

MAPPING AND MEASURING DIFFERENCES BETWEEN FREE-FORM  
PROGRESSIVE LENSES

by

James Boutros

Has been approved

March 13th, 2015

APPROVED:

\_\_\_\_\_, Faculty Advisor



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PROGRESSIVE LENSES

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James Boutros

This paper is submitted in partial fulfillment of the requirements of the degree of

Doctor of Optometry

Ferris State University  
Michigan College of Optometry

March 13th, 2015

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Ferris State University  
Doctor of Optometry Senior Paper  
Library Approval and Release

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PROGRESSIVE LENSES

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James Boutros  
Doctoral Candidate

03/15/2015  
Date

## ABSTRACT

*Background:* This experimental study aims to test the repeatability of the fabrication of identical free form progressive lens orders between five optical laboratories. *Methods:* Five identical orders of free form progressive lenses were placed to five separate optical laboratories. The right and left lenses of each order were then mapped by the Rotlex Class Plus lens analyzer. The Class Plus supervisor mode software was then used to create a comparison map between all right and left lenses to one another. *Results:* Small differences were found between sphere and cylinder power measurements from comparison maps. The largest variance in measurements was found in comparing addition power between lenses. These values had the highest standard deviation and variance. *Conclusion:* Possible explanations for larger inconsistencies in addition power measurement include incorrect identification of near zone power secondary to user misalignment during measurement, and environmental or mechanical differences in lens production between optical laboratories. A small contribution of inaccuracy may be attributed to variation in base curve and central thickness measurement.

## ACKNOWLEDGMENTS

I would like to thank first and foremost my advisor, James Brady, for his invaluable aid and education in the world of ophthalmic optics. His immeasurable experience and passion for teaching has left an impression on me that will last for a lifetime. Further, I could not have completed my coursework without the help and support of my family and loved ones. The endless support they have given me to complete my education can never be repaid.

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## CHAPTER 1

### INTRODUCTION

Progressive addition lenses (PAL) have become today's ophthalmic industry standard in presbyopic correction. These lenses are characterized by a far zone which contains the wearer's distance prescription, and a corridor of gradually increasing plus power at the end of which lies a reading zone, containing the reading prescription.<sup>1,2</sup> Some advantages compared to the popular flat-top 28 (FT-28) lens design include improved cosmesis with no visible line, clear vision at an intermediate range, occupational uses for computer or special viewing tasks, and customizable lens designs for the wearer.<sup>1,2,3</sup> With more room for versatility it follows that manufacturers benefit by dedicating a larger proportion of resources to improving progressive lens designs. This continual development has birthed the technology of free form surfaced progressive lenses.

Although there are options with respect to PAL designs, "hard" vs. "soft" designs, "short" vs. "long" corridors, the fundamental PAL design has remained constant.<sup>3</sup> A far zone focused for distance viewing and a gradual increase in curvature by applying plus cylinder along the lens to yield a reading addition, thereby blending the far and near zones together with an intermediate zone.<sup>1,3</sup> However, the method by which this design is achieved has been improved with free form technology.<sup>2</sup> Traditional production of PAL's involves the use of a cast molded semi-finished lens blank from a vast inventory which is

then machined on the back surface to incorporate the wearer's prescription.<sup>2</sup> While this method is consistent, it inherently has limitations.

Free form surfacing technology removes the need for an inventory of semi-finished lens blanks by creating a unique progressive lens design based on variably input data.<sup>2,4</sup> This data can be specific to any wearer, which allows the production of a lens based on the needs of each individual.<sup>2,4</sup> This is accomplishable through computer modeling, which is then sent to a computer controlled free form generator with a diamond cutter in the form of a points file.<sup>2,4</sup> This points file may be a modified file made up of data which is optically maximized to benefit a single wearer, or a generic "surface description file" from the manufacturer.<sup>2</sup> The surface description files would then produce lenses similar to the traditional cast molded semi-finished blanks.<sup>2</sup> By drawing this conclusion, we speculate that lenses that are received based on these surface description files should have very little differences between one another. In order to test this hypothesis, the repeatability of these surface description files can be evaluated by mapping the lenses that were shaped by them.

## CHAPTER 2

### METHODS

The Varilux S Fit, being a free form surfaced design, was the lens of choice for this study. Five separate optical laboratories (Harbor Optical, Traverse City, MI; Soderberg Optical, Jackson, MI; Optical Supply Inc, Grand Rapids, MI; Vision Craft, Walled Lake, MI; and Twin City Optical, Traverse City, MI) received identical orders for lenses with specifications of: Varilux S Fit in 1.586 refractive index, right lens +2.00 - 0.50 axis 060, left lens +2.00 -0.50 axis 072, add power of +2.50 with a segment height of 28mm. The lenses were cut to a Duraflex metal frame of style # 4190 with size parameters of 50-18-140. The amount of pantoscopic tilt was ordered to be 7.5 degrees.

The lenses were measured at the Michigan College of Optometry using the Rotlex Class Plus lens analyzer, which utilizes a technique known as moiré deflectometry.<sup>5,6</sup> This technique is based on gratings within the device that produce a defined fringe pattern.<sup>5,6</sup> When this defined fringe pattern becomes distorted after a laser is shone through the lens to be measured, tens of thousands of data points can be plotted to form a real map of the lens measured.<sup>6</sup> While other methods of measuring lens properties exist, Huang et al. found that three common methods, including the Class Plus, were comparable.<sup>5</sup>

The measurement of the lenses using the Class Plus requires multiple inputs of data. The center thickness and base curve was measured on all lenses, these values can be found in Table 1. When these values are inputted, the software requires the selection of the lens type (Lens, Mold, Back progressive, Mixed progressive), lens stamp (Manual, Single vision, User type-R, and User type-L), and finally, the frame type or whether the lens is cut or uncut.<sup>6</sup> The lenses were measured with the following selections; lens type: Lens, lens stamp: Manual, frame type: Cut. The manual lens stamp selection requires that the user identify the area of the fitting cross and match the markings of the lens within the grid.<sup>6</sup> This also required the selection of "Enable alignment" before commencing measurement of the lenses for the grid to be matched with the progressive markings.<sup>6</sup> The lenses were placed with the convex surface down with the fitting cross directed inward towards the machine. During the process of measurement, the "Set contour" button was selected, which allows the user to place points to trace the edges of the lens.<sup>6</sup> This is especially useful for cut lenses. After this tracing was complete, the lens was measured and a map was created. These measurements were completed for all right and left lenses from all five optical laboratories, producing a collection of 10 maps total. It is important to note that after a lens is mapped, the power of the lens can be viewed in terms of minus cylinder, plus cylinder, or an average of the powers between axes. This selection will only toggle the display of the powers, and not the readings of data, therefore the decision was made to leave the view as default on "Avg Power".

Selecting average power does however display the cylinder as a positive number.<sup>6</sup>

Inherent within the software is a function to compare maps. This function subtracts one lens from the other point by point, producing a comparison map.<sup>6</sup> To eliminate the possibility of imperfect alignment between separate maps, it also has an "Allow shift" selection which will move one map in reference to the other to where the square of differences is minimal, thus producing the most accurate comparison.<sup>6</sup> This process was completed for all right and left lens maps against one another. The final collection was then 20 comparison maps, 10 for the right lenses and 10 for the left. These maps are the basis of our results.

Table 1.

The measured center thicknesses and base curves of the received lenses.

| <b>Optical Laboratory</b>  | <b>Center Thickness (mm)</b> | <b>Base Curve (D)</b> |
|----------------------------|------------------------------|-----------------------|
| <b>Harbor Optical</b>      | OD: 3.100                    | OD: 5.18              |
|                            | OS: 3.050                    | OS: 5.13              |
| <b>Optical Supply Inc.</b> | OD: 2.950                    | OD: 5.25              |
|                            | OS: 3.200                    | OS: 5.25              |
| <b>Soderberg</b>           | OD: 3.300                    | OD: 5.13              |
|                            | OS: 3.300                    | OS: 5.25              |
| <b>Twin City Optical</b>   | OD: 3.000                    | OD: 5.13              |
|                            | OS: 3.100                    | OS: 5.13              |
| <b>Vision Craft</b>        | OD: 2.500                    | OD: 5.25              |
|                            | OS: 3.000                    | OS: 5.00              |

## CHAPTER 3

### RESULTS

As can be seen in Table 1, some differences were measured in the center thicknesses and base curves. While these differences are not very large, fluctuations in these values and their implications will be discussed in the next chapter. Figures 1 and 2 depict these differences in a column graph.

Figure 1. Differences in center thicknesses of right and left lenses between optical laboratories.

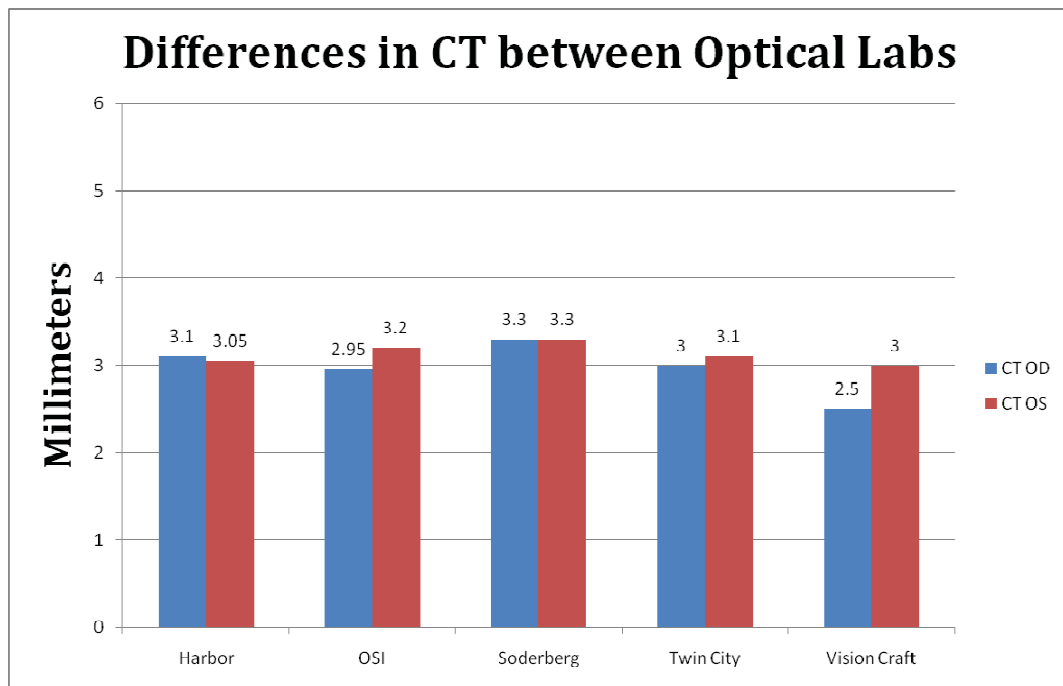
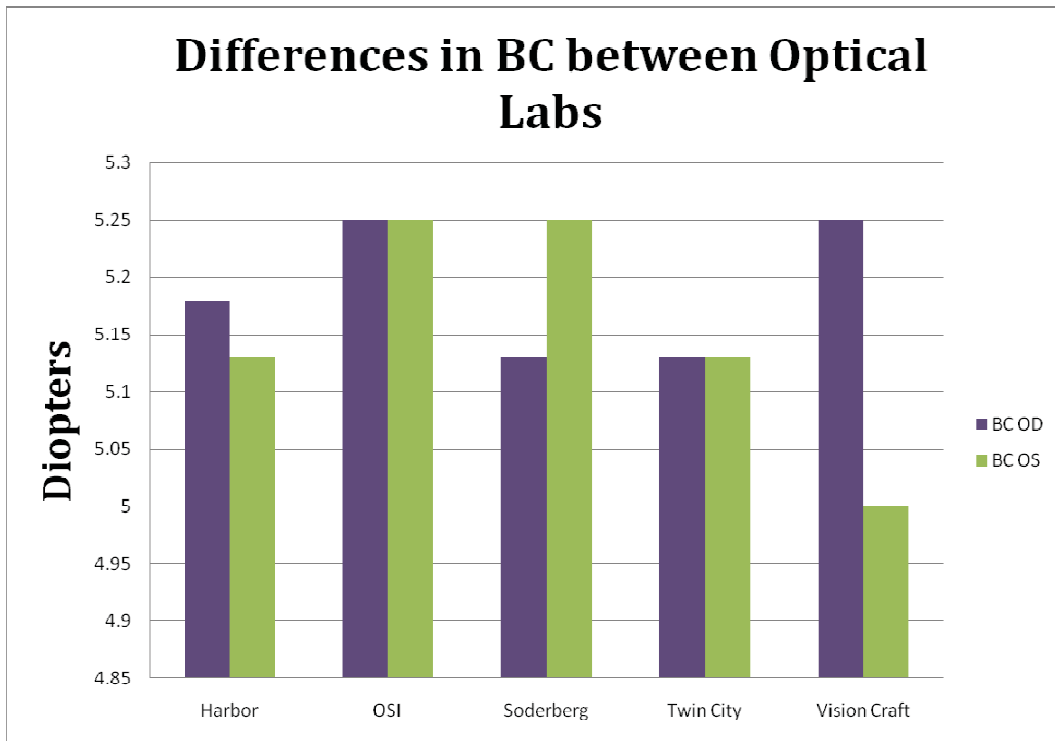


Figure 2. Differences in base curve of right and left lenses between optical laboratories.



All figures of comparison maps can be found in appendices A through T. These images depict all right and left lens comparison maps as exported from the Rotlex class plus software. All values measured by the Rotlex were recorded and organized into an excel spreadsheet. The data was arranged from smallest to largest dioptric difference for demonstrative purposes. Figures 3, 4, 5 and 6 show these differences.



Figure 3. The bar graph of dioptric differences between sphere, cylinder, and addition power of all right lenses. The measured difference by the Rotlex analyzer is printed adjacent to each respective bar.

