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Optical Centration in Multifocal Lens Design and its Effect on Vision

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Optical Centration in Multifocal Lens Design and its Effect on Vision

Abstract
Multifocal contact lenses rely on a complex optical delivery system to provide the needed optics to the eye. Proper centration of these optics is vital to success. Conventionally these lenses are fitted over the center of the cornea (pupillary axis). This method of fitting contact lenses does not necessarily ensure proper alignment of the multifocal optics over the visual axis. Our purpose is to investigate the effect of multifocal optical centration on objective (distance acuity) and subjective (clarity, visual ghosting, and visual fluctuation) vision.

Five clinical emmetropes (with no existing ocular or systemic diseases) was recruited for our study. Medmont Corneal Topography was used to identify the optical location of the multifocal contact lenses and their distances from the visual axis. Visual acuity and subjective vision was compared to identify the effect multifocal contact lens centration had on vision.

Findings show consistent correlation between optical centration to both objective and subjective vision. Lenses appear to consistently decenter superiorly and temporally despite a manufactured 1.00mm nasal offset of optical centration. There appears to be an association between increasing ADD power and decreasing subjective vision. This association was not evident on objective distance vision.

With this study we hope to identify a variable clinician can consider when fitting multifocal contact lenses. The corneal topographer is an instrument that is capable of detecting the location of the multifocal optics on the eyes. We hope to improve the success of multifocal contact lenses in the management of presbyopia and other accommodative disorders. In addition, the use of high add multifocal soft contact lenses have proven successful in myopia control. We hope to apply what we learned to further the success of these lenses with children and ensure a good visual outcome.

Degree Type
Thesis

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OPTICAL CENTRATION IN MULTIFOCAL LENS DESIGN AND ITS EFFECT ON VISION

by

FRANK G. ZHENG

A THESIS

Submitted to the Graduate Faculty of Pacific University Vision Science Graduate Program, in partial fulfillment of the requirements for the degree of Master of Science in Vision Science

PACIFIC UNIVERSITY COLLEGE OF OPTOMETRY FOREST GROVE, OREGON

JANUARY 2016
This thesis of Frank G. Zheng, titled "Optical Centration in Multifocal Lens Design and its Effect on Vision", is approved for acceptance in partial fulfillment of the requirements of the degree of Master of Science.

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OPTICAL CENTRATION IN MULTIFOCAL LENS DESIGN AND ITS EFFECT ON VISION

FRANK G. ZHENG

Master of Science in Vision Science College of Optometry Pacific University Oregon, 2016

ABSTRACT

Multifocal contact lenses rely on a complex optical delivery system to provide the needed optics to the eye. Proper centration of these optics is vital to success. Conventionally these lenses are fitted over the center of the cornea (pupillary axis). This method of fitting contact lenses does not necessarily ensure proper alignment of the multifocal optics over the visual axis. Our purpose is to investigate the effect of multifocal optical centration on objective (distance acuity) and subjective (clarity, visual ghosting, and visual fluctuation) vision.

Five clinical emmetropes (with no existing ocular or systemic diseases) was recruited for our study. Medmont Corneal Topography was used to identify the optical location of the multifocal contact lenses and their distances from the visual axis. Visual acuity and subjective vision was compared to identify the effect multifocal contact lens centration had on vision.

Findings show consistent correlation between optical centration to both objective and subjective vision. Lenses appear to consistently decenter superiorly and temporally despite a manufactured 1.00mm nasal offset of optical centration. There appears to be an association between increasing ADD power and decreasing subjective vision. This association was not evident on objective distance vision.

With this study we hope to identify a variable clinician can consider when fitting multifocal contact lenses. The corneal topographer is an instrument that is capable of detecting the location of the multifocal optics on the eyes. We hope to improve the success of multifocal contact lenses in the management of presbyopia and other accommodative disorders. In addition, the use of high add multifocal soft contact lenses have proven successful in myopia control. We hope to apply what we learned to further the success of these lenses with children and ensure a good visual outcome.

Keywords: multifocal lens, optical centration, contact lens and visual axis, lens centration, multifocal contact lens
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# TABLE OF CONTENTS

Abstract ii  
Acknowledgement iii  
Table of Contents iv  
List of Tables v  
List of Figures vi  
Introduction 1  
Methods 4  
Materials 7  
Results 9  
Discussion 22  
Conclusion 27  
Reference 28
LIST OF TABLES

Table 1: List of lenses evaluated for each subject 5

Table 2A&B: Mixed Model Analysis of Horizontal and Vertical Centration and ADD Power on Objective and Subjective Vision. 11

Table 3: Mixed Model Analysis of Horizontal Centration, Vertical Centration, and ADD Power on Objective and Subjective Vision 21
LIST OF FIGURES

Figure 1: Aspheric multifocal contact lens design 7

Figure 2A&B: Bland-Altman Plots of Horizontal and Vertical Centration 9, 10

Figure 3A&B: Horizontal and Vertical Centration (mm) and Distance Acuity Graph 12, 13

