Article • Binocular Vision and Accommodative Testing in the Tele-Optometric Comprehensive Eye Examination in a Student Population

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ABSTRACT

Background: Current research in the realm of tele-optometric examinations is largely focused on the refractive and ocular health components of the exam. The purpose of this study was to evaluate the validity of binocular vision and accommodative testing in a tele-optometric examination compared to an in-person examination.

Methods: Thirty students, ≥18 years old, at the Illinois College of Optometry were recruited to participate in this study. A tele-optometric examination was completed using the DigitalOptometrics platform, followed by a standard in-person examination. The following tests were performed in both examinations: near horizontal heterophoria by von Graefe, near negative and positive fusional vergences (NFV and PFV, respectively) by Risley prism, and accommodative testing with fused cross-cylinder (FCC).

Results: The mean near horizontal heterophoria by von Graefe was $2.09^{\Delta} \pm 6.73^{\Delta}$ exophoria in the tele-optometric examinations and $2.07^{\Delta} \pm 6.54^{\Delta}$ exophoria in the in-person examinations, with no statistically significant difference between the two examinations (p=0.98). The mean NFV break and recovery in the tele-optometric examination were $10.85^{\Delta} \pm 3.17^{\Delta}$ and $7.08^{\Delta} \pm 3.03^{\Delta}$, respectively, and $23.40^{\Delta} \pm 7.71^{\Delta}$ and $15.38^{\Delta} \pm 7.31^{\Delta}$, respectively, in the in-person examination, with a statistically significant difference (for both, p<0.0001). The mean PFV break and recovery in the tele-optometric examination were $13.50^{\Delta} \pm 4.24^{\Delta}$ and $9.36^{\Delta} \pm 4.68^{\Delta}$, respectively, and $25.86^{\Delta} \pm 10.48^{\Delta}$ and $16.54^{\Delta} \pm 7.18^{\Delta}$, respectively, in the in-person examination, with a statistically significant difference (break: p=0.001, recovery: p=0.004). Agreement of NFV and PFV between the two examinations was poor. The average FCC in the tele-optometric versus in-person examination was +0.67 D ± 0.51 D and +0.96 D ± 0.33 D, respectively, with a statistically significant difference between the two examinations (p=0.012).

Conclusions: The tele-optometric and in-person examinations had fair agreement on near heterophoria but poor agreement on break and recovery values of NFV and PFV. Accommodative testing with FCC was not equivalent between the two exams.

Keywords: accommodative testing, binocular vision, tele-optometry

Introduction

The field of tele-health has had exponential growth in recent years due to innovations in digital technologies, the basic need to provide healthcare to a growing and aging population, and an increasing interest, largely driven by the COVID-19 pandemic, from both the public and medical communities.[1,2] In 2019, the World Health Organization (WHO) released recommendations to include digital interventions in an effort to strengthen our current health system.[3] These guidelines recognized the use of digital technology in strengthening the health system and in reducing health inequalities, particularly in rural and

underserved areas. While the WHO recognized that tele-health technologies can positively impact access to healthcare for many globally, careful evaluation of their benefits versus risks should be weighed before implementing these technologies on a large scale to avoid taking resources away from other, non-digital means of healthcare.[3,4]

Tele-health in eye care has been catapulted by new improvements in digital technologies, as well as by legislative changes during the COVID-19 pandemic. The global crisis provided a unique opportunity to test new platforms and to expand patient outreach via tele-health platforms.[1,5,6] These services allow eye care providers to reach underserved and remote communities, as well as to open the doors for co-management between optometrists and ophthalmologists in areas where there may be a shortage of specialists.[7-10] Thus far, tele-health services and research in eyecare have predominantly focused on spectacle prescriptions and anterior and posterior segment health examination, with a heavy emphasis on retinal health and glaucoma diagnosis and treatment.[11-21] To date, there have been no studies that compare the binocular vision and accommodative test results between tele-optometric and in-person examinations.

This study aimed to evaluate the validity of binocular vision and accommodative testing in tele-optometric examinations compared to in-person comprehensive examinations. Both binocular vision and accommodative testing are important aspects of the comprehensive eye examination, especially in the pre-presbyopic population.[22-25] As interest in tele-optometry grows and emerging eye examination innovations become more widely accepted, it is imperative to know how these components of the comprehensive eye examination compare in a tele-optometric examination versus an in-person examination. From this information, we can gain a better understanding of what improvements need to be made in the tele-optometric examination.