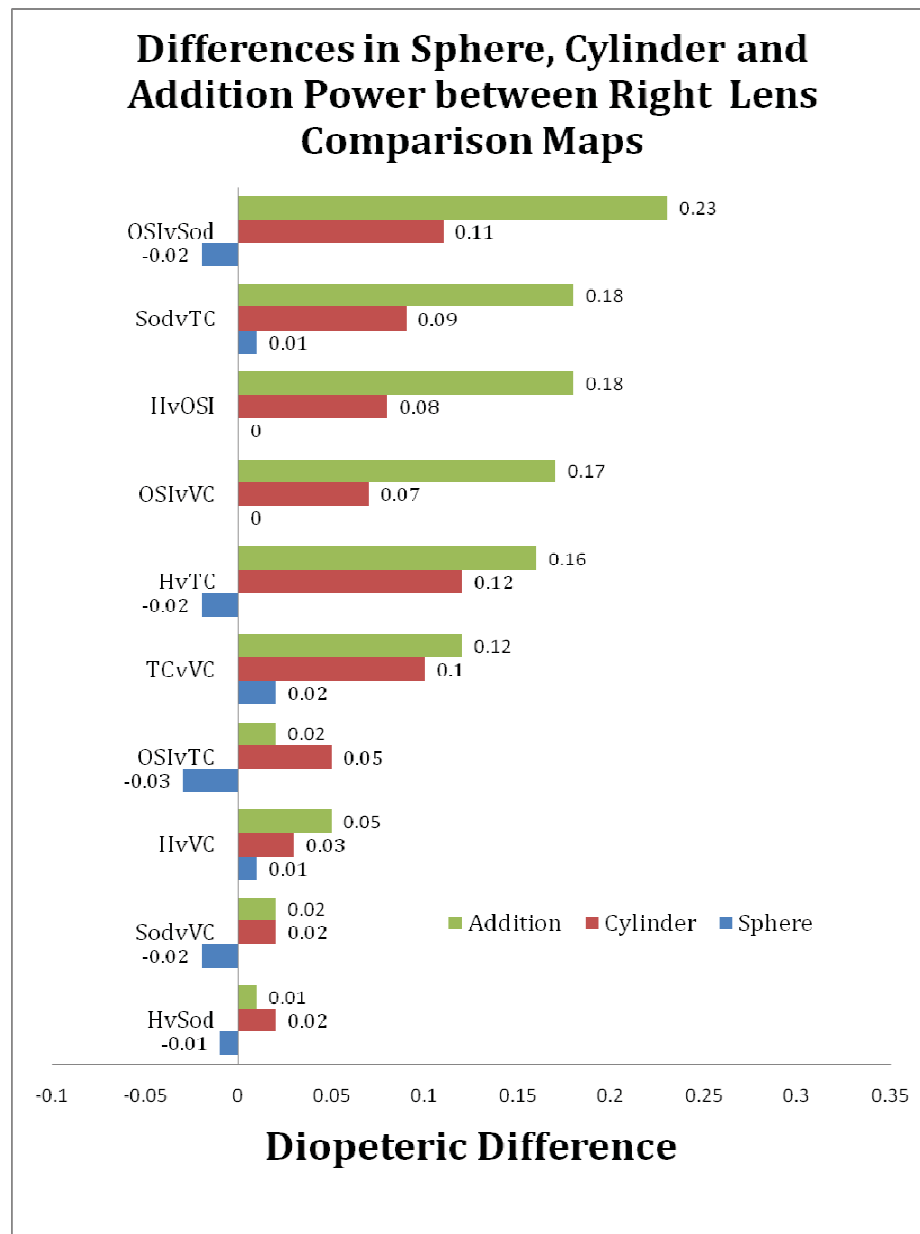
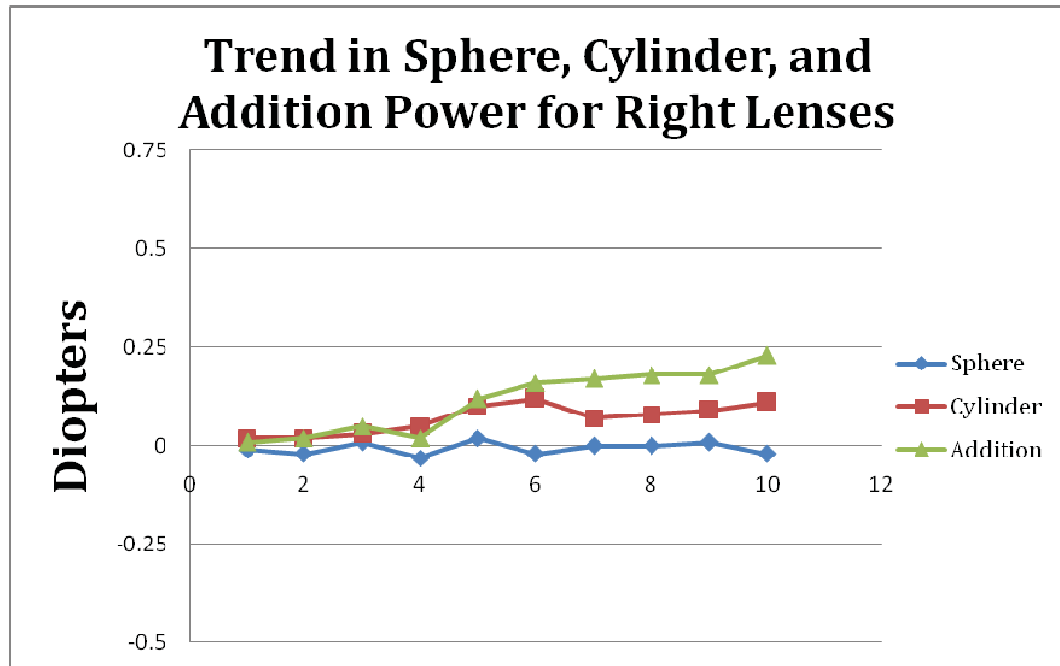


Figure 4. The line graph showing the trend of which measured power differs the most.



As can be seen from both figures 3 and 4, the sphere power differs the least between all comparison maps. All sphere powers for the right lenses were within a narrow range of zero difference to three hundredths of a diopter. Cylinder powers had a larger range, from two hundredths of a diopter up to slightly under one eighth of a diopter. Addition power had the largest range of dioptric difference. Addition power ranged from as little as one hundredth of a diopter to just under a quarter diopter. The same trend is true for the left lens comparison maps. Figure 5 and 6 show the values for all left lenses.

Figure 5. A bar graph similar to figure 3, comparing all left lenses instead.

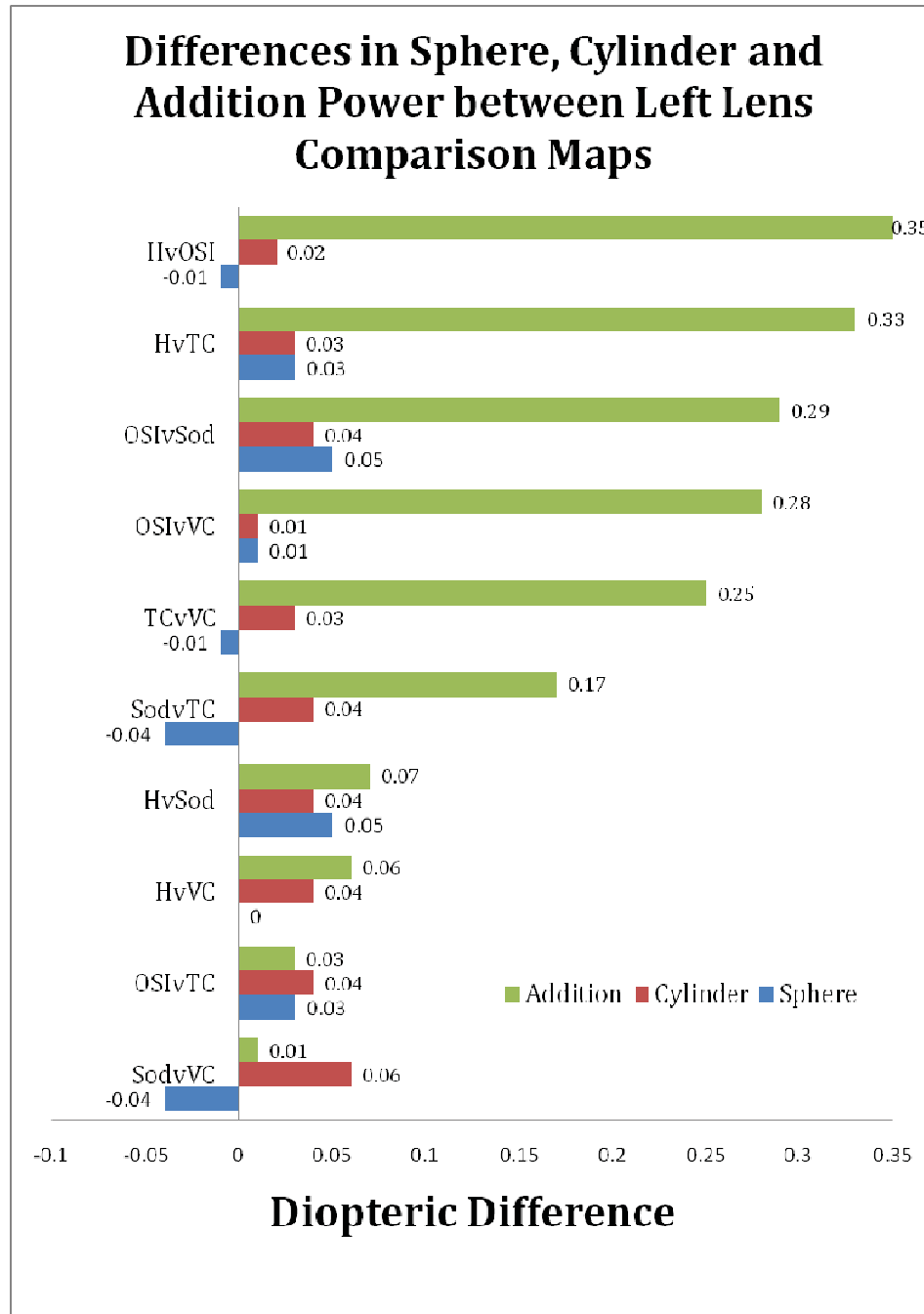
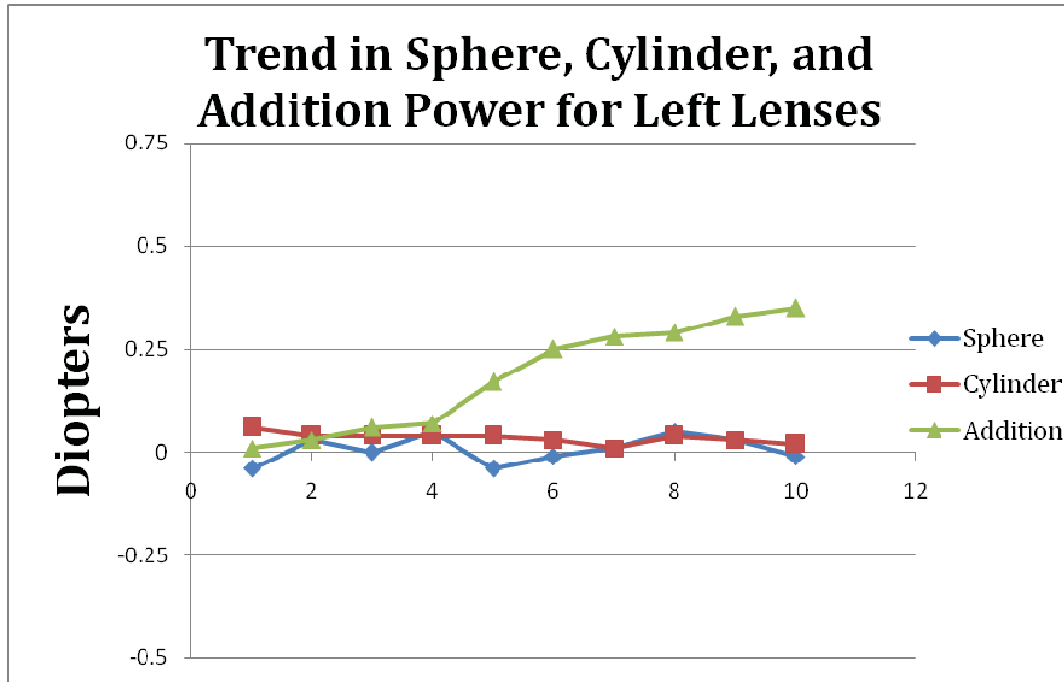


Figure 6. The line graph for all left lenses.



A similar trend is observed with all left lenses when compared to the right lenses, sphere power differs the least, while addition power has a much larger range.

Table 2. Standard deviations and variances for sphere, cylinder, and addition powers for both right and left lenses.

|                 | Right Lenses |          | Left Lenses |          |
|-----------------|--------------|----------|-------------|----------|
|                 | Std Dev      | Variance | Std Dev     | Variance |
| <b>Sphere</b>   | 0.01562      | 0.00024  | 0.03132     | 0.00098  |
| <b>Cylinder</b> | 0.03534      | 0.00125  | 0.01285     | 0.00017  |
| <b>Addition</b> | 0.07749      | 0.006    | 0.125       | 0.01562  |

When looking at Table 2, the conclusion that addition powers fluctuated more than sphere and cylinder powers can be made. This is true for both right and left lenses. Standard deviation and variance values for both sphere and cylinder powers were quite low. Addition powers had surprisingly higher standard deviation values, most notably the left addition power which had a standard deviation of a eighth diopter.

## CHAPTER 4

### DISCUSSION

When comparing values between most variables, it does not appear that there are many differences. The only variable that had large inconsistencies was the addition power. Sphere and cylinder powers were very accurate and hundredths of a diopter differences seem negligible. The question that must be answered is what could have cause such large inconsistencies in the addition power.

One possible source of this could be the differences in base curve and central thickness of the lenses. The initial thought was that lenses from optical laboratories that had the largest differences in these variables would have the poorest comparison maps. However, after looking at the differences in comparison maps, no single optical laboratory stands out as having particularly worse differences than the rest. For example, the Vision Craft left lens had approximately a quarter diopter lower base curve than the other lenses. When looking at the left comparison maps however, we can see that Vision Craft addition powers differed very little when compared to Harbor Optical and Soderberg. Although the Vision Craft addition power differed a larger amount compared to OSI and Twin City optical, there is no apparent pattern that could link a difference in base curve solely to inconsistent addition powers from the data. The Rotlex manual states that inaccuracies in central thickness, base curve, and refractive index measurement may cause slight decrease in accuracies of measurements.<sup>6</sup> In order to check these changes

during data collection, the data input for the individual maps was changed to have incorrect refractive indices and central thicknesses. The change in measured power observed was considered to be negligible, most of which did not exceed three hundredths of a diopter.

Another consideration for loss of consistency in addition power measurements could be from the individual measured maps for each lens. The lenses were scanned in the Rotlex by matching the progressive lens markings on the "Manual" measurement type. If the measurement type was selected as "User Layout-R" and "User Layout-L" as discussed in the methods chapter, a custom lens design file could have been created to take measurements of specified areas. In this measurement type the far and near zones must be identified by correctly measuring these zones and creating a schematic of these zones within the lens design file. The "Manual" measurement type will arbitrarily detect far and near zones based upon the map measured. If our study involved the use of different progressive lens designs from multiple manufacturers, perhaps specific lens design files would have to have been created for each. Therefore, the assumption was made that since our study included identical progressive lens designs the far and near zones would be detected similarly between lenses. This may have not been the case.

This leads to the notion that perhaps the far and near zones for each lens should be identified and incorporated into a specific lens design file for each separate lens. This may improve accuracy of addition power measured, thus decreasing the amount of difference between measurements in our comparison maps.

This measurement method may be considered in the future for comparison to the measurements taken by arbitrary definition of far and near zones.