Figure 3C: ADD Power as a Function of Horizontal and Vertical Centration on Acuity 13

Figure 4A&B: Horizontal and Vertical Centration (mm) and Subjective Clarity Graph 14, 15

Figure 4C: ADD Power as a Fxn of Horizontal and Vertical Centration on Subjective Clarity 15

Figure 5A&B: Horizontal and Vertical Centration (mm) and Visual Fluctuation Graph 16, 17

Figure 5C: ADD Power as a Fxn of Horizontal and Vertical Centration on Visual Fluctuation 17

Figure 6A&B: Horizontal and Vertical Centration (mm) and Visual Ghosting Graph 18, 19

Figure 6C: ADD Power as a Fxn of Horizontal and Vertical Centration on Visual Ghosting 19

Figure 7A&B: Tangential display demonstrating position of multifocal optics 22, 23

Figure 8: Topographical scans of the control lenses 24
Introduction
Presbyopia, the progressive process in which the eyes lose its ability to focus on near objects, is a normal part of life. Although no one can avoid the loss of accommodation with age, considerable progress has been made to manage this condition with contact lenses. Currently, multifocal lenses have become the largest growing sector in the contact lens industry. Presbyopes are projected to be the single largest group of potential contact lens wearers by 2018 (28% of all potential contact lens wearers, approximately 13.5 million people)\(^2\) and the demand for constant advancement is ever present.

Although multifocal soft contact lenses have seen some success in managing presbyopic patients they are not without drawbacks. These lenses are designed to provide patients with clear vision at both distant and near ranges simultaneously. This is accomplished through incorporating different optical powers within the contact lenses. Sheedy et al. showed in their study of concentric bifocal contact lenses that these lenses result in a reduction of task and visual performance (increased performance times and errors as well as decreased visual acuities and stereopsis) compared to those who wore distant only contact lenses with near spectacles. Despite this, over 50% of their subjects still decided to continue with their multifocal contact lenses on a regular basis at the conclusion of the study.\(^3\) Ardaya et al. also showed suboptimal visual performance (decreased visual acuity, decreased contrast sensitivity, and increased ghosting, visual fluctuations, and glare) when subjects wore Acuvue Bifocal contact lenses; especially with increasing near powers.\(^4\)

Yet despite these shortcomings multifocal contact lenses are still a favored choice in managing presbyopia.

Multifocal contact lenses rely on a complex optical delivery system in order to provide the needed optics to the eyes. Proper centration of these lenses is vital for a successful fit. Conventionally these lenses are fitted over the center of the cornea (pupillary axis). The fovea is the anatomical position in the retina which is responsible for the clearest point of vision. For the purpose of this discussion, the point at which the cornea aligns with the fovea is defined as the “visual axis”. The conventional method of centering the contact lens over the center of the cornea may not necessarily align the optics over the visual axis. This leads to hypothesizing that the reduction seen in vision and task performance with
multifocal contact lenses may be mitigated if we optimize the centration of contact lens optics to align with the visual axis.

The importance of optical alignment within the visual system is not a new theory. Angle kappa was first defined by Swiss-born ophthalmologist Edmund Landolt as the angle between the visual axis (line connecting the fixation point with the fovea) and the pupillary axis (line that perpendicularly passes through the entrance pupil and the center of curvature of the cornea). Refractive surgeons have approached the topic by either using the corneal light reflex or the corneal vertex (the apex of the cornea) as an approximation of where the visual axis is located on the cornea.

Wachler et al. reported on a single case in which a patient had laser refractive surgery where one eye was ablated with the centration over the pupillary axis while the other, over the corneal light reflex. In their report the eye that had the ablation over the reflex resulted in better visual outcome. In a larger study Chan et al. also reported better visual outcomes in 21 hyperopic eyes when the LASIK ablation zone was centered over the corneal light reflex instead of the pupillary center. Arbelaez et al. utilized corneal videography (topography) to determine the location of the corneal apex and compared the clinical outcomes of pupil-centered versus corneal apex-centered LASIK ablations. Their study showed less induced ocular aberrations and asphericity in the group that utilized the corneal apex compared to the pupil centered group.

Kermani et al. adopted a point midway between the corneal light reflex and the pupillary center when choosing the ablation center. In their retrospective review of 170 eyes they found a significant reduction in induced coma aberration in patients who had ablation center closer to the corneal light reflex compared to those who had pupil centered ablations. In a large prospective study by Khakshoor et al., patients were split into two groups pre-operatively based on their angle kappa values. Group A (166 eyes) had angle kappa values of less than 5 degrees while Group B (182 eyes) had values greater than 5 degrees. Ablation centration in Group A utilized the pupillary center while in Group B, utilized the corneal light reflex. They found no significant difference between the two groups in terms of visual outcome at both the 6 and 12 month follow up. They concluded that utilizing the corneal light reflex as the ablation center may provide better refractive
outcomes when angle kappa is large. Their conclusion is bold based on their findings. Perhaps a more appropriate assumption is the conclusion that in individuals with higher angle kappa the utilization of the corneal light reflex as the ablation center results in visual outcomes similar to those with smaller angle kappa. Nevertheless, their results demonstrate that angle kappa has an effect on visual outcome and should not be ignored when performing refractive surgery. Prakash et al. reported that patients who had complaints about glare and halo showed a positive correlation ($R^2 = 0.26$, $P < 0.05$) with preoperative values of angle kappa. Finally, Park C. et al. (2012) and Moshirfar et al. (2013) independently performed a large literature review analyzing all the current reports and studies on the subject and both concluded that compensating for angle kappa in refractive surgery, especially in hyperopes, is of great importance for visual outcome.

