Clinical and Experimental Optometry

ISSN: 0816-4622 (Print) 1444-0938 (Online) Journal homepage: www.tandfonline.com/journals/tceo20

Tele-refraction in tele-eye care settings

Nicolas Blais, Benoît Tousignant & Jean-Marie Hanssens

To cite this article: Nicolas Blais, Benoît Tousignant & Jean-Marie Hanssens (2022) Tele-refraction in tele-eye care settings, Clinical and Experimental Optometry, 105:6, 573-581, DOI: 10.1080/08164622.2021.2009736

To link to this article: https://doi.org/10.1080/08164622.2021.2009736

CLINICAL AND EXPERIMENTAL OPTOMETRY
2022, VOL. 105, NO. 6, 573–581
https://doi.org/10.1080/08164622.2021.2009736

SCOPING REVIEW

Tele-refraction in tele-eye care settings

Nicolas Blais, Benoît Tousignant and Jean-Marie Hanssens

School of Optometry, Universite de Montreal, Montreal, Canada

ABSTRACT

Refraction is an important part of a comprehensive eye examination, and when performed remotely through information and communication technology or when its results are transmitted for remote analysis, this procedure is called tele-refraction. Uncorrected refractive errors are the main reason for consultation in primary eye care, and an increasing number of eye care providers offer tele-refraction services in response to the global demand. Even so, very little literature exists on how the correction of refractive errors can be managed through tele-eye care. The objectives of this review are to examine the integration of tele-refraction in different eye care models and to report the existing findings regarding patient satisfaction towards tele-refraction and the efficacy of tele-refraction. Searches were undertaken on Medline, Embase, EBM Reviews, CINAHL and Web of Science to identify relevant articles. All original studies describing a clinical tele-refraction service and its outcomes were included. Out of 1322 articles, 15 were retained for analysis and have shown that tele-refraction has been provided for general eye care (n = 10; 67%), refractive-only examinations (n = 3; 20%) or disease-specific screening (n = 2; 13%). Ten (67%) had a hybrid telemedicine modality. Given the small number of included studies and the lack of outcomes comparing refractive errors between face-to-face and remote refraction, it is concluded that the current scientific literature does not reflect the increasing availability of tele-refraction in clinical practice. More studies on remote refraction should be conducted to better understand its efficacy, cost-effectiveness and impacts on patient satisfaction and management.

ARTICLE HISTORY
Received 2 June 2021
Revised 10 November 2021
Accepted 17 November 2021

KEYWORDS
Refraction; tele-eye care; tele-ophthalmology; tele-optometry; tele-refraction

Introduction

Telemedicine is defined as the use of information and communication technologies (ICT) to provide remote health care to patients.[1] It can be classified within the following categories: store-and-forward, real-time and hybrid telemedicine. Store-and-forward is the asynchronous component of telemedicine and refers to the in-person collection of data followed by a remote analysis by a specialist, while real-time telemedicine implies that data are collected and reviewed in a face-to-face videoconference with the care provider.[2] The hybrid modality, often used in specialities relying on medical imaging like in tele-eye care, allows for a remote review of the collected clinical data before or after live teleconsultations.[3]

Tele-eye care is a branch of telemedicine that includes both tele-ophthalmology and tele-optometry. In this review, tele-ophthalmology is considered the use of telemedicine to perform medical and surgical interventions in a secondary or tertiary level of care, while tele-optometry refers to the provision of remote primary eye care through telemedicine such as comprehensive eye exams, disease-specific screening and treatment of certain eye conditions.[4,5] Up to now, tele-optometry in diabetic retinopathy screening has been well studied,[6] but it may also target other eye conditions, such as uncorrected refractive errors.

When refractive measurements are analysed remotely, this procedure is called tele-refraction.[7] It can either be self-performed online by patients with app-based refractive tests on their cellphone[8] or be a clinical service, with on-site staff assisting the patient while the eye care provider is working remotely. However, the American Optometric Association considers that self-administered eye care 'does not constitute telemedicine in optometry unless used under the direction of a doctor of optometry'.[9] Since eye care management depends highly on clinical judgement and because asymptomatic eye diseases are often diagnosed through opportunistic findings,[10,11] this review focuses on the clinical type of tele-refraction in which an eye care professional is involved remotely.

According to the World Report on Vision,[12] uncorrected refractive errors constitute the leading cause of visual impairment globally. Due to the high prevalence of uncorrected refractive errors, Fricke et al.[13] estimated in 2012 that 'approximately 47,000 additional full-time functional clinical refractionists and 18,000 additional ophthalmic dispensers would be needed to deal with all cases of vision impairment due to uncorrected refractive errors'. In order to respond to the increasing demand for optometric care, many tele-optometric services and devices, such as the platforms of DigitalOptometrics® and 20/20NOW™, have recently emerged on the market, allowing eye care providers to offer remote services to many thousands of people over the past years.[8,14] Precise figures regarding the magnitude of use of tele-optometric examinations performed each year in countries like the United States are not available, since providers are not in the obligation to share that kind of data publicly.

The Covid-19 pandemic has been a turning point in widespread acceptance towards technology in health care and a considerable trigger of this recent tendency towards remote eye care.[15–17] As a result, some general guidelines on tele-optometry have been adopted by various professional associations and regulatory bodies.[5,9,18] Even though there are numerous health care professionals and stakeholders involved

CONTACT Nicolas Blais nicolas.blais.1@umontreal.ca School of Optometry, Universite de Montreal, Montreal, Canada
Supplemental data for this article can be accessed here.

in eye care, there appears to be no clear consensus on how clinical remote refraction can be used remotely and how it compares to in-person clinical standards of care.