Lastly, the consideration must be made that these differences truly exist and are due to differences in machinery or methods of lens production from optical laboratories. It is possible that differences in lab environment, free form surfacing techniques, or precision of equipment can account for variably displaced near zones, resulting in differences in addition power at a standard corridor length between comparison maps. More investigation would need to be done in order to discern which particular techniques or machinery each participating optical laboratory has used for the lens products in our study.



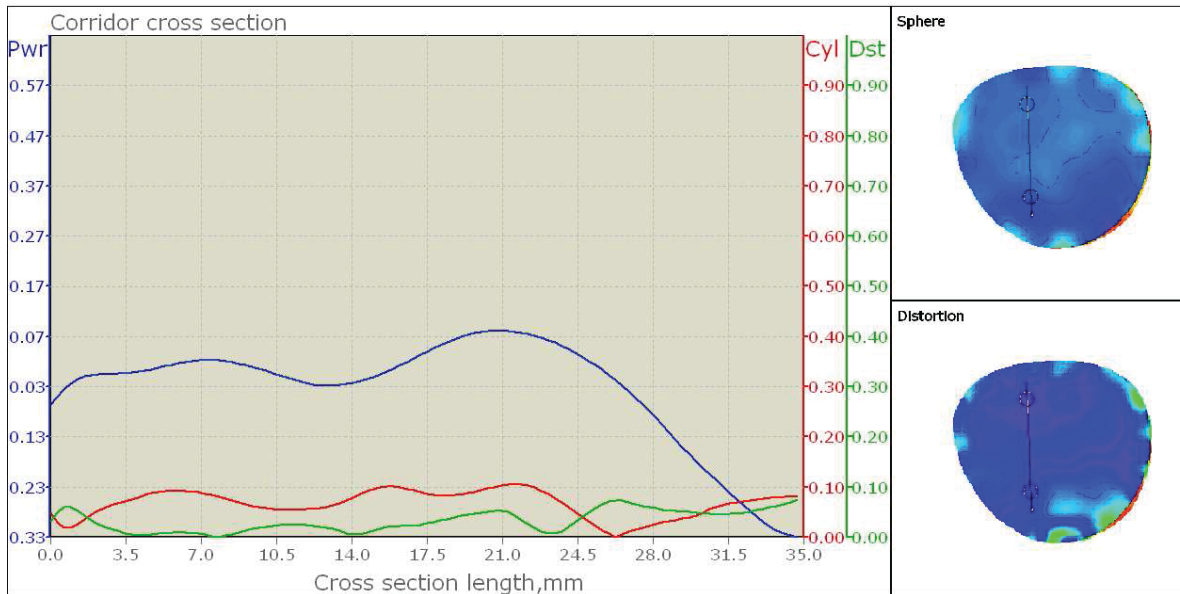
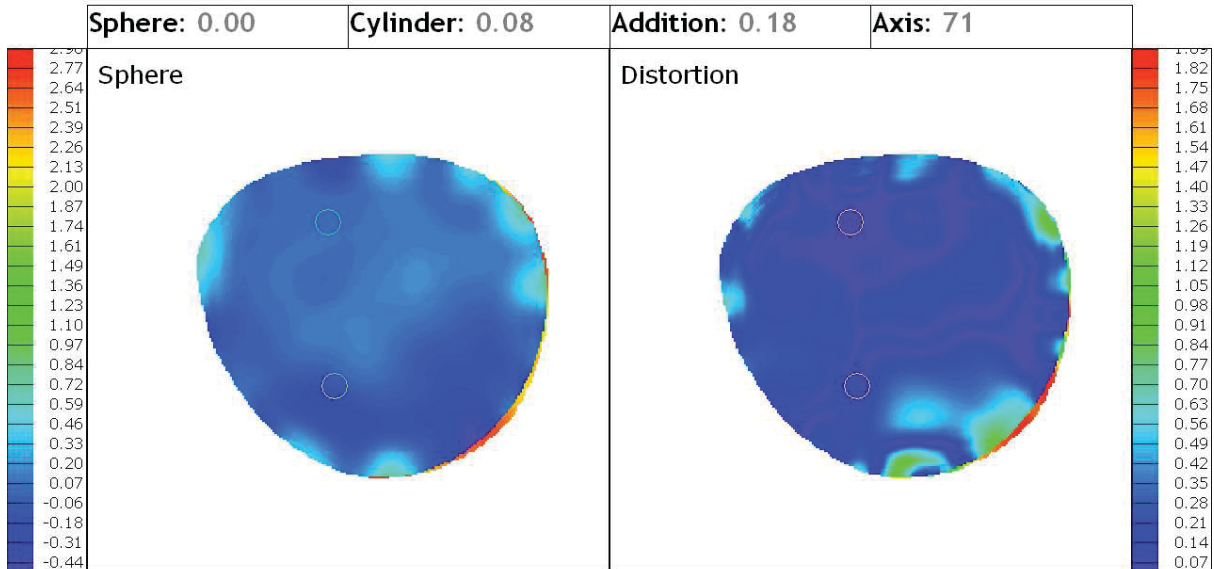
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5. Huang C, Raasch T, Yi A, Sheedy J, Andre B, and Bullimore M. Comparison of Three Techniques in Measuring Progressive Addition Lenses. *Optometry and Vision Science* 2012;89(11):1564-1573.
6. Rotlex. (2003). *Class Plus User Manual*.

APPENDIX A

HARBOR OD VS OSI OD COMPARISON MAP

## HARBOR OD VS. OSI OD

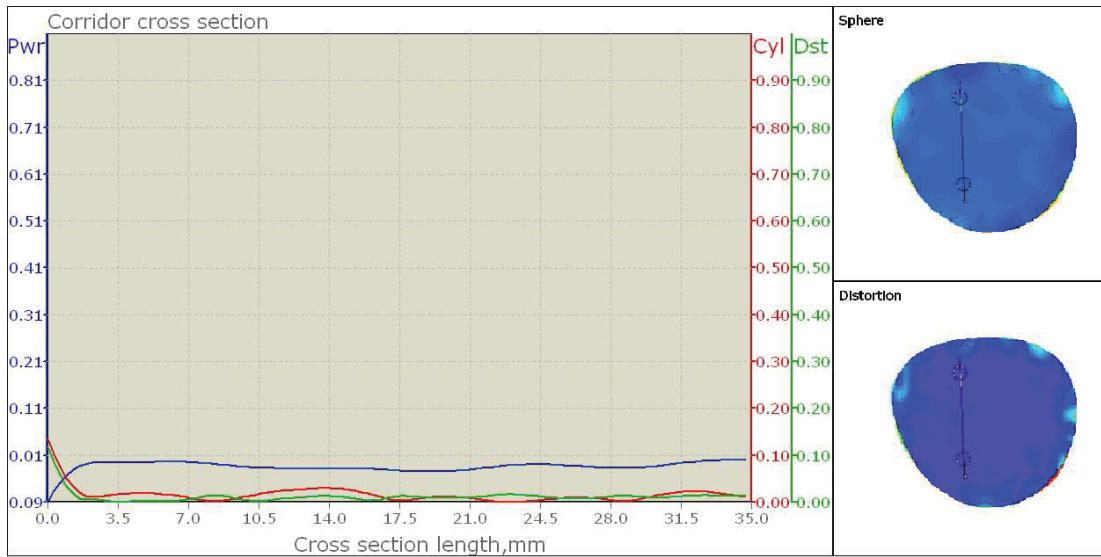
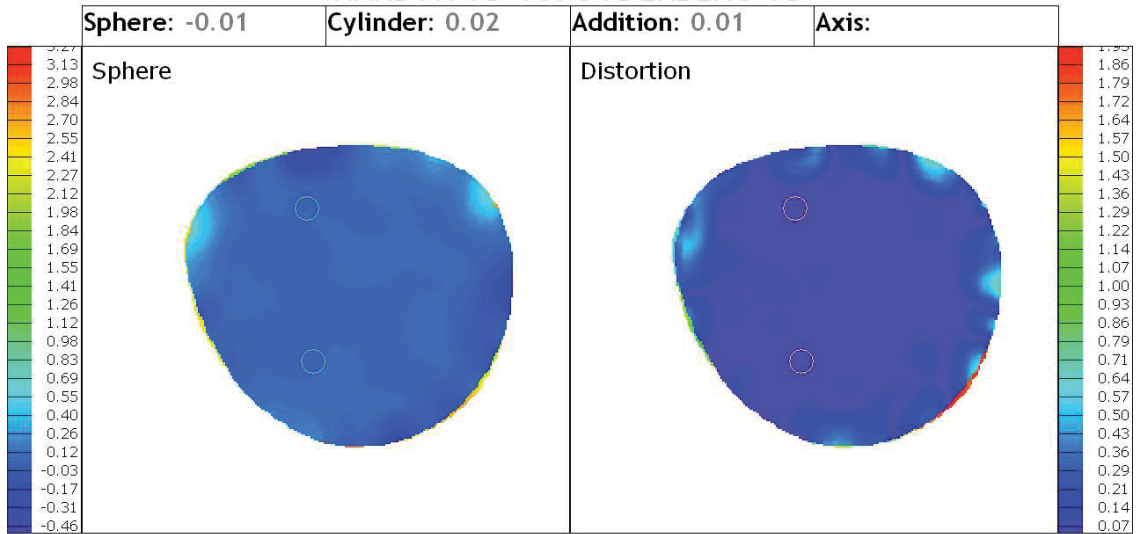


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX B

HARBOR OD VS SODERBERG OD COMPARISON MAP

### HARBOR OD VS. SODERBERG OD

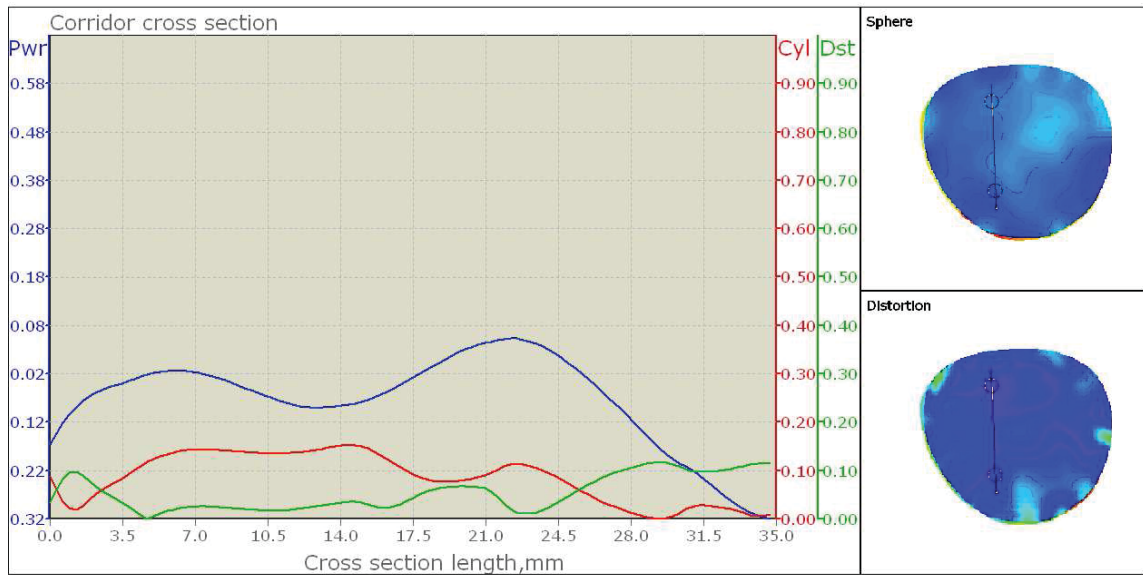
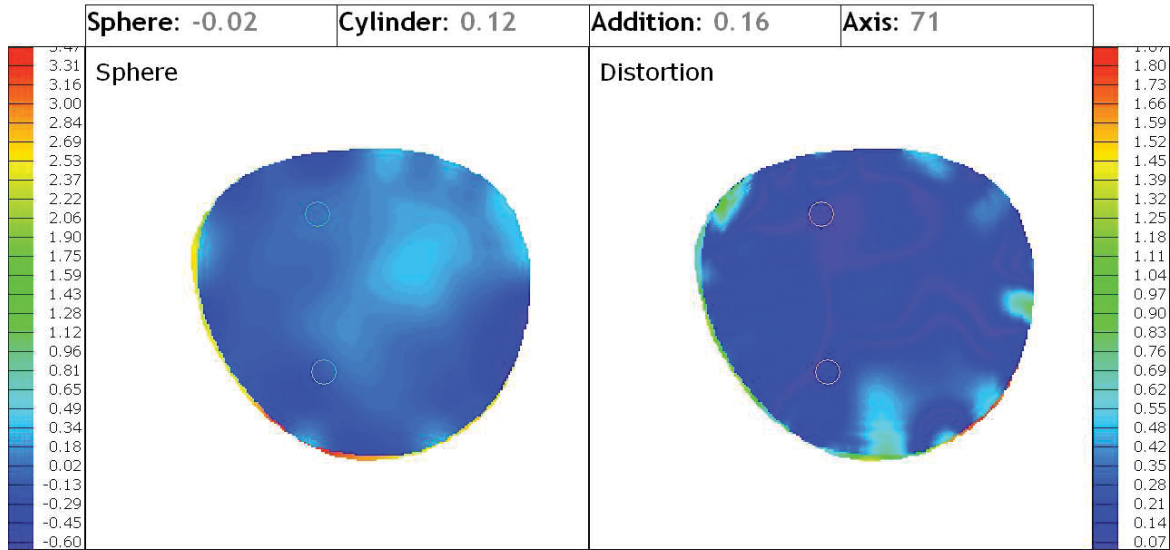


