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Tele-ophthalmology: A systematic review of randomized controlled trials

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ABSTRACT

Introduction: The aim of this systematic review was to investigate the impact of tele-ophthalmology on screening, monitoring and treatment adherence in eye diseases.

Material and Methods: A systematic review of controlled and randomized clinical trial studies without time limit was explored by searching keywords in the title, abstract and keywords of the studies in the reliable scientific databases Embase, Web of Science, Scopus, PubMed on April 20, 2022. A gray literature search was also conducted using the Google search engine to identify the most recent possible evidence. The quality of the studies was evaluated using the Joanna Briggs Institute (JBI) checklist; that the studies with a score above 7 were included in the analysis.

Results: A total of 40 articles were identified after removing duplicates. After screening the full text of the articles, 5 studies met the inclusion criteria. In four of the studies, tele-ophthalmology was used for tele-screening and tele-monitoring using tele-imaging approaches, live video conferencing, and websites. Also, in one case, telemedicine reminder studies were used to improve treatment adherence. In the majority of studies, tele-ophthalmology was at least as effective as in-person visit services in screening, monitoring, and adherence to treatment.

Conclusion: The results of our systematic review showed that a well-designed tele-ophthalmology program with high-quality cameras and equipment and the use of multiple technologies has the potential to replace or complement in-person visits to an ophthalmologist.

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INTRODUCTION

Eye diseases such as cataracts, glaucoma, age-related macular degeneration (AMD) and diabetic retinopathy are the four main causes of vision loss in the elderly. Diabetic retinopathy is the leading cause of blindness among people of working age. There are approximately 93 million people worldwide with diabetic retinopathy (DR). It is estimated that there are 17 million people with proliferative diabetic retinopathy, 21 million people with diabetic macular edema, and 28 million people with sight-threatening diabetic retinopathy worldwide [1].

Meanwhile, AMD is the most common cause of severe visual impairment in adults over 65 years of age in developed countries [2-4]. Studies have shown that less than 50% of people with diabetes receive annual screening examinations for diabetic retinopathy, and obtaining eye examinations from eye care providers has been problematic for minorities because of problems with transportation, access to eye care providers, treatment costs, and other issues. There are the costs of eye examination or not having health insurance [5, 6].

Due to the progressive nature of eye diseases, proper follow-up of eye care and adherence to eye medications are necessary to preserve vision [7, 8]. Barriers to pursuing eye care may be personal or situational, including lack of awareness, forgetfulness, limited access to transportation, or lack of financial resources for eye examination costs [9].

Since the prevalence of eye diseases increases with age; Therefore, the demand for screening, intervention, and post-intervention monitoring will continue to grow exponentially, resulting in a greater demand for eye care services and professionals. Several studies have shown that vision loss and relapse are common after discontinuation of treatment [10, 11]. The high risk of disease recurrence after the termination of treatment makes it necessary to create a preventive and vigilant maintenance monitoring phase for patients with stable and inactive disease. Post-treatment support programs have been shown to be cost-effective for the health care system, ensuring that unnecessary treatments are not given, as well as reducing the need for patient and family travel, costs, morbidity and time spent [12].

Information technology-enabled medical services such as telemedicine and e-health have been developing rapidly since the recent past to support tele-healthcare services. The term is often used as an umbrella term that includes telehealth, electronic medical records, eHealth, and other components of health information technology [13-16].

Telemedicine and e-health is the use of electronic information and advanced telecommunication technologies to support tele clinical health care, patient health records, patients and health-related professional education, public health and health management [14].

Telemedicine can play an important role in screening patients at the basic level; Telemedicine is defined as the provision of health care at a distance using various information and communication technologies [13].

With the continuous development of technology, telemedicine has become cheaper and easier to access, and provides the possibility of wider use of medical care services. In other words, telemedicine leads to the maximum efficiency of providing health services in health care systems [14]. Several studies have been conducted to investigate the effect of telemedicine services in the treatment of various diseases [15, 16]; however, no study has been designed to evaluate the effect of tele-ophthalmology in various eye diseases [17]. Therefore, the aim of this systematic review was to investigate the effect of tele-ophthalmology on screening, monitoring and adherence to treatment in eye diseases.