Based on these conclusions we hypothesize that, as with refractive surgery, centering the optics of multifocal contact lenses to compensate for angle kappa is of great importance. Soft contact lenses are commonly observed to decenter temporally. In an average eye, the nasal ocular surface, specifically the sclera and the overlying conjunctiva, is typically more flat compared to the other quadrants of the eye. As a consequence, the nasal region is more elevated compared to the other meridians impacting how contact lens orients on the eye. Precise control of the soft contact lens position is difficult given the lack of dexterity of the material and limited base curve and diameter options. However, SpecialEyes LLC have developed the lathing software necessary to create multifocal contact lenses in which the location of the optical centers can be specified. Our study will attempt to utilize this technology and evaluate the effect multifocal optical centration has on objective (visual acuity) and subjective (clarity and degree of visual fluctuation and ghosting) vision.
Methods

Students of Pacific University College of Optometry were recruited through an advertisement email for this study. A total of five clinically emmetropic (uncorrected visual acuity of 20/20 vision or better in both eyes and with refractive error within the range of Plano to +0.50D with less than 0.50D of corneal astigmatism) were recruited with no preference given to gender or ethnicity. All subjects were within the range of 18-35 years of age with normal medical and ocular health.

Each subject was contacted initially for a screening in which verbal confirmation was made regarding their ocular and systemic history, lack of current ocular or systemic medication use, and no previous history of contraindications to contact lens wear (normal ocular corneal surface and no history of contact lens intolerance). Subjects cannot be pregnant or nursing, nor have any binocular visual abnormalities (i.e. no complaints of diplopia, ocular eye strain, or other history of ocular alignment abnormalities). Also subjects with a history of corneal irregularity including keratoconus, pellucid marginal degeneration, corneal transplant, or other conditions that may cause irregular astigmatism were excluded.

During this brief screening, corneal topographies were taken and best corrected visual acuity was measured. A baseline subjective manifest refraction was performed for each subject to confirm their refractive error. A slit lamp examination was performed to evaluate corneal integrity on both eyes to determine if the subject meets the eligibility/exclusionary criteria for the study (mentioned above). Finally, a preliminary contact lens fitting was conducted to confirm that an acceptable fit can be achieved with our standard study contact lens parameter (SpecialEyes 54% Multifocal Base Curve: 8.3, Diameter: 14.2, Aspheric 2.00mm Optical Zone Center Distance, Plano D.S. +0.00 ADD Power).

After the initial screening appointment had taken place, the study was conducted over two evaluation appointments in which subjects wore a number of multifocal contact lenses of different optical placement and ADD powers (Table 1). Subjects served as both control and experimental groups by wearing either conventional contact lenses or optically decentered lenses. The order of which lenses were worn was randomized and the subjects were masked from learning which lenses were being evaluated.
<table>
<thead>
<tr>
<th>Right</th>
<th>Left</th>
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<tbody>
<tr>
<td>Plano DS +0.00 Add, Centered O.Z.</td>
<td>Plano DS +0.00 Add, Centered O.Z.</td>
</tr>
<tr>
<td>Plano DS +1.00 Add, Centered O.Z.</td>
<td>Plano DS +1.00 Add, Centered O.Z.</td>
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<td>Plano DS +2.00 Add, Centered O.Z.</td>
<td>Plano DS +2.00 Add, Centered O.Z.</td>
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<td>Plano DS +3.00 Add, Centered O.Z.</td>
<td>Plano DS +3.00 Add, Centered O.Z.</td>
</tr>
<tr>
<td>Plano DS +4.00, Add Centered O.Z.</td>
<td>Plano DS +4.00, Add Centered O.Z.</td>
</tr>
<tr>
<td>Plano DS +1.00 Add, 0.50mm Nasal Decentered O.Z.</td>
<td>Plano DS +1.00 Add, 0.50mm Nasal Decentered O.Z.</td>
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<tr>
<td>Plano DS +2.00 Add, 0.50mm Nasal Decentered O.Z.</td>
<td>Plano DS +2.00 Add, 0.50mm Nasal Decentered O.Z.</td>
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<td>Plano DS +4.00 Add, 0.50mm Nasal Decentered O.Z.</td>
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<tr>
<td>Plano DS +4.00 Add, 1.00mm Nasal Decentered O.Z.</td>
<td>Plano DS +4.00 Add, 1.00mm Nasal Decentered O.Z.</td>
</tr>
<tr>
<td>*Plano DS +4.00 Add, 1.00mm Nasal Decentered O.Z.</td>
<td>*Plano DS +4.00 Add, 1.00mm Nasal Decentered O.Z.</td>
</tr>
</tbody>
</table>

