# AUTOREFRACTION COMPARED TO SUBJECTIVE REFRACTION – A LITERATURE REVIEW

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

Doctor of Optometry

Ferris State University
Michigan College of Optometry

May, 2017

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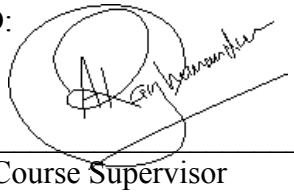
Has been approved
31 May, 2017

APPROVED:

Faculty Advisor:

ACCEPTED:



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AUTOREFRACTION COMPARED TO SUBJECTIVE REFRACTION – A LITERATURE REVIEW

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Date

ABSTRACT

*Background:* Autorefraction is ubiquitous throughout the optometric profession, as it aids in the managing and prescribing of refractive error correction for patients. Subjective refraction is currently the gold standard for measurement of refractive errors, but autorefraction continues to evolve with advancements in technology. The goal of this review was to assess studies done on the general accuracy and precision of autorefraction technology and how it compares with the conventional subjective refraction. Included in this review were studies involving the different types of features that can be incorporated into autorefractors, such as wavefront analysis, portability, and open-view construction. Also discussed are studies that assess newer automated refractive technologies, which includes portable videorefractors and smartphone-based autorefractors. *Methods:* A literature search was performed using PubMed and the Ferris State University Flite Library databases regarding the validity of autorefraction. Studies that were published within the past twenty years and that compared autorefraction to subjective refraction were selected and reviewed. *Results:* Content analysis showed that there is no consistent data to support the replacement of subjective refraction with autorefraction. However, the studies assessed indicate that variability in autorefraction accuracy and precision is based on many factors, including: refractive error type, age of the subject, use of mydriatics, and type of autorefractor used. *Conclusions:* Autorefraction is not ready to take the place of subjective refraction due to the inadequate evidence available to support their accuracy

and precision as acceptable alternatives. This is largely based upon the studies' significant differences in accuracy when autorefraction is compared to subjective refraction and their lack of evaluating the refractive methods in clinically relevant settings. However, autorefractors may be useful in certain situations and settings when subjective refraction is unavailable.

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# CHAPTER 1

## INTRODUCTION

Tabletop and handheld autorefractors (ARs), also called automated refractors, are widely used in today's optometric practices for aiding in the determination of a patient's refractive error. ARs can quickly and easily provide objective refraction measurements, which typically serve as a starting point for subjective refraction (SR). Optometrists conventionally accept SR as the gold standard method for determining refractive errors, as patients are most likely to accept its values for their spectacle prescriptions (Goss & Grosvenor, 1996). That being said, autorefraction technology is continuously evolving; there are emerging models of ARs on the market that include additional, more advanced features that constantly are changing the way ARs evaluate refractive error.

There are many AR models on the market; however, there is not just one study that evaluates all of them against each other and against SR. The goal of this literature review is to overview a selection of various studies done on the general accuracy and precision of AR technology. This review looks at studies that use different types of technology incorporated into ARs, such as wavefront analysis, portability, and open-view construction. Also discussed are studies that assess the more recent automated refractive technologies, which include portable videorefractors and smartphone-based autorefractors. The literature analysis will be broken into parts, exploring separate themes

by drawing conclusions and insights from various studies that are relevant to each section. This review evaluates current literature regarding the effectiveness and capability of ARs and how they can best be utilized within the field of optometry.

# CHAPTER 2

## METHODS

An accumulation of current and historical literature was performed using PubMed and the Ferris State University Flite Library database. Relevant articles that were published within the past twenty years and contained a comparison of autorefraction to SR were selected and reviewed. Studies were excluded if they utilized subjects affected by a surgical or medical procedure(s), if they only assessed the precision aspect of ARs, or if they did not directly compare refractive error measurements determined by both autorefractive and subjective methods. After all possible literature was found, pertinent information from the studies were reviewed and summarized.

# CHAPTER 3

## TRADITIONAL AUTOREFRACTORS

The use of autorefraction is widespread throughout the optometric field. However, the term “autorefractor” is very broad. These devices vary widely in their capabilities and modes of function. The first part will be a look at the general accuracy and precision of closed-view, traditional autorefractors. These types of autorefractors require the patient to look into a tabletop supported machine, which then takes monocular measurements. These particular models are not mobile and do not used advanced wavefront analysis.

Researchers (Hashemi, Khabazkhoob, Asharlous, Soroush, & Yekta, 2015) in the Tehran Eye Study used an AR on 3,482 subjects to compare cycloplegic autorefraction with SR. SR was performed before cycloplegia; all AR measurements were cycloplegic and thus taken after 1% cyclopentolate was instilled. The AR utilized was the Topcon KR-8000. The mean spherical equivalent (MSE) was calculated for each refractive method and amounted to 0.31 ± 1.80 diopters (D) for cycloplegic autorefraction and -0.32 ± 1.61 D for SR. The 95% limits of agreement (LoA) between both methods ranged from -0.40 to 1.70 D for all subjects. The 95% LoA was further assessed for emmetropic, myopic, and hyperopic groups and determined to be -0.16 to 0.91 D, -0.53 to 0.91 D, and -0.10 to 1.80 D, respectively. The 95% LoA became tighter for subjects who were both myopic and greater than 20 years old. The researchers concluded that due to the SR’s

decreased sensitivity in detecting hyperopia, especially within the 5-10 year age range, that cycloplegia can be necessary in order to achieve an accurate prescription and to reduce the likelihood of developing amblyopia or other binocular conditions.

