the vergence selected for far vision, and −1.75 D the one selected for near vision, because of the small displacement in the peaks introduced by the negative spherical aberration [18], which was more noticeable at larger pupils.

From Figure 4, it can be seen how the monofocal design (gray solid curves) provides only good optical quality for the far distance, and it does not vary vastly as the pupil size increases. The center-near design (black solid curves) shows good optical quality outcomes for near distance with smaller pupils. This design starts showing acceptable values of optical quality for far distance when pupil size is larger than 3 mm. The behaviour of the center-distance (black dashed curves) design is opposite to the behaviour of the center-near design.

Figure 5 shows the modulation transfer functions (MTF) obtained for each design when the pupil diameter is 3 mm (upper row) and 5.5 mm (lower row), for both far (left column), and near distances (right column). The dotted black curves represent the diffraction-limited MTF in each case.

## Discussion

A methodology that allows for a rapid and thorough assessment of the optical quality of rotationally symmetrical CLs, based just on a power profile, has been presented. It can be particularly useful in optical quality evaluation of simultaneous image CLs [1,2] since the effect of the pupil size on these elements is paramount [19]. This methodology presents a series of advantages with regards to the direct evaluation of power profiles, since further information, other than power distribution, can be extracted. It can show also how an object would be seen through one of these lenses allowing for more representative comparisons between different designs. Another perk is the rapid evaluation of the optical quality at different work distances and for different pupil sizes, which is essential when compensating presbyopia [19].

As an example, Figure 6 shows simulated images of four letters that correspond to a visual acuity of 0.2 logMAR as they were seen through the different designs considered in this work, for both far and near distances, and for pupils of 3 mm and 5.5 mm. The monofocal design offers high quality vision for far whereas the bifocal designs offer good quality for far and adequate for near vision, depending on the aperture size.

Regarding the definition of acceptable vision adopted here, it should be noted that different thresholds could be selected for this purpose. First, it depends on the quality metric used to present the results. There are a wide variety of metrics [11] based on wavefront, PSF, OTF, or even based on the simulated images, like the cross-correlation [20]. The use of the VSOTF was justified here because of its good correlation with visual acuity [16]. Also, a 0.2 logMAR threshold was chosen [17], but another one can be selected with proper justification. For example, a threshold could be estimated by measuring subjective visual performance with different simultaneous image CLs and correlate it with objective results derived from this methodology.

One important limitation of this technique is the fact that the calculations were performed for monochromatic light, thus not considering the effects of chromatic aberration. Nevertheless, this can be partially solved by performing the same calculations for different wavelengths, or adding polychromatic light to the methodology [21]. Nevertheless, for adding the effect of polychromatic light to the methodology, measurements of the power profiles of the lenses at different wavelengths are required. Another limitation is that this methodology is valid only for rotationally symmetric CLs. However, it is still useful since the majority of simultaneous image CLs present rotational symmetry. Evaluating asymmetric CLs, such as toric CLs for compensating astigmatism, requires a more complex technique that would allow for the direct integration of the entire refractive power map.

This technique may be useful to evaluate the optical quality of CLs, in particular simultaneous image CLs, by means of optical and visual quality metrics. Coupling the wavefront of presbyopic eyes with the CL wavefront obtained as explained here could be used for predicting the visual quality of the subject with a particular CL design. To do so, a transfer of the lens wavefront from the lens plane to the pupil plane of the subject should be performed, although a direct sum of wavefronts could work as an approximation. This could help to choose the most suitable lens for each subject's visual demands and to study the effect of residual astigmatism and of higher-order aberrations, especially spherical aberration, since it plays a major role in the depth of focus of the eye [15,22,23], and on the visual quality of subjects wearing simultaneous image CLs. Moreover, this methodology could be of use in designing new simultaneous image CLs, aiming to improve patient satisfaction, by selecting the most suitable addition, design and spherical aberration that provides the subject with the best visual performance at the desired range of distances.

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## Figure legends

**Figure 1.** Power profiles of the three CLs designs considered in this study. Solid gray curve stands for the monofocal design, black solid curve for the two-zones bifocal center-near design, and black dashed curve corresponds to the four-zones bifocal center-distance design.

