Article • Refraction in the Tele-Optometric Examination Compared to Traditional In-Person Refraction in an Adult Population

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ABSTRACT

Background: Globally, access to reliable, affordable tools that provide refractions and ultimately accurate spectacle prescriptions will aid in improving eye health. Our study aimed to evaluate a tele-optometric remote refraction compared to a traditional in-person subjective refraction.

Methods: A cohort of 30 pre-presbyopic participants ≥18 years of age at the Illinois College of Optometry were recruited to participate in this pilot study. Participants completed two comprehensive eye examinations. First, the tele-optometric comprehensive eye examination was completed using the DigitalOptometrics platform. A remote technician completed refraction, followed by videoconferencing with an investigator optometrist. This remote eye examination was then followed by the in-person comprehensive eye examination by a different investigator optometrist, with a traditional manifest refraction. Both modalities used a Reichart VRx digital phoropter.

Results: A total of 60 eyes were evaluated using both testing methods. The mean spherical equivalent, spherical power, cylindrical power, and axis in the tele-optometric remote refractions were -3.69 D ± 2.81 D, -3.35 D ± 2.68 D, -0.70 D ± 0.81 D, and 78 ± 77 degrees, respectively, compared to -3.58 D ± 2.80 D, -3.23 D ± 2.69 D, -0.68 D ± 0.71 D, and 81 ± 76 degrees in the in-person refraction group, respectively. No statistically significant difference was found between the spherical equivalent, spherical, cylindrical, and axis components of the prescriptions found in the tele-optometric examination compared to the in-person examination (p=0.82, p=0.82, p=0.93, p=0.85, respectively). Ten percent (6) of the eyes (4 hyperopic and 2 myopic) were over-minused in the tele-optometric examination.

Conclusions: Using the DigitalOptometrics platform, tele-optometric remote refraction by a technician was not significantly different when compared to a traditional in-person manifest refraction in a young, healthy, pre-presbyopic adult-student cohort. Attention must be paid to low hyperopes and high myopes to ensure that they are not over-minused in remote refractions.

Keywords: remote refraction, tele-health, tele-optometry

Introduction

Visual impairment is a large global burden that reduces quality of life and productivity.[1-9] It is estimated that approximately 400 million individuals suffer from visual impairment globally; about half of this impairment is due to uncorrected refractive error. Uncorrected refractive error is the largest cause of preventable blindness, as noted by the World Health Organization.[1,3,10-12] Globally, access to reliable, affordable tools that provide refractions and ultimately accurate spectacle prescriptions will aid in improving eye health, especially those in rural or underserved areas, where access to eye care practitioners may be limited.

Tele-health is an advancing field with the advent of new technology, software, and legislation to support the ever-changing role of healthcare, especially in the eye care industry. To date, there have been numerous studies demonstrating the benefit of tele-retinopathy[13-21] and tele-glaucoma[22-41] evaluations to provide care in rural areas or as an adjunct to eye care providers. The COVID-19 pandemic has created a surge in eye care providers using tele-health techniques to supplement their practice. New companies are being developed in the hopes of creating a tele-optometry approach to the comprehensive eye examination. Most critically, many patients are hoping to use tele-optometry as an effective and efficient method to complete refraction and to update their spectacles. There are products on the market that promote remote refractions with varying modalities, where companies have used proprietary technology for use at home or at the office. There are at-home products that claim to provide accurate refractions for patients. There are also remote eye examinations at an optometrist's office, during hours when an optometrist is not present, that can provide refractions.

This study aimed to evaluate the validity of a remote refraction and determine whether this is an effective and accurate method for spectacle prescription in an adult-student population. This method of remote refraction occurs at an eye care physician's office, with the aid of an on-site technician. It does not require an optometrist to be physically present, but one must be present remotely. Remote optometrists can finalize a patient's glasses prescription virtually. This method can broaden a clinic's ability to prescribe during hours when an optometrist is not physically present. It may also enhance outreach in rural areas where clinics are not easily accessible via travelling clinics or offices without optometrists, with the goal of reducing the burden for individuals with uncorrected refractive error.