Jorge, Queirós, Almeida, and Parafita (2005) measured the agreement amongst the Nidek ARK-700A AR, retinoscopy, and SR. In this study, 192 eyes of subjects ranging in age from 18 to 34 years old were evaluated without cycloplegia. The refractive data was analyzed in component parts using Fourier analysis (with MSE as "M" and astigmatism in vectored forms as $J_0$ and $J_{45}$) and evaluating the percentage of accuracy. The mean refractive values (D) of SR subtracted from AR for M, $J_0$, and $J_{45}$ were -0.44, 0.05, and -0.02, respectively. The mean refractive values (D) of SR subtracted from retinoscopy for M, $J_0$, and $J_{45}$ was -0.02, 0.07, and -0.01, respectively. The spherical powers for autorefraction and retinoscopy were within ±0.25 D of SR about 44.3% and 74.5% of the time. The cylinder power of AR and retinoscopy was within ±0.25 D about 89.6% and 96.9% of the time. The axis of AR and retinoscopy was within $\pm 10^{o}$ of the SR results 55.2% and 65.6% of the time. Overall, this study shows that retinoscopy has a higher agreement with SR than autorefraction, making it more accurate and a better starting point for the SR.

Asiedu, Kyei, and Ampiah (2016) also had similar results when they assessed the refractive errors from ARs, retinoscopy, and SR findings. In their study, autorefraction and retinoscopy measurements were assessed and compared with SR findings for

spherical equivalent and astigmatism. There were 36 subjects with a mean age (SD) of 28 +/- 16.5 years. An optometrist performed retinoscopy and was masked to any AR findings. The same Humphrey Zeiss 599 autorefractor/keratometer was used on all subjects. The mean differences amongst retinoscopy, AR, and SR for the MSE were statistically insignificant. However, only retinoscopy produced total astigmatism that "substantially agreed" with subjective refraction total astigmatism, and it was also much more accurate at predicting the cylinder axis than the AR. As a result, Aseidu et al. (2016) concluded that "only retinoscopy may satisfactorily replace subjective refraction when subjective refraction is not applicable" (p. 5).

In a study conducted by Elliot, Simpson, Richter, and Fonn (1997), the repeatability of refractive error measurements were assessed for the Nikon NRK-8000, Nidek AR-1000, and conventional SR. The accuracy of the Nikon and Nidek ARs were also evaluated in comparison to SR. The right eyes of thirty subjects (age range of 22 – 85) were assessed; the range of ametropia was +2.25 to -7.75 D with up to -4.00 D of astigmatism. Potential subjects with disorders affecting the best-corrected visual acuity (BCVA) and/or function of vision were excluded from this study. The repeated measurements were taken on a separate occasion (at least 24 hours apart) by the same examiner. Elliot et al. (1997) determined that each method demonstrated a small variation in repeated measurements, which may have been influenced by factors such as "changes in fixation, pupil diameter, accommodation, and diurnal variations that are inherent in an

optical system" (p. 438). Overall, subjective refraction was the most repeatable method, and the Nidek was the more accurate of the two ARs. Both ARs could provide reasonably accurate refractions of normal eyes within the study's determined limits.

Similarly, Pesudovs and Weisinger (2014) also compared then accuracy of two ARs with SR. Data was collected from 190 subjects using either the Nidek ARK-700A, the Topcon KR-8000, and SR. SR was performed prior to autorefraction to maintain masking, and only one eye per subject (chosen at random) was included in the study. Using a Bland-Altman analysis, they determined that the SR and ARs gave similar results for the mean spherical equivalent (MSE). Although the difference between the MSE was "significantly different" between the two ARs, the actual value was only 0.14 D. Despite having similar median scores for astigmatism, major outliers with the ARs were more likely with Topcon, suggesting a small advantage with the Nidek for avoiding large astigmatic errors. The authors concluded that refraction alone, whether subjective or automated, does not substitute for prescribing. Rather, "…the latter involves a thought process that considers the previous prescription, the likelihood of the new prescription being tolerated, the needs of the patient, and so on" (p. 557).

Joubert et al. (1997) compared the readings from an Allergan Humphrey Model 580 AR to SR on 50 subjects separated into five age groups. Group one consisted of subjects between 1 and 10 years old, group two was 11 to 20 years old, group three was 21 to 30 years old, group four was 31 to 40 years old, and group five was subjects over

41 years old. The results showed an excess AR reading of -0.25 -0.18 x 180 in group one. The spherical component increase by approximately 0.1 D per group while the cylindrical power excess stays constant. The standard deviation of refractive error measurements also tend to decrease as the age increases. The AR results were statistically different compared to SR for the different age groups, showing that the AR measurements were not as accurate as SR measurements.

The studies mentioned so far formulate their reasoning from a limited number of traditional, tabletop ARs included in their study design. The extent to which general deductions can be applied for other ARs is not completely addressed by any particular study. However, there are themes that can be drawn from them. First of all, none of the studies regarding tabletop autorefractors state or support that autorefraction is a substitute for SR. In fact Pesudovs and Weisinger (2014) did not believe that refraction alone, whether subjective or objective, could substitute for prescribing. Instead, they stated that "…the latter involves a thought process that considers the previous prescription, the likelihood of the new prescription being tolerated, the needs of the patient, and so on" (Pesudovs & Weisinger, 2014, p. 557).