While there is an increasing uptake of tele-refraction by eye care providers worldwide, there is also a scarcity of literature on how to judiciously integrate it within models of comprehensive primary eye care. This scoping review was conducted to examine the integration of tele-refraction in different eye care models and to report the existing findings regarding patient satisfaction towards tele-refraction and the efficacy of tele-refraction.

Methods

The protocol of this review was not published *a priori* and was conducted using the Preferred Reporting Items for Systematic reviews and Meta-Analyzes extension for Scoping Reviews (PRISMA-ScR).[19] In order to identify relevant studies, the search strategy detailed in Appendix A was developed with a reference librarian at the Health Library of the *Universite de Montreal*. Searches were undertaken on Medline, Embase, EBM Reviews, CINAHL and Web of Science on August 3rd, 2021 and were not time constrained. Gray literature including clinical guidelines from different countries (see Appendix B) was also manually searched with the main research terms (telemedicine, teleophthalmology, tele-optometry and tele-refraction). All search results were imported in Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia. www.covidence.org), in which duplicate articles were removed.

The identification, screening and selection process are detailed in a PRISMA Flowchart[20] shown in Figure 1. An optometry student (NB) performed the first screening of all records for title, abstract and, as needed, full text. The same investigator as well as an eye care professional (JMH) screened all remaining full text records for eligibility. A manual search of reference lists of included articles did not provide new publications, but additional records were identified through searching on Google Scholar and also through hand-searching relevant reviews and key journals like the Investigative Ophthalmology & Visual Science (IOVS) ARVO journal. These additional records were either added to the included dataset or excluded after full text screening. Conflicts for full text eligibility were resolved by mutual agreement between the two reviewers.

To be included, each article must have reported on objective and/or subjective refraction with the transmission and remote analysis of refractive measurements. It had to provide outcomes specific to refractive results. In alignment with the objectives of this review to examine the integration of tele-refraction in different primary eye care models, it was decided that an eye care professional must have been involved in the remote analysis of transferred refractive data in every included article. It also must have been written in French, English or Spanish and the full text of the article had to be available unless it was a conference proceeding. All study designs were included, except reviews and published protocols.

For each study that met inclusion criteria, a single investigator (NB) extracted year of publication, country of service, sample size, primary eye care type and context, in-person and

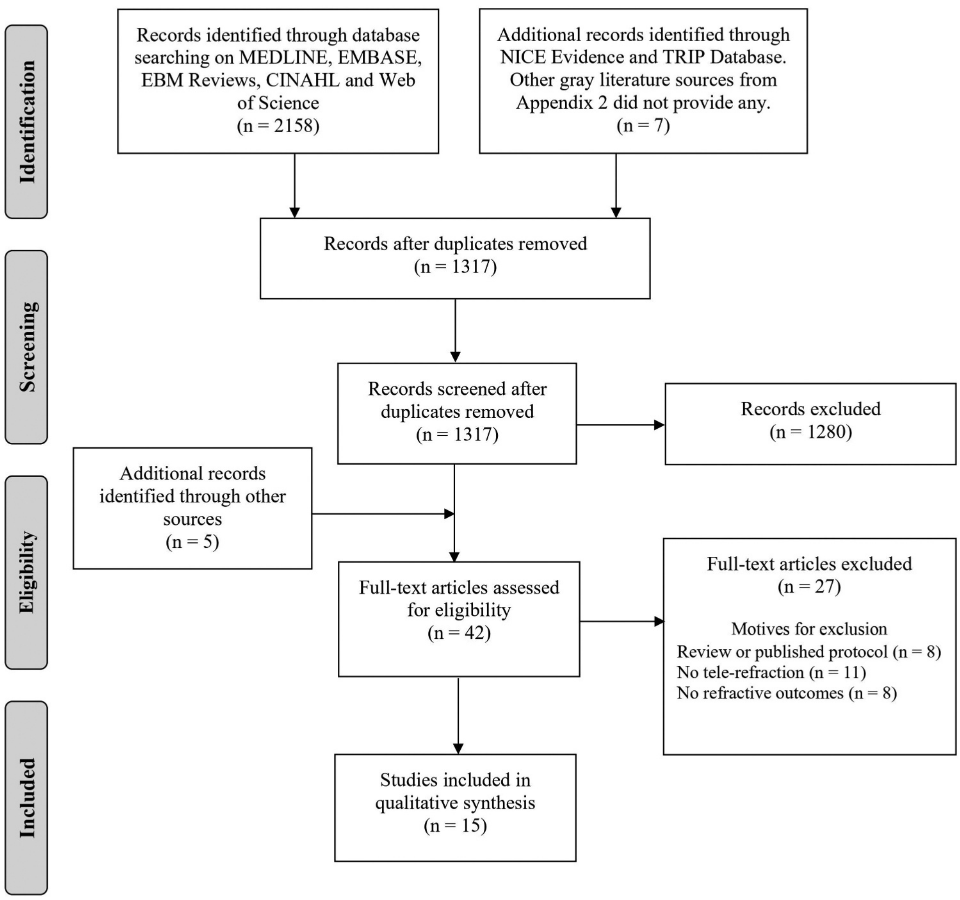

Figure 1. PRISMA flowchart for a scoping review on tele-refraction.

remote tele-refraction provider, tele-refraction modality (asynchronous, synchronous or hybrid), type of refraction performed (for example, autorefraction or manifest refraction), provision of spectacle prescriptions and spectacles, service description, patient satisfaction and refractive outcomes (Supplementary Table 1), including the resolution capacity[21] for refractive errors of each study when possible, which is the ability of each tele-refraction service to fully address the refractive needs of patients.