**Figure 2.** VSOTF maps with respect to the vergence (or work distance) and the pupil diameter for the monofocal (upper panel), the center-near (mid panel) and the center-distance (lower panel) designs. Black color indicates very poor optical quality, whereas white color indicates very good optical quality. The white curves surround the areas of acceptable vision (VSOTF $\geq 0.12$).

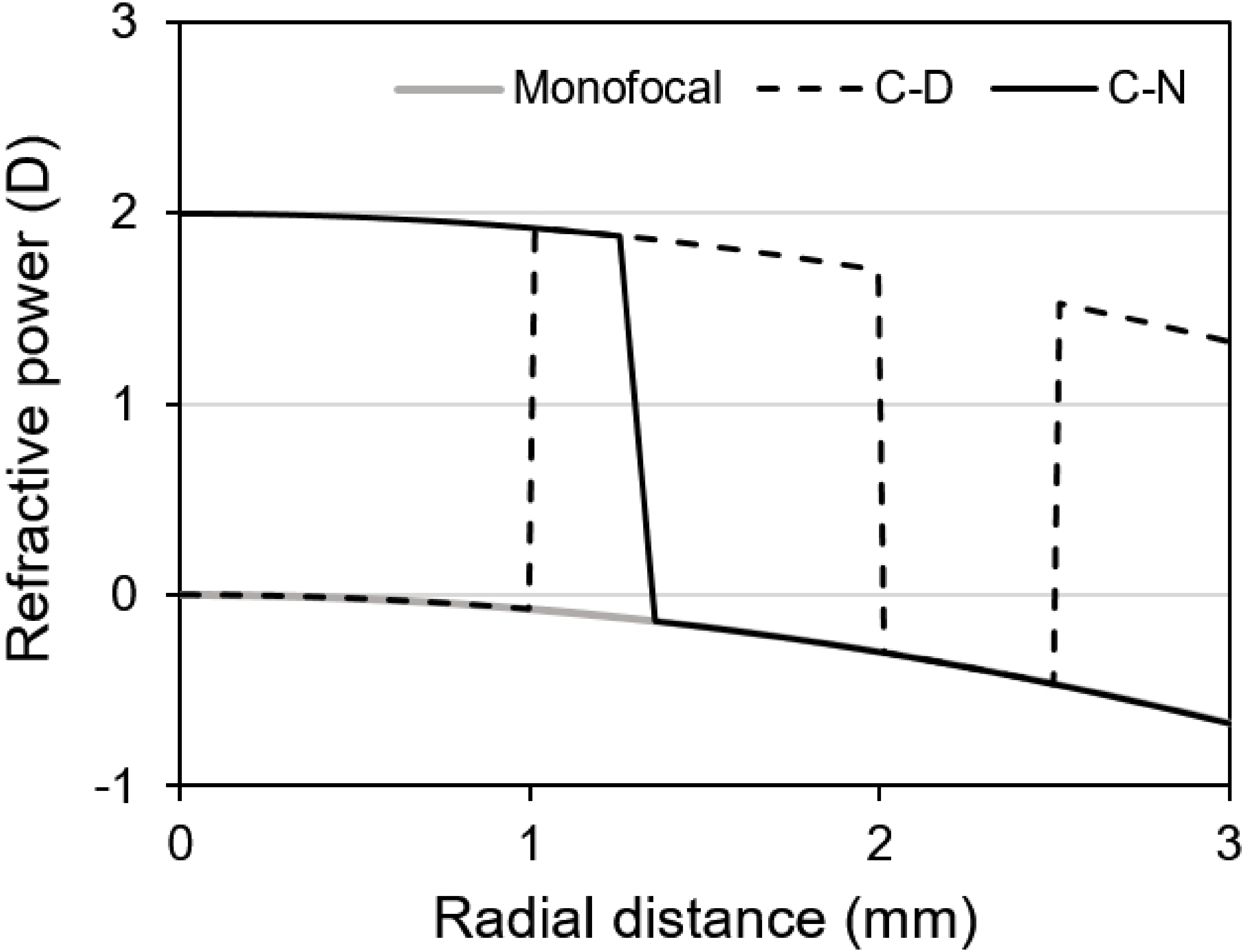
**Figure 3.** Variation of the optical quality (VSOTF) with respect to the vergence, or working distance, obtained for the different designs when the pupil size is 3 mm (right panel) and 5.5 mm (left panel). In both graphs the gray solid curves correspond to the monofocal design, the black solid curves stand for the center-near design, and the black dashed curves represent the center-far design. The dotted black line indicates the 0.12 threshold.