In the study by Hashemi et al. (2015), they found that cycloplegic AR and non-cycloplegic SR had similar results in the general population. The results showed a MSE difference between AR and SR values to be about a +0.60 D difference. Also, as the age increased, the amount of variance between AR and SR results narrowed. However, one

weakness of this study was a comparison between non-cycloplegic SR and cycloplegic AR. This is not clinically equivalent. For any patient that has latent hyperopia, cycloplegia will bring that out and ultimately result in a more positive refractive error. It is worth noting that the type of refractive error changed the limits of agreement, or range of difference; for example, myopic subjects showed the narrowest LoA compared to hyperopic subjects. .

Joubert et al (1997) agreed with Hashemi et al. (2015) on an increased agreement between AR and SR findings as the subject becomes older. Joubert et al. (1997) looked at the agreement of AR and SR between different age groups without cycloplegia. The older the population, the better the agreement. This is most likely due to a weaker accommodative system preventing the subject from overcorrecting their eyes or inducing "instrument myopia." This may lead one to question if the AR and SR results from Hashemi et al. (2015) would have been as similar if both of the refractive measurements were performed on cyclopleged subjects.

The majority of these studies seem to agree with the AR's refractive error measurements as being a great starting place when determining a final spectacle prescription. Aseidu et al. (2016) and Pesudovs et al. (2014) found that the mean spherical equivalent was reasonably agreeable between AR and SR. Jorge et al. (2005) and Elliot et al. (1997) found that the spherical components of the refractive error determined by AR to be in close agreement with the SR. However, the AR's cylinder

power and axis components were not as agreeable with SR. Since retinoscopy proved to be more adept at locating the cylinder power and axis than ARs, the majority of the studies believed retinoscopy to be a more reliable and accurate objective method.

Precision, or repeatability of measurements, is another factor that can be examined by these studies. Bullimore et al. (1998) studied the repeatability of refraction with the Hoya 570 AR and compared its results to conventional SR. Two optometrists examined each of the 86 recruited subjects from ages 11-60. Throughout a period of two months, each subject participated in a one hour session where both types of refractions were performed in a randomized order. The examiners were masked to the subjects' spectacle prescriptions and to all AR results. For the MSE, the average difference between the two sets of AR recordings was +0.01 D and 95% LoA of -0.36 to +0.40 D; the difference for the two clinicians in subjective refractions was -0.12 D and 95% limits of agreement -0.90 D to +0.65 D. They summarized that the automated refraction is more repeatable than clinician refraction for both spherical and cylindrical components. However, the validity of each method was not addressed. For further research, allowing the subjects to assess their quality of vision with each prescription could be a viable way for determining validity.

# CHAPTER 4

## OPEN-VIEW AUTOREFRACTORS

Following the emergence of traditional, tabletop AR, newer models soon were being manufactured that allowed binocular, open-viewing. These open field-of-view instruments allow clinicians and researchers to use external targets of their choosing placed at any distance (Gwiazda and Weber, 2004). This is done with the intention of removing any "instrument myopia" that may be seen from closed-view ARs with targets placed at a fixed distance.

One of the oldest models for open-view ARs, the Canon R-1, was first manufactured in 1981. Twenty years later in 2001, a newer model called the Grand Seiko WR-5100K emerged. Gwiazda et al. (2004) compared the results of refractions obtained with these two open-view ARs in addition to those obtained from the more traditional, closed-field Nidek ARK-700A. Subjects for this study were 50 adults with ages ranging from 17 to 59 years. The MSEs obtained from each AR were -2.66 D with the Nidek, -2.44 D with the Canon, and -2.01 D with the Grand Seiko. In addition, the mean absolute values for differences in cylinder power between each pair of ARs was analyzed; they showed that the Nidek and Grand Seiko had the greatest similarity, with 46/50 eyes (92%) with a difference of less than or equal to -0.25 D. Only 21/50 (42%) and 20/50 (40%) eyes had this small of an amount when comparing the differences between the

Canon - Grand Seiko and the Canon – Nidek. Gwiazda et al. noted that Canon's differences in astigmatism was likely because it "…relies on measurements from only three axes separated by 60° intervals, whereas the Nidek ARK-700A measures along each degree for a full sweep of 180°, and the Grand Seiko WR-5100K uses image analysis techniques that can track moderate changes in eye position" (p.60).

The Grand Seiko WR-5100K was assessed again in a study done by Davies, Mallen, Wolffsohn, and Gilmartin (2003), who compared its validity and repeatability with SR. This was done on 99 subjects (198 eyes) who ranged from 18 to 60 years old. To assess the Grand Seiko's intersession repeatability, its measurements were taken at two different sessions. The results for assessing its accuracy in comparison with SR determined that approximately 50% of the Grand Seiko's measures were with 0.25 D of the spherical component and 85% within 0.50 D. The intersession repeatability illustrated that approximately 95% of the second visit's refractive findings were within 0.50 D of the initial visit's findings. The authors of this study felt that given its accuracy and reliability, the Grand Seiko would make a valuable addition to the objective instrumentation that was currently available.

Mallen, Wolffsohn, Gilmartin, and Tsujimura (2001) did a similar study where they compared the Grand Seiko against SR for precision and accuracy. The population studied ranged in age from 18 to 58 years old with 74% under the age of 26 years of age. Two-hundred eyes were tested. The investigators tested the accuracy of the Grand Seiko

to SR and the repeatability of measurements of the Grand Seiko over two visits. The average spherical component measured with the AR was more plus by 0.15 ± 0.46 D as well as the mean spherical equivalent by 0.16 ± 0.44 D. The percentages of readings within ± 0.25 and ± 0.50 D of the SR were also calculated. The measured spherical component with the Grand Seiko was within ± 0.25 D and ± 0.50 D 43% and 78% of the time while the cylinder measurement was within the same ranges 47% and 81% of the time. The axis power was reported to be less reliable but improved if cylinder powers ≥-0.75 D were analyzed. The cylinder axis of all prescriptions read were within ±05 $^{o}$, ±10 $^{o}$, ±15 $^{o}$, and ±20$^{o}$ of the SR axis 21%, 40%, 58%, and 65% of the time. If only cylindrical prescriptions ≥-0.75 D are analyzed, the percentages were 29%, 57%, 80%, and 88%.