The primary eye care type of each article was categorised in 'general eye care' for studies regarding comprehensive eye care models, 'disease specific screening' for studies describing an investigation method for certain eye conditions or pathologies and 'refractive exam only' for publications focusing mostly on refractive measurements. Primary eye care context was classified as 'health care access', 'academic research' or 'commercial product'. An Excel spreadsheet was then exported from Covidence and extraction was reviewed by the other investigator (JMH). Conflicts were again resolved by mutual agreement upon discussion between the reviewers.

Results

The search strategy performed on 3 August 2021 identified 2165 records (517 from Medline; 394 from Embase; 89 from EBM Reviews; 251 from CINAHL; 907 from Web of Science; three from NICE Evidence; four from TRIP Database) (Figure 1). After duplicates removal, 1317 publications underwent title and abstract screening, out of which 1280 did not meet inclusion criteria. Many of these excluded records described diabetic retinopathy or glaucoma remote screening in which refraction was not performed. Five supplementary articles were then added to the remaining 37 studies: one from Google Scholar, one from hand-searching a relevant review[22] and four came from the IOVS ARVO journal.

All 42 records went through full-text screening that removed 27 articles including eight for wrong design (five reviews and three published protocols), 11 in which no tele-refraction was performed and eight due to the absence of refractive outcomes. A total of 15 publications (11 articles, four conference proceedings) were retained for analysis and charting.

Evidence characteristics

The included studies were published between 2011 and 2021 with an increasing number of articles in recent years (47% published in 2020 or 2021). The tele-eye care services described in these publications are from five different countries, the majority taking place in the United States (33%) and India (33%). These services provided general eye care (n = 10; 67%), refractive-only examinations (n = 3; 20%) including one for low-vision patients,[23] and disease-specific screening (n = 2; 13%). All studies took place in tele-optometric settings due to the primary level of care they displayed.

Most studies were conducted in contexts looking to improve access to health care (n = 12; 80%). Many took place in remote or rural areas[24–28] and one was an epidemiological study structured as a community-based screening program.[29] Some also described different eye care programs ongoing in Brazil[21] and in France[30] within their public health system. An American program implemented in the Veteran Affairs Healthcare System was also described.[31,32] There were a few studies (n = 2; 13%) that came from academic settings[7,33] and only one (7%) that analysed the efficacy of a commercial product for remote refraction.[34]

Refraction providers

Various care providers were involved in refraction and its remote analysis. Most studies (n = 12; 80%) had a technician as an on-site refraction provider.[14,23–26,28,29,31–35] Slightly different titles were used to designate technicians from one study to another but based on their role within each protocol, the following assistants were all considered as technicians: ophthalmic technologists,[23] ocular technicians,[29] vision technicians,[24,25] ophthalmology technician,[31] ophthalmic technician[32] and mid-level ophthalmic personnel.[28] Apart from technicians, the other on-site refraction providers were nurses, who shared on-site assistance with technicians in a study by Lutz de Araujo et al.,[21] one paramedical ophthalmic officer,[26] one orthoptist[30] and one optometrist.[27]

Ophthalmologists were involved as remote refraction providers in 13 (87%) studies.[14,21,23–32,34,35] One study by Kapoor and et al.[29] had an optometrist or an ophthalmologist as remote eye care providers and another by Randhawa et al.[33] described a tele-refraction service involving a remote refractionist, whose refraction was then taken over by a remote optometrist to confirm measurements. One more study by Blais et al.[7] report on how two optometry students alternatively played a technician and a refractionist to compare in-person and remote refractive measurements and patient satisfaction.

Tele-refraction modalities

In two articles,[24,27] only patients with ocular abnormalities making them eligible for teleconsultation had their refractive measurements sent for remote analysis. In the remaining 13 studies, refractive results were systematically transmitted.

Five (33%) studies had a store-and-forward design since the remote eye care practitioner would review refractive measurements along with other clinical data when available. The remote provider would either make diagnoses and treatment plans or give management recommendations to the on-site provider regarding ametropias and pathologies. Among these, data transmission was made via an electronic medical record in two studies,[30,31] via a secure network in another one[29] and one by Li et al.[34] used a telemedicine platform. The mean used for transferring data was not specified in one asynchronous study.[32]

Ten (67%) articles described a hybrid telemedicine modality, meaning that there was a teleconsultation between patients and eye care practitioners during the eye exams. Some teleconsultations took place during the exams to perform remote objective refraction[23] or even manifest refraction[7,21,23,33] or were at the end of the eye exam to review clinical findings and treatment plans with patients and on-site providers. Three of these studies used an EMR,[24,25,27] three more used a telemedicine platform,[7,21,33] one used a secure server[35] and another used the TeamViewer software to connect to the on-site laptop.[23] Two articles did not specify how data were transmitted for remote analysis.[26,28] One study by Lutz de Araujo et al.[21] described how their hybrid model of tele-eye care services allowed the ophthalmologist to remotely control various function of on-site robotic cameras like rotation and zoom to better evaluate patients.

Refractive techniques

Most studies (n = 4; 27%) used only an autorefractor[27,29,32] or wavefront-sensing technology[34] to measure refractive errors. An autorefractor was used in four (27%) studies where in-person subjective refraction was performed.[24,25,30,31] It was also used in four (27%) studies where refraction was performed remotely with digital phoropters enabling remote providers to control manifest refractions through videoconferencing with patients.[7,21,23,33] Among these four studies, an article by Curtis et al.[23] described how an ophthalmologist remotely controlled an automated binocular photorefractor combined with an adaptor scope accessory. A remote manifest refraction using a head-mounted digital phoropter was then performed based on the objective results of the photorefractor.

One study used trial frames instead of a manual or digital phoropter[31] and in three others, no refractive technique was specified,[26,28,35] but one mentioned that retinoscopy was performed when required.[26] Only six compared remote refraction with an in-person modality control group. One compared spectacles remake rates[31] and five compared refractive measurements (spherical and cylindrical components or only spherical equivalents values).[7,23,32–34] The refractive outcomes of each of these studies are presented in the following sections.