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX C

HARBOR OD VS TWIN CITY OD COMPARISON MAP

### HARBOR OD VS. TWIN CITY OD



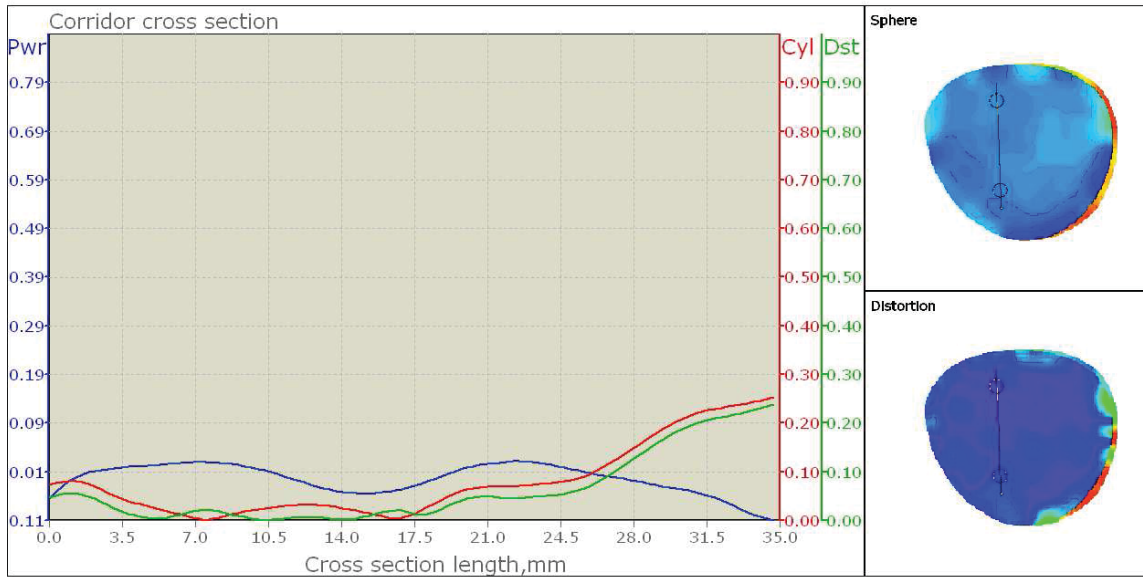
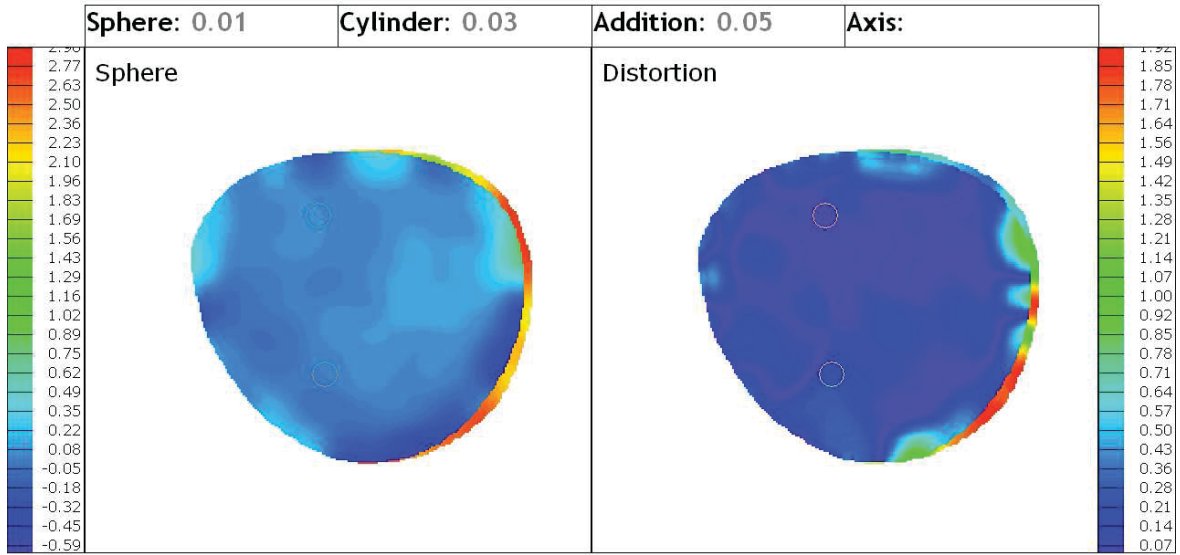
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info@rotlex.com*

APPENDIX D

HARBOR OD VS VISION CRAFT OD COMPARISON MAP



# HARBOR OD VS. VISION CRAFT OD

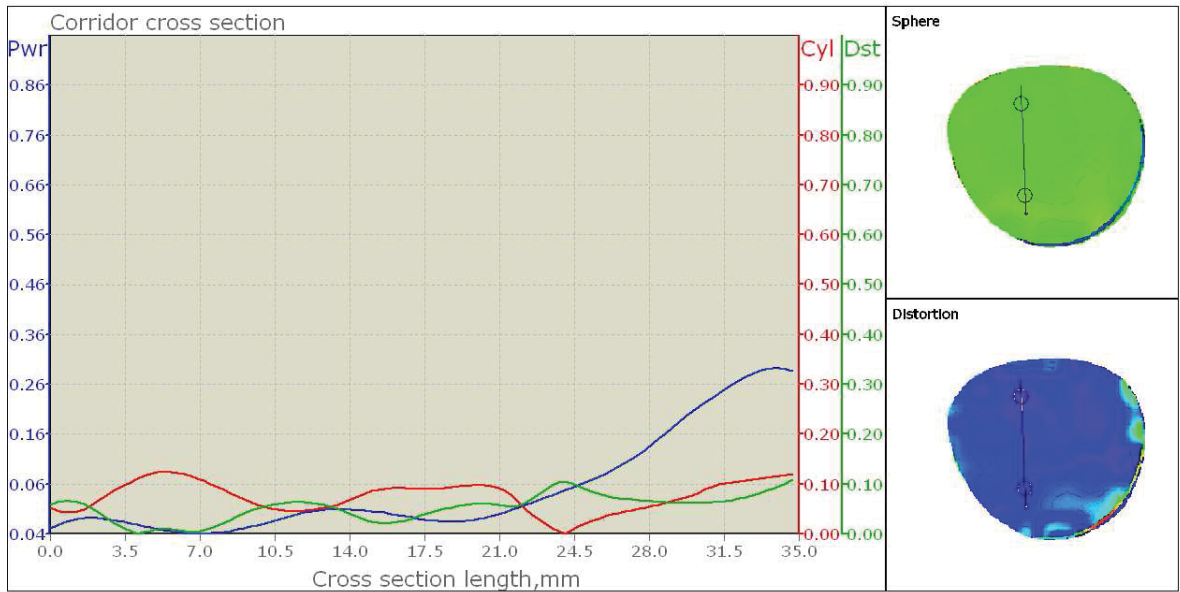
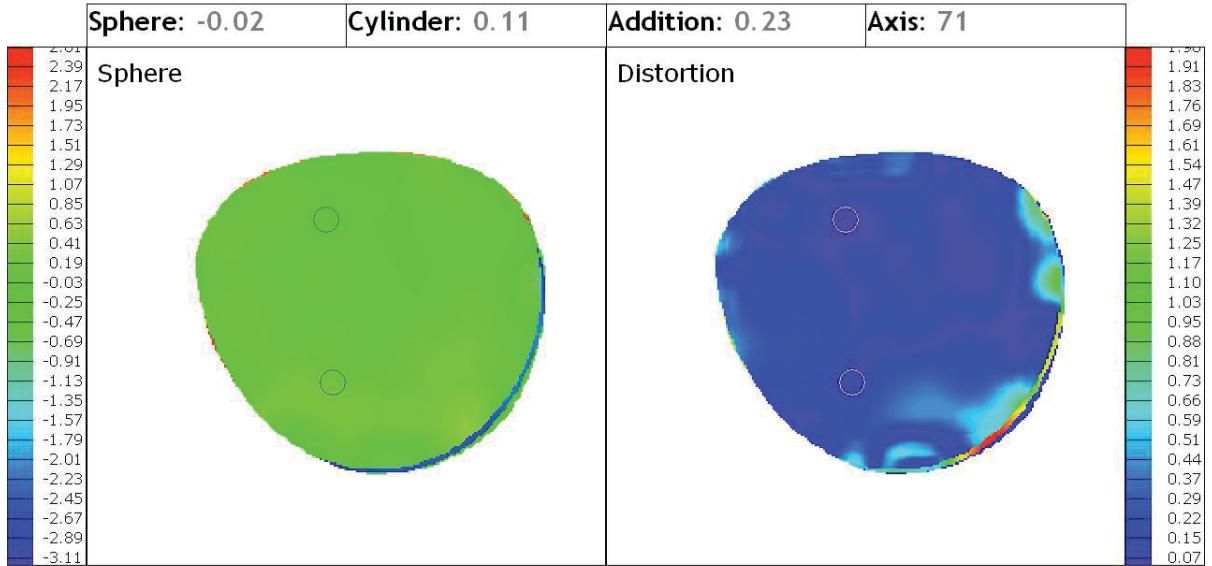


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX E

OSI OD VS SODERBERG OD COMPARISON MAP

### OSI OD VS. SODERBERG OD

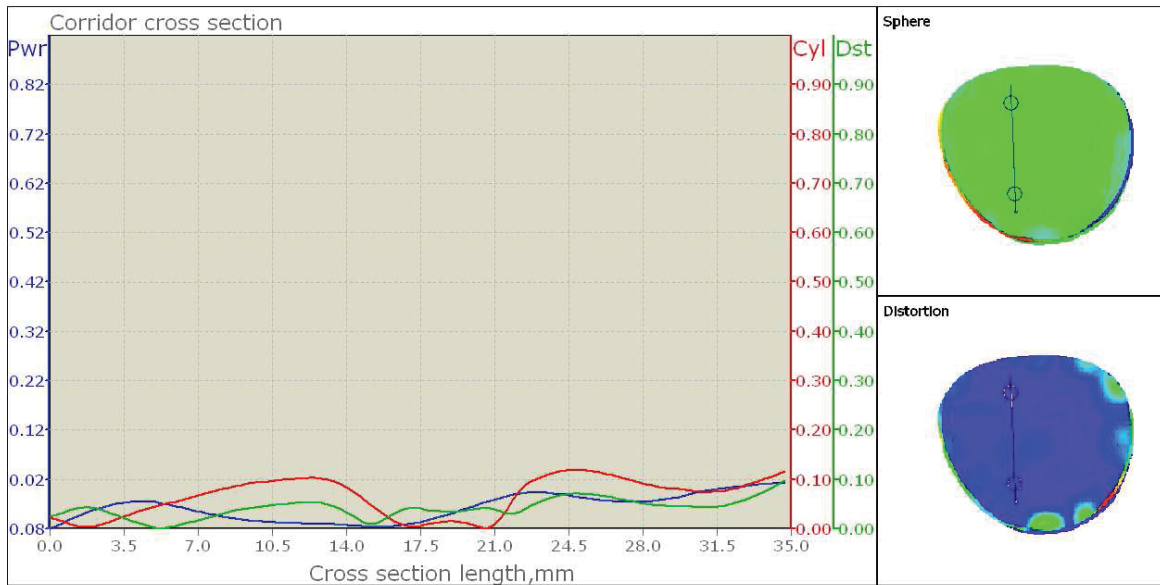
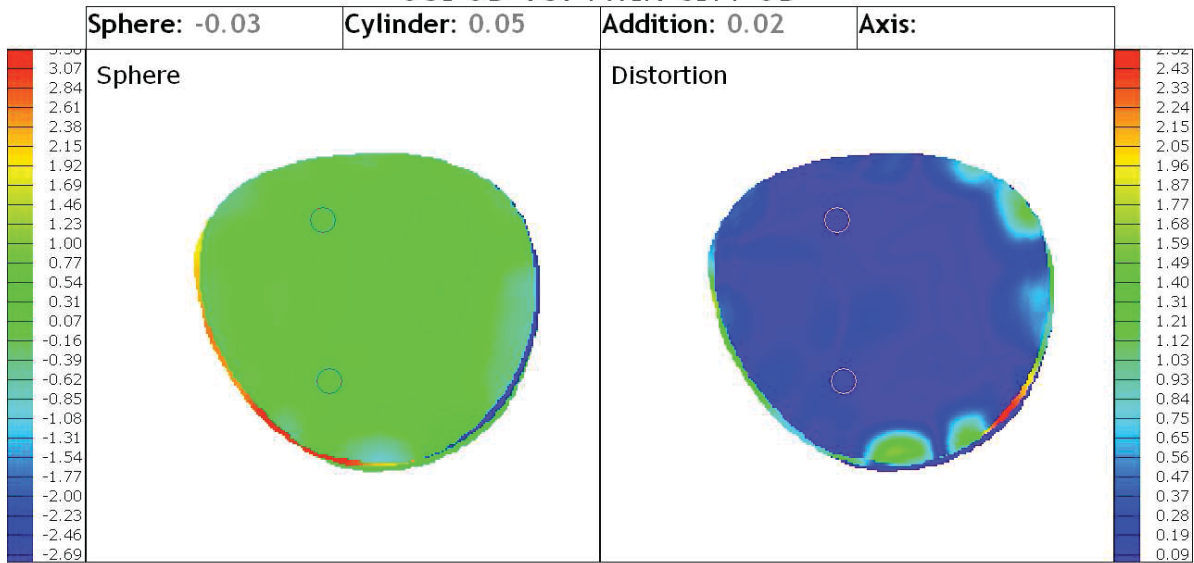


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX F

OSI OD VS TWIN CITY OD COMPARISON MAP

### OSI OD VS. TWIN CITY OD

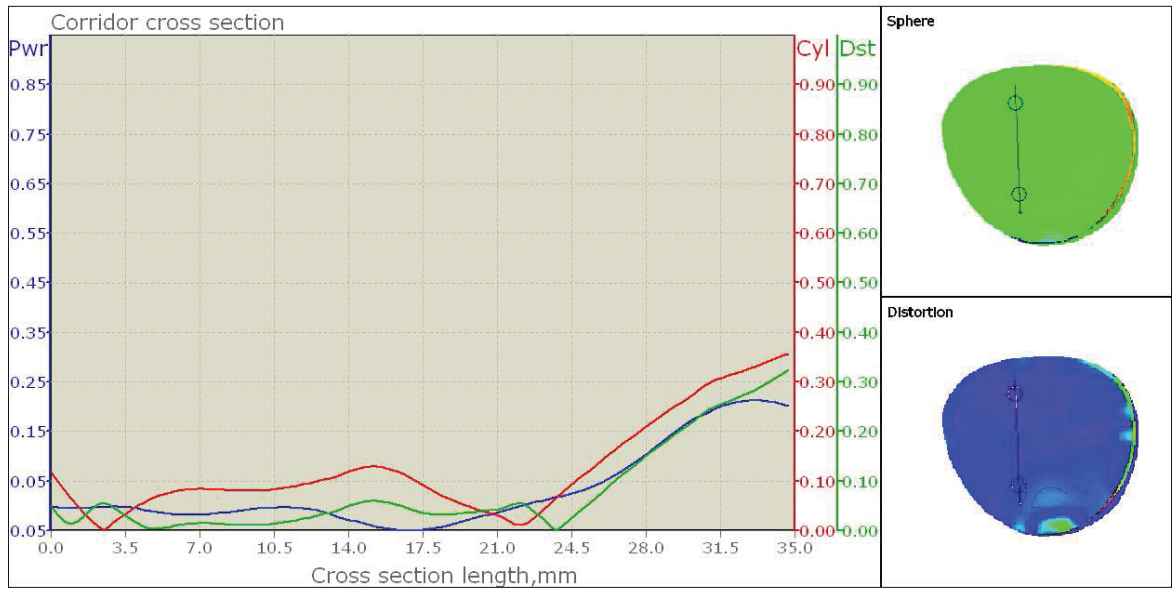
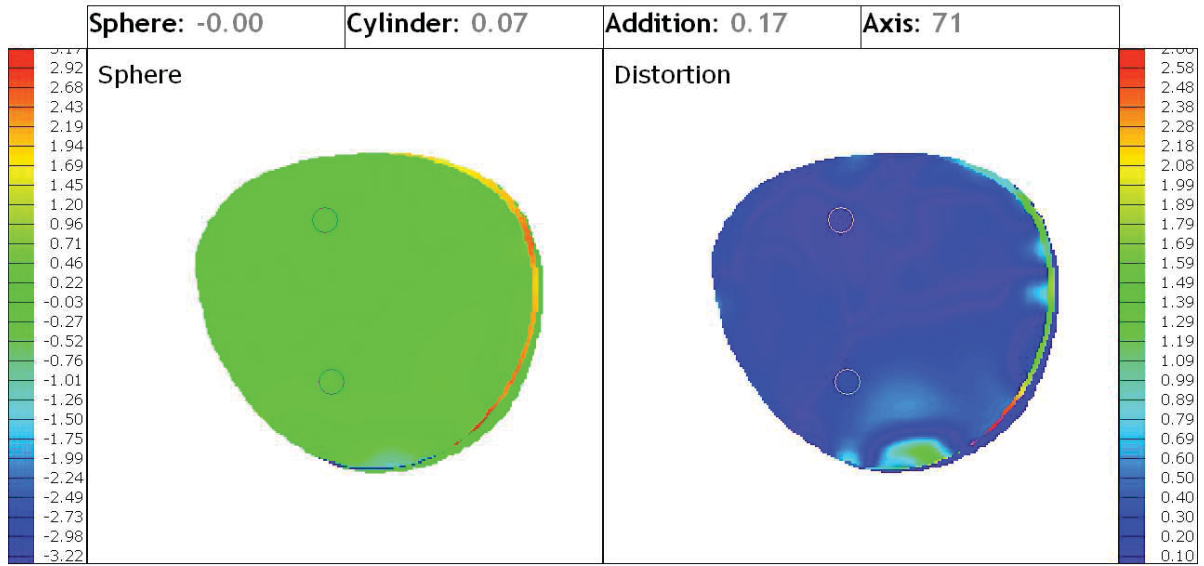