The studies reviewed show that open-viewing ARs, particularly the Grand Seiko WR-5100K, demonstrated less myopic readings in comparison to other ARs. This was the case in Gwiazda et al. (2004), where the Grand Seiko showed less minus (more plus) readings compared to both the Canon R-1 and the Nidek 700A. The Mallen et al. (2001) study also showed that its readings, on average, were more plus for both spherical and cylindrical components in comparison to SR. The inter- and intrasession repeatability of the Grand Seiko seemed to fare well, with improved repeatability if the cylindrical component was ≥ -0.75 D (Davies et al., 2003). Most of the examiners agreed that the Grand Seiko could be a valuable addition, but not worthy of substituting with conventional subjective refraction.

# CHAPTER 5

## HANDHELD AUTOREFRACTORS

There were studies done to evaluate another type of ARs, which are referred to as "handheld" ARs. Unlike their table-mounted counterparts, these ARs are portable and have the capability to be used in settings outside of a clinic or laboratory (Farook et al., 2005).

The Retinomax was one of the first handheld ARs available. The original Retinomax is a monocular autorefractometer; the Retinomax K-Plus series is a newer model that also acts as an autokeratometer (Wesemann and Dick, 2000). In their study, Wesemann et al. assessed the accuracy of measurements obtained by the Retinomax and its ability to relax accommodation. They divided their assessment into two groups of subjects, based upon age: Group 1 consisted of 50 young adults (100 eyes) with ages 24 through 29, Group 2 was 67 children (129 eyes) with ages 2 through 12. The young adults were not cyclopleged; the children were cyclopleged, but only after initial non-cycloplegic measurements were obtained. The cycloplegia was administered with 1% cyclopentolate for children older than 3 years and with 0.5% atropine for those in the 2 -3 year age range. The readings of the Retinomax were compared with subjective refraction of the young adults and with cycloplegic retinoscopy of the children. Results from the group of young adults showed that a difference in mean spherical equivalent, cylinder

component, and cylinder axes "….were not larger than 0.50 or 0.62 in 87 – 95% of all cases" (p.68). The handheld AR had good reliability for the young adults and the children under cycloplegia, and it was comparable to that of conventional tabletop instruments in terms of accuracy. Without cycloplegia, however, a substantial minus overcorrection ("instrument myopia") was found in all children, especially those younger than the age of four. Specifically, a minus overcorrection of 2.00 D was observed in 24% of cases; as a result, they determined that the Retinomax had reduced sensitivity and specificity in its methods for children without cycloplegia.

The Retinomax was used again in a pilot study conducted by Cliner et al. (2012), where it was compared with another handheld AR in order to assess their ability to detect significant vision disorders in preschool children. The Retinomax and the Palm Automatic Refractometer (Palm-AR) were used to screen 181 preschoolers ages 3 to 5; a comprehensive examination was done on a subsequent day by an optometrist or ophthalmologist and involved the following types of testing: cycloplegic retinoscopy, distance and near cover test and monocular threshold visual acuity (VA) using crowded HOTV optotypes on the Electronic Vision Assessment (EVA) system. Based on the results from the examination, the subjects were classified as having normal vision or one/more vision disorders (such as strabismus, amblyopia, reduced VA, significant refractive error, etc.). The vision disorders were grouped into four categories according to severity and importance of early detection. Sixty-five (35.9%) of the screened children

were classified as having one/more of the specified "vision disorders." The sensitivities for the Palm-AR and the Retinomax for detecting any of the targeted conditions were similar (74% and 78%, respectively) at 90% specificity and were the same (66%) at 94% specificity. Overall, the sensitivities for detecting refractive error were very similar between the two ARs at both levels of specificity. They felt that these results indicated that the Palm-AR and the Retinomax may both be useful instruments in a screening setting for preschool children.

Farook et al. (2005) evaluated the accuracy of the Retinomax and the tabletop mounted Topcon RM-8000 AR when compared to subjection refraction performed in a trial frame. There were 100 adults involved, and this study restricted subjects to only those correctable to 20/20 visual acuity. A Bland-Altman analysis was performed, which determined that the differences in the spherical equivalent measurements (D) between SR and Retinomax, the Topcon AR and Retinomax, and the SR and Topcon AR to be at 0.78, 0.63, and 0.15, respectively. This study found that the table mounted Topcon AR was in high agreement with SR, with only a 0.15 difference in spherical equivalent (M). The results for the handheld Retinomax are much less accurate, having a difference in M of 0.78 D compared to SR and 0.63 D compared to the Topcon AR. This is largely because the Retinomax read more minus compared to both the Topcon and SR. This study recommends that the Retinomax should not replace the Topcon AR nor SR in a clinical setting.