Methods

A cohort of 30 pre-presbyopic, adult-student participants ≥18 years of age at the Illinois College of Optometry were recruited to participate in this pilot study. Exclusion criteria included those with active ocular disease or ocular surgery within the last 90 days. The study proposal was approved by the institutional review board (IRB) at the Illinois College of Optometry, and it adhered to the tenets of the Declaration of Helsinki. Written and verbal consent was obtained from all participants.

Participants completed two eye examinations with refractions. First, the tele-optometric eye examination was completed. There were three points of contact in this examination. First, the patient was greeted by an in-person technician for data collection at the office. Second, a remote technician via the DigitalOptometrics platform completed the remote refraction. Third, videoconferencing with an investigator optometrist was completed. The remote investigator optometrist reviewed the data collected during manifest refraction and had the ability to re-refract or to make adjustments with the digital phoropter. This remote eye examination was then followed by the gold-standard in-person comprehensive eye examination by a different investigator optometrist. A Reichart VRx digital phoropter was used by both the remote technician and the in-person investigator optometrist.

Distance vision with habitual correction (if available) was measured. A Nidek autorefractor was used to obtain an autorefraction by the on-site technician, which was the starting point for the manifest refraction by the remote technician. Distance and near best-corrected visual acuity were recorded after subjective manifest refraction in both arms of the study. Both eye examinations included entering visual acuities, objective and subjective manifest refraction, baseline binocular vision testing, baseline accommodative testing, anterior and posterior segment evaluation, and intraocular pressure.

Spectacle prescriptions were compared by two independent reviewers to determine whether they were valid and accurate. Parameters were set to ensure that prescriptions were equivalent: spherical component ±0.50 D, cylindrical component ±0.50 D, and axis component ±015 degrees. Paired samples t-test and Wilcoxon signed rank test were used for statistical analysis, and Bland-Altman analysis was used to evaluate the agreement between two measurements using 95% limits of agreement (LoA).

Results

Thirty participants (60 eyes) were included in this study. There were 9 males and 21 females, and the mean age of the participants was 24.7 years (range 22-33 years). Best-corrected visual acuity was tested at the completion of both the tele-optometric refraction and the in-person manifest refraction. All participants achieved best-corrected visual acuity of 20/20 in both arms of the study for all eyes.