Methods

A cohort of 30 pre-presbyopic students, ≥18 years old, at the Illinois College of Optometry were recruited to participate in this pilot study, excluding 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 were obtained from all participants.

Participants completed two separate comprehensive eye examinations on the same day. First, a tele-optometric examination was completed via the DigitalOptometrics platform, including a remote refraction with binocular vision and accommodative testing by a remote technician and videoconferencing with an investigator optometrist. This was followed by a standard in-person examination by a different investigator optometrist. Entering visual acuities, entrance testing, objective and subjective manifest refraction, near binocular vision testing, accommodative testing, intraocular pressure, and anterior and posterior segment evaluation were included in both the tele-optometric and in-person examinations.

An autorefraction was obtained with a Nidek autorefractor. This was used as an objective starting point for refraction by both the remote technician in the tele-optometric examination and the investigator optometrist in the in-person examination. In both examinations, the manifest refraction was performed with the Reichart Phoroptor VRx Digital Refraction System. Both the remote investigator optometrist and the in-person investigator optometrist reviewed the data to determine the final spectacle prescription to be released. This spectacle prescription was used as the control lens for binocular vision and accommodative testing.

Binocular vision and accommodative testing were performed behind the Reichart Phoroptor VRx Digital Refraction System in both the tele-optometric and the in-person examinations. The following binocular vision measurements were collected for both examinations: near horizontal heterophoria by von Graefe and near negative fusional vergences (NFV) and positive fusional vergences (PFV) by Risley prism. Near horizontal heterophoria was performed first. NFV was then measured before PFV; base-in blur, break, and recovery were performed before base-out blur, break, and recovery. Paired samples t-tests were used for statistical analysis, and Bland-Altman analysis was used to evaluate the agreement between the two examinations using the 95% limits of agreement (LoA).

In both the tele-optometric and the in-person examinations, accommodative testing was performed after binocular vision testing. Fused cross cylinder (FCC) testing was performed in both the tele-optometric and in-person examinations to measure the accommodative response. Paired samples t-test and Wilcoxon signed rank test were used for statistical analysis.

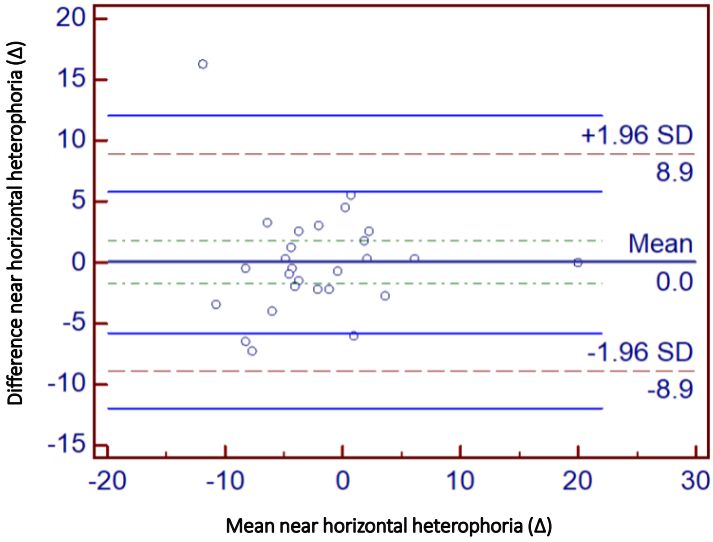

Figure 1. Bland-Altman plot showing the agreement in near horizontal heterophoria measurement between the tele-optometric and the in-person examination. The mean difference in near horizontal heterophoria between the tele-optometric and the in-person examination is plotted against the mean of the two examinations.