The Welch Allyn SureSight is another type of hand-held AR. Shimitzek and Wesemann (2002) did a study to assess the accuracy of the SureSight AR and the influence of accommodation on its results. SureSight is a handheld wavefront-based AR with a large working distance of 0.35 meters. It was used to assess 159 subjects (291 eyes) from 1 to 81 years old. To obtain information about its accuracy, all readings were compared to the results of cycloplegic retinoscopy. Cycloplegia was carried out by application of 1 drop of cyclopentolate 1% and a second drop 10 minutes later. In children younger than 3 years, tropicamide 5% was used in place of cyclopentolate. After a waiting period of 20 minutes, retinoscopy with handheld lenses and another measurement with the SureSight was performed. With cycloplegia, the difference in MSE for each method was less than 0.51 D for 68% of the values. Without cycloplegia, the difference in MSE was less than 0.51 Din only 33% of the values. Shimitzek and Weseman determined the SureSight AR to be "…less accurate than other conventional autorefractors. A benefit is its application in infants and disabled and uncooperative subjects" (p. 1668). Since 47% of the younger subjects (1through 17 years) were over-minused by more than 2.00 D, they suggested cycloplegia as a necessary step for younger patients.

Videtch, Jones, and Wrubel (2013) used the SureSight in their study when they evaluated the accuracy of the SureSight, the Retinomax, and the Topcon KR-8000 in comparison to SR. There were 126 refractive errors measured in subjects ranging from 18

to 33 years old. There were no ocular pathologies included in the study. The accuracy of spherical, cylindrical and axis component of the prescription to the SR results were analyzed. This study found the following results:

| Type of Refractive Error | Tabletop Autorefractor | SureSight | Retinomax |
|---|---|---|---|
| Spherical Power within ±0.50 D | 84.92% | 64.96% | 65.08% |
| Cylindrical power within ±0.50 D | 93.65% | 84.96% | 84.13% |
| Axis within ±10 degrees | 62.75% | 64.90% | 54.17% |
| Axis within ±20 degrees | 90.20% | 84.31% | 77.08% |

Balentine and Bigari (2008) compared the refractive error readings of the Retinomax K-Plus 2 and the closed-viewing, table-top Grand Seiko GR-2100 AR to SR in 20 subjects. There was no cycloplegia involved. The results were measured on how many AR spherical readings were within ±0.50 D of the SR results. The Retinomax K-Plus 2 had 21.67% of its spherical readings within ±0.50 D, while the Grand Seiko had 43.33% spherical readings within ±0.50 D of the SR results.

In terms of accuracy, the majority of studies reviewed concluded that the handheld was not as valid of an autorefracting device in comparison to their

conventional, tabletop counterparts. In the studies by Farook et al., Vidtech et al., and Balentine et al., the handheld ARs assessed were not as accurate as the conventional tabletop refractors when compared to SR findings. However, Wesemann and Dick (2000) felt that the handheld AR performed as well as a tabletop AR in terms of accuracy for both young adults and children when under cycloplegia. They suggested that cycloplegia for children should be done in order to increase its accuracy, especially for those under the age of 4. Most of the studies did not feel that the handheld could be an option to completely replace SR nor conventional AR; however, they did agree that it could be useful in certain settings and situations, such as a screening tool for large populations (Videtich et al., 2013), when other methods of refraction are not possible due to off-site location, or when other methods of refraction are not possible due to the patient because of their age or health condition.

# CHAPTER 6

## WAVEFRONT AUTOREFRACTORS

Autorefraction utilizing aberrometry is another deviation from the traditional, tabletop devices. This type of AR will be referred to as wavefront AR in this review. This technology analyzes a patients' refractive error while taking into account both higher and lower order wavefront aberrations of a patients' ocular system. Aberrations are deviations of light waves entering and exiting an optical system such as the human eye. (Unterhorst, 2015). The main aberrations are classified as zero, first, second, and third order aberrations. The most recognizable aberrations may be the second order aberrations, as they involve the aberrations responsible for determining the spherical and cylindrical components of a refractive error. The use of this type of technology may give hope to perfecting human vision to its maximum potential by reducing higher order, potentially bothersome aberrations. The following studies evaluate the refractive error measurement of different aberrometers compared to traditional AR and SR.

Linh, Chen and Lee (2013) compared AR using aberrometry to both non-wavefront AR (Topcon RM-A7000) and SR. Thirty-one eyes of 17 subjects were analyzed with a non-cyclopleged SR followed by a cyclopledgic autorefraction from both devices using 1% tropicamide. The wavefront AR used was the Wavelight Allegretto-Wave analyzer. This study reports that a cylcopleged AR is not much different than a dry

SR. They evaluated the spherical error, cylindrical error, and spherical equivalent of the each refractive error finding. The difference between SR and the non-wavefront AR (Topcon) for spherical error, cylindrical error, and spherical equivalent was 0.10 D, 0.00 D, and 0.03 D with similar standard deviation, respectively. Overall, the cycloplegic wavefront AR read more minus in all analyzed values compared to SR and non-wavefront AR. The spherical error, cylindrical error, and spherical equivalent for the three refractive error measurement methods are listed below:

| Type of Error | Subjective Refraction | Wavefront AR | Non-wavefront AR |
|---|---|---|---|
| Spherical Error | -5.87 ± 0.32 | -5.93 ± 0.30 | -5.77 ± 0.33 |
| Cylindrical Error | -0.47 ± 0.08 | -0.64 ± 0.05 | -0.47 ± 0.08 |
| Spherical Equivalent | -6.10 ± 0.32 | -6.25 ± 0.30 | -6.07 ± 0.33 |