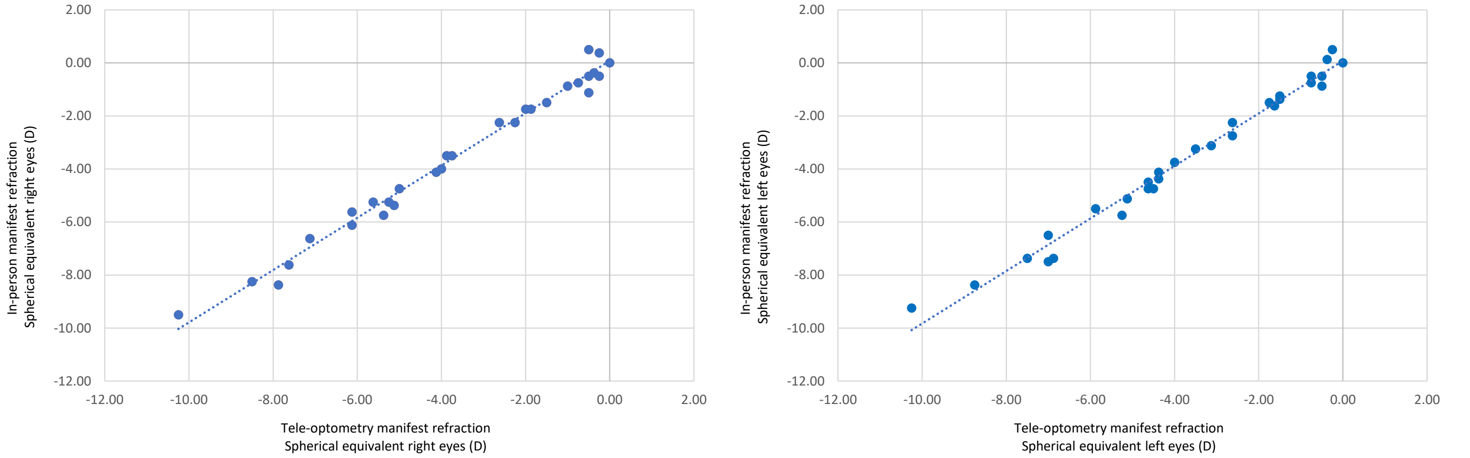

Figure 1. Scatterplots comparing spherical equivalent measurement between tele-optometry remote refraction and in-person manifest refraction with trendline analyses between right and left eyes

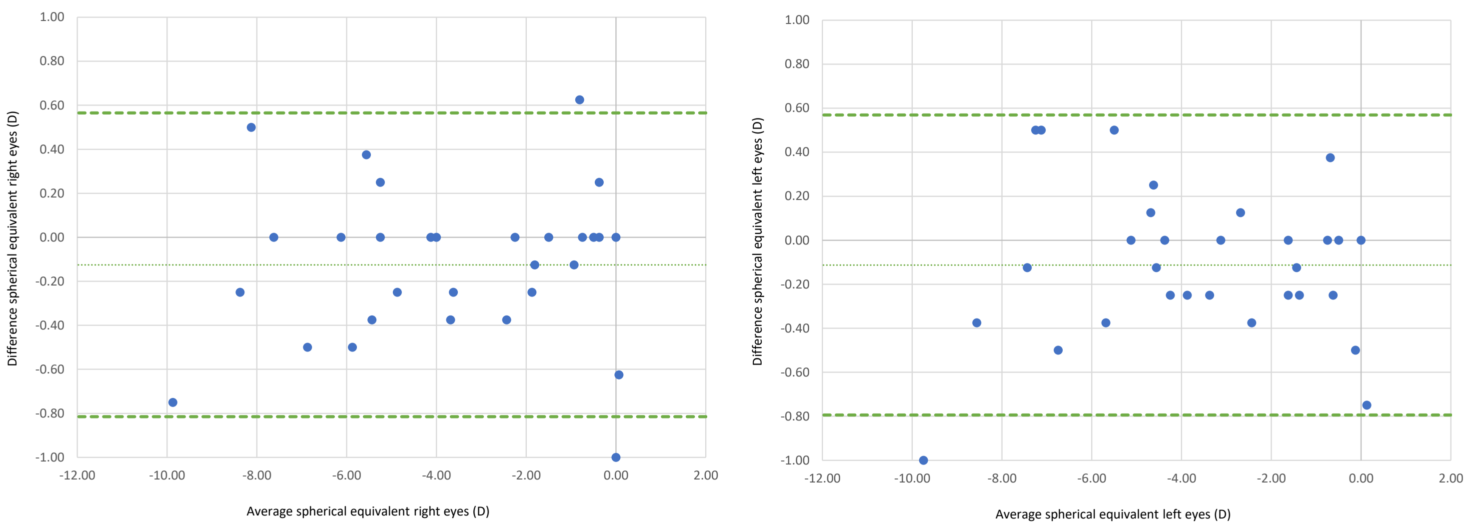

Figure 2. Bland-Altman plots comparing difference in spherical equivalent measurement between tele-optometry remote refraction and in-person manifest refraction for right and left eyes. Average difference line is plotted with upper and lower confidence intervals.