O.Z. = Optical Zone  *Duplicated Lens

Table 1: Lenses evaluated for each subject. The first two lenses were utilized as control lenses and also used to determine whether subjects could achieve an acceptable contact lens fit with the standard base curve and diameter. A duplicate lens (Plano DS +4.00 ADD 1.00mm Nasal Decentered) was ordered for each eye. (See “*” in discussion)

The subjects began by first applying a pair of multifocal soft contact lenses (either normal centered optics or customized decentered lenses of 0.5mm or 1.00mm nasal) on their eyes. The lenses were allowed a settling period of 15 minutes prior to lens evaluation. Slit lamp evaluation was performed to ensure proper centration and stability of the contact lenses on the eye. Once centration and stability has been confirmed, the subjects were asked to fill out a brief subjective questionnaire regarding their quality of vision. Subjects were asked to grade their vision in terms of subjective clarity, degree of visual fluctuation, and degree of visual ghosting from a scale of 1 to 10, with 1 providing the worst and 10 providing the best vision. Corneal topography scans were then acquired over the multifocal contact lenses. Finally, objective visual acuity was measured with a Snellen chart under
monocular and binocular conditions. The purpose of evaluating subjective vision through the questionnaires first was to limit the bias that may arise if the patient’s read the vision chart first.

Once visual acuity was measured, the contact lens were removed from the eyes and another 15 minutes of rest was allowed before the next lens was applied. Each appointment was concluded with slit lamp evaluation to ensure no adverse effect had occurred during the experiment.
Materials

**Soft Multifocal Contact Lenses:** SpecialEyes multifocal aspheric soft contact lenses (Hioxifilicon D 54% material, FDA 510(k) approval # K101122) with centered distant 2.0mm optical zone (Base Curve: 8.3 Diameter: 14.2) was utilized in this study. (Figure 1)

(Figure 1): Aspheric multifocal contact lens design with center 2.00mm distance optics and gradual aspheric ADD power in the periphery reaching full near prescription at 5.00mm.)

**Snellen Visual Acuity Chart:** The Clear Chart 2 digital acuity chart was used in this study to measure the distance visual acuity. This is an electronic visual acuity chart manufactured by Reichert Technologies that is used at the Pacific University College of Optometry Eye Clinic.

**E300 Corneal Topographer (Medmont)** - computerized video-keratometer utilized in this study. It uses placido discs to map the anterior surface of the human cornea without coming in contact with the eye. It allowed visualization of the axial power across the cornea, as well as analysis of the elevation data and assess corneal irregularity. We utilized the tangential function of the topographer to detect centration of the multifocal lens optics. It has received FDA clearance for ophthalmic use (regulation # 886.1350).
Haag-Streit Slit Lamp (with fundus camera attachment) – microscope used to assess corneal integrity and clarity of the eye.
Results:
A total of 140 randomized topographical scans were independently analyzed by two optometrists (masked from the identity of the scans assessed) and their results averaged to determine the optical centration of the lenses. Of the 140 scans analyzed, 5 scans were not of appropriate quality and could not be analyzed. Of the resulting 135 scans, 92.5 (68.5%) lenses were decentered temporally and 22.5 (16.7%) nasally, and 20 (14.8%) lenses centered along the horizontal meridian. Along the vertical axis, 109.5 (81.1%) lenses were decentered superiorly and 9 (6.7%) inferiorly, and 16.5 (12.2%) lenses centered along the vertical meridian.

A paired T-test and Bland-Altman analysis was performed to determine the correlation between the two evaluators in horizontal and vertical centration analysis. Analysis of the horizontal centration had a correlation of .977 (p value < 0.001) and the vertical, a correlation of .911 (p value < 0.001). The mean difference for horizontal assessment was -0.014mm, SD Dev: 0.104mm, (p value = 0.097) and vertical, of -0.020mm, SD Dev: 0.095mm, (p value = 0.011). (See Figure 2A&B)

![Bland-Altman Plot with limits of agreement ± 2.00SD (SE μ = 0.009)](image_url)
Figure 2B: Bland-Altman Plot with limits of agreement ± 2.00SD (SE μ = 0.008)
Optical Centration and ADD Power on Vision Results:
A repeated measure within subject analysis of variance with maximum likelihood method (Proc Mix) was performed to analyze the effect optical centration and ADD power had on objective and subjective vision. (Table 2A&B)