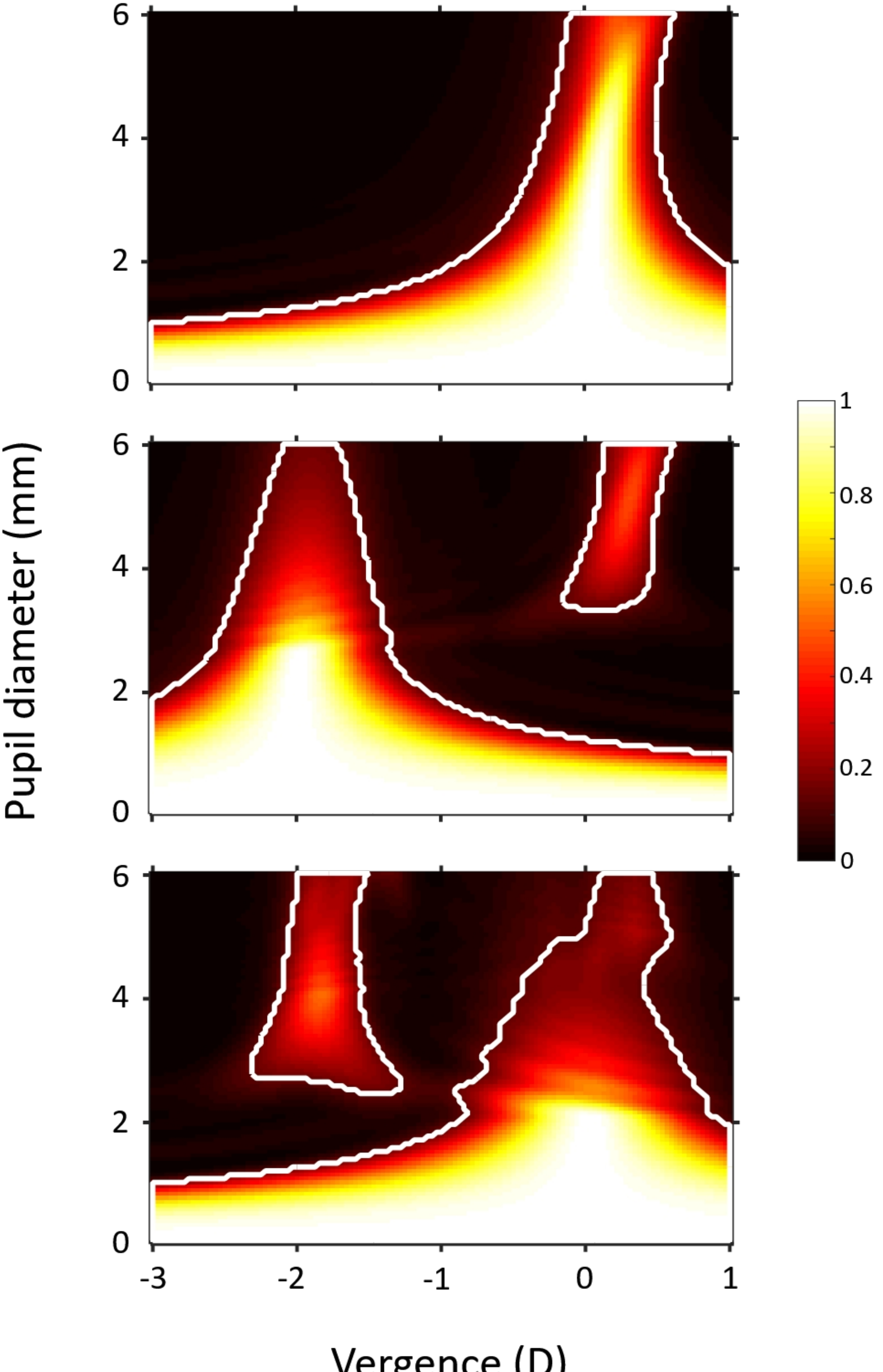
**Figure 4.** Variation of the optical quality (VSOTF) with respect to the pupil size, obtained for the different designs for far distance (right panel) and near distance (left panel). Other details as in Figure 3.