Table 1. Comparison of Refractive Measures Obtained between Tele-Optometric Remote Refraction and In-Person Refraction

	In-person manifest refraction (N=60 eyes)				Tele-optometric remote refraction (N=60 eyes)				Difference (N=60 eyes)				
Variable	Mean (SD)	Min	Max	Median	Mean (SD)	Min	Max	Median	Mean (SD)	Min	Max	Median	*P*
SE (D)	-3.58 (2.80)	-9.50	+0.50	-3.50	-3.69 (2.81)	-10.25	Plano	-3.81	0.26 (0.25)	0	1.00	0.25	0.82
Sphere (D)	-3.23 (2.69)	-9.25	+0.75	-3.38	-3.35 (2.68)	-10.25	+0.25	-3.50	0.24 (0.25)	0	1.00	0.25	0.82
Cylinder (D)	-0.68 (0.71)	-3.25	Plano	-0.50	-0.70 (0.81)	-3.75	Plano	-0.50	0.13 (0.18)	0	0.50	0	0.93
Axis (degree)	81 (76)	1	180	62	78 (77)	5	180	49	4 (7)	0	44	2	0.85

Scatterplots of the relationship between the spherical equivalents of tele-optometric remote refractions and in-person manifest refractions were completed (Figure 1). A strong positive linear relationship is noted amongst right and left eyes. The spherical equivalent between the two methods demonstrates a strong correlation (Figure 2) without a significant difference between the right and left eyes ($p=0.87$ and $p=0.88$, respectively).

No statistically significant difference was found between the spherical equivalent, spherical, cylindrical, and axis components of the prescriptions found in the tele-optometric examination compared to the in-person examination given ($p>0.05$; Table 1). The mean spherical equivalent in the tele-optometric remote refraction was -3.69 D ± 2.81 D, compared to -3.58 D ± 2.80 D in the in-person manifest refraction ($p=0.82$). The mean sphere power in the tele-