<table>
<thead>
<tr>
<th></th>
<th>ADD Power (Hz)</th>
<th>Horizontal Centration</th>
<th>Add x Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LogMar Acuity</strong></td>
<td><strong>NS (F = 1.437, p = 0.215; Effect Size = 0.05 to 0.47)</strong></td>
<td><strong>F = 113.507, p&lt;0.001; Slope: 0.113961</strong></td>
<td><strong>NS (F =0.575, p=0.719)</strong></td>
</tr>
<tr>
<td><strong>Subjective Clarity</strong></td>
<td><strong>F =4.274, p = 0.001; Effect Size = 0.74 to 1.36</strong></td>
<td><strong>F = 89.895, p&lt;0.001; Slope: -1.672242</strong></td>
<td><strong>NS (F =1.686, p=0.143)</strong></td>
</tr>
<tr>
<td><strong>Subjective Fluctuation</strong></td>
<td><strong>F =3.046, p = 0.013; Effect Size = 0.18 to 0.69</strong></td>
<td><strong>F = 13.191, p&lt;0.001; Slope: -1.08</strong></td>
<td><strong>F=2.361, p=0.044</strong></td>
</tr>
<tr>
<td><strong>Subjective Ghosting</strong></td>
<td><strong>F=2.931, p = 0.015; Effect Size = 0.24 to 0.69</strong></td>
<td><strong>F = 6.630, p = 0.011; Slope: -0.401880</strong></td>
<td><strong>NS (F =1.237, p=0.296)</strong></td>
</tr>
</tbody>
</table>

Table 2A: Mixed Model Analysis of Horizontal Centration and ADD Power on Objective and Subjective Vision.

<table>
<thead>
<tr>
<th></th>
<th>ADD Power (Vt)</th>
<th>Vertical Centration</th>
<th>Add x Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LogMar Acuity</strong></td>
<td><strong>F = 3.198, p = 0.009; Effect Size = 0.15 to 0.44</strong></td>
<td><strong>NS (F = 0.308, p = 0.580)</strong></td>
<td><strong>F = 5.258, p&lt;0.001</strong></td>
</tr>
<tr>
<td><strong>Subjective Clarity</strong></td>
<td><strong>F = 3.595 , p = 0.005; Effect Size = 0.31 to 0.69</strong></td>
<td><strong>NS (F = 0.939, p = 0.334)</strong></td>
<td><strong>F = 2.888, p = 0.017</strong></td>
</tr>
<tr>
<td><strong>Subjective Fluctuation</strong></td>
<td><strong>F = 3.427 , p = 0.006; Effect Size = 0.02 to 0.53</strong></td>
<td><strong>NS (F = 1.590, p = 0.210)</strong></td>
<td><strong>F = 2.758, p = 0.021</strong></td>
</tr>
<tr>
<td><strong>Subjective Ghosting</strong></td>
<td><strong>F = 2.582 , p = 0.029; Effect Size = 0.21 to 0.73</strong></td>
<td><strong>NS (F = 0.049, p = 0.825)</strong></td>
<td><strong>NS (F = 1.242, p = 0.294)</strong></td>
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</table>

Table 2B: Mixed Model Analysis of Vertical Centration and ADD Power on Objective and Subjective Vision.
**Objective Visual Acuity (LogMar) and Centration:**

Mixed model analysis found horizontal centration ($F = 113.507, p < 0.001$; Slope: 0.113961) to be statistically significant in its effect on visual acuity, but ADD power ($F = 1.437, p = 0.215$; Effect Size = 0.05 to 0.47) was not. The interaction between ADD power and horizontal centration ($F = 0.575, p = 0.719$) was not found to be statistically significant. (Figure 3A and 3C)

![Graph showing horizontal centration and objective distance vision acuity](image)

Vertical centration by itself was not statistically significant in its effect on acuity. However, the effect of ADD power ($F = 3.198, p = 0.009$; Effect Size = 0.15 to 0.44) on acuity was dependent on the level of vertical centration ($F = 0.308, p = 0.580$) suggesting that ADD power by itself was not significant, but the interaction between ADD power and vertical centration ($F = 5.258, p < 0.001$) was. (Figure 3B and 3C)
Figure 3B: Vertical Centration (mm) and Objective Distance Vision - Acuity (LogMar) Graph

Figure 3C: ADD Power as a Function of Horizontal and Vertical Centration on Acuity
Subjective Vision (Clarity) and Centration:

Mixed model analysis found that horizontal centration ($F = 89.895$, $p < 0.001$; Slope: $-1.672242$) and ADD power ($F = 4.274$, $p = 0.001$; Effect Size = 0.74 to 1.36) to be statistically significant in its effect on subjective clarity. The interaction between ADD power and horizontal centration ($F = 1.686$, $p = 0.143$) was not found to be statistically significant. (Figure 4A and 4C)

![Graph of Subjective Clarity vs Horizontal Centration](image)

Figure 4A: Horizontal Centration (mm) and Subjective Clarity Graph. Subjective clarity was graded on a scale of 1 (worst vision) to 10 (best vision).

Vertical centration by itself was not statistically significant in its effect on subjective clarity. The effect of ADD power ($F = 3.595$, $p = 0.005$; Effect Size = 0.31 to 0.69) on subjective clarity was dependent on the level of vertical centration ($F = 0.939$, $p = 0.334$) suggesting that ADD power by itself was not significant, but the interaction between ADD power and vertical centration ($F = 2.888$, $p = 0.017$) was. (Figure 4B and 4C)
Figure 4B: Vertical Centration (mm) and Subjective Clarity Graph. Subjective clarity was graded on a scale of 1 (worst vision) to 10 (best vision).