In 2014, Bennet, Stalboerger, and Hodge did a study to assess the Nidek OPD-II scan wavefront aberrometer and compare it the Nidek 530-A AR and SR. Sixty adults aged 18 to 59 years were assessed; measurements of both eyes were taken by a technician with the wavefront AR (set to a 4mm zone) and the non-wavefront AR and the SR by an optometrist. The optometrist was masked to the results of non-wavefront AR and wavefront AR and the technician was masked to the SR results. Data obtained was

analyzed using Bland-Altman plots; it showed that when comparing the AR to the SR, about 80% of values were within +/- 0.25 D. When comparing the wavefront AR to SR, about 73% of values were within +/- 0.25 D. The non-wavefront AR showed slightly better agreement to SR than the wavefront AR, but overall they determined that the difference "was not statistically significant." The authors felt that although the wavefront AR may provide information explaining symptoms from higher-order aberrations, it did not provide an advantage over non-wavefront AR when determining a spectacle prescription at the time.

Lebow and Campbell (2014) used the Canon RK-F2 AR and the Zeiss i.Profiler aberrometer in comparing traditional non-wavefront and wavefront ARs to each other and to SR. They assessed 174 eyes of 100 subjects; clinical technicians obtained the ARs and one optometrist (masked from the AR data) performed all SRs. The examiners used 0.25 D as "clinically significant difference;" with that reference, they determined that both ARs had mean differences between their spherical equivalent findings and the subjective findings that were less than the clinically significant difference of 0.25 D. The i.Profiler, on average, refracted slightly more minus than the SR (-0.11 D). The RK-F2, on average, was the same as the SR (0.03D). In addition, the RK-F2 showed a smaller difference in mean cross-cylinder power differences with SR than the i.Profiler did in regards to the SR. The examiners concluded that the RK-F2 performed just as well as the

i.Profiler and suggested that when it comes to routine refractive analysis, a non-wavefront AR might be all that is necessary.

The studies done by Lin et al. (2013), Lebow and Campbell (2014), and Bennet et al. (2014) all indicate that non-wavefront AR and wavefront AR get very similar refractive error results when compared to each other and compared to SR. Bennett et al. and Lebow and Campbell state that standard, traditional AR is good enough for routine refractive error measurement. Lin et al. performed AR using cycloplegia, unlike Lebow and Campbell and Bennet et al. His findings suggest that there is not a significant difference between cycloplegic results from both AR devices and non-cyclopleged results from the SR. However, the results from Lin et al. do support the idea that there is, although slight, a higher agreement between cycloplegic AR refractive error measurement and dry SR refractive error measurement. Lin et al. found about 0.10 D difference in the MSE for wavefront and non-wavefront AR and SR, no difference between non-wavefront AR and SR, and only 0.03 D difference between non-wavefront AR and SR.

In their study done in 2011, Cooper, Citek and Feldman compared the refractive error measurements amongst the Ophthonix Z-View Aberrometer, the Humphrey non-wavefront AR, and SR using the visual acuity as a comparison point. Overall, the Z-View tends to undercorrect myopia, the Humphrey AR tends to overcorrect myopia, and both types of ARs had a high error in determining the axes for astigmatism. Ninety-seven

subjects were evaluated on each refractive error measurement method.. The Snellen equivalent mean (range) was 20/20.6 (20/15-20/40), 20/19.9 (20/15-20/30), and 20/18.2 (20/15-20/25) for the Humphrey AR, Z-View aberrometer, and SR, respectively.

Nissman, Tractenberg, Saba, Douglas and Lustbader (2006) assessed the repeatability and validity of measurements obtained with the Nidek 3D Wave OPD Scan ARK 10,000 aberrometer in comparison to SR findings. Data was obtained from 105 eyes of 53 subjects who ranged in age from 19 to 87 and had a BCVA of at least 20/40. For the 6 millimeter (6 mm) zone, a single drop of phenylephrine 10% was instilled in both eyes to induce dilation without cycloplegia, and a pupil diameter of at least 6 mm was confirmed. Three consecutive wavefront measurements at both a 4mm zone and a 6mm zone were obtained. Results showed that the aberrometer had good repeatability amongst measurements with both the 4mm and 6mm scans; thus, "a single measurement is sufficient in clinical practice to obtain an AR with this device" (p. 574). The acuities obtained with the 4mm and 6mm were better than the SR acuities in 19% and 16.2% of the eyes, suggesting at least the potential for the AR to obtain superior results for some patients.

Cooper et al. (2011) and Nissman et al. (2006) evaluated the refractive error measurement of wavefront AR by visual acuity. Both studies showed that SR gave better visual acuity outcome compared to wavefront AR and non-wavefront AR. Cooper et al. showed a better visual acuity outcome with SR on average, but the difference was

minimal with not all subjects getting 20/20 outcome even with SR. On average, the Z-View aberrometer and SR gave the subject better than 20/20 vision. Nissman et al. stated that wavefront AR had better visual acuities 16-19% of the time when compared to SR; therefore, it may be possible in certain circumstances to have better visual outcomes when aberrations of the human visual system are taken into account.

Pesudovs, Parker, Cheng, et al. (2007) measured the precision of wavefront ARs reading high and low order aberrations compared to SR and closed viewing non-wavefront AR. The autorefractors used were the Nidek AR-800, Topcon KR-8000, and Wavefront Sciences Complete Ophthalic Analysis System G200. Four different examiners evaluated sixteen subjects, who averaged in age to about 24 years old. In almost all cases, objective refraction including wavefront aberrometers and traditional AR were more repeatable across examiners compared to subjective refraction.