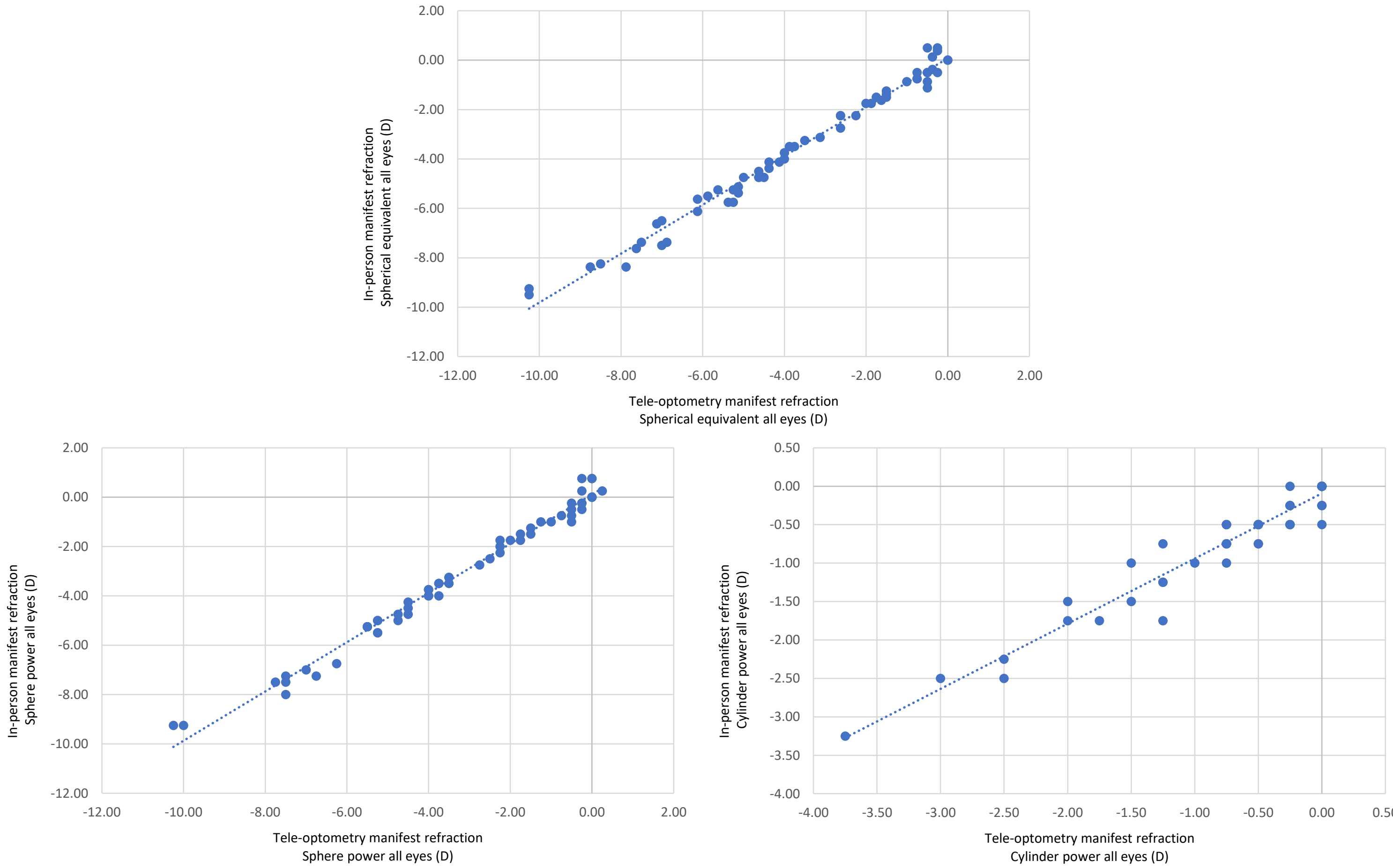

Figure 3. Scatterplots comparing spherical equivalent, sphere power, and cylinder power for all eyes (N=60) between tele-optometry remote refraction and in-person manifest refraction with trendline analyses