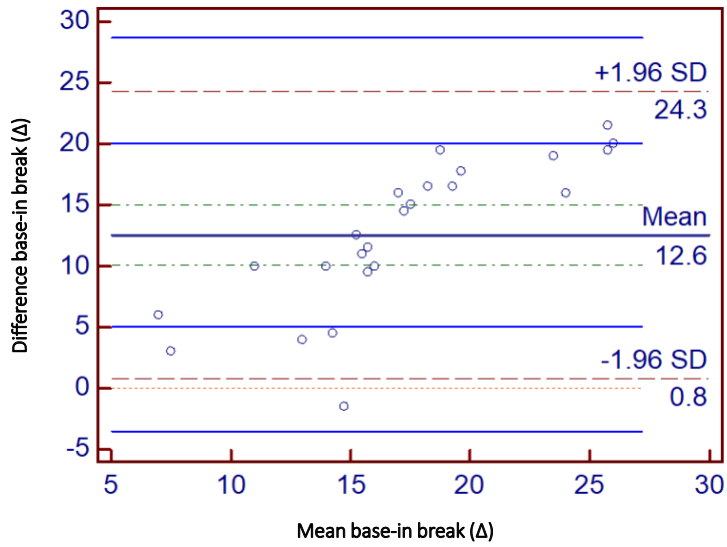

Figure 2. Bland-Altman plot showing the agreement of base-in break between the tele-optometric and the in-person examination. The mean difference in base-in break between the tele-optometric and the in-person examination is plotted against the mean of the two examinations.

Results

Thirty participants were included in this study. There were 9 males and 21 females, and the mean age of the participants was 24.7 years, with ages ranging from 22-33 years. All participants' best-corrected visual acuity was 20/20 OD and OS. All participants were able to complete the binocular vision and accommodative testing in both the tele-optometric and the in-person examinations.

The mean near horizontal heterophoria by von Graefe was $2.09^{\Delta} \pm 6.73^{\Delta}$ exophoria in the tele-optometric examination and $2.07^{\Delta} \pm 6.54^{\Delta}$ exophoria in the in-person examination, with no statistically significant difference between the two examinations ($p=0.98$). Agreement of near horizontal phoria between the two tests was fair, with 95% limits of agreement (LoA) of ±8.9Δ (Figure 1). The mean NFV break and recovery in the tele-optometric examination were $10.85^{\Delta} \pm 3.17^{\Delta}$ and $7.08^{\Delta} \pm 3.03^{\Delta}$, respectively, and $23.40^{\Delta} \pm 7.71^{\Delta}$ and $15.38^{\Delta} \pm 7.31^{\Delta}$, respectively, in the in-person examination, with a statistically significant difference noted (for both, $p<0.0001$). Agreement of NFV between the two examinations was poor, with 95% LoA of $\pm 11.80^{\Delta}$ and $\pm 12.47^{\Delta}$ for break (Figure 2) and recovery (Figure

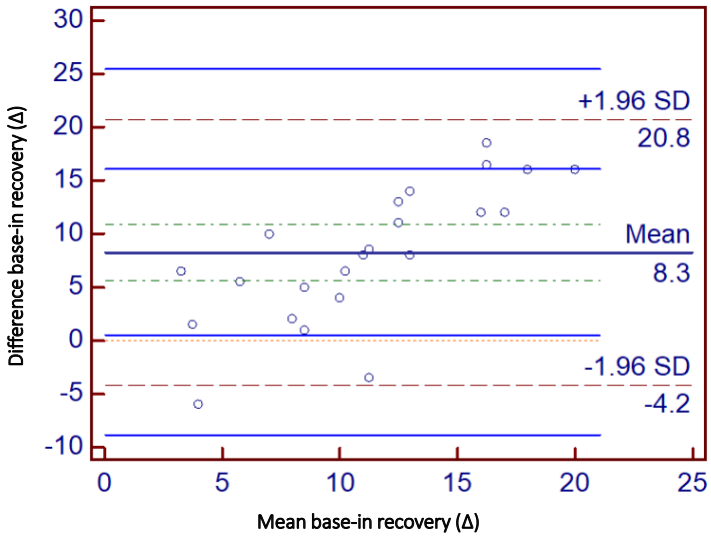

Figure 3. Bland-Altman plot showing the agreement of base-in recovery between the tele-optometric and the in-person examination. The mean difference in base-in recovery between the tele-optometric and the in-person examination is plotted against the mean of the two examinations.