**Figure 5.** MTFs for the three different designs, plus the diffraction-limited MTF (black dotted curves). The upper left panel shows the MTFs for far distance and a pupil diameter of 3 mm; the upper left panel shows the same, but for near distance. Lower

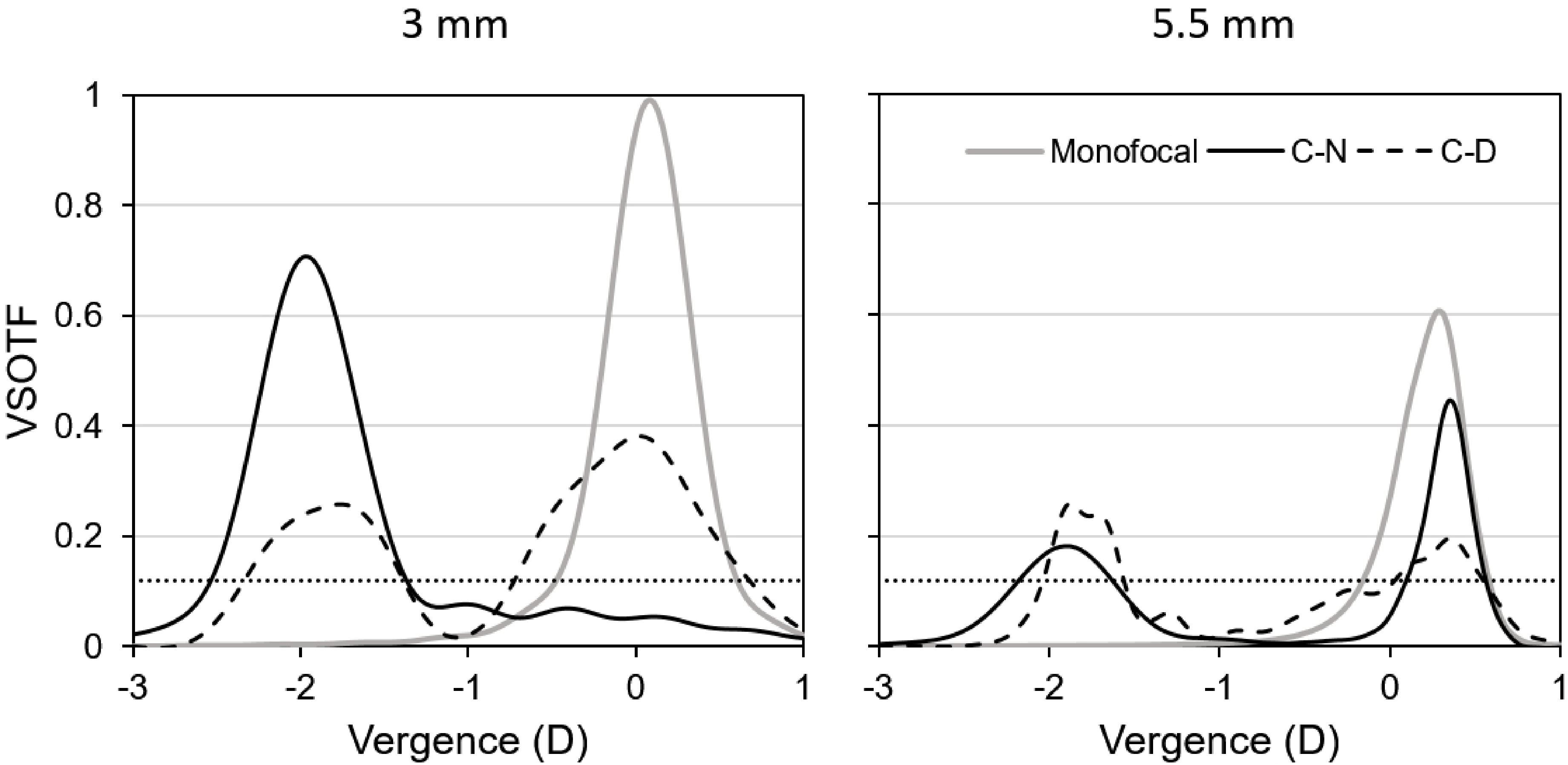
row represents the same, but for a pupil diameter of 5.5 mm. Other details as in Figure 3.