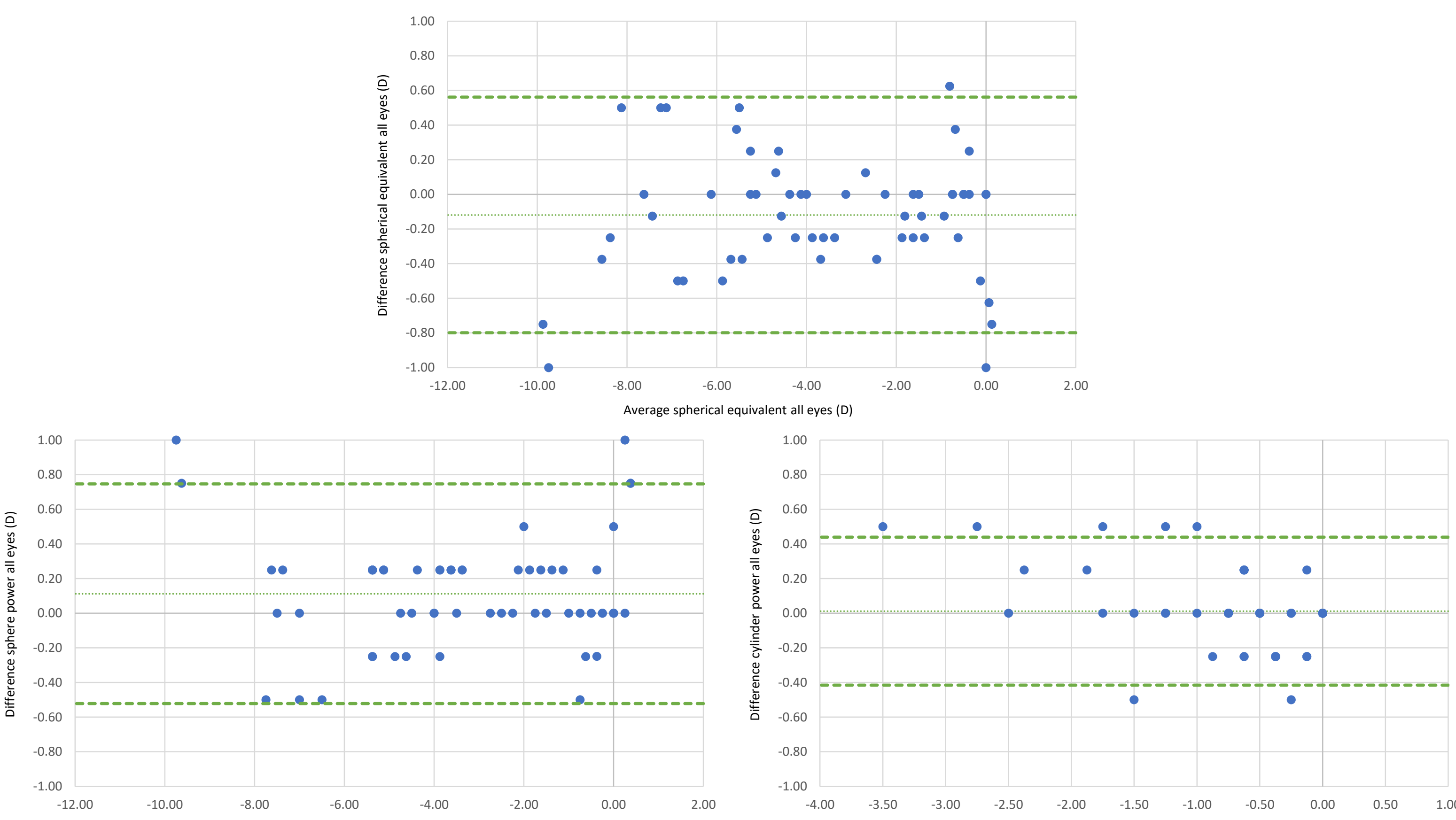

Figure 4. Bland-Altman plots comparing difference in spherical equivalent, sphere power, and cylinder power for all eyes (N=60) between tele-optometry remote refraction and in-person manifest refraction. Average difference line is plotted with upper and lower confidence intervals.

optometric remote refraction was -3.35 D ± 2.68 D, compared to -3.23 D ± 2.69 D in the in-person manifest refraction ($p=0.82$). The mean cylinder power in the tele-optometric remote refraction was -0.70 D ± 0.81 D, compared to -0.68 D ± 0.71 D in the in-person manifest refraction ($p=0.93$). The mean axis in the tele-optometric remote refraction was 78 ± 77 degrees compared to 81 ± 76 degrees in the in-person manifest refraction ($p=0.85$). Scatterplots of the relationship between spherical equivalent, sphere power, and cylindrical power and Bland-Altman plots are demonstrated for all eyes (N=60) in Figures 3 and 4. A strong positive linear relationship is noted for all measurements.

Based on the criteria outlined in the methods, 27 of 30 (90.0%) spectacle prescriptions were equivalent between the two examinations. Of the three prescriptions that were not equivalent, two cases were low hyperopes who were given a low myopic prescription in the tele-optometric examination, and the third case was a high myope who was given extra minus in the tele-optometric examination, outside the parameters listed.

Discussion

There are more than 650 million people worldwide who have insufficient or no refractive error correction.[5] Uncorrected refractive error accounts for approximately 45% of all visual impairments worldwide.[1-4, 7-9, 42] Globally, to achieve adequate visual acuity, approximately 60% of individuals require spectacles or contact lenses.[8,43] Tele-optometry may provide access to refractions, and ultimately spectacle prescriptions, where traditional methods may fail. While there are many companies that are entering the arena of remote refractions, the data presented suggest that most spectacle prescriptions via remote examination are accurate for a healthy and straightforward patient population. Our data suggests that manifest refractions, and ultimately spectacle prescriptions, were equivalent between tele-optometric remote and the gold-standard in-person comprehensive eye examinations in this adult-student population. This is one of the first studies that has evaluated the difference between remote refractions and in-person refractions. Our study suggests that the differences between spherical equivalent, sphere power, cylinder power, and axis are not significant in a healthy, pre-presbyopic population. This adult-student cohort allowed us to validate the technology under optimal circumstances to see whether it could be applicable to a broader audience. If this technology revealed differences in this optimal population, future studies would not be warranted. Our results indicate that in this population, the tele-optometric remote refraction was similar to the traditional in-person refraction for all parameters.