MATERIAL AND METHODS

This systematic review was conducted based on the preferred guidelines for systematic reviews and meta-analyses (PRISMA) [18, 19] to report evidence from studies included in this systematic review. The literature search was conducted on April 20, 2022 in PubMed, Embase, Scopus and Web of Science databases. A gray literature search was also conducted using the Google search engine (first 10 pages were reviewed) to identify the most recent possible evidence. MeSH and Emtree keywords and phrases were used in the following categories to search the databases:

1. ("Telemedicine" OR "Telehealth" OR "Tele consultation" OR "tele" OR "ehealth" OR "mHealth" OR "Mobile Health" OR "emedicine" OR "video conferencing" OR "teleconsultation")

2. ("ophthalmology" OR "optometry") OR ("teleophthalmology" OR "teleoptometry" OR "tele-ophthalmology")

Eligibility criteria

Studies were included in the study if they met all the inclusion criteria: 1) randomized controlled trial studies that used tele-ophthalmology methods in the prevention, diagnosis, control and treatment of eye diseases and conditions. 2) The full text of the articles was available in English. On the other hand, the exclusion criteria include: 1) studies including books, review articles, letters, studies that are in the form of letters to the editor, and conference summaries; 2) lack of availability of the full text in English; 3) Lack of relevance of the title, abstract or full text of the articles with the purpose of study.

Data extraction and synthesis

The same checklist was used for data extraction. The data elements in this checklist was included the title of the paper, year of publication, country, number of participants, duration of the intervention, the approach based on the technology used, population under study, control and intervention groups, type of diseases and the measured outcome, objectives of the study, results of the study, and final conclusion of the study.

Quality control

In order to evaluate the quality of the studies included in this research, the Joanna Briggs JBI quality assessment checklist for randomized controlled trial studies was used [20]. This checklist included 13 questions to evaluate the quality of studies. If the answer to a question was positive, it was scored 1, otherwise it was scored 0; Therefore, the maximum quality assessment score that each study could obtain was 13, and studies with a score lower than 7 were excluded from this study.

RESULTS

Study selection

The process of identifying and selecting studies based on the PRISMA diagram is shown in Figure 1. A total of 4203 documents were retrieved by searching databases and 100 studies by searching Google (first 10 pages). After removing repeated studies (1976 articles), 2227 articles were obtained, and their screening was examined based on the titles and abstracts of the articles. After completing the review, 2187 articles that were not related to the purpose of this study were removed. Then, 40 articles were selected to review their full text, of which 5 main articles were included in the study (Fig 1).

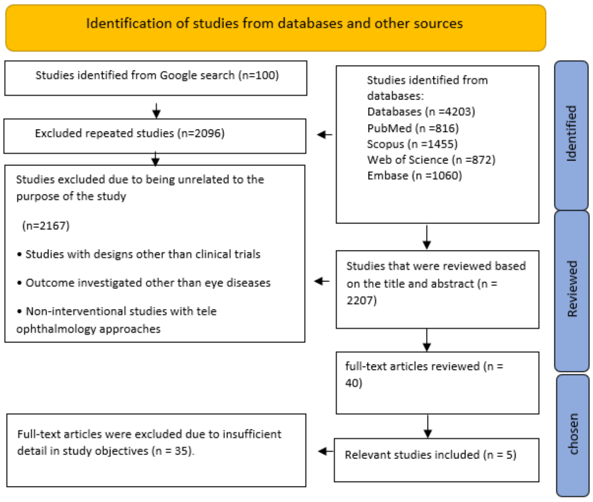

Fig 1: Study search and selection diagram.

Characteristics of the study

According to Table 1, the included studies were in 2022 [21], 2020 [22, 23], 2015 [24] and 2013 [17]. Out of 5 included studies, 2 studies (40%) were conducted in Canada [22, 24] and other studies were conducted in the United States of America [17], India [21] and Singapore [23]. Studies were classified into two categories: randomized clinical trial (4.5, 80%) [17, 22-24] and cluster randomized controlled trial (1.5, 20%) [21]. In total, the included studies included 2251 participants. The duration of intervention in each study varied from 6 weeks [23] to 5 years [17].