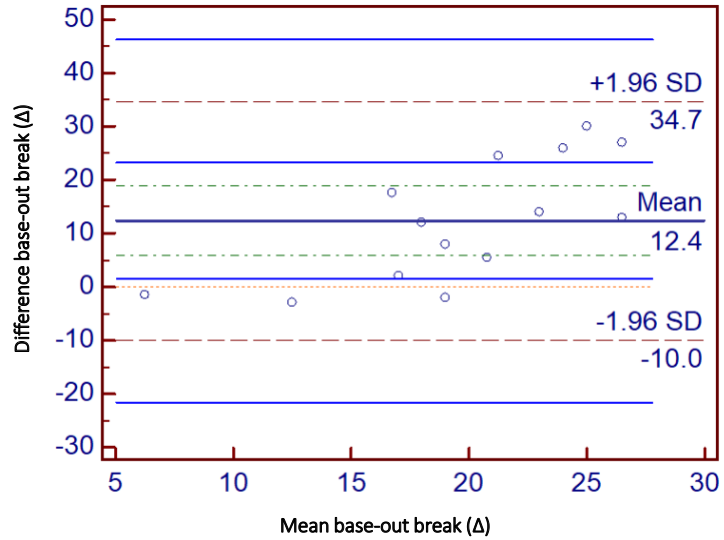

Figure 4. Bland-Altman plot showing the agreement of base-out break between the tele-optometric and the in-person examination. The mean difference in base-out break between the tele-optometric and the in-person examination is plotted against the mean of the two examinations.

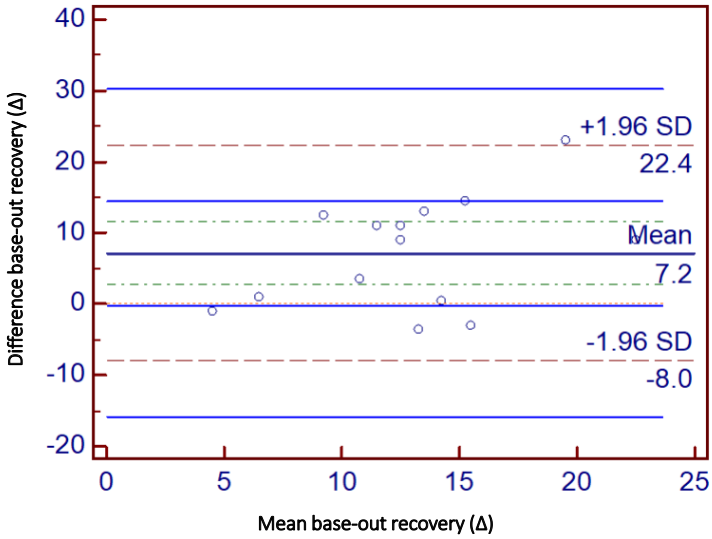

Figure 5. Bland-Altman plot showing the agreement of base-out recovery between the tele-optometric and the in-person examination. The mean difference in base-out recovery between the tele-optometric and the in-person examination is plotted against the mean of the two examinations.

3), respectively. The mean PFV break and recovery in the tele-optometric examination were 13.50$^{\Delta}$ ± 4.24$^{\Delta}$ and 9.36$^{\Delta}$ ± 4.68$^{\Delta}$, respectively, and 25.86$^{\Delta}$ ± 10.48$^{\Delta}$ and 16.54$^{\Delta}$± 7.18$^{\Delta}$, respectively, in the in-person examination, with statistical significance (break: p=0.001, recovery: p=0.004). Agreement of PFV between the two examinations was poor, with 95% LoA of ±22.39$^{\Delta}$ and ±15.21$^{\Delta}$ for break (Figure 4) and recovery (Figure 5), respectively. In the tele-optometric examinations, 10% (3/30) of the subjects were found to have abnormal binocular vision compared with the in-person examinations, which found 27% (8/30) of the subjects to have abnormal binocular vision.

The average FCC in the tele-optometric versus in-person examination was +0.67 D ± 0.51 D and +0.96 D ± 0.33 D, respectively, with a statistically significant difference between the two examinations (p=0.012). When further analyzing the tele-optometric versus in-person results, 27% (8/30) of the subjects showed equal findings, and 13% (4/30) of the subjects showed greater lag of accommodation with the tele-optometric examination. Conversely, 60% (18/30) of the subjects showed a greater lead of accommodation with the in-person examination.

Discussion

With increasing interest in tele-optometric eye examinations and new digital technologies advancing at a rapid rate, it is important to evaluate the reliability of binocular vision and accommodative testing using a tele-optometric eye examination. This modality of health care delivery may attract a higher percentage of young, pre-presbyopic patients, who may be more likely to have abnormal binocular vision or accommodative findings. The 2021 State of Healthcare Report[26] surveyed patients from 225 health systems in the United States on digital health. The results showed that the perception of digital health care delivery was dependent on the patient's generational category. In the younger generations, including Gen Z, millennials, and Gen X, 71% preferred tele-health to in-person because of the convenience, with 44% of Gen Z and millennials reporting that they would consider switching providers if a tele-health option was not offered post-pandemic.[26] Additionally, these younger, pre-presbyopic patients may be more susceptible to digital eye strain due to the nature of their avocation and vocation, as well as the shift to greater use of digital devices in school and at work during the COVID-19 pandemic. Digital eye strain has a multifactorial etiology due to the use of digital screens and may cause a variety of symptoms. Binocular dysfunction and accommodative problems are commonly contributing factors in patients who are symptomatic for digital eye strain, and comprehensive eye examinations are important to identifying these factors and alleviating the patients' symptoms.[27,28]