As 90% (27 of 30) of refractions were deemed equivalent, close attention was given to the three outliers. Two cases were low hyperopes who were prescribed low myopic prescriptions in the remote refraction. The third case was a high myope who was also over-minused in the remote refraction. Careful binocular balance should be employed to ensure that patients are not over-minused. To ensure accuracy, remote optometrists should consider this information with low hyperopes and high myopes and may want to confirm the binocular balance in this pre-presbyopic cohort prior to finalizing the spectacle prescription.

One area of research that has been well documented is that of portable autorefractors.[44,45] A systematic review by Samanta et al.[46] evaluated four portable autorefractors (NETRA, Quicksee, Retinomax, and SVOne) against subjective refractions. Although some differences were found between the devices, they had high patient acceptance in spectacle prescriptions. A widely studied portable auto-refractor is a cell phone-based refractive device, Near Eye Tool for Refractive Assessment (NETRA). This was developed at the Massachusetts Institute of Technology. It provides an interactive and inexpensive screening method to estimate the refractive error using mobile phones.[42,45-47] It has been shown to be comparable to other auto-refractors on the market, with a mean absolute error of 0.31 ± 0.37 D compared to manifest refraction. However, unassisted use of the NETRA in pre-presbyopic adults showed a significantly more myopic overcorrection of 0.60 D (median) when compared to conventional subjective refraction.[48] The findings mirrored similar findings in a different study of the NETRA, where absolute differences in spherical error of more than 0.50 D for approximately 60% of eyes were seen when compared to subjective refraction.[49] SVOne is a portable Hartmann-Shack wavefront aberrometer developed by Smart Vision Labs in New York that also utilizes a smartphone-based auto-refractor to aid in refraction for patients. When compared to manifest refraction, no significant difference was found.[50] More research is needed in this field to confirm the diagnostic accuracy of such systems; however, preliminary data is promising.

Autorefractors can complement remote refractions; in our study, we used this as the objective starting point for subjective refractions.

In 2017, a study out of the Atlanta Veterans Affair Eye Clinic hospital-based system evaluated their Technology-Based Eye Care Services (TECS) protocol, essentially using auto-refraction for a largely presbyopic cohort.[51] Their study noted that eyeglass prescriptions derived mostly from autorefraction alone seemed to be well tolerated by the majority of patients. The TECS eyeglasses did not result in significantly higher returns compared to eyeglasses from an in-person examination, whose prescriptions derived from traditional manifest refraction techniques. This has been stated by others in the literature.[51-54]

A group in the Netherlands developed a Web-based test (Easee website https://www.easee.online/en/) that measures visual acuity and both spherical and cylindrical refractive errors. This system can measure refractive error with a smartphone and standard computer screen. They noted that their system was a valid and safe method for measuring refractive error in healthy eyes, particularly for mild myopia.[55] This is a system that can provide reliable at-home measurements for spectacle prescriptions without the use of a phoropter; however, the remote modality studied in this project has the ability to perform additional testing (such as binocular vision and accommodative testing) and is a responsible means of implementing digital eye health beyond the glasses prescription to more underserved or rural areas.