Tele-ophthalmology approaches

According to the findings, the approaches used for tele-monitoring (2.5, 40%) [17, 24], tele-screening (4.5, 80%) [17, 21-24] and treatment adherence [23] including Netra technology (a smartphone-based subjective refraction system) [22], tele digital non-mydriatic fundus camera [17, 21], tele-consultation with an ophthalmologist via live videoconferencing [21], telemedicine reminders (1.5, 20%) [23] and websites (1.5, 17%) [24]. All these interventions for eye diseases such as diabetic retinopathy [17], maculopathy [24], glaucoma [23], myopia and visual acuity [17], age-related macular degeneration, AMD [24], diseases of the posterior part of the eye [21]. It was aimed at screening examinations, monitoring and adherence to the treatment and management of eye diseases. None of the studies used sophisticated technologies such as artificial intelligence or robots.

Table 1: Characteristics of the participants in the included studies

Reference	Mean of participants	Participants number	Country/ year
[21]	52.3	Total=1447 Control=737 Intervention=710	India/ 2022
[23]	Not mentioned	Total=59 Control=30 Intervention=29	Singapore/ 2020
[22]	26.5	Total=36 Control=36 Intervention=36	Canada/ 2020
[24]	81	Total=106 Control=54 Intervention=52	Canada/ 2015
[17]	51.3	Total=567 Control=271 Intervention=296	USA/ 2013

Tele-ophthalmic effects

Screening and tele-monitoring

In the majority of included studies (80%), telemedicine was used to screen patients with eye disorders [17, 20, 21, 23]. Tousignant et al. [22] randomly assigned 36 optometrist participants (18-35 years old) to three refraction methods, including professional subjective refraction, unaided Netra (by the participants alone), and refined Netra (eyeball results determined by a physician refined). Using a randomized, double-blind design, the refraction results were installed in a test frame and visual acuity was measured. Subjective judgment and visual comfort were assessed using a questionnaire and overall preferences were rated. They reported that unaided Netra resulted in overcorrection of myopia (D: 0.60; IQR: 0.25 to 0.94) compared with professional subjective refraction. Median equivalent sphere with unaided Netra (D: -1.40; IQR: 3.10 to 0.90) significantly more myopic than refined Netra (D: -0.070; IQR: -1.60 to -0.30) followed by subjective refraction (D: -0.80; IQR: -0.60) ($p<0.01$). Median visual acuity with professional subjective refraction (D: -16.1; IQR: -0.22 to -0.09) from unaided Netra (D: -0.0; IQR: -1.60 to -0.30) was superior ($p<0.01$). As a result, mental refraction was ranked first in the test results preference by 72% of the participants. The median preference rating of professional mental refraction preferred it to both Netra results (all cases: $p<0.01$). Overall, they found that the Netra device resulted in significant overcorrection of myopia and lower levels of visual acuity, especially when used without professional assistance and when compared with subjective refraction, subjective judgment and visual comfort.

In another study, Li et al. [24] conducted a study aimed at evaluating ophthalmology in two ways as a tool for screening and monitoring neovascular AMD. So that new referrals of patients suspected of neovascular AMD and patients with stable neovascular AMD were divided into two groups: control and tele-ophthalmology. In the control group, patients received a clinical evaluation and diagnostic imaging at a hospital-based retina clinic, and in the tele-ophthalmology group, patients received an initial examination and diagnostic imaging at an independent tele-ophthalmology site (where patient's information and imaging studies were obtained and sent electronically to retina specialists at a tertiary hospital). Patients in the tele-ophthalmology group were recalled to the tertiary care center if the tele-ophthalmology dataset suggested pathology or was inconclusive for diagnosis. At the end of the study, they did not observe any difference between the visual acuity in the two groups (p=0.99). They reported that the association of delay in referral with time to treatment was not detectable when comparing tele eye screening for suspected neovascular AMD with retina specialist-based screening. Tele eye monitoring for neovascular AMD relapse resulted in a longer waiting time to restart treatment, but no adverse visual outcomes were identified.