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX G

OSI OD VS VISION CRAFT OD COMPARISON MAP

### OSI OD VS. VISION CRAFT OD



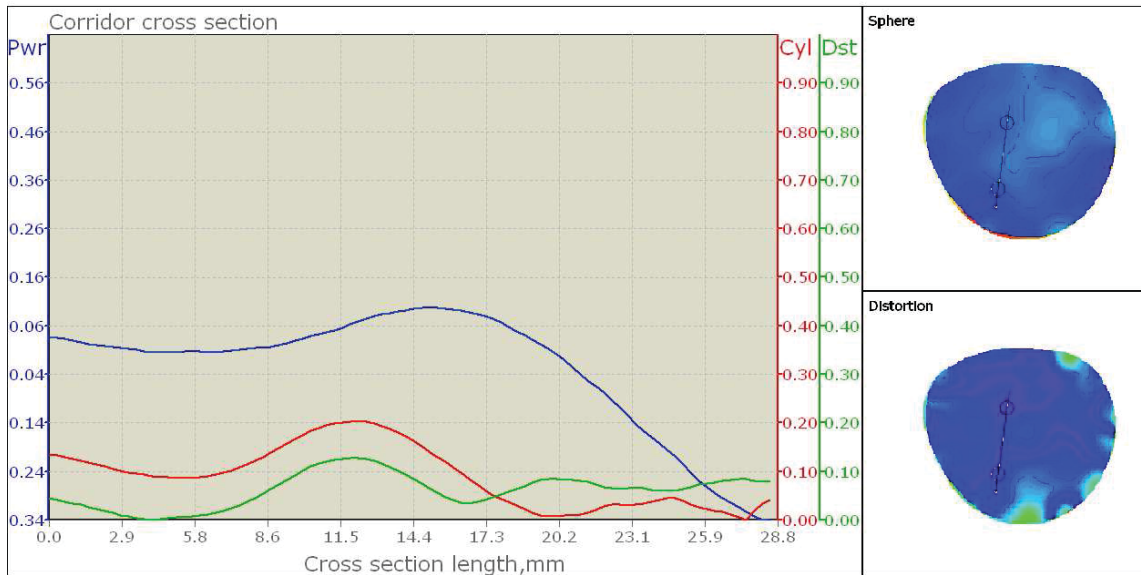
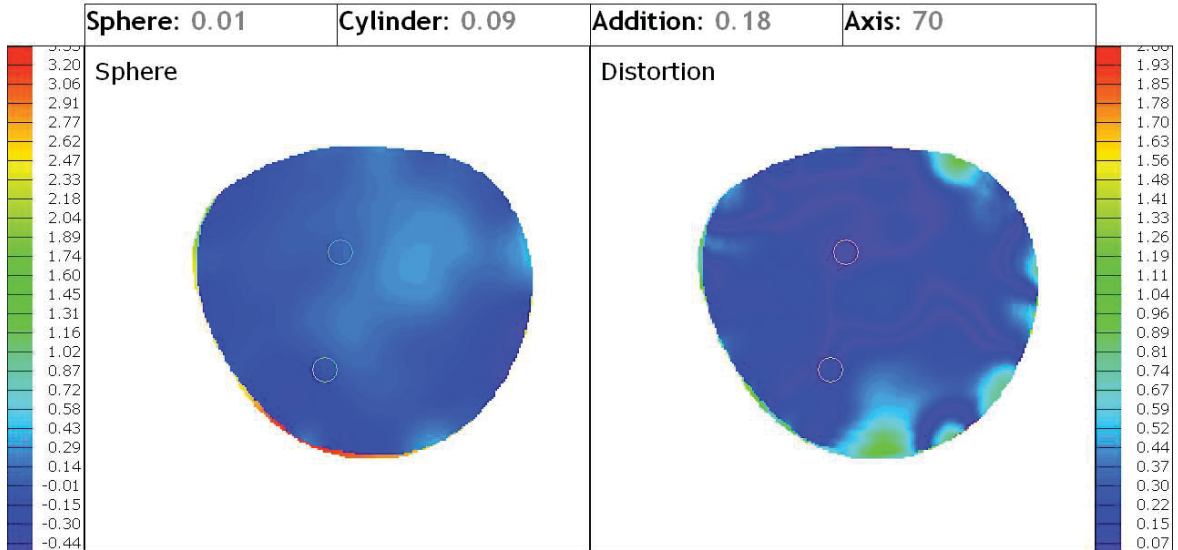
*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX H

SODERBERG OD VS TWIN CITY OD COMPARISON MAP



### SODERBERG OD VS. TWIN CITY OD

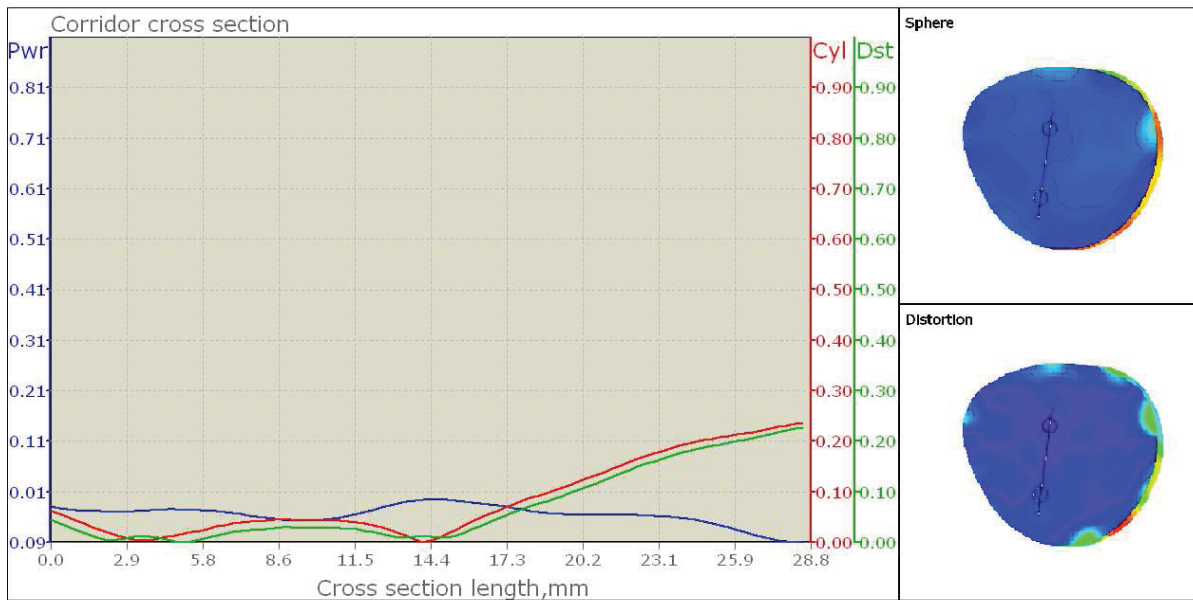
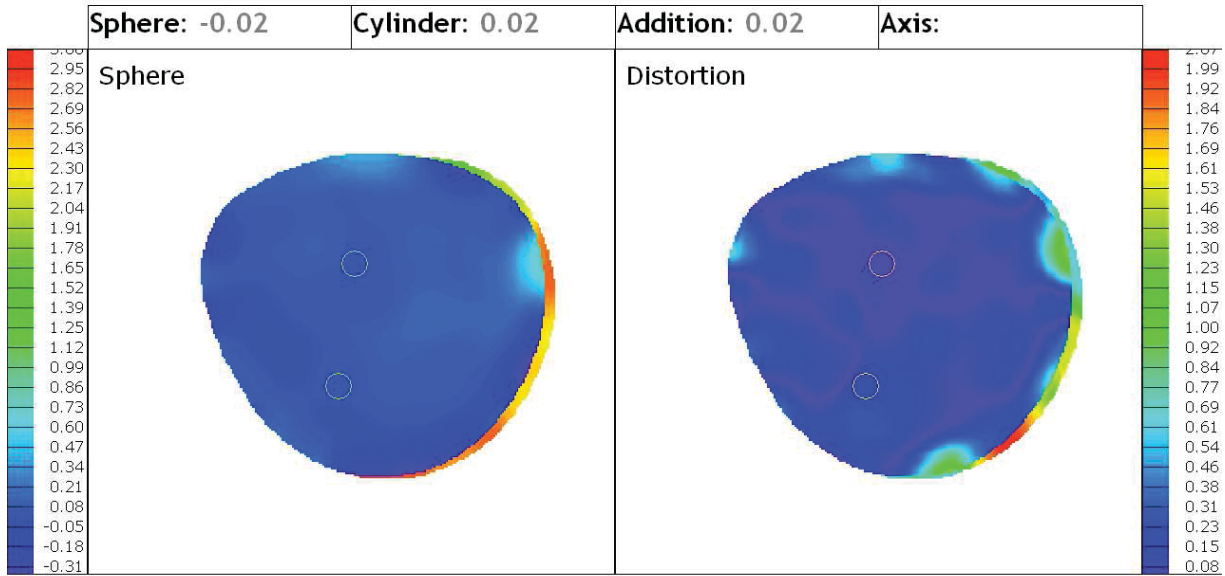


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX I

SODERBERG OD VS VISION CRAFT OD COMPARISON MAP

### SODERBERG OD VS. VISION CRAFT OD

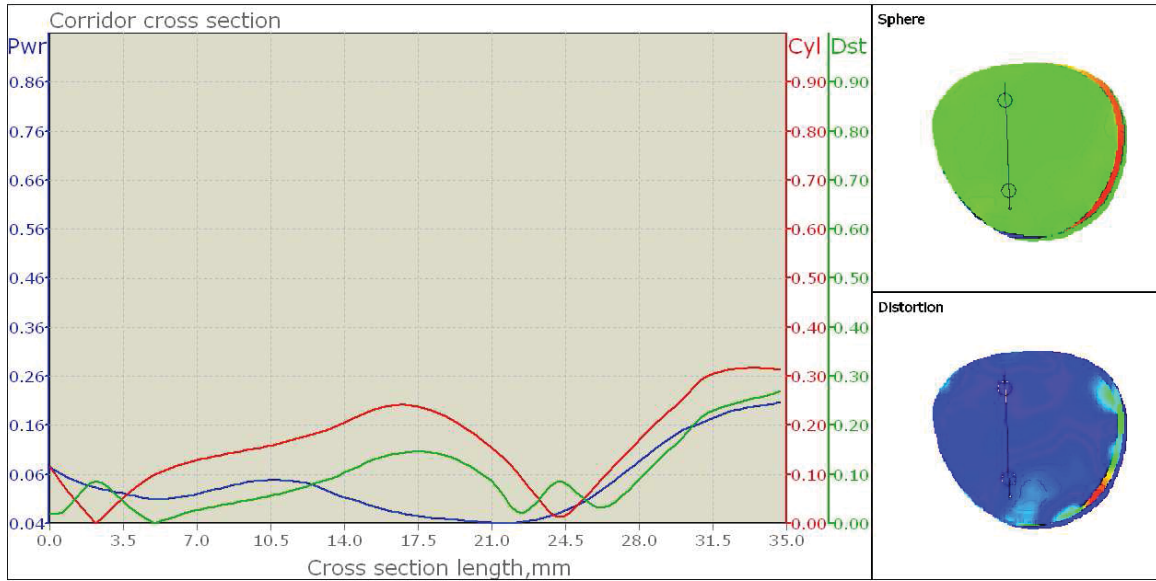
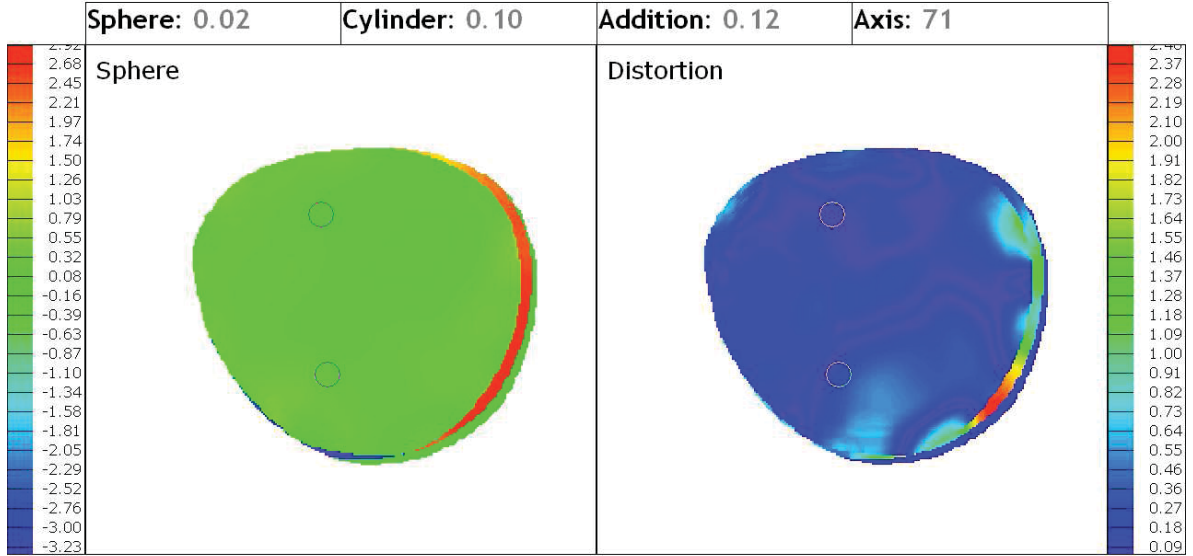