Refractive outcomes

Six (40%) studies compared two types of refraction. Maa et al.[32] compared a transmitted autorefraction and face-to-face subjective refraction. The difference between the spectacle prescriptions of both techniques was within American National Standards Institute for lens manufacturing guidelines.[36] Another article by Maa et al.[31] compared the spectacles remake rate between a cohort of patients with spectacles prescriptions based on the measurements of the autorefractor and another cohort whose subjective refraction was used to prescribe spectacles. They concluded that there was no statistically significant difference between spectacles remake rate for change in distance prescription between both cohorts.

Using a smartphone with an on-site technician assisting, Li et al.[34] compared wavefront-based autorefraction results to the prescriptions of a remote eye care practitioner. Remote prescriptions by the ophthalmologist were based on the same autorefractor measurements, on the comments of the technician and on the lensometry of the actual spectacles of the patient, when available. Prescriptions differed by an average of 0.40 D. Randhawa et al.[33] focused on comparing remotely controlled manifest refraction to in-person manifest refraction. They found that 90% of prescriptions from tele-refraction were within a clinical range of ±0.50D of spherical equivalent and were therefore equivalent between the two same refractive techniques, but 10% were given extra spherical minus. Similarly, Blais et al.[7] found that 88% of prescriptions were equivalent to a gold standard prescription based on subjective refraction, within a clinical range of ±0.25 D of spherical equivalent, while 3% were given extra spherical minus and 9% were given extra spherical plus.

Curtis et al.[23] compared standard refractive equipment with remote devices between low-vision patients and normally sighted patients. They concluded that the differences in spherical equivalent between in-person and remote autorefraction (0.701 D) and between in-person and remote manifest refraction (−0.116 D) were clinically acceptable for both groups of patients.

Apart from these six studies comparing types of refraction, an additional study by Bon et al.[35] provided refractive outcomes regarding a tele-refraction service. They obtained a statistically significant improvement of distance and near visual acuity for patients in a nursing home. The proportion of low-vision eyes even decreased from 54% to 39% after the completion of tele-refraction.

Resolution capacity

Another relevant refractive outcome to point out is the resolution capacity of the included services of tele-refraction. This is defined by Lutz de Araujo et al.[21] as 'the ability to fully address the eye complaints of patients in primary care with remote assistance from ophthalmologists'. Among the included studies, six (40%) stated the prevalence of refractive errors in their research sample[21,24,26–28,32] and four (27%) mentioned the total number of participants in need of new prescribed spectacles.[25,28,29,35] Among these articles, the prevalence of refractive errors detected with tele-refraction ranged from 16% in a study by Das et al.,[25] without specification as to whether or not presbyopia was included in this prevalence, to 70% for refractive errors and 56% for presbyopia in a study by Lutz de Araujo et al.[21]

Lutz de Araujo et al.[21] also found that spasm of accommodation had the highest resolution capacity (90%), followed by lid disorders (78%), presbyopia (75%) and refractive errors (77%). Similarly, Misra et al.[24] were able to treat 83% of patients at primary care level, including those who were diagnosed with refractive errors. However, in this study, refractive measurements were only transmitted to a remote ophthalmologist if an obvious ocular pathology was found, otherwise refractive errors were entirely handled by the on-site technician, while Lutz de Araujo et al.[21] had all their patients undergo a manifest refraction performed remotely by ophthalmologists. Muraine et al.[30] obtained a resolution capacity of 96% with a store-and-forward manifest refraction, the remaining 4% being mostly children in need of a cycloplegic eye exam. Their protocol was the first to allow French ophthalmologists to delegate subjective refraction to orthoptists while no ophthalmologist was on-site to supervise the delegation.

Refractive error management

Although refractive data were transmitted to the remote eye care providers in all tele-refraction services, the management of refractive errors varied between studies. The remote providers were in charge of making the spectacles prescriptions for patients in nine (60%) studies,[7,21,26,28,30,31,33–35] which includes two academic studies in which no real prescriptions were given,[7,33] while the on-site providers were in charge of making spectacles prescriptions in four (27%) other articles.[24,25,27,32]

No prescription was issued in one (7%) 'disease-specific screening' study by Kapoor et al.[29] that described the use of a kiosk composed of ophthalmic and systemic instruments for screening purposes. This systemic and ocular screening examination generated a report that included results like the measurements of the autorefractor and it was sent to patients after revision by a remote eye care practitioner. Among all included studies, spectacles appear to have been dispensed in only five (33%).[21,24,25,27,31] One (7%) study did not specify whether or not patients received a prescription or spectacles.[23]

Patient satisfaction

Patient satisfaction regarding tele-eye care was assessed in only four (27%) studies. According to three of them, between 95% and 99% of attendants were satisfied with tele-eye care.[26,30,31] One study by Blais et al.[7] focused more precisely on patient satisfaction towards remote refraction and found that their patients, a cohort of people who had easy access to in-person primary eye care on a daily basis, preferred the in-person modality. However, most patients trusted the results obtained remotely just as much and did not notice a qualitative difference for visual comfort between both spectacles prescriptions in a double-blind set-up.

Discussion

This scoping review aimed to summarise the existing literature on the integration of tele-refraction in tele-eye care services and to report the existing findings on patient satisfaction towards tele-refraction and its efficacy. Although uncorrected refractive errors are the leading cause of vision impairment in the world[12] and represent the main reason for consultation in primary eye care, only 15 studies were included in this review, mostly because refraction is not often the main subject of interest when studying tele-eye care. Specific screening for eye diseases like diabetic retinopathy and glaucoma are far more present in literature than refractive error remote management or comprehensive eye care.