Mansberger et al. [17] also conducted a study to determine the effectiveness of telemedicine for providing diabetic retinopathy screening examinations compared to the effectiveness of face-to-face monitoring in community health clinics with a high proportion of minorities, including American Indians or Alaska Natives. Diabetic participants were assigned to one of two groups: 1) telemedicine with a non-mydriatic camera; or 2) in-person monitoring with an ophthalmologist. They reported that the telemedicine group (n=296) was significantly more likely to receive a diabetic retinopathy screening examination in the first year of enrollment compared to the in-person monitoring group (n=271) (94% vs. 56%; p<0.001). In the telemedicine group, 20.5% required further evaluation with an ophthalmologist, and 86% of these referrals were due to poor quality digital images. As a result, they found that telemedicine using non-mydriatic cameras increased the proportion of participants who received diabetic retinopathy screening examinations, and most did not require follow-up with an ophthalmologist. Telemedicine may be a more effective way to screen patients for diabetic retinopathy and triage further evaluation with an ophthalmologist. Low-quality imaging reduction methods improve the effectiveness of telemedicine for diabetic retinopathy screening examinations.

On the other hand, Shekhawat et al. [21] conducted a study to evaluate whether routine fundus photography (RFP) to screen for posterior segment disease in community eye clinics in South India increases referral to an urban hospital for ophthalmic care. Patients in two standard care groups included ophthalmologist examination, optional fundus photography, and the RFP group included ophthalmologist examination, forced dilation and 40-degree fundus photography, and tele-consultation with an ophthalmologist. They reported that 1447 patients were admitted to the vision centers, of which 737 were in the standard care group and 710 were in the RFP group. Compared with standard care, the RFP group had a higher proportion of referrals due to fundus photography findings (11.3% vs 4.4%), non-urgent referrals due to fundus photography (9.3% vs 3.3%), and urgent referrals due to fundus photography (1.8% in contrast to 1.1%). The RFP intervention was associated with a two-fold increase in the odds of referral due to photographic findings compared with standard care (OR: 2.07, CI: 0.98-4.40, p=0.058). As a result, they found that adding RFP to community eye clinics is associated with an increased likelihood of referral compared to standard care. This increase in referrals was mostly attributed to non-urgent posterior segment disease.

Adherence to treatment

In one of the included studies (20%), adherence to topical eye pressure lowering treatment was evaluated by introducing a personal illustrated medication reference chart and a tele-reminder. The participants in this study were randomly divided into 3 control groups, intervention with reference chart only and intervention with reference chart along with tele-reminder. They completed a survey on demographics, barriers to glaucoma medication adherence, and self-adherence (measured with the Morisky Adherence Scale) before and 6 weeks after the intervention. Logistic regression analysis was performed on barriers contributing to non-adherence and paired t-tests were performed for pre- and post-intervention effects on adherence score. They reported that 71% of nonadherent participants had multiple barriers to adherence, with lack of self-efficacy and forgetfulness being the most common factors. Only the reference chart with the tele-reminder group showed a significant increase in the mean adherence score, from 7.18 to 7.69 (p=0.047) [23].

DISCUSSION

The aim of this systematic review is to investigate the impact of tele-ophthalmology on tele-screening, tele-monitoring and treatment adherence of eye diseases and conditions such as diabetic retinopathy, maculopathy, glaucoma, myopia and visual acuity, AMD, posterior segment diseases and other vision disorders in primary care. The results of our systematic review showed that tele-ophthalmology using the Netra device, on-site imaging, tele-consultation with an ophthalmologist improved tele-diagnosis, monitoring, and screening [22, 24]. However, there were contradictory results. In one study, imaging through the site made the patient's next visit longer [24].

While in two tele-ophthalmology studies, it increased in-person visits to the ophthalmologist [17, 21]. In particular, the main cause of this result was poor quality imaging by tele-ophthalmology. Therefore, it seems that improving the quality of tele-ophthalmology equipment is one of the most important factors for improving the effect of telemedicine in eye care and diseases. On the other hand, due to the fact that tele-ophthalmology reminders potentially improve patients' adherence to treatment and tele-counseling through video conferencing improves the screening and monitoring of patients with eye disorders [23, 24].