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX J

TWIN CITY OD VS VISION CRAFT OD COMPARISON MAP

### TWIN CITY OD VS. VISION CRAFT OD

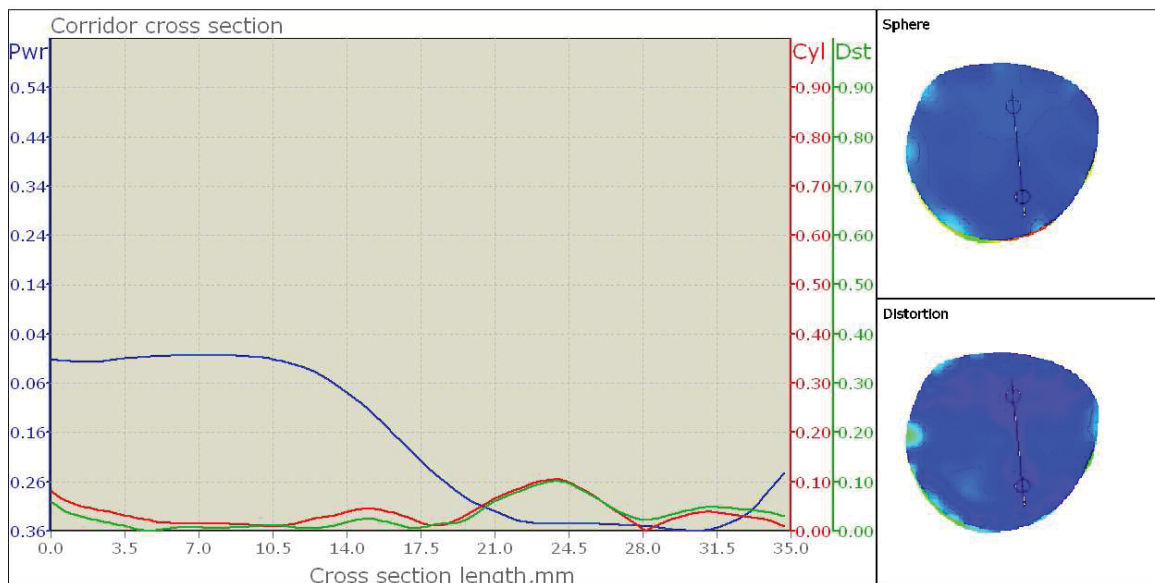
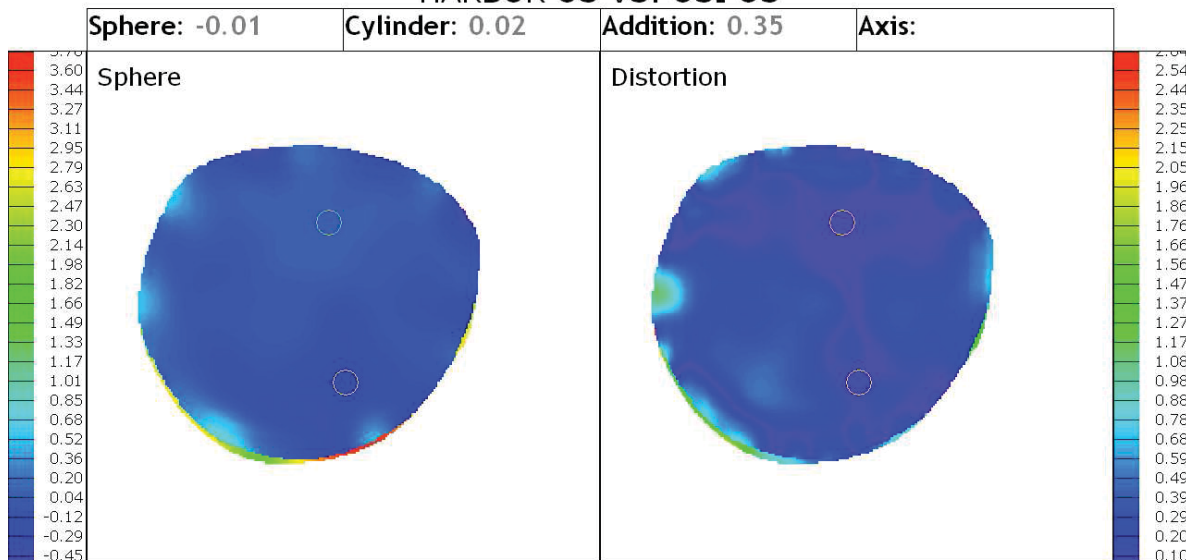


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX K

HARBOR OS VS OSI OS COMPARISON MAP

### HARBOR OS VS. OSI OS



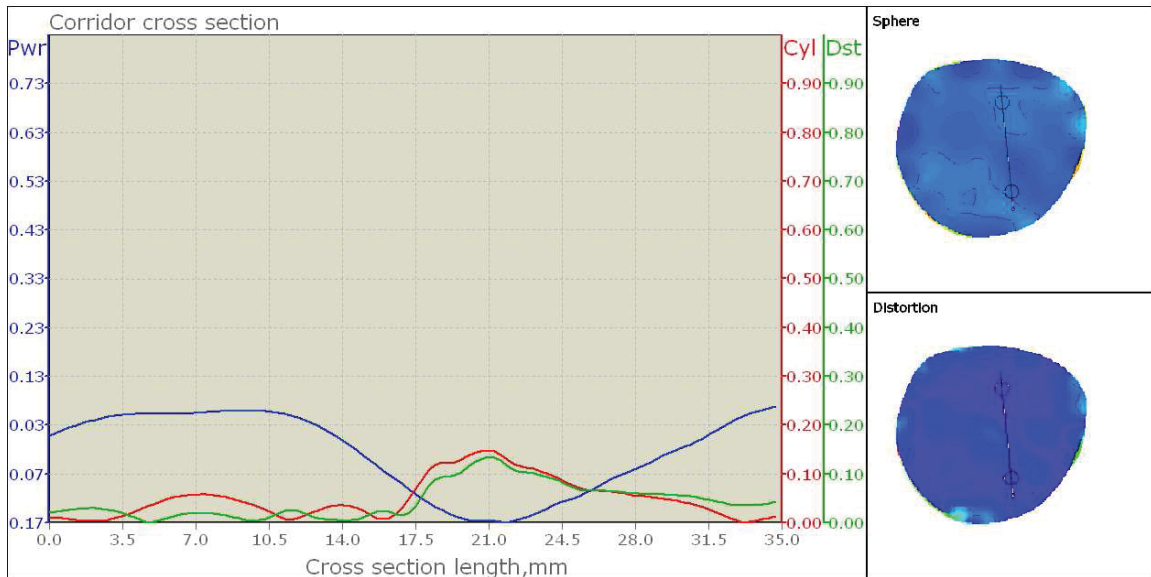
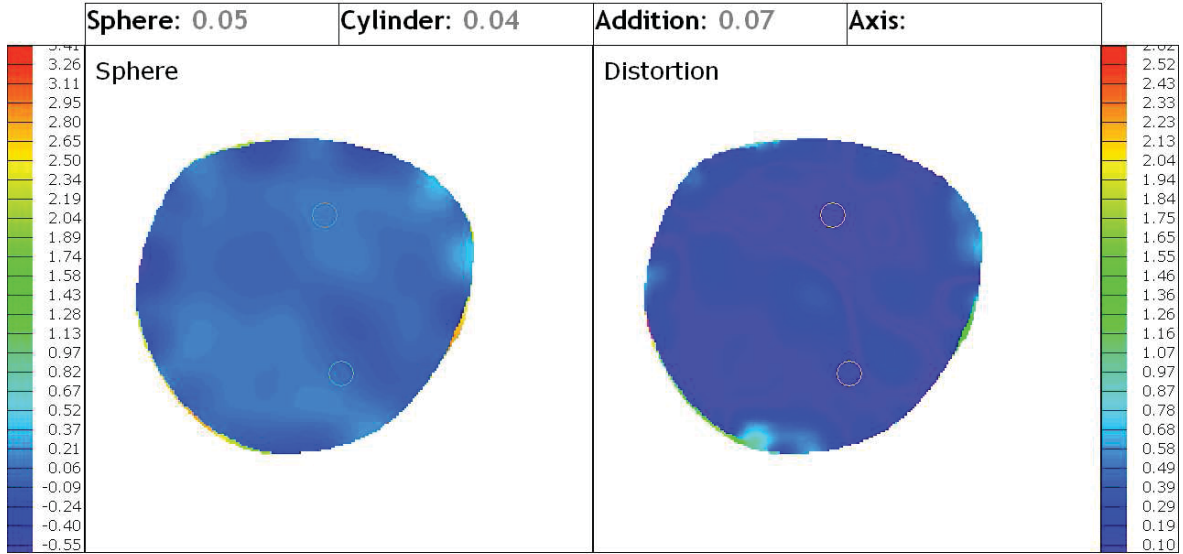
*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX L

HARBOR OS VS SODERBERG OS COMPARISON MAP



## HARBOR OS VS. SODERBERG OS

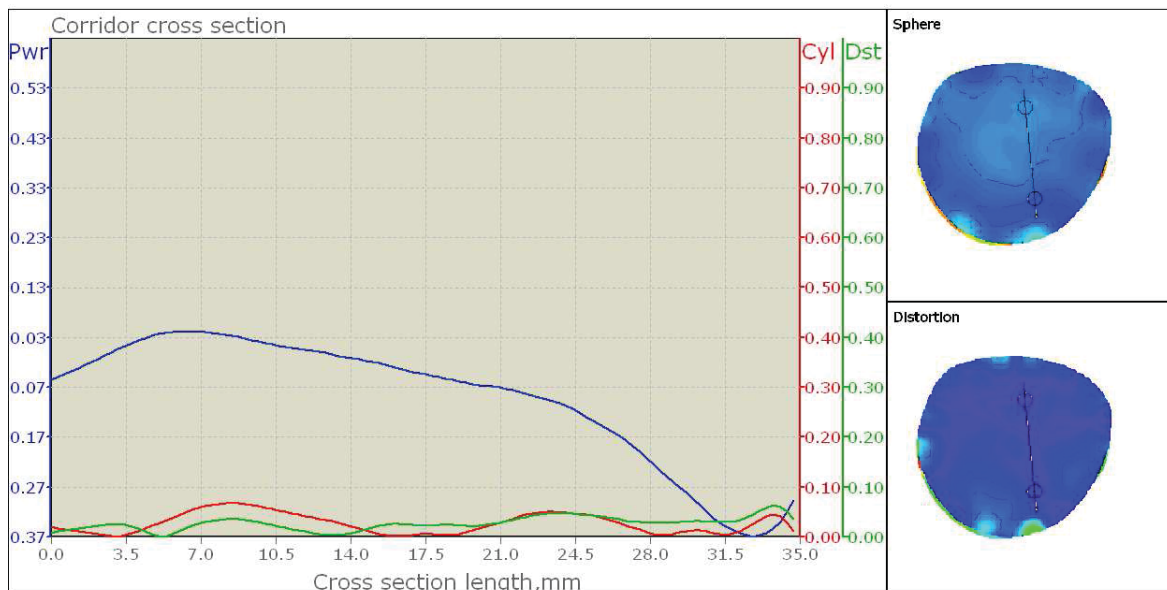
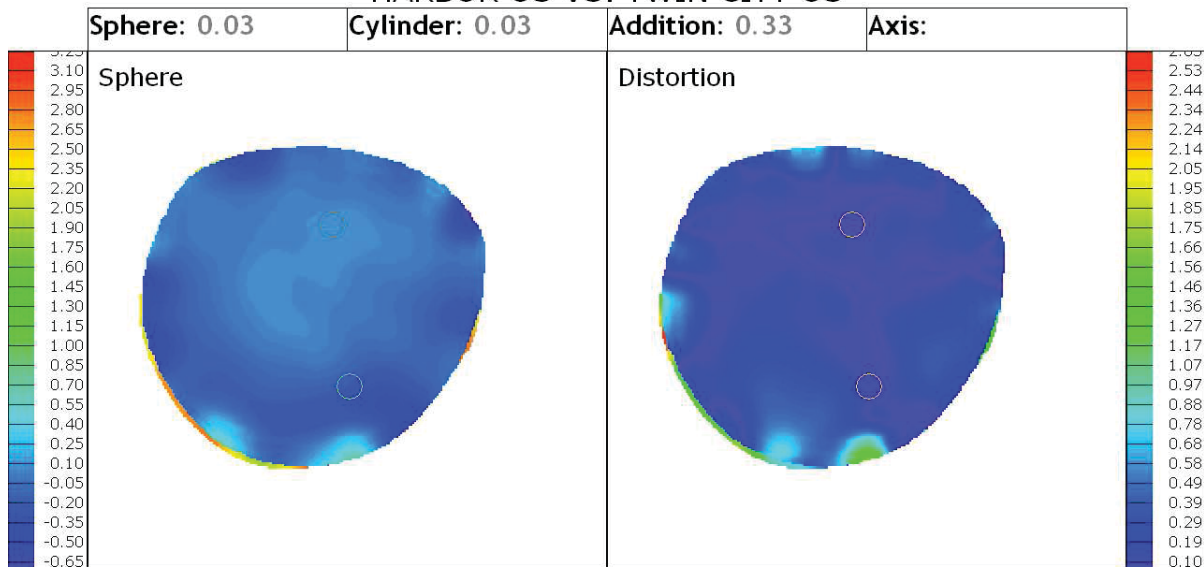