**Figure 6.** Simulation of images of a chart of letters corresponding to a 0.2 logMAR visual acuity as seen through a pupil of 3 mm (upper block) and 5.5 mm (lower block), for each design at both far and near distances.

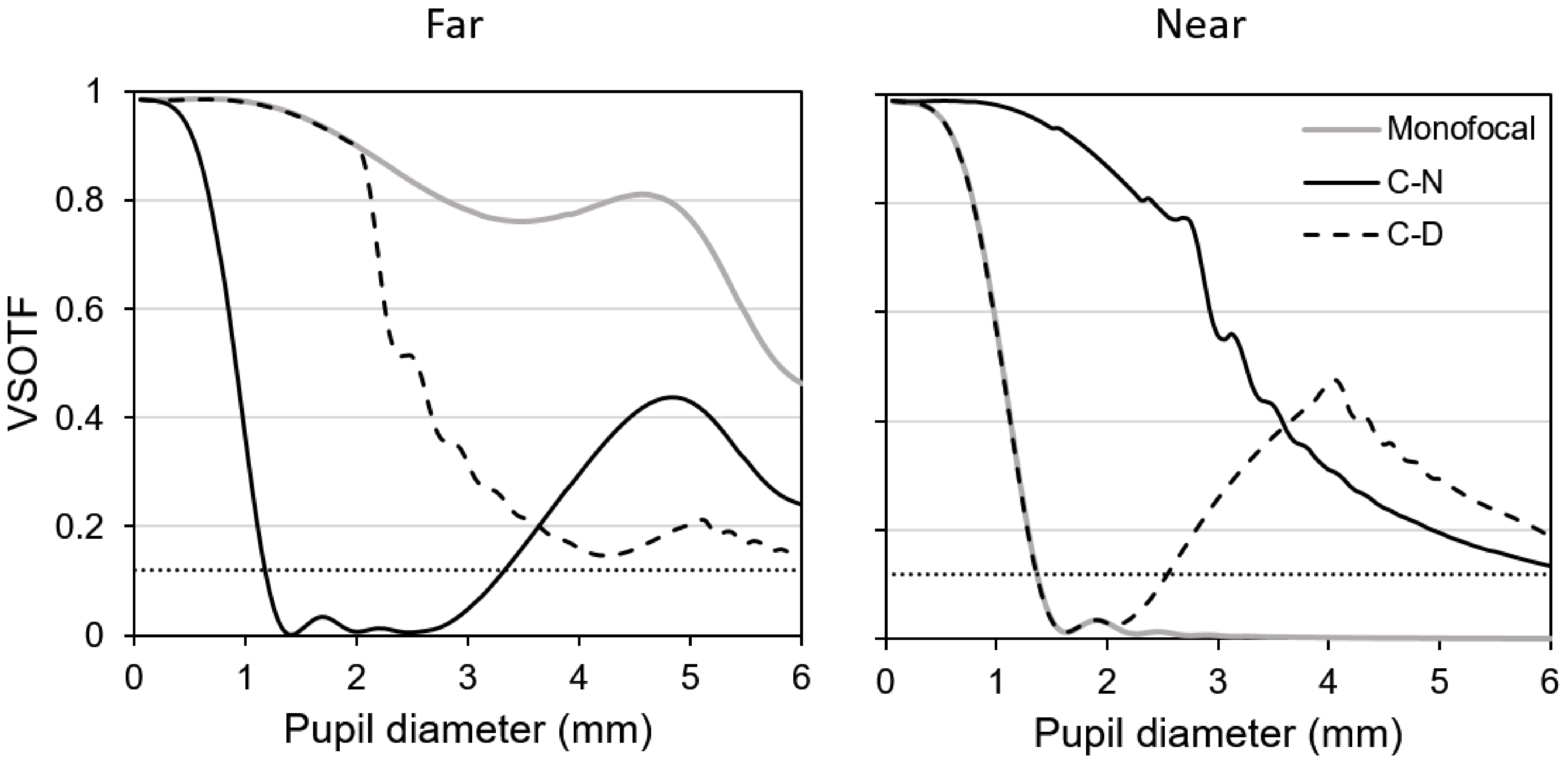

Monofocal
C-D
C-N
Refractive power (D)
3
2
1
0
-1
0
1
2
3
Radial distance (mm)