Only a few articles discussed patient satisfaction or compared a type of remote refraction with a gold standard in-person refraction, which limits our capacity to report on the efficacy or cost-effectiveness of tele-refraction. This highlights a clear knowledge gap in those aspects of tele-refraction. However, there appears to be an increasing interest for tele-refraction in research, especially for remote manifest refraction, which may be the most appropriate type of remote refraction considering its uptake in most recent research.

Three of the included studies reported very high resolution capacity rates regarding refractive errors when managed remotely through tele-optometry.[21,24,30] The included studies have also described various tele-eye care models that had a focus on primary eye care, ocular disease screening or refractive examination throughout the world, from low-resource to high-resource settings. The absence of studies on tele-ophthalmology including refraction may be explained by the fact that refractive measurements are usually performed at a primary level of care.

Five (33%) studies[7,23,31–33] discussed the efficacy of tele-refraction by comparing the refractive outcomes of tele-refraction with in-person refraction. Another compared a remote autorefraction with the spectacle prescription of a remote eye care practitioners based on the objective measurements.[34] These studies tend to show that different types of tele-refraction may be equivalent to in-person in refractive errors measurements, which is quite promising for the evolution of tele-refraction. However, the prevalence of refractive errors and the number of patients in need of new prescribed spectacles are not outcomes that are compared between both modalities of refraction. Instead of focusing on whether two modalities of refraction can detect the same prevalence of refractive errors, there is more relevance in knowing whether the refractive measurements resulting from such modalities are equivalent in terms of clinical and statistical differences and also in terms of patient satisfaction.

Interestingly, only three (20%) 'refractive exam only' studies were identified in this review. One described a tele-refraction service and excluded ocular health assessment,[34] while another reported on tele-refraction within a comprehensive model of eye care, by comparing remote and in-person refraction.[7] Curtis et al.[23] also conducted a study on a refraction-only examination for low-vision patients. The majority (n = 10; 67%) of all publications were 'general eye care' studies and described clinical settings in which patients received a comprehensive eye exam. This model of tele-optometry may offer better outcomes to patients compared to specific screening or tele-refraction services, since patients are not just screened for specific conditions, but rather examined thoroughly and treated for all presenting ocular conditions.

Among all models of refraction described in the included articles, those which include both objective refraction and remotely performed subjective refraction through videoconference are the closest type of refractive management to gold standard in-person manifest refraction. Indeed, subjective refraction is more accurate than autorefraction, particularly in children,[37] and leads to better patient satisfaction,[38] while hybrid telemedicine allows for a patient–provider interaction that is closer to in-person care compared to store-and-forward telemedicine. Only four (27%) of the included publications reported the use of remote manifest refraction, but these represent 57% of all the included articles that were published since the beginning of 2020.[7,21,23,33] One of them by Lutz de Araujo et al.[21] stated, at the time of publication in 2020, that their study was 'the first teleophthalmology program in the world that performs real-time subjective refraction'. The three other studies concluded that remote manifest refraction was equivalent or within an acceptable clinical difference to in-person refraction in terms of spectacles prescriptions.[7,23,33]

According to Maa et al.,[32] autorefraction alone provided refractive measurements within American National Standards Institute for lens manufacturing guidelines compared to in-person manifest refraction. Interestingly, autorefraction was performed without subjective refraction in 27% of the included studies (n = 4). Of course, subjective refraction is not a standard of care in every country, nor in all clinical encounters like comprehensive examination versus eye disease screening. For instance, the American Optometric Association states that 'autorefraction may be used as a starting point, but not necessarily as a substitute, for subjective refraction',[39] meaning that a subjective refraction is necessary for a comprehensive adult eye and vision examination.

Interestingly, the American Academy of Ophthalmology states that refraction 'may be performed objectively by retinoscopy, an autorefractor, or a wavefront analyser or it may be done subjectively'.[38] In ophthalmology, subjective refraction is the preferred standard of care for cooperating patients, while other means of refraction measurement may be acceptable in some cases. The World Health Organisation (WHO) Regional Office for Africa states that optometrists should be able to 'determine the refractive status of the eye (subjectively and objectively)'.[40] Similarly, the International Agency for the Prevention of Blindness (IAPB) Refractive Error Program Committee affirm in their Technology Guidelines that 'technology should be used to support the expansion and improved quality of refractive care, but only in the context of comprehensive eye care – technology should not be used as a replacement for skilled people performing, or linked into, comprehensive eye care'.[41]

The IAPB Standard school eye health guidelines for low and middle-income countries also states that 'objective refraction can be done by retinoscopy. An autorefractor validated for use in children can also be used, but this MUST be followed by subjective refraction'.[42] Depending on guidelines, autorefractors can be used without subjective refraction since they are less time-consuming than phoropters and require less training to use, but subjective refraction remains the overall clinical standard.

On-site technical assistance is crucial to most services described in the literature, even though the role of the on-site providers regarding refraction measurement varied greatly between studies. In addition to providing physical human interactions to patients, some of the included studies emphasised how valuable having a skilled technician on-site was to perform tele-optometric exams, especially if this technician played a role in diagnosing ocular conditions.[25,32] Interestingly, a study by Paudel et al.[43] assessed the clinical competency of 1-year trained vision technicians in detecting and managing refractive errors compared to standard optometrists and found that technicians competently detected 83% of refractive errors and made spectacles prescriptions that were accurate 76% of the time for mean spherical equivalent and 65% for astigmatism, meaning that the inclusion of properly trained technicians to tele-eye care could increase the efficacy of future tele-refraction services. A review by Caffery et al.[22] confirms that 'appropriate training on diagnostic instruments and imaging has been identified as a success factor in tele-ophthalmology'.