Pesudovs et al. (2007) and Nissman et al. (2006) evaluated the repeatability or precision of wavefront AR compared to SR. Pesudovs et al. measured repeatabilty amongst different examiners while Nissman evaluated repeatability within the same examiner on AR only. Both studies agreed that AR has adequate repeatability. Pesudovs et al. stated that AR devices, both with and without wavefront technology, have better repeatability than SR. Nissman et al. noted that the repeatability of the Nidek 3D Wave aberrometer was precise enough to only need one measurement instead of taking multiple measurements and averaging them.

# CHAPTER 7

## AUTOREFRACTION IN UNIQUE SITUATIONS

The following studies evaluated AR and SR using unique methods and situations. The first two studies looked at the actual subject's assessment of the two prescriptions with eyeglasses and the next two studies compared AR and SR in subjects with ocular pathology. All the other studies in this review evaluated, for the most part, "normal" participants without significant ocular pathology affecting visual acuity.

Strang, Gray, Win, and Pugh (1998) evaluated the subject's tolerance of spectacle prescriptions as determined by autorefraction and SR. Forty-seven subjects were included in the study and instructed to wear a pair of distance vision spectacles with a prescription generated either by AR or SR in a random order. The subjects were to wear each set of glasses for a two-week duration. No cycloplegia was used, and no patients with ocular pathology other than refractive error were included in the study. The subjects completed a questionnaire form to evaluate their experience with the glasses. There were six different ARs used in the study, but a source was cited that stated equal precision and accuracy between the selected ARs. The results stated a higher acceptance rate of SR compared to autorefraction, but it was by a small margin. After two weeks of wear, 17% and 12.7% of the subjects could not adapt to the prescription for the AR or SR, respectively. The questionnaire also inquired about the subject's perception of the visual quality of the

prescription they were wearing. In the AR group, 68% stated the prescription was good or very good while 85.1% stated good or very good in the SR group. When asked if the subject would return to the optometry office to complain about the prescription, 18 reported that they would. Of these 18, 38.3% reported that they would return to complain about the AR prescription while 10.6% would return to complain about the SR prescription. At the end of the two weeks, a questionnaire asked each subject which pair of glasses they preferred; 51.1% preferred the SR prescription, 19.1% preferred the AR prescription, and 29.8% preferred either set of glasses.

Sun, Qin, and Aiello (2012) compared ending visual acuities (Vas) between prescriptions in 878 eyes of 456 subjects determined by AR and SR. There were several different AR devices used in the study, since it was a multi-center study. This study included participants diagnosed with diabetes mellitus and with a wide range of BCVAs. Approximately 60% of the subjects had center involving macular edema. The results of the study indicated a better VA outcome with SR when compared to AR.

In their 2001 study, Orr, Cramer, Hawkins, and Bressler performed dry AR and SR on 62 eyes to compare the refractive results and final visual acuities. The AR used was the Marco AR-1600G Auto Refractometer. The subjects were enrolled in the Submacular Surgery Trials Pilot Study and were diagnosed with a history of subfoveal choroidal neovascularization. MSE of SR was +1.04 D (1.10 Standard deviation [SD])

than AR. The average visual acuity difference was 1.5 letters better with SR compared to AR measurements.

Sun et al. (2012) and Orr et al. (2001) compared refractive error measurements of AR to SR by assessing subjective responses. Both studies agreed that SR gave a better VA result. Sun et al. believed that the repeatability of VA results determined from the AR's values was less consistent when compared with the repeatability for VA determined by SR. These two studies are contrast to Pesudovs et al. (2007) and Nissman et al (2006). Keep in mind that Sun et al. and Orr et al. used VA to measure repeatability instead of a comparison of refractive error measurements. These studies indicated that despite differences in refractive error measurements SR may give a more usable and pleasing prescription for a subject to look through. These results also agree with Strang et al. (1998), who evaluated the patient's experience with refractive error corrections determined by autorefraction and SR. The SR seemed to fair better overall, but, surprisingly, not by an overwhelming majority. This study is more dated compared to the recent AR evaluations, so it is reasonable to suggest that the new AR technology may cause the patient to notice even less of a difference between SR and AR. However, as Sun et al. (2012) showed, the accuracy of an AR, as determined by ending VA, decreases as a patient's BCVA decreases. SR will continue to remain an important standard of care for determining the refractive error for patients with ocular pathology affecting their BCVA.

# CHAPTER 8

## NEWER AUTOREFRACTION TECHNOLOGY

Advancements with technology in recent years have lead to the emergence of newer forms of ARs. Many of these "smart products" were developed with the intent of measuring refractive errors in order to provide correction for people living in both developing as well as industrial countries. Two products that utilize this technology include the Near Eye Tool for Refractive Assessment (NETRA) autorefractor and the SVOne aberrometer. In addition to these "smart products," there have also been newer modes of autorefractors produced, such as the videorefractor. An online solution, Opternative, has also recently emerged and utilizes telemedicine technology to guide its users and relies on their feedback in order to determine their refraction errors (Ohlendorf, Leube, & Wahl, 2012).