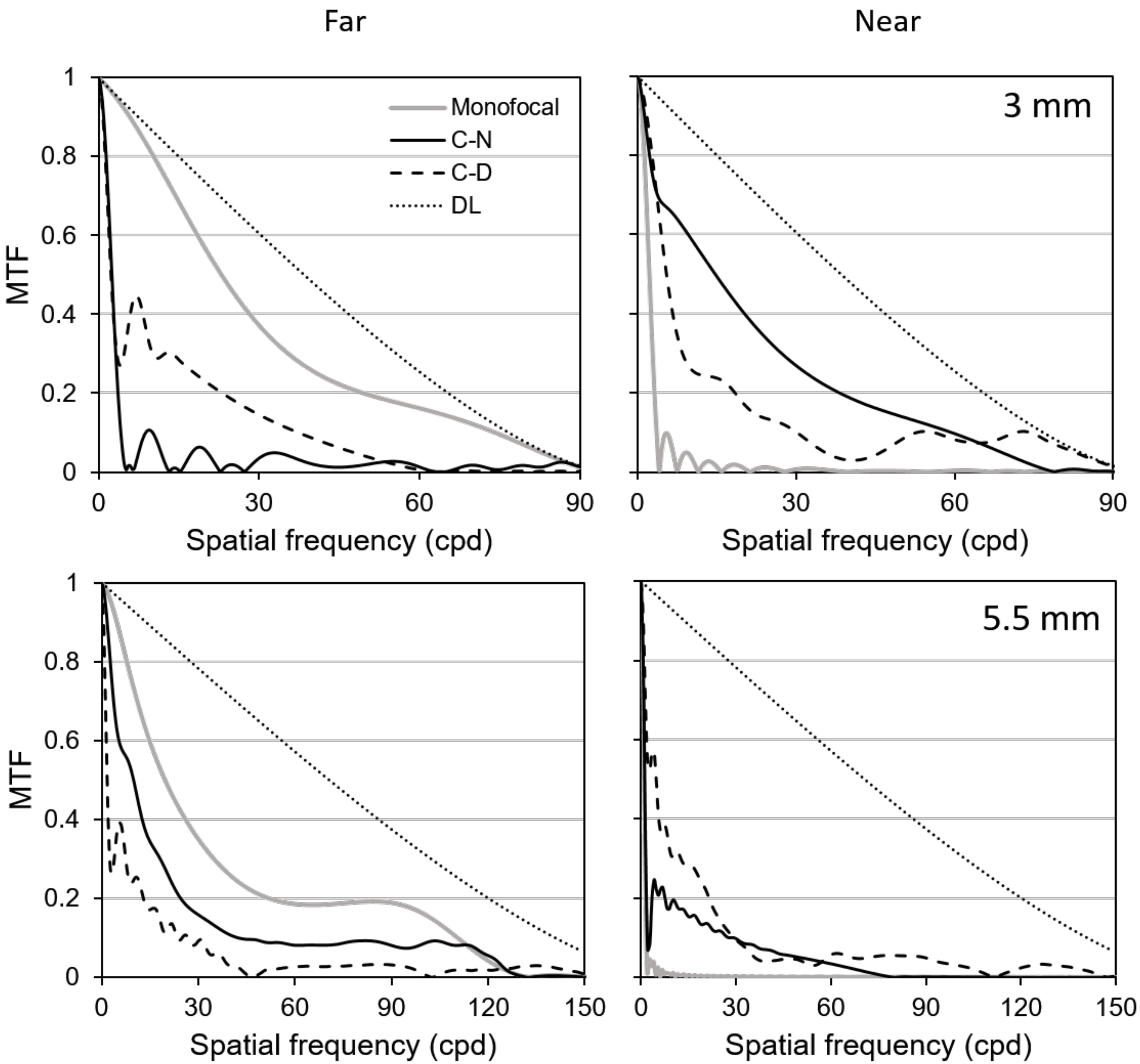
Pupil diameter (mm)
Vergence (D)
6
4
2
0
-3
-2
-1
0
1
0.2
0.4
0.6
0.8