*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX M

HARBOR OS VS TWIN CITY OS COMPARISON MAP

### HARBOR OS VS. TWIN CITY OS

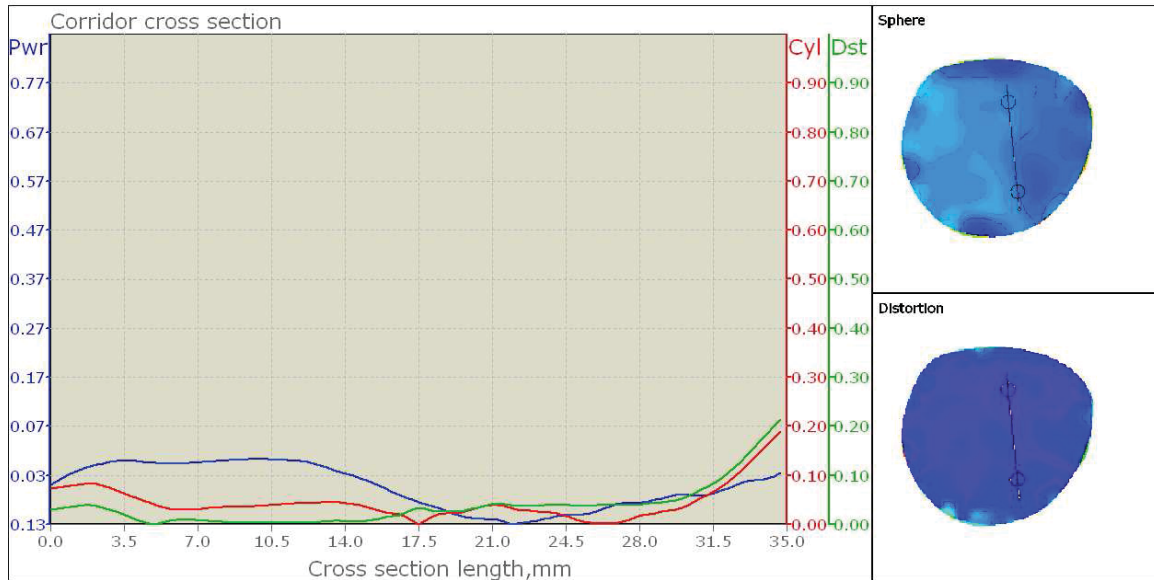
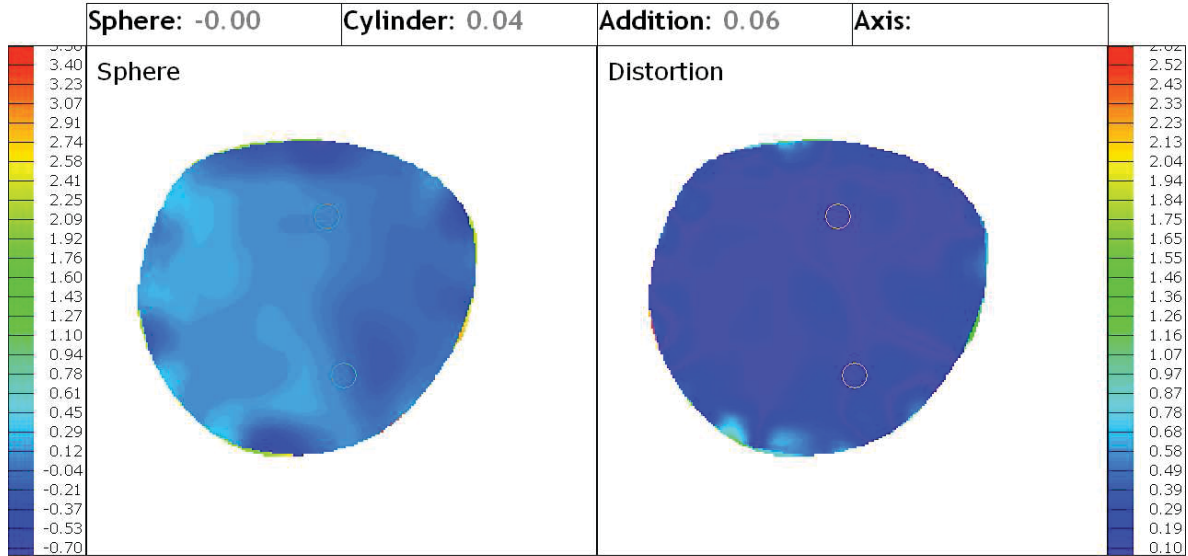


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info@rotlex.com*

APPENDIX N

HARBOR OS VS VISION CRAFT OS COMPARISON MAP

### HARBOR OS VS. VISION CRAFT OS

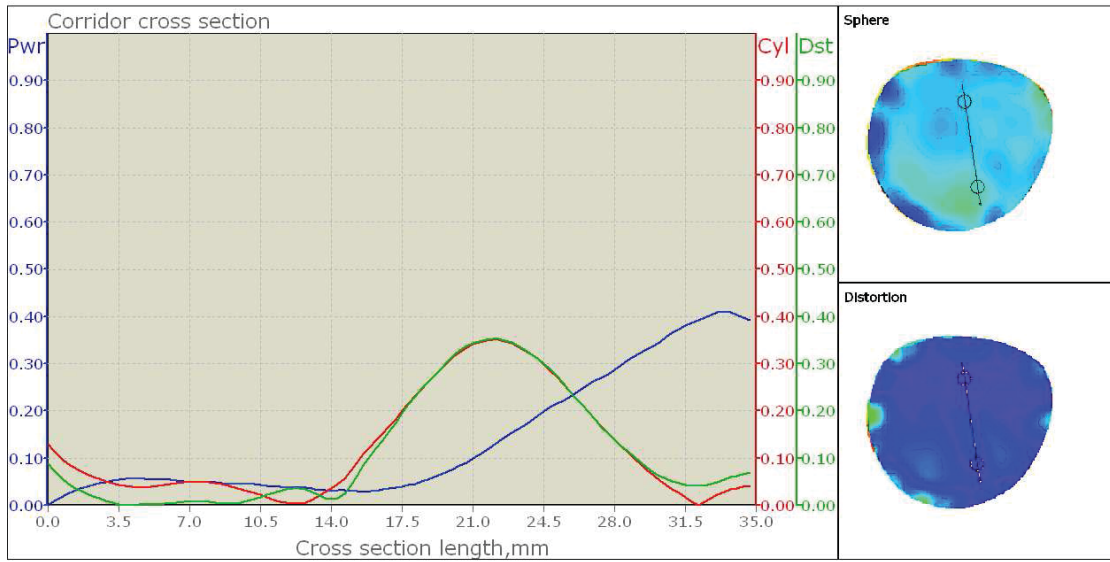
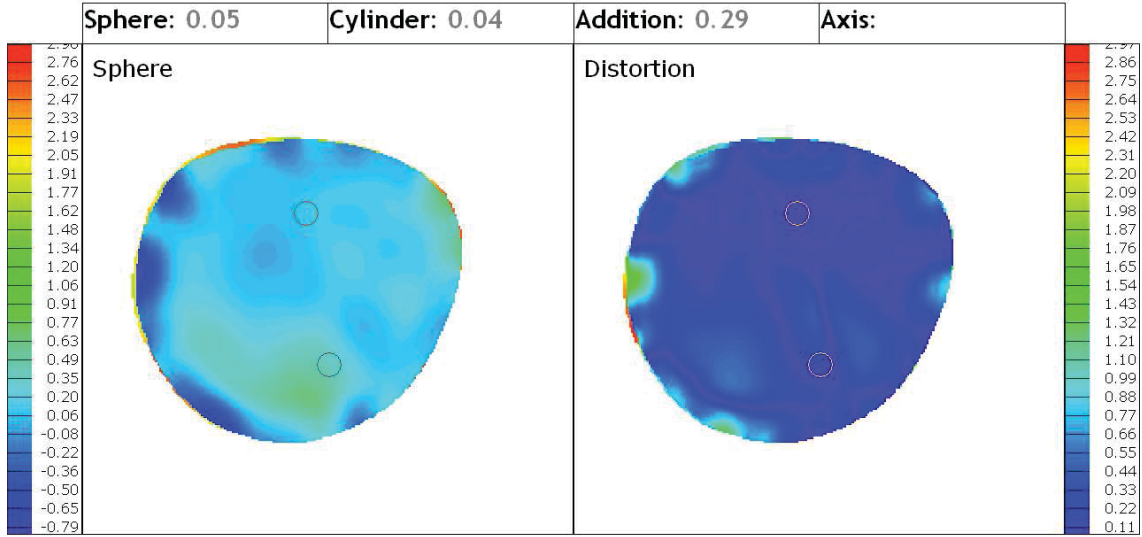


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info@rotlex.com*

APPENDIX O

OSI OS VS SODERBERG OS COMPARISON MAP

### OSI OS VS. SODERBERG OS



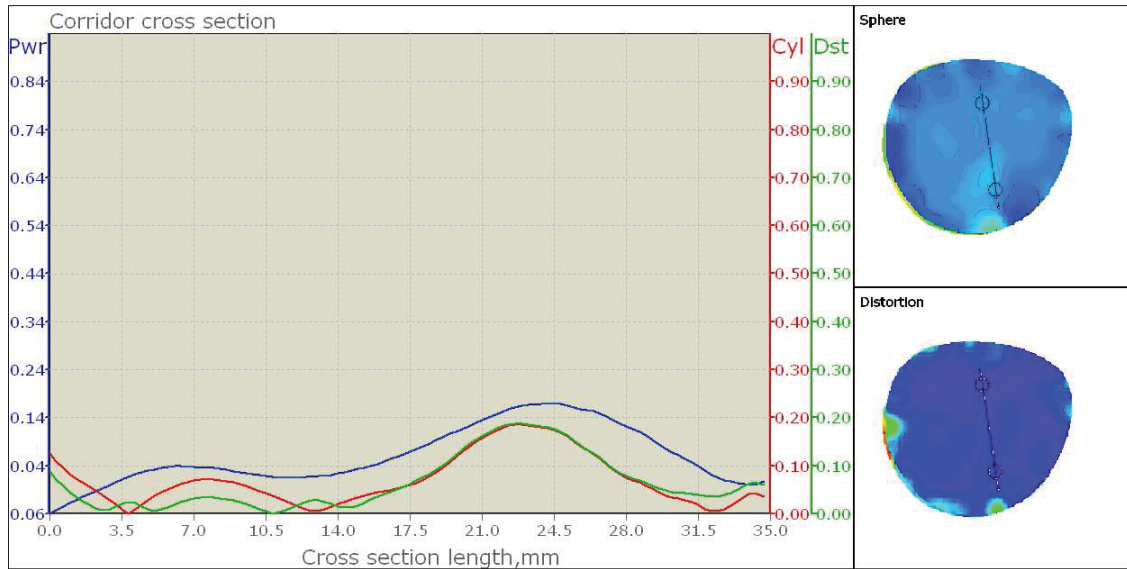
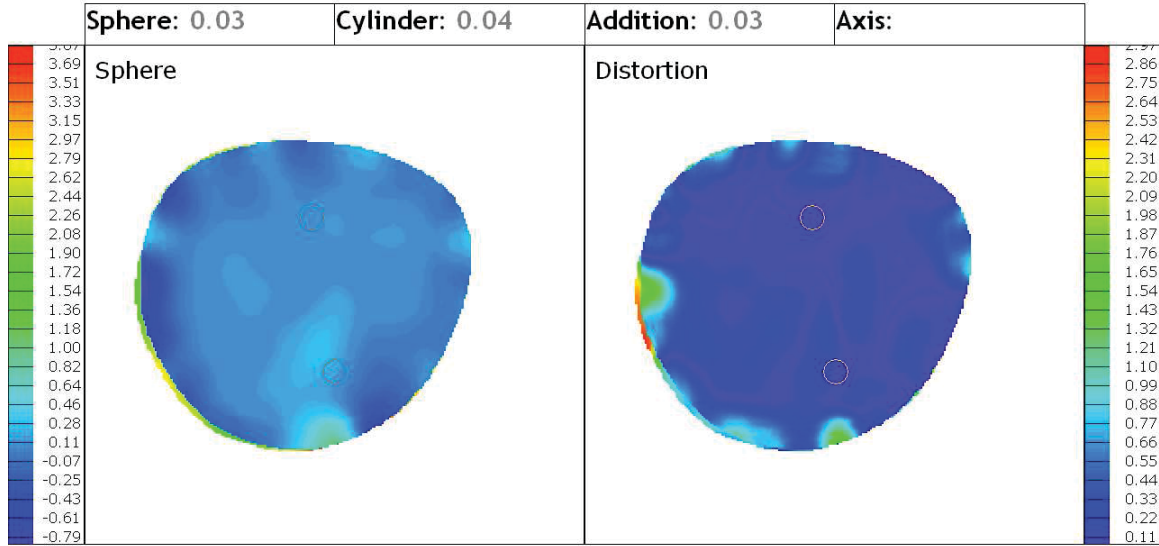
*Measured by Rotlex Class Plus  
info@rotlex.com*

APPENDIX P

OSI OS VS TWIN CITY OS COMPARISON MAP



### OSI OS VS. TWIN CITY OS

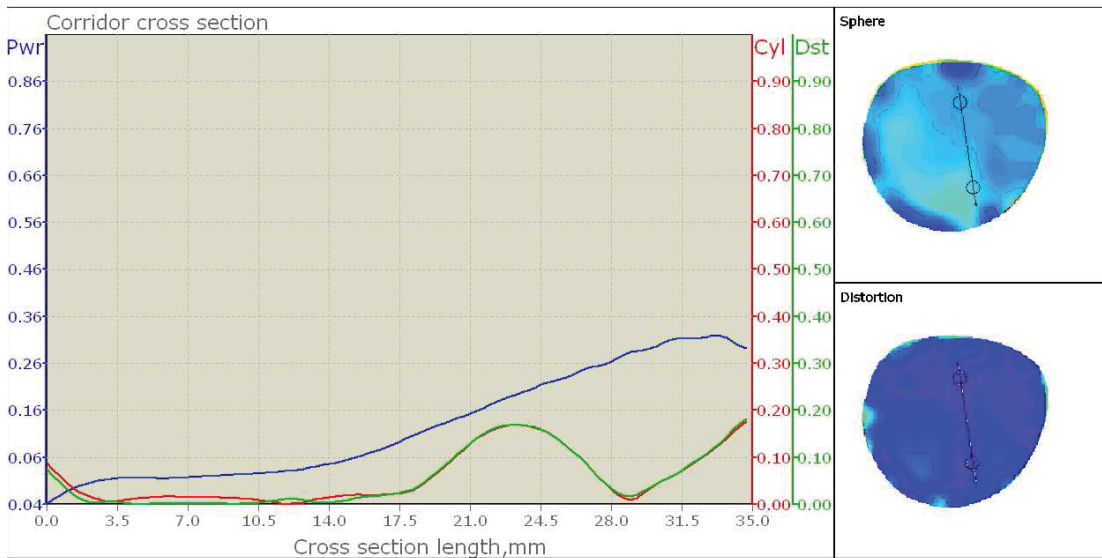
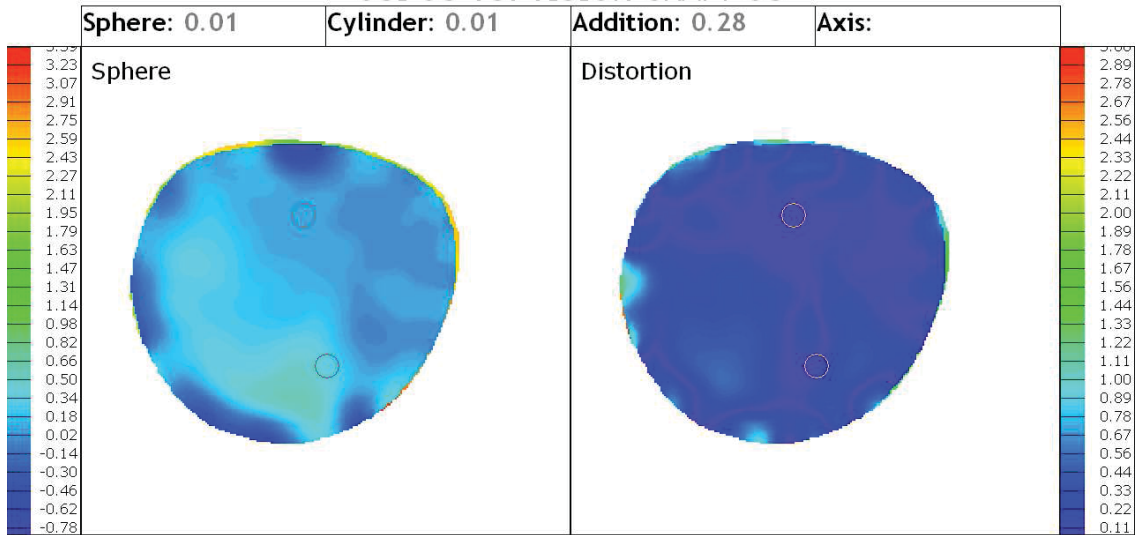