The Near Eye Tool for Refractive Assessment (NETRA) is a portable refractometer that attaches to a smartphone. In a pilot study by Bastawrous, Leak, Howard, and Kumar (2012), the correlation between SR and NETRA in refraction values, and the resulting BCVAs obtained from NETRA (BCNVA) and SR (BCVA) compared to uncorrected VA (UCVA) were assessed. This study assessed 34 eyes of 17 subjects ranging in age from 23 to 81. The mean difference of SR's BCVA to UCVA was 0.58 LogMAR, (i.e. a Snellen equivalent of 6 lines of improvement). The mean difference

between NETRA's BCNVA with the UCVA was 0.44 LogMAR (i.e. a Snellen equivalent of 4 lines of improvement). Of the 34 eyes, the MSE measured with NETRA was found to agree within 0.25 D of the SR in only 15% of the measured eyes. The authors feel that the NETRA could be useful in settings where access to a trained refractionist is not possible, as it has the potential to estimate refractions closely enough to render an individual no longer visually impaired due to uncorrected refractive error. A drawback to the NETRA device is its limitations on who can use it; since it relies on subjective feedback, it may not work well on children or cognitively impaired individuals.

Another smartphone-based autorefractor is the SVOne (Smart Vision Labs, New York), where a portable wavefront aberrometer is attached to a smartphone. Ciuffreda and Rosenfield (2015) assessed the validity and use of the SVOne wavefront aberrometer. In this study they compared pre and post-cycloplegic measurements that were taken with five different methods: retinoscopy, subjective refraction, the Topcon KR-1W autorefractor, the Righton Retinomax-3 autorefractor, and the SVOne wavefront aberrometer. This study was conducted on 50 adults from age 18 to 31; 1% tropicamide was used for cycloplegic measurements. Analysis of the study concluded that when it comes to spherical equivalent refractive error, the findings from the SVOne were not significantly different the other techniques, both with and without cycloplegia. For the precycloplegic and postcycloplegic findings, the mean value of M for the SVOne showed

-0.43 and -0.38 D more myopia, respectively, when compared with the SR. The authors of this study feel that the SVOne could be valuable for vision screenings and examinations that take place outside of the clinical office. A similar study that expands the range of refractive errors and ages is suggested to examine it further.

Ogbuehi, Almaliki, and Osuagwu did a comparison of the handheld 2Win eccentric videorefractor with the Topcon KR-8800 AR and SR in their study. Eighty-six eyes from 86 subjects ranging in age from 20 to 24 years old were assessed. The cylindrical power component, as determined by the 2Win videorefractor, was less reliable than the axis component, returning significantly higher negative cylinder values than SR and the Topcon AR. However, the Topcon measured significantly more minus spherical refractive error values than the 2Win videorefractor. The authors determined that overall, the 2Win videorefractor compares well, on average, with SR. Since the reproducibility values for the 2Win videorefractor were considerably worse than either SR or AR, its use as a primary screening device is limited.

The studies evaluated tend to agree that the "smart devices" show promise and could be useful as screening devices, especially in remote areas. Some, such as the NETRA, were created with the intent of reducing uncorrected refractive error (URE) as a leading cause of blindness. Specifically, Bastawrous et al. (2012) stressed, "The goal of this tool is not to replace the optometrists/refractionists but to be a reliable, cost- effective refractive error screening tool" (p. 14). The authors of the studies done by Bastawrous et

al. and Ciuffreda and Rosenfield seemed to suggest that both devices may not be as accurate as SR, but they could serve as worthy, cost-friendly solutions for screening devices and have the capability of changing the lives of those inhibited by URE. All studies did not think that AR would be a viable alternate to SR, as long as SR was available.

# CHAPTER 9

# CONCLUSION

The types of ARs in use today can vary immensely in their appearance, method of obtaining refraction error data, and interpretation of data. The studies that were reviewed covered a variety of ARs, including tabletop devices, handheld devices, video recorders, and smartphone-based devices and with features such as open-viewing, wavefront aberrometry, or fogging lenses in an effort to be more accurate and precise. On basis of review, it can be determined that autorefraction can act a substitute for retinoscopy, as a screening device, for situations when the patient is unable to subjectively respond, and for situations that are located outside of a typical clinical environment. However, there it is not recommended as a substitute for conventional subjective refraction.

There were a few common weaknesses found amongst the studies assessed in this literature review. Some of the studies, particularly the "pilot" type studies, involved a smaller number of subjects being assessed. In addition, besides the two studies mentioned in the "Unique Situations" chapter, all of studies' subjects had a BCVA of 20/40 or better and did not have any coinciding ocular pathology. Subjects were often excluded based on being either too young or too old; the majority of subjects used were in their 20's to 50's and capable of subjectively responding. All of these factors reduce the validity of these

devices for an actual "real world" clinical setting, as there is a greater chance of encountering those who do not fall within the selected criteria.

Another common weakness found amongst studies was determining the AR's validity solely by comparing its refractive error values against those obtained from SR. Although the SR is determined to be the "gold standard," it is hard to discern which method is more accurate unless the subject is presented with both refractions and allowed to compare the two subjectively. A fairer and truer assessment of the AR's accuracy could be based upon the subject's decision as to which type of refraction provides better quality of vision or which refraction has the better resulting VA.

From the studies assessed, it is suggested that further research involving greater numbers of subjects, wider ranges of prescriptions, wider ranges of ages, and more inter-examiner repeatability would be helpful ways of assessing the "real world" use of ARs. Additionally, future studies could incorporate the subject's resulting VAs from both AR and SR measurements, which could provide valuable insight as to how valid and accurate the two methods really are when compared to each other. More studies are also warranted for the newer, emerging "smart" types of devices, as there is very little research in existence to evaluate their precision and accuracy. This is especially important with new technologies and online refractions coming into the market. Given the ever-changing, dynamic field of optometry, it is exciting to see what new instrumentation emerges next and how it can be used to help improve the vision of people from all parts of the world.

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