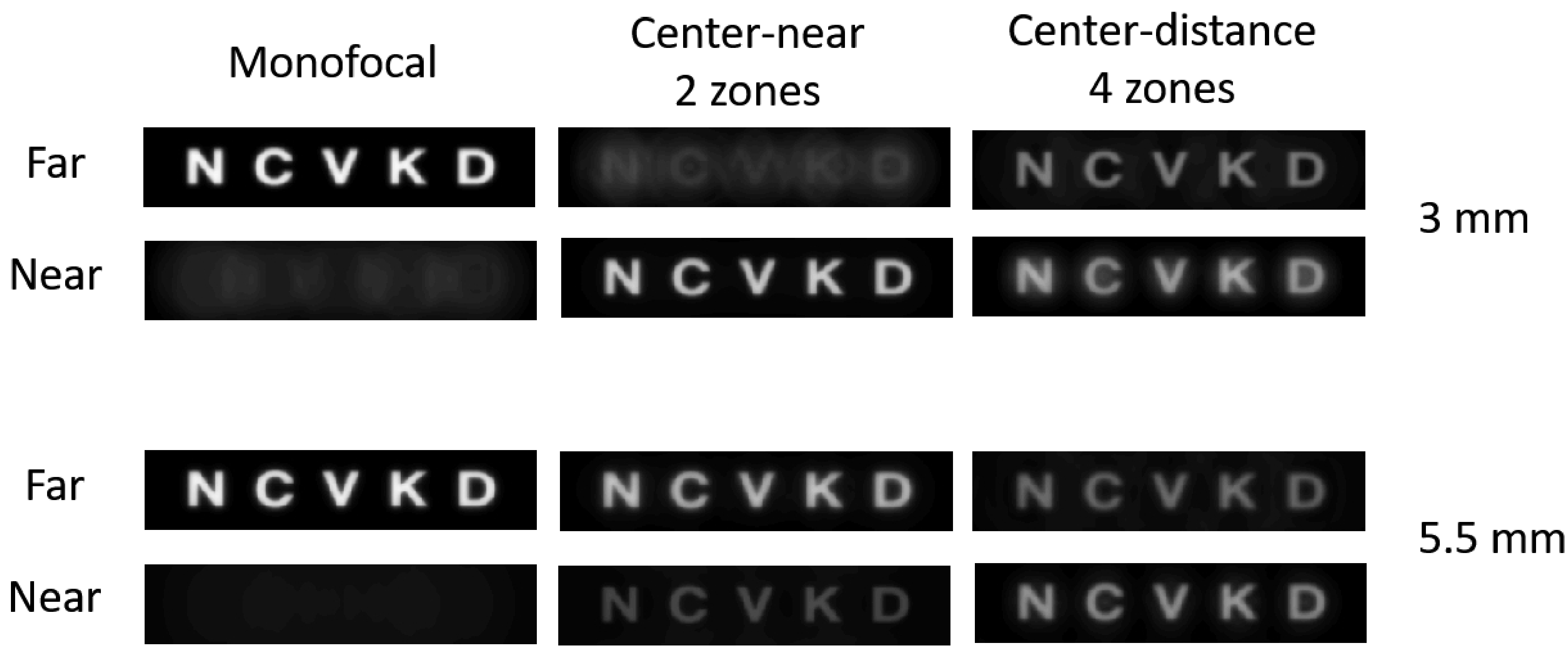
3 mm
5.5 mm
VSOTF
1
0.8
0.6
0.4
0.2
0
-3
-2
-1
0
1
Vergence (D)
Monofocal
C-N
C-D



Far
Near
VSOTF
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
Pupil diameter (mm)
Monofocal
C-N
C-D



Far
Near
Monofocal
C-N
C-D
DL
3 mm
5.5 mm
MTF
MTF
1
0.8
0.6
0.4
0.2
0
0
30
60
90
120
150
Spatial frequency (cpd)
Spatial frequency (cpd)
Spatial frequency (cpd)
Spatial frequency (cpd)


Monofocal
Center-near
2 zones
Center-distance
4 zones
Far
Near
3 mm
Far
Near
5.5 mm
N C V K D

- A methodology for evaluating the optical quality of contact lenses is proposed.
- It only needs one power profile from the lens.
- Effect of pupil size and work distances can be rapidly assessed.

# Optical quality of rotationally symmetrical contact lenses derived from their power profiles

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