Around 80% of studies (n = 12) were conducted to increase access to eye care and took place in areas lacking eye care providers, resulting in less travel cost and time for patients. This echoes literature stating that tele-eye care may be effective in increasing access to general and specialised eye care.[44] In addition, patient satisfaction was studied in only four (27%) articles among all the included studies and three of them reported a high level of satisfaction among patients benefiting from tele-optometric services. Satisfaction is a complex metric to measure and to compare between studies, due to the use of different types of questionnaires and because patients underwent very different types of tele-refraction services from one study to another. However, very similar outcomes of high patient satisfaction are found in other tele-optometric studies.[45–50]

Investigators performing patient satisfaction assessments after the beginning of the COVID-19 pandemic should consider that acceptance towards remote health care is influenced by the new lifestyle that includes telemedicine more naturally due to social distancing.[51] Similarly, the lack of access to in-person care is likely to increase satisfaction towards remote care,[44] therefore the level of accessibility to in-person cares should also be taken into account when assessing the patient satisfaction of a certain population.

Studies describing online refraction and other self-administered types of refraction were not included in this review since they are non-assisted and therefore not compatible with clinical tele-optometry. In fact, in agreement with the results of Jeganathan et al.,[52] Tousignant et al.[53] compared the accuracy of a smartphone-based refractive device, assisted and unassisted by an on-site refractionist, with in-person manifest refraction. They found that such self-performed refraction may induce a significant myopic overcorrection, especially when performed without professional assistance, and lowered levels of visual acuity, subjective preference and visual comfort. However, a study by Wisse et al.[54] compared a web-based refractive tool with in-person manifest refraction and obtained results indicating that online eye testing is 'a valid and safe method for measuring visual acuity and refractive error in healthy eyes, particularly for mild myopia'.

Unfortunately, an issue with online refraction is that patients using it may be led away from the need for a comprehensive eye exam, which includes ocular health assessment. Michaud and Forcier,[10] as well as Robinson,[11] have stated that a significant percentage of patients with eye disease are asymptomatic, which means that online refraction services and other self-administered refractive tests are likely to miss more opportunistic findings than clinical tele-optometry.

Limitations

The findings of this review should be considered in light of certain limitations. First, having only one reviewer involved in the initial screening for title and abstract introduces a bias for the primary selection of articles that could have been avoided by performing screening with two reviewers form the start. Second, a significant number of additional articles were identified through hand-searching relevant reviews and journals, which suggests that the search strategy, including the initial choice of databases, might have needed to be reconsidered to include other search resources that include conference proceedings, such as ARVO's IOVS Journal. Also, the fact that eight articles describing a tele-eye care model that included tele-refraction were excluded in the screening process, due to the absence of refractive outcomes, limited the extend of this review. Finally, this review was unlikely to capture all existing models of tele-eye care services, which are in growing numbers globally, since many exist without being described in scientific literature and academic research.[14]

Conclusion

This scoping review examined the integration of tele-refraction in tele-optometric services, including comprehensive models of tele-eye care, eye disease screenings and refractive errors remote management. It also reported the existing findings regarding patient satisfaction and the efficacy of tele-refraction. Given the small number of included studies and the lack of outcomes comparing refractive measurements between face-to-face and remote refraction, insufficient evidence is found to pronounce conclusions regarding its efficacy, cost-effectiveness and its impacts on patient satisfaction and management.

Considering the rapid growth of refractive devices and services on the tele-eye care market and the fact that these new technologies are now used on thousands of patients every year,[14] more studies on remote refraction should be conducted to better report on these aspects. However, this paper did demonstrate that different types of tele-refraction can be equivalent to in-person refraction and that the accuracy of manifest refraction is preferred to the convenience of autorefraction. The reported resolution capacity of tele-refraction will most probably facilitate its integration into many more comprehensive models of tele-eye care.

Acknowledgements

The authors thank and acknowledge the role of Patrice Dupont, reference librarian at the Health Library of the Universite de Montreal, for his assistance in the elaboration of the search strategies and for providing advice regarding the scoping review process."