As our study was a pilot project, a limitation is that only one modality of remote refraction was tested. While this study evaluated the DigitalOptometrics platform, which used a remote technician who performed the refraction and a remote optometrist who could refine the prescription, it did not evaluate other proprietary technology. Results may vary for each method. This method relied heavily on a remote technician to perform the refraction in the tele-optometry arm of the study. Although the remote optometrist had the ability to repeat manifest refraction with the digital phoropter, the reliability of the remote refraction was heavily based on the quality of the remote technician. In this study, the remote technician was a third-year optometry student who had been well trained in collecting data and using optometric equipment. This study also did not evaluate the accuracy of at-home refraction methods. Future studies may look to evaluate different remote refraction modalities. Another limitation of this pilot study is the cohort of participants. The participants in this study were all pre-presbyopic, without concomitant ocular disease, and were currently enrolled optometry students. Hence, these subjects were adult students who understood the testing that was being performed and who might outperform a non-student cohort. Future studies may evaluate refractions in a presbyopic cohort and in patients with concomitant ocular disease, who are not currently enrolled students, to see whether these results are reproducible. The results in this study show that this technology performs well in an optimal cohort, and future data is promising for a broader subject base. Another limitation is that the calculated power was 0.57, which is lower than the traditional 0.8 value.

As it pertains to cost, the equipment used can be found at traditional eye care practices. This lowers the barrier to entry for a lot of private practices. The company in this study (DigitalOptometrics) uses a majority of equipment that is already standing in practices. The expense for practices would be the fee for the company platform and the on-site technician. The on-site technician, however, would be a cost savings compared to an optometrist on-site. Many private practices might use this technology alongside regular business hours to see more patients or to expand their business hours. This modality could expand business hours to weekends or weeknights, when working individuals could be seen when it is convenient for their schedules and have a digital eye examination with glasses prescription. Some practitioners could even fit straightforward soft contact lenses with this modality using the video slit lamp to assess the contact lens fit. The company reports that they excel in rural jurisdictions and urban areas where they cannot find eye doctors to serve the community. The charge for the online platform operates on a cost-per-examination fee schedule. The company has 2 fee structures: an open and closed structure. The open structure allows for a practice to use one of the company's contracted remote optometrists. The closed structure allows for a practice to use their own hired optometrists to remote into the examination to keep continuity of care. This may be used in a remote area where an eye doctor can remote into multiple practices and still maintain seeing their patients from a central location.

Although tele-optometry is not a replacement for an in-person eye examination, it may offer some benefits in specific situations. For example, it may be used for spectacle prescriptions for routine care in a pre-presbyopic cohort, as a screening tool for patients who require an in-person eye examination, to provide access to patients in remote communities, and to ensure minimal contact for patients who have concerns due to the COVID-19 pandemic. Participants were older than 18 to exclude children and teens. As this was a pilot study on graduate students, we hope that future studies will evaluate this modality in children and its role in vision screenings to allow for greater eye care accessibility. At present time, legislation has not kept up with the technology that is being developed in tele-optometry. In most states, the optometrist needs to be present on-site for remote eye care. With studies such as this, as well as other larger-scale studies, we hope to demonstrate the role for this type of eye care delivery and its value and use in preventative health care and for eyeglass prescriptions for straightforward cases. This can increase eye care delivery and screenings nationwide (and perhaps internationally as well) to those who have limited access. With ongoing advances in tele-optometry, remote refractions may provide earlier intervention for corrective lenses in rural and underserved communities, where an optometric eye examination is difficult to attend.

Conclusions

With the increase in digital exposure across all professions to meet the needs of consumers, it is likely that tele-optometry will continue to be adopted, not only for disease management in rural areas, but also for the comprehensive eye examination, including refractions. Our data suggests that for a healthy, pre-presbyopic patient population, a tele-optometric remote refraction is not statistically different from an in-person refraction. Careful attention should be paid to low hyperopes and high myopes who may be over-minused in the remote refractions, as these cases accounted for the 10% of refractions that were deemed non-equivalent. This novel delivery of eye care may hold possibilities for earlier intervention for refractive conditions and may provide more widespread access to alleviate the burden of uncorrected refractive error.

Acknowledgements: DigitalOptometrics

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