Figure 4C: ADD Power as a Function of Horizontal and Vertical Centration on Subjective Clarity.
Subjective Vision (Fluctuation) and Centration:

Mixed model analysis found horizontal centration ($F = 13.191, p < 0.001$) and ADD power ($F = 3.046, p = 0.013$; Effect Size = 0.18 to 0.69) to be statistically significant in its effect on subjective fluctuation of vision. Also an interaction between ADD power and horizontal centration ($F = 2.361, p = 0.044$) was found to be statistically significant as well. (Figure 5A and 5C)

Vertical centration by itself was not statistically significant in its effect on subjective fluctuation. The effect of ADD power ($F = 3.427, p = 0.006$; Effect Size = 0.02 to 0.53) on subjective fluctuation was dependent on the level of vertical centration ($F = 1.590, p = 0.210$) suggesting that ADD power by itself was not significant, but the interaction between ADD power and vertical centration ($F = 2.758, p = 0.021$) was. (Figure 5B and 5C)
Figure 5B: Vertical Centration (mm) and Subjective Visual Fluctuation Graph. Subjective visual fluctuation was graded on a scale of 1 (worst vision) to 10 (best vision).

Figure 5C: ADD Power as a Function of Horizontal and Vertical Centration on Subjective Visual Fluctuation
Subjective Vision (Ghosting) and Centration:

Mixed model analysis found that horizontal centration \( (F = 6.630, p = 0.011; \text{Slope: -0.401880}) \) and ADD power \( (F = 2.931, p = 0.015; \text{Effect Size: 0.24 to 0.69}) \) to be statistically significant in its effect on subjective ghosting. The interaction between ADD power and horizontal centration \( (F = 1.237, p = 0.296) \) was not found to be statistically significant. (Figure 6A and 6C)

Figure 6A: Horizontal Centration (mm) and Subjective Visual Ghosting Graph. Subjective visual ghosting was graded on a scale of 1 (worst vision) to 10 (best vision).

The effect of ADD power \( (F = 2.582, p = 0.029; \text{Effect Size: 0.21 to 0.73}) \) on subjective ghosting was found to be statistically significant. Vertical centration \( (F = 0.049, p = 0.825) \) did not show a statistically significant effect on subjective ghosting. Also, the interaction between ADD power and vertical centration \( (F = 1.242, p = 0.294) \) was not found to be statistically significant in its effect on subjective ghosting. (Figure 6B and 6C)
**Figure 6B**: Vertical Centration (mm) and Subjective Visual Ghosting Graph. Subjective visual ghosting was graded on a scale of 1 (worst vision) to 10 (best vision).

**Figure 6C**: ADD Power as a Function of Horizontal and Vertical Centration on Subjective Visual Ghosting
Multicollinearity between ADD power, Horizontal Centration, and Vertical Centration

Finally, to account for multicollinearity between horizontal and vertical centration, a mixed model analysis including both variable was performed. Under this model horizontal and vertical centration did not show a statistical significance correlation in its effect on objective and subjective vision. In addition, ADD power did not have a significant correlation with horizontal or vertical centration in its effect on objective and subjective vision. However, interaction between ADD power, horizontal centration, and vertical centration was found to be significant for objective visual acuity, subjective visual clarity, and subjective fluctuation but not for subjective visual ghosting. (See Table 3)
### Table 3: Mixed Model Analysis of Horizontal Centration, Vertical Centration, and ADD Power on Objective and Subjective Vision

<table>
<thead>
<tr>
<th></th>
<th>ADD Power</th>
<th>Horizontal Centration</th>
<th>Vertical Centration</th>
<th>Add x Vertical</th>
<th>Add x Horizontal</th>
<th>Horizontal x Vertical</th>
<th>ADD x Horizontal x Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual Acuity (LogMar)</strong></td>
<td>NS (F=2.268, p = 0.52)</td>
<td>F = 63.718, p &lt; 0.001</td>
<td>NS (F=1.245, p = 0.267)</td>
<td>NS (F=1.044, p = 0.395)</td>
<td>NS (F=1.672, p = 0.158)</td>
<td>NS (F=0.002, p = 0.968)</td>
<td>F = 4.351, p = 0.001</td>
</tr>
<tr>
<td><strong>Subjective Clarity</strong></td>
<td>F = 5.581, p &lt; 0.001</td>
<td>F = 58.256, p &lt; 0.001</td>
<td>NS (F=5.179, p = 0.25)</td>
<td>NS (F=0.312, p = 0.905)</td>
<td>NS (F=0.696, p = 0.628)</td>
<td>NS (F=0.043, p = 0.835)</td>
<td>F = 3.022, p = 0.009</td>
</tr>
<tr>
<td><strong>Subjective Fluctuation</strong></td>
<td>NS (F=2.750, p = 0.22)</td>
<td>F = 34.341, p &lt; 0.001</td>
<td>NS (F=3.166, p = 0.078)</td>
<td>NS (F=0.796, p = 0.555)</td>
<td>NS (F=1.225, p = 0.302)</td>
<td>NS (F=0.032, p = 0.858)</td>
<td>F = 2.449, p = 0.029</td>
</tr>
<tr>
<td><strong>Subjective Ghosting</strong></td>
<td>F = 2.921, p &lt; 0.001</td>
<td>F = 6.606, p = 0.016</td>
<td>NS (F=0.079, p = 0.779)</td>
<td>NS (F=2.009, p = 0.082)</td>
<td>NS (F=0.789, p = 0.560)</td>
<td>NS (F=0.268, p = 0.606)</td>
<td>NS (F = 0.348, p = 0.883)</td>
</tr>
</tbody>
</table>
Discussion:

The purpose of this study was to focus on answering three main questions in regards to fitting multifocal contact lenses. 1.) Was it possible to determine the optical centration of multifocal contact lenses with corneal topography? 2.) What are the effects of decentered multifocal contact lens optics on objective and subjective (clarity, fluctuation, and ghosting) vision? 3.) Do increasing ADD powers in multifocal soft contact lens have an effect on objective and subjective vision?

The Medmont corneal topographer is commonly utilized for their axial (refractive power) and elevation (corneal surface height) analysis of the cornea. These displays are critical when fitting corneal gas permeable lens as well as diagnosing corneal abnormalities. One display that is not commonly utilized is the tangential display. The tangential display allows the practitioner to assess surface curvature changes on the cornea. In our study we utilized this function to analyze the subtle curvature changes of the multifocal contact lenses in hopes of identifying the different transition zones of the contact lens power. By doing this, we can identify the location of the optical centers of the contact lenses. (See Figure 7A&B)

Figure 7A: Tangential display demonstrating position of multifocal optics. Notice the relatively well centered distance center optical zones in relations to the pupillary center (black “+”) and the visual axis (white “★”).
Given that the center optical zone diameter of an average multifocal contact lenses is about 2.00mm, the mean difference in horizontal and vertical assessment between the evaluators was significantly below clinical relevancy. The consistent and statistically significant correlations between the evaluators suggests that the corneal topographer may be a suitable tool that practitioners can utilize when fitting multifocal contact lenses to ensure proper centration.

One thing to note however is that the topographer’s tangential analysis relies heavily on the difference in surface curvatures to accurately display the location of the multifocal lens optics. In the case where there is insufficient curvature change the topographer’s reliance on reflected placido rings becomes more difficult and the results are not as coherent. This is the case with our control lens, which has a distance power of Plano DS, and 0.00 ADD power. (See Figure 8) Despite this, the corneal topographer was successful in determining the optical centration of multifocal contact lenses with ADD powers of at least Plano +1.00D. Further studies should be performed to see the limit of the topographer in assessing a range of different multifocal prescriptions (ie. hyperopic prescriptions).
*After data analysis of the first subject, defective lens manufacturing was suspected in one pair of lenses (Plano DS +4.00 ADD 1.00mm Nasal Decentered) due to the inconsistency of the lenses’ centration pattern. A duplicate lens (see above) was ordered for each eye to determine if this was the case. Analysis suggests that the manufacturing of the new right lens to be statistically insignificant compared to the original lens ordered. However, the left lens was statistically different compared to the first lens ordered. Given the small sample size and the possibility of “practice effect”, it’s difficult to draw any significant conclusion from this single lens difference. A future study should be performed to assess the consistency and repeatability of customized optical centration in multifocal contact lenses.

Despite the manufactured 0.50mm and 1.00mm nasal decentered optics, a majority of these lenses still displayed a temporal decentered pattern when applied to the eyes. This suggests the level of lens centration bias on the eye is larger than we previously anticipated. We had originally expected a 0.50mm and 1.00mm nasal decentered optics to compensate for the temporal bias of soft contact lenses. This was shown to not be true. A future product would need to utilize larger decentration steps to successfully compensate and provide visual benefits.

At the time of the original study design, manufactured optical centration was expected to be a key factor in the study. However, because vision is based on the actual centration of the contact lens on the eyes our study results are based on topographical determined centration. Manufactured optical centration became irrelevant compared to the actual centration of the contact lenses on the eyes.

What was interesting was the consistent superior decentered pattern of the contact lenses as previous studies (Walker, et. al) suggested that contact lenses tend to have an
inferior temporal position. Our findings was likely due to a technical difficulty with the
topographer and the palpebral lid position’s interaction with the contact lenses. During
topography, subjects were asked to open their eyes widely to facilitate good quality scans.
Since the topographer relies on placido reflections, the cilia often casts shadows on the
reflected mires resulting in poor quality scans. When subjects open their eyes wider, the cilia
is lifted off the reflection allowing the scans to be captured. We speculate that this artificial
widening of the palpebral aperture contributes to the consistent superior decentered
position of the contact lens because as the downward force of the superior palpebral is
relieved, it allows the contact lenses to move upwards when the scans are captured.
Whether the centration of the horizontal position may be affected by the eyelids is unknown.
Due to the anatomical structure of the eyelids and the palpebral fissure, it’s unlikely that
horizontal centration is affected by the superior and inferior eyelids and if it is, likely non-
significantly. Future studies are needed to determine whether palpebral apertures have an
effect on lens centration.