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

ORCID

Benoît Tousignant http://orcid.org/0000-0002-0395-5027

References

[1] O W. H. Global observatory for eHealth. Telemedicine: opportunities and developments in member states: report on the second global survey on eHealth. Geneva: World Health Organization; 2010.
[2] Tan IJ, Dobson LP, Bartnik S, et al. Real-time teleophthalmology versus face-to-face consultation: a systematic review. J Telemed Telecare. 2016;23:629–638.
[3] Levin YS, Warshaw EM. Teledermatology: a review of reliability and accuracy of diagnosis and management. Dermatol Clin. 2009;27:163–176, vii.
[4] Smythe J, Yolton RL, Leroy A, et al. Use of teleoptometry to evaluate acceptability of rigid gas-permeable contact lens fits. Optometry. 2001;72:13–18.
[5] Optometry Australia. Telehealth Clinical Practice Guide. South Melbourne, Vic; 2021.
[6] Ullah W, Pathan SK, Panchal A, et al. Cost-effectiveness and diagnostic accuracy of telemedicine in macular disease and diabetic retinopathy: a systematic review and meta-analysis. Medicine (Baltimore). 2020;99:2.
[7] Blais N, Le Borgne M, Hanssens JM. Téléréfraction: comparaison d'une réfraction présentielle et d'une réfraction réalisée à distance. In: Poster presented at the 18e Journée scientifique de l'École d'optométrie et du GRSV; Montreal, QC; 2021.
[8] Barlas S. Vision correction goes online. EyeNet Magazine. 2017 Aug. p. 41–46.
[9] American Optometric Association. Position statement regarding telemedicine in optometry. St. Louis, MO; 2020.
[10] Michaud L, Forcier P. Prevalence of asymptomatic ocular conditions in subjects with refractive-based symptoms. J Optom. 2014;7:153–160.
[11] Robinson B. Prevalence of asymptomatic eye disease prévalence des maladies oculaires asymptomatiques. Rev Canadienne D'Optométrie. 2003:1.
[12] World Health Organization. World report on vision. Geneva: World Health Organization; 2019.
[13] Fricke T, Holden B, Wilson D, et al. Global cost of correcting vision impairment from uncorrected refractive error. Bull World Health Organ. 2012;90:728–738.
[14] Karp A, Mark T. Virtual vision care grows up. Vision Monday. 2020;34:14–17.
[15] Chong JC, Tan C-HN, Chen DZJAAMS. Teleophthalmology and its evolving role in a COVID-19 pandemic: a scoping. Ann Acad Med Singap. 2021;50:61–76.
[16] New Zealand Association of Optometrists. Practical Guidance for COVID-19 Level Three. New Zealand; 2020.
[17] Hayhurst C. A turning point for telehealth: COVID-19 spurs rapid uptake of connected care. Biomed Instrum Technol. 2020;54:242–250.
[18] Federation Optometric Regulatory Authorities Canada. Policy on Teleoptometry. Toronto (ON); 2019.
[19] Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169:467–473.
[20] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6:e1000097.
[21] de Araujo Lutz A, Moreira TdC, Varvaki Rados DR, et al. The use of telemedicine to support Brazilian primary care physicians in managing eye conditions: the TeleOftalmo project. PLoS One. 2020;15:e0231034.
[22] Caffery LJ, Taylor M, Gole G, et al. Models of care in tele-ophthalmology: a scoping review. J Telemed Telecare. 2017;25:106–122.
[23] Curtis R, Hazari H, Eden K, et al. Validation of a portable, remotely delivered refraction approach compared to standard in-clinic refraction in a low-vision population. J Telemed Telecare. 2020;1357633X20960628:1-7.
[24] Misra N, Khanna RC, Mettla AL, et al. Role of teleophthalmology to manage anterior segment conditions in vision centres of south India: EyeSmart study-I. Indian J Ophthalmol. 2020;68:362-+.
[25] Das AV, Mididoddi S, Kammari P, et al. App-based tele ophthalmology: a novel method of rural eye care delivery connecting tertiary eye care center and vision centers in India. Int J Telemed Appl. 2019;2019:8107064.
[26] Krishna KSR. A study on the benefits of teleophthalmology in eye care management. J Evol Med Dent Sci. 2018;7:3229–3233.
[27] John S, Sengupta S, Reddy SJ, et al. The Sankara Nethralaya mobile teleophthalmology model for comprehensive eye care delivery in rural India. Telemed J E Health. 2012;18:382–387.
[28] Khurana M, Ramakrishnan R, Kader MA. Teleophthalmology aided vision centres in rural South India: role and utilization of services. Invest Ophthalmol Vis Sci. 2011;52:4228–4228.
[29] Kapoor R, Yuksel-Elgin C, Patel V, et al. Detecting common eye diseases using the first teleophthalmology GlobeChek Kiosk in the United States: a pilot study. Asia-Pac J Ophthalmol. 2020;9:315–325.
[30] Muraine M, Frete C, Frichet J, et al. Setting up the first French protocol of ophthalmology task delegation with telemedicine in the Bray Normandy. Rev Francophone d'Orthoptie. 2016;9:234–237.
[31] Maa AY, Wojciechowski B, Hunt KJ, et al. Early experience with Technology-Based Eye Care Services (TECS): a novel ophthalmologic telemedicine initiative. Ophthalmology. 2017;124:539–546.
[32] Maa AY, Evans C, DeLaune WR, et al. A novel tele-eye protocol for ocular disease detection and access to eye care services. Telemed J E Health. 2014;20:318–323.
[33] Randhawa H, Morettin C, McLeod H, et al. The validity of spectacle prescriptions via tele-optometric comprehensive eye examinations; a pilot study. Invest Ophthalmol Vis Sci. 2020;61:1604–1604.
[34] Li KY, Tran H, Shu D. Wavefront-based autorefraction on a telemedicine platform. Invest Ophthalmol Vis Sci. 2017;58:3.
[35] Bon V, Ghemame M, Fantou P, et al. Feedback on ophthalmologic telemedicine in a nursing home. J Fr Ophtalmol. 2020;43:e293–e297.
[36] The Vision Coucil of America. Quick Reference Guide - AINSI Z80.1. USA, 2015.