Hybrid telemedicine (using several technologies together) seems to be another important factor in improving the effectiveness of tele-ophthalmology. However, tele-ophthalmology services compared to face-to-face visits in 20% of the studies, although there was an improvement in terms of lengthening the time of the next visit and patient monitoring; However, this difference was not statistically significant [22, 24]. In one of these studies, conducted by Bouffard-Saint-Pierre, a smartphone-based refraction system was used, the results of which were compared with professional refraction results. The results of their comparison showed that refraction from the Netra device, either unaided or by a trained refractor, resulted in overcorrection of myopia and less visual comfort compared to professional subjective refraction. Differences and variability in dioptric measurements, visual acuity, and subjective preferences are clinically significant and reduced when a trained clinician corrects the refraction of Netra results.

Therefore, while Netra used as a screening tool to estimate refractive error, using it to prescribe spectacles without additional evaluation by an optometrist carries significant clinical risks of accommodative stress and reduced spectacle comfort compared to professional subjective refraction [22].

Also, in a study conducted by Li et al., comparing tele-ophthalmic screening for suspected neovascular patients with face-to-face screening by a retinal specialist in Canada; Tele-ophthalmology screening did not identify a relevant mean delay in all waiting time measures. This study found that a tele eye-monitoring program for neovascular recurrence resulted in a longer mean waiting time to restart treatment, but a worse visual outcome was not identified with such a delay. This work specifically supports the need for a computerized network of ophthalmic imaging sites in tele areas, allowing general ophthalmologists and optometrists to provide basic ophthalmology services remotely [24].

However, considering that tele-ophthalmology did not have adverse consequences in any of the studies, and on the other hand, in some studies that used high-quality equipment, it was at least as efficient as face-to-face consultations, and it reduces the cost of patient visits. The results show that educational interventions in the fields related to eye diseases have improved patients' awareness of their eye disease diagnosis and have the potential to reduce the rate of vision loss by strengthening adherence to subsequent eye examinations [25].

In addition, tele-ophthalmology interventions such as screening for eye diseases such as neovascular may be able to reduce the number of unnecessary visits to ophthalmologists, thus reducing workload and waiting time in optometry clinics. Reducing the patient load in clinics helps to improve access, faster follow-up and reduced waiting time for patients with acute eye conditions and better management of needs [24].

Telemedicine can be used to triage patients with diabetes for further evaluation by ophthalmologists, especially in settings that face a shortage of resources and specialists and low access [17]. While tele-ophthalmology programs based on text message reminders significantly affect the rate of absenteeism, attendance, or cancellation of outpatient appointments, this means that the content of text message reminders may account for a large part of their overall impact.

The more general concept is that improving the performance of the health system does not depend only on technical solutions, but the therapeutic and educational content plays a more key role in the success of such systems [26-28]. Four studies used tele-screening technology for eye diseases [21, 22, 29, 30]. In three of these studies, better improvement was seen in the tele-ophthalmology group compared to face-to-face visits [21, 29, 30]. Only one of the included studies that used diagnostic support websites for AMD patients reported significant cost savings for the tele-rehabilitation intervention group, and no complications were reported in these tele-rehabilitation interventions [24]. In two studies, tele-monitoring was used in patients with diabetic retinopathy, which caused an increase in diabetic retinopathy examinations in the intervention group compared to the in-person group, which led to the early detection of choroidal neovascularization growth and the possibility of better visual outcomes after treatment with road rehabilitation far reported [17, 31].

Raman et al compared the prevalence of diabetic retinopathy in self-reported people with diabetes in rural India who were screened by two different methods. Between 2004 and 2005, 3522 people with diabetes underwent ophthalmologist-led diabetic retinopathy screening and 4456 people with diabetes underwent ophthalmologist-led diabetic retinopathy screening (tele-screening) between 2004 and 2005. Two population groups were randomly separated. In the ophthalmologist-based program, a trained retina specialist would travel with the camp team and screen patients for diabetic retinopathy at the camp site.

In the ophthalmologist-led program (tele-screening), fundus photographs were transferred to the base hospital for further evaluation and grading. A total of 519 subjects (14.7%) in the ophthalmologist-based model and 853 subjects (19.1%) in the tele-screening model were diagnosed with diabetic retinopathy. More vision-threatening retinopathies were found in the tele-screening model than in the ophthalmologist-based model (6.3% vs. 0.5%). The results of this study showed that the tele-screening model detected more cases of diabetic retinopathy (19.1%) than the face-to-face ophthalmologist-based model (14.7%) and was reported to be a cost-effective and actively controlled intervention that can easily be delivered. Increase rehabilitation services from this platform. Therefore, tele-screening is a good method for diabetic retinopathy screening in rural India because the need for travel by the ophthalmologist is eliminated [32].