In this study, the tele-optometric and in-person examinations showed fair agreement on near horizontal heterophoria but poor agreement on break and recovery values for NFV and PFV. When fusional vergences were repeated, it was recognized that the second measurement might have been significantly different from the first measurement.[29-31] The tele-optometric examinations also missed a significant number of subjects with abnormal binocular vision compared with the in-person examination. One explanation is that due to using a remote investigator in the tele-optometric examination, a cover test was not and could not be performed. It is possible that if a patient had a strabismus and was suppressing, this finding would not be identified during the tele-optometric examination.

Our data suggests that accommodative testing with the FCC method is not equivalent between the tele-optometric and in-person eye examinations. A greater lead of accommodation was found in the in-person examination versus the tele-optometric examination in 53% of patients. One explanation is that FCC is a subjective test, and it is possible that the subjects' responses may have varied between the

two examinations. The endpoint of FCC relies on the patient's ability to relax accommodation. This study also examined FCC on only pre-presbyopic patients, who may not have a static accommodative response.[32] It is important to note that the control lenses used for the tele-optometric examination may have been different from the in-person examination, depending on the spectacle prescription that was found on both examinations. Lag of accommodation can be attributed to accommodative deficiency, but it also may be a result of uncorrected or under-corrected hypermetropia.[32] The refractive results of this study revealed that two hyperopes were prescribed low myopic prescriptions in the remote refraction in the tele-optometric examination. This may have affected their response on FCC testing in the tele-optometric examination. In comparing the repeatability of accommodative response, one study compared Nott retinoscopy, monocular estimation method (MEM) retinoscopy, FCC, and near autorefractometry. It was found that Nott retinoscopy was the most repeatable measurement of accommodative response, with FCC being second.[32] Therefore, careful consideration should be given when choosing FCC as the sole method in evaluating the accommodative system.

One limitation of this study is that only pre-presbyopic students from the Illinois College of Optometry were recruited to participate. A patient population of only optometry students may be a biased sample from which to draw a conclusion for comparison, as this population is exposed to greater than average binocular and accommodative stress. However, this age range of patients may also be more likely to undergo a tele-optometric examination than other generations.

The results from this study highlight several key areas that should be taken into consideration that could help to improve the quality of tele-optometric examinations. With binocular vision testing, it should be noted that digital phoropters only allow for Risley prism fusional vergences to be measured with a step vergence technique rather than the standard smooth prism technique. In young adults, there is fair repeatability in results when Risley prism fusion vergences are measured with smooth prism.[33] Furthermore, several studies have shown that the findings between smooth and step vergences are different.[34,35] If digital phoropters and tele-optometric platforms can correct for this, horizontal fusional vergences may be more repeatable between the two exams. In addition, measurement of accommodative function with minus lens amplitude may prove to be less statistically different between the tele-optometric and the in-person examinations. This method is more repeatable than push-up and pull-away techniques and can be performed in-phoropter for both the tele-optometric and the in-person examination and therefore should be considered in future studies.[36]

Conclusions

As digital innovations continue to advance the field of tele-health, there is growing promise with the role of tele-health in eye care. Current research and technology thus far have focused on the refractive and ocular health components of the comprehensive eye examination. There is value in assessing the validity of tele-health in binocular vision and accommodative testing to better understand which patient populations may be best served with the option for tele-optometric eye examinations. Our findings indicate that near horizontal heterophoria measurements are comparable between tele-optometric and in-person examinations, and there is no statistical significance between the two examinations. However, there is poor agreement on the break and recovery results of NFV and PFV. Accommodative testing with FCC is also not equivalent between the tele-optometric and the in-person examinations. Further studies with a larger and more diverse subject pool are required to determine whether these results can be extrapolated to the general population, as this modality of eye care continues to attract interest and holds potential in reducing disparities in access to eye and vision care in rural and underserved areas.

Acknowledgements: DigitalOptometrics

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