[37] Durrani K, Khan A, Ahmed S. A comparison of automated and manifest refraction: the effect of age. Invest Ophthalmol Vis Sci. 2006;47:1179–1179.
[38] Chuck RS, Jacobs DS, Lee JK, et al. Refractive errors & refractive surgery preferred practice pattern. Ophthalmology. 2018;125:P1–P104.
[39] American Optometric Association. Evidence-based clinical practice guideline. In: Comprehensive Adult Eye and Vision Examination; St. Louis, MO; 2015.
[40] WHO. Core Competencies for the Eye Health Workforce in the WHO African Region. 2019.
[41] Holden B, Fricke T, Naidoo K. Strategy for the elimination of vision impairment from uncorrected refractive error. Meeting of the Refractive Error Program Committee and IAPB Board of Trustees Chittagong; Bangladesh; 2008.
[42] Gilbert C, Minto H, Morjaria P, et al. Standard school eye health guidelines for low and middle-income countries [Internet]. The International Agency for the Prevention of Blindness; 2018 Feb.
[43] Paudel P, Cronjé S, O'Connor PM, et al. Clinical competency of 1-year trained vision technicians in Andhra Pradesh, India. Ophthalmic Epidemiol. 2015;22:409–416.
[44] Sreelatha OK, Ramesh SV. Teleophthalmology: improving patient outcomes? Clin Ophthalmol. 2016;10:285–295.
[45] Blázquez F, Sebastián M, Antón AJAdl SEdO. Detección de glaucoma mediante telemedicina con SisGlaTel: satisfacción y aceptación entre los participantes y problemas detectados. Arch Soc Esp Oftalmol. 2008;83:533–538.
[46] Kumar S, Tay-Kearney M-L, Constable I, et al. Internet based ophthalmology service: impact assessment. Br J Opthalmol. 2005;89:1382–1383.
[47] Kurji K, Kiage D, Rudnisky CJ, et al. Improving diabetic retinopathy screening in Africa: patient satisfaction with teleophthalmology versus ophthalmologist-based screening. Middle East Afr J Opthalmol. 2013;20:56.
[48] Paul PG, Raman R, Rani PK, et al. Patient satisfaction levels during teleophthalmology consultation in rural South India. Telemed J e-Health. 2006;12:571–578.
[49] Sreelatha OK, Ramesh SV, Jose J, et al. Virtually controlled computerised visual acuity screening in a multilingual Indian population. 2014.
[50] Tuulonen A, Ohinmaa T, Alanko HI, et al. The application of teleophthalmology in examining patients with glaucoma: a pilot study. J Glaucoma. 1999;8:367–373.
[51] Orrange S, Patel A, Mack WJ, et al. Patient satisfaction and trust in telemedicine during the COVID-19 pandemic: retrospective observational study. JMIR Hum Factors. 2021;8:e28589.
[52] Jeganathan VSE, Valikodath N, Niziol LM, et al. Accuracy of a smartphone-based autorefractor compared with criterion-standard refraction. Optom Vis Sci. 2018;95:1135–1141.
[53] Tousignant B, Garceau M-C, Bouffard-Saint-Pierre N, et al. Comparing the Netra smartphone refractor to subjective refraction. Clin Exp Optometry. 2020;103:501–506.
[54] Wisse RPL, Muijzer MB, Cassano F, et al. Validation of an independent web-based tool for measuring visual acuity and refractive error (the Manifest versus online refractive evaluation trial): prospective open-label noninferiority clinical trial. J Med Internet Res. 2019;21:e14808.

Appendices

Appendix A. Medline search strategy

Database(s): Ovid MEDLINE(R) ALL 1946 to August 02, 2021 (search performed on August 03, 2021)

Concepts & Strategy	Line #	Searches	Results
	1	((mobile or tele or remote*) adj20 (eye refraction? or ocular refraction? or refractive error? or refractive disorder? or Ametropia? or subjective refraction? or manifest refraction? or objective refraction? or retinoscopy or autorefraction? or auto-refraction? or autorefractor? or auto-refractor?)).tw.	33
	2	((teleop* or tele-optom* or tele-ophtalm* or teleeye or tele-eye or telemedecine or tele-medecine* or teleglaucoma or tele-glaucoma) and (eye refraction? or ocular refraction? or refractive error? or refractive disorder? or Ametropia? or subjective refraction? or manifest refraction? or objective refraction? or retinoscopy or autorefraction? or auto-refraction? or autorefractor? or auto-refractor?)).tw.	7
A (Telerefraction)	3	1 or 2	39
	4	telemedicine/ or exp remote consultation/ or Videoconferencing/ or Telenursing/	34709
	5	(telehealth or telemedic* or emedical* or emedici* or ehealth or mhealth or e-health or m-health or teleconsult* or telediagnos* or teleconferenc* or videoconferenc* or medical telecommunication? or telenursing).tw.	31768
	6	((mobile or tele or remote) adj (health or consult* or conferenc* or video-conferenc* or diagnos* or screening? or referral? or care or healthcare or nursing)).tw.	7130
	7	(virtual adj (care or healthcare)).tw.	452
B (Telepractice)	8	4 or 5 or 6 or 7	51596
	9	vision tests/ or refraction, ocular/ or vision screening/ or visual acuity/ or emmetropia/ or exp contact lenses/ or eyeglasses/	109295
	10	((vision or visual or oculovisual or oculo-visual or ocular or eye* or glasses or eyeglasses) adj1 (screen* or acuit* or resolution? or test* or exam* or prescri*)).tw.	86151
	11	(eyesight? or eye sight? or eyecare or eye care or eye refraction? or ocular refraction? or refractor or autorefract* or auto-refract* or phoropt* or optotype? or optometer? or optometre? or photoscreener? or emmetropi* or contact lens* or eyeglasses or glasses or spectacles).tw.	40891
C (Refractive exam)	12	9 or 10 or 11	170025
	13	refractive errors/ or anisometropia/ or astigmatism/ or hyperopia/ or myopia/ or myopia, degenerative/ or presbyopia/	33644
	14	(anisometropi* or hyperopi* or hypermetropi* or nearsight* or presbyopi* or myopi* or farsight* or astigmati* or refractive error? or refractive disorder? or Ametropia?).tw.	40737
D (Refractive error)	15	13 or 14	49662
(B AND C) NOT 1st set	16	(8 and 12) not 3	479
(B AND D) NOT (1st set OR 2nd set)	17	(8 and 15) not (3 or 16)	12
A OR (B AND (C OR D))	18	3 or 16 or 17	530
A OR (B AND (C OR D)) Limited (for exportation)	19	limit 18 to (english or french or spanish)	517

Appendix B. Sources searched for grey literature

Meta-search Engines
National Institute for Health and Care Excellence (NICE), UK
TRIP Medical Database, UK
Clinical Practice Guidelines
BMJ Best Practice (British Medical Journal)
Canadian Ophthalmological Society (COS)
The Canadian Association of Optometrists (CAO)
Canadian Medical Association (CMA)
American Academy of Ophthalmology (AAO)
American Optometric Association (AOA)
The College of Optometrists, UK
International Council of Ophthalmology (ICO)