Hark's study aimed to evaluate factors affecting follow-up eye care in participants enrolled in the tele glaucoma diagnosis and follow-up study, such as awareness of eye diagnosis, availability of transportation methods, and reasons for not seeking eye care. He concluded that people in need of eye care can receive more benefit from social workers regarding continuous reminders of eye examination appointments, explanations and in-depth knowledge of their eye diagnosis [25].

In line with the results of this study, Kawaguchi et al. conducted a systematic review and meta-analysis with the aim of comparing face-to-face screening with tele-ophthalmology screening in AMD and diabetic retinopathy patients. Six studies met the inclusion criteria and were included in this review. Four studies included participants with diabetes and two studies investigated choroidal neovascularization. For the meta-analysis, only the data on diagnosis and participation in the screening program were used, which showed that tele-ophthalmology had a 14% higher chance of diagnosis than in-person examination. However, the result was not statistically significant and their meta-analysis results showed that the probability of diabetic retinopathy screening in the tele-ophthalmology group was significant compared to the face-to-face screening program. Evidence from this study showed that tele-ophthalmology for diabetic retinopathy and AMD is as effective as in-person examination and potentially increases patient participation in screening [33].

In addition, a systematic review by Tan et al. aimed to determine whether simultaneous tele-ophthalmology provides comparable accuracy to face-to-face consultation in the diagnosis of common eye diseases. He concluded that in terms of diagnostic accuracy, simultaneous tele-ophthalmology was better than face-to-face consultation in one study and comparable in six studies. In addition, they found that saving and sending images along with live video conferencing is a suitable alternative to overcome the poor transmission speed of the Internet [34].

In general, many studies today support the increasing impact of telehealth services through technology [35-49]; Considering the positive result of using tele-ophthalmology in screening, monitoring, adherence to treatment and improving the clinical conditions of patients with various eye diseases and the lack of reporting of side effects in therapeutic and monitoring approaches based on telemedicine, it can be concluded that the use of telemedicine in eye disorders using high-quality equipment and using multiple technologies in combination cause maximum effect and efficiency. As a result, policy makers and planners in this field should work on maximizing the quality of tele-ophthalmology equipment. Future studies are suggested for the cost effectiveness of tele-ophthalmology equipment versus face-to-face ophthalmology visits.

One of the strengths of our systematic review was the inclusion of only randomized controlled trial studies, which reduces study bias and provides valid and reliable evidence. On the other hand, in this study, we did not apply a filter in the type of eye outcome to widely investigate the effect of tele-optometry and ophthalmology in all types of eye diseases. On the other hand, the limitations of this study may be that the searched keywords were not sufficient and complete to receive more studies, and some prominent and relevant studies were not included in this review. In addition, since the studies had very heterogeneous designs, meta-analysis was not possible.

CONCLUSION

The results of our systematic review showed that tele-ophthalmology improves screening and tele-monitoring and improves treatment adherence. The most important effective factor in tele-imaging is the quality of the cameras, which in the case of low quality would increase the number of visits of patients to the ophthalmologist. However, a well-designed tele-ophthalmology or optometry program to improve eye diseases by early diagnosis, determining the prevalence of eye diseases and identifying related risk factors, tracking eye patients and preventing missed appointments can complement or replace face-to-face rehabilitation programs and improve the patient's health.

In addition, with the aging of the population and the increasing incidence of eye diseases, it is hoped that tele-ophthalmology will bring potential opportunities for saving treatment and travel costs for the health care system and patients, professionals and health care providers. In addition, it seems that with the use of newer technologies with more communication facilities and the use of these technologies in combination, the probability of the effectiveness and success of tele-ophthalmology will increase.

AUTHOR'S CONTRIBUTION

All authors contributed to the literature review, design, data collection and analysis, drafting the manuscript, read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this study.

FINANCIAL DISCLOSURE

No financial interests related to the material of this manuscript have been declared.

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