Our findings showed a consistent correlation between horizontal optical decentration
on both objective and subjective vision. As the optical zones of the multifocal contact lenses
increases in its horizontal distance from the visual axis, all aspects of measured vision (acuity,
subjective clarity, visual fluctuation, and visual ghosting) decreases. This confirms our notion
that fitting multifocal contact lenses is a complex task and that the location of the optics in
regards to the patient’s visual axis should be considered.

Vertical centration however, in the course of this study did not show an association
with vision. As mentioned above, our spurious results from the vertical centration is likely
attributed to the technical aspect of acquiring topographical scans. More studies in the
future are needed to confirm whether vertical centration has an impact on vision.

Finally, ADD power was evaluated independently in two different statistical models,
horizontal and vertical. The results between the two models consistently demonstrated that
increasing ADD power had a statistically significant impact on subjective vision (clarity, visual
fluctuation and ghosting). The only instance where ADD power’s effect on vision was not
shown to be statistically significant was on distance acuity (objective vision) under the
horizontal model. However, ADD power under the vertical model conflicted with this finding
as it showed a statistically significant association with distance acuity. Given the spurious
results of vertical centration and the previous mentioned inconsistency with vertical
centration due to technical limitations, the horizontal model may provide a more accurate
estimate to ADD power’s effect on objective visual acuity. Vertical centration and the effect
of ADD power should be repeated in future studies. Regardless, our findings agrees with
Ardaya’s conclusion in her study claiming that with increasing ADD powers, subjective vision
decreases. However, ADD power’s effect on measured distance acuity was inconclusive in
our study.
In terms of ADD power and its effect on lens centration, the results are also inconsistent between the horizontal and vertical centration models. According to the horizontal centration model, ADD power appears to not have any correlation with how lenses centered horizontally, (with the solo exception of subjective fluctuation). However, given the small number of sample size of our study, the marginal significance of this value (0.044) is questionable. More studies are needed to confirm the effects of ADD power on centration. Under the vertical model, ADD power appears to have a consistent correlation with vertical centration on vision with the exception of subjective ghosting. Again, this discrepancy between horizontal and vertical model is likely due to the error induced by the vertical decentration induced when obtaining the topographical scans. Given the circumstances of the experimentation, it is the opinion of this author that ADD power likely does not have a correlation with optical centration and the correlation between ADD power and vertical centration demonstrated under the vertical model was likely as a result of the variance not accounted for due to the process in which topographical scans were acquired.

Also, when studying ADD power on vision, the control lenses (ADD of 0.00) appears to consistently yield poor subjective vision across clarity, fluctuation, and ghosting and to a lesser degree, objective acuity. The control lenses, with conventional centration of its optics and no ADD power, should have provided vision comparable to baseline vision. However, the results suggests that the control lens consistently provided worst vision compared to lenses with increasing ADD power. The reason for these findings is uncertain, but could possibly be due to a defect in the lens production process, poor surface wetting of the lenses, or possible due to sampling error stemming from the small sample size of our study. The control lens was also the first lens that patients wore from baseline because this was the lens utilized to determine if a successful fit could be achieved with the standard parameters. This could have possibly introduced a systematic bias in our results. Further studies with an increase test sample size should be conducted to investigate and confirm our findings.
Conclusion:

With this study we hoped to identify a possible variable clinicians can consider when fitting multifocal contact lenses. Based on our study, we conclude that multifocal optical centration does affect both subjective and objective distant vision. Corneal topography is an instrument that is capable of detecting the location of the multifocal optics and its relationship to the visual axis. For clinicians that do not have the aid of a corneal topographer, a manual re-centration technique can possibly provide a gross estimate on the location of the optics from the visual axis although further studies are needed to investigate this. Finally, there appears to be a correlation with increasing ADD power and multifocal optical centration’s effect on subjective distant vision, but not on objective (acuity) vision.

What this may mean for the future of contact lens fitting is the use of diagnostic lenses to confirm the degree of multifocal decentration and lenses custom made to compensate for the level of decentration. Also of importance is for clinicians to realize that objective visual acuity may not be the sole factor in determining visual success with multifocal contact lenses. Subjective vision is an important consideration as well and may benefit from better centered optics over the visual axis. Fitting multifocal soft contact lenses on the eyes is synonymous with fitting progressive spectacle lenses. However, with progressive spectacle lenses a skilled eye care provider always takes in to account the visual axis and the placement of the optics within the spectacle lenses. However, the attention to this detail appears to be neglected in multifocal contact lens fitters. Hopefully with these findings practitioners can improve the success of multifocal contact lenses in the management of presbyopia and other accommodative disorders. In addition, the use of high add multifocal soft contact lenses have proven successful in myopia control. We hope to apply what we learned to further the success of these lenses with children and ensure a good visual outcome.
References