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info@rotlex.com*

APPENDIX Q

OSI OS VS VISION CRAFT OS COMPARISON MAP

### OSI OS VS. VISION CRAFT OS

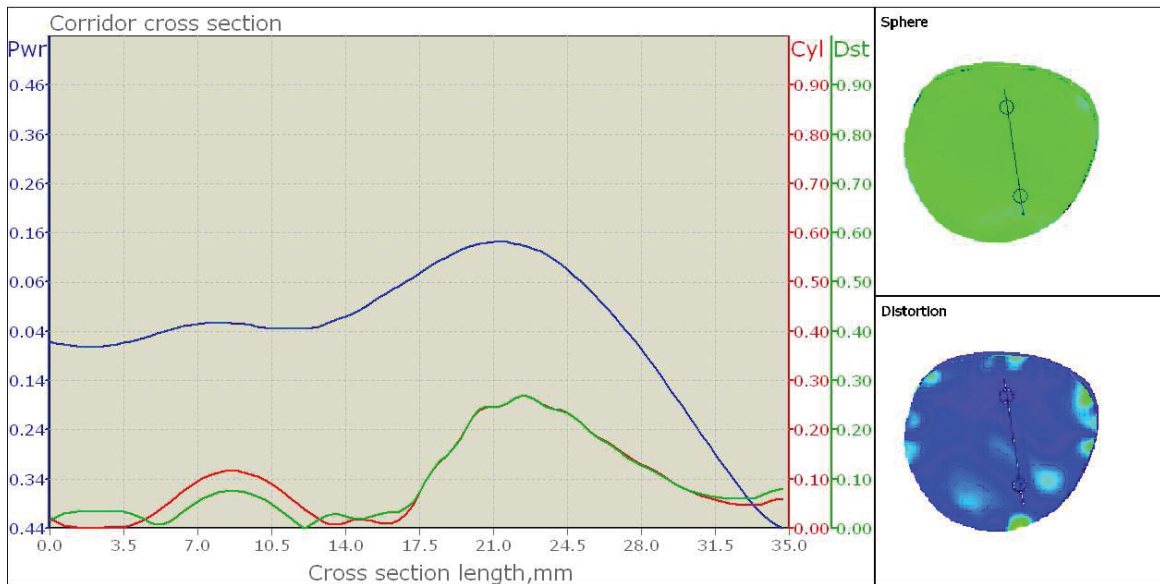
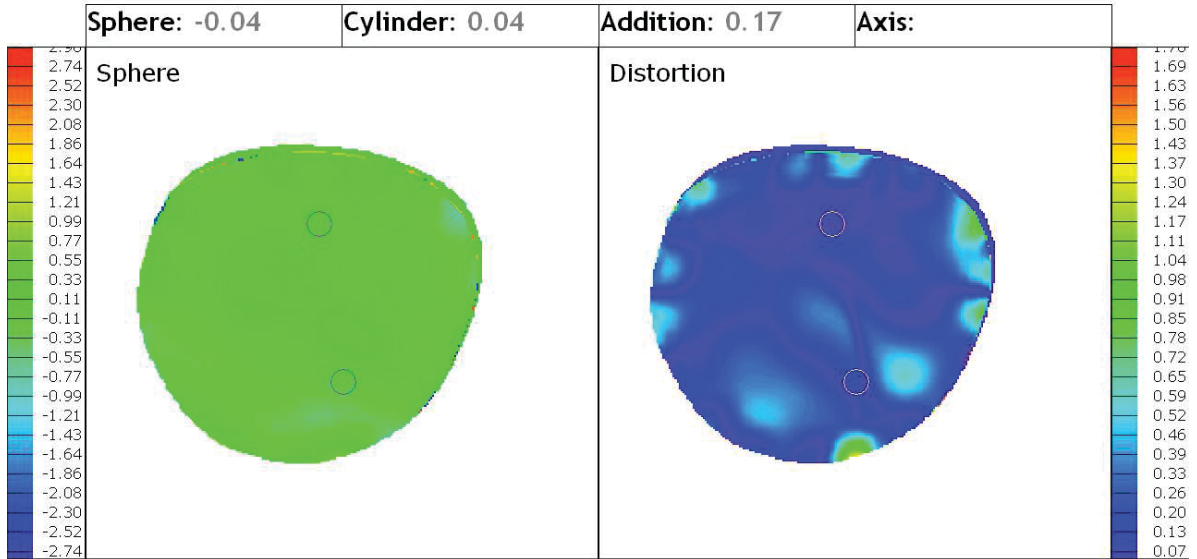


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APPENDIX R

SODERBERG OS VS TWIN CITY OS COMPARISON MAP

### SODERBERG OS VS. TWIN CITY OS

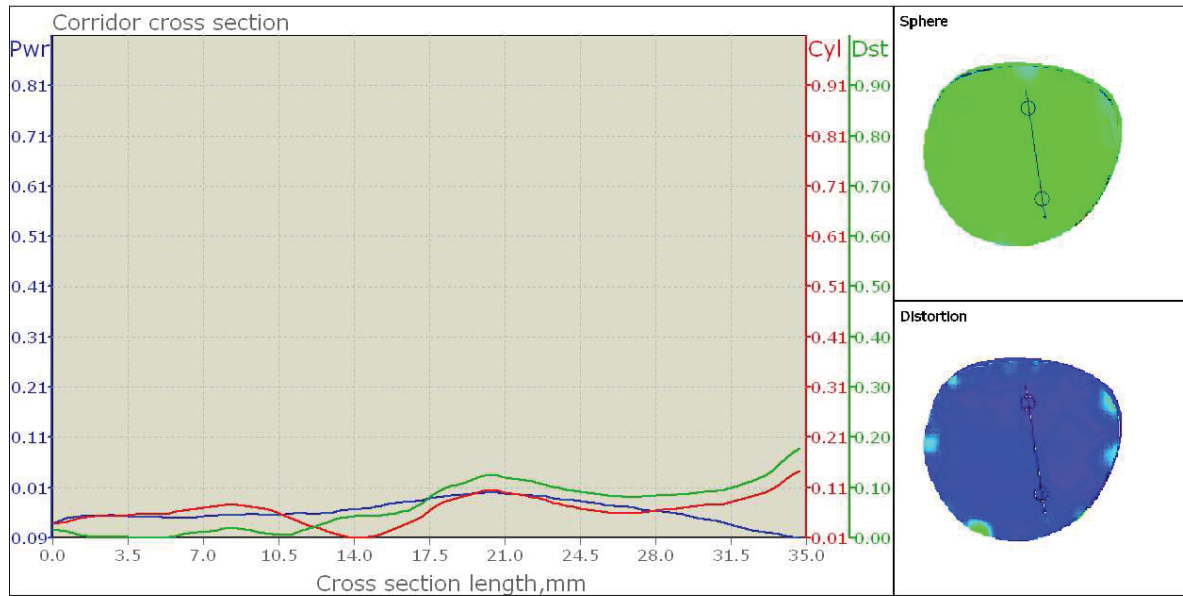
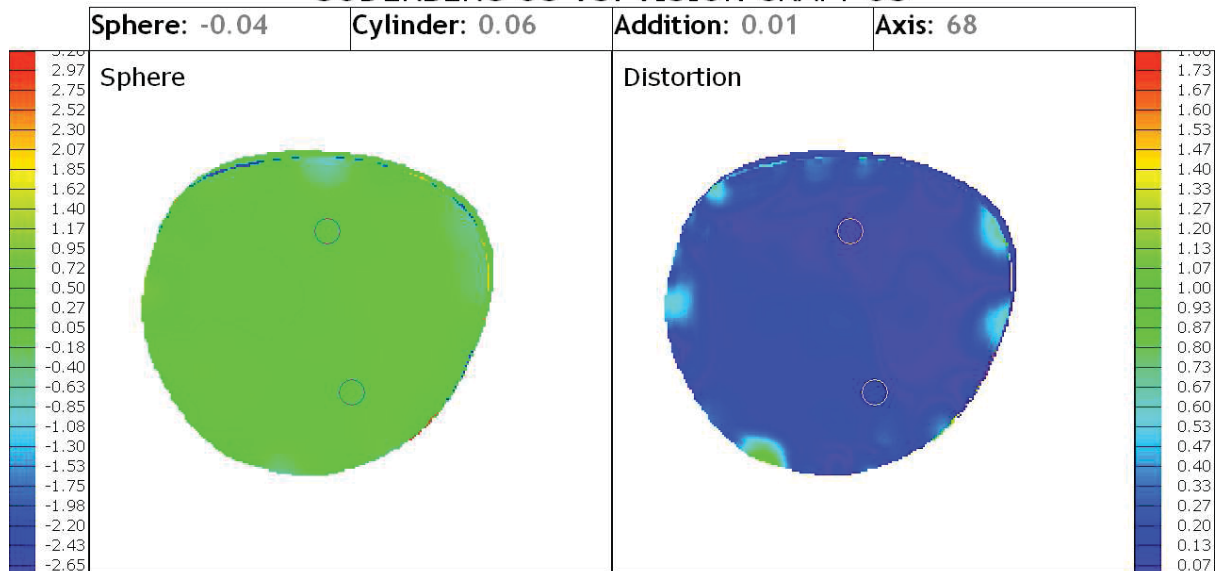


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APPENDIX S

SODERBERG OS VS VISION CRAFT OS COMPARISON MAP

### SODERBERG OS VS. VISION CRAFT OS



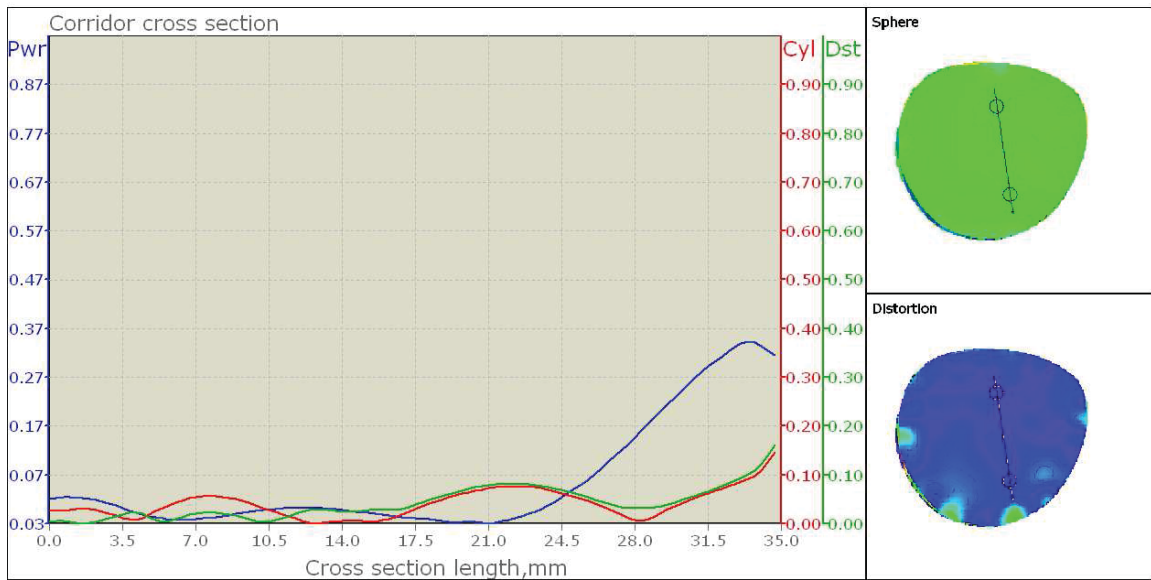
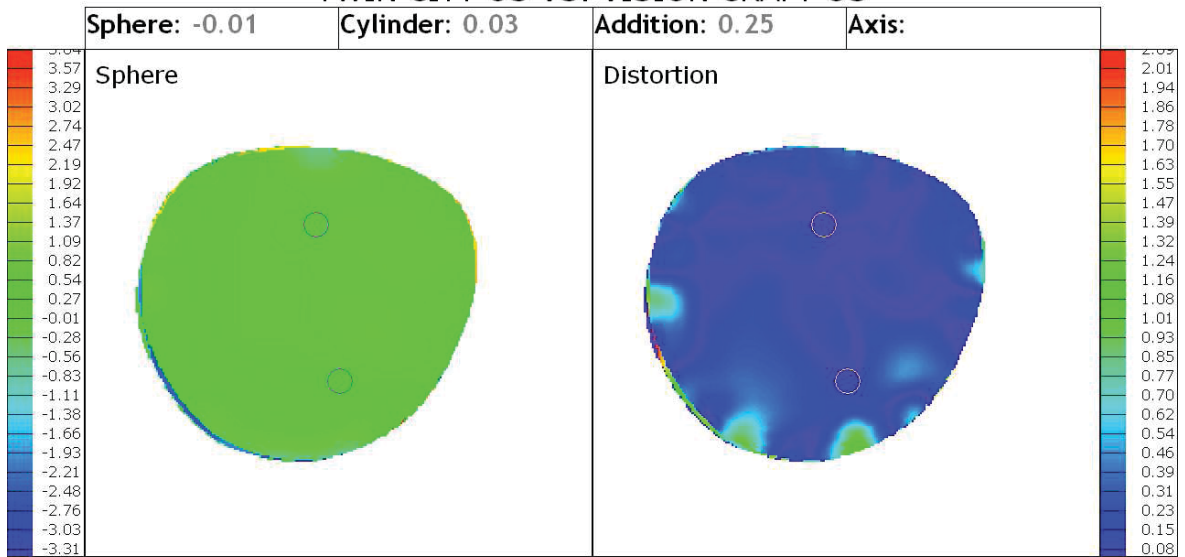
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info@rotlex.com*

APPENDIX T

TWIN CITY OS VS VISION CRAFT OS COMPARISON MAP



TWIN CITY OS VS. VISION CRAFT OS



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