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TELEMEDICINE ASSISTED NON-MYDRIATIC FUNDUS IMAGING FOR DETECTION OF DIABETIC RETINOPATHY IN COLOMBIA

by

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MASTER'S THESIS

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Abstract

Diabetic retinopathy (DR) is a well-recognized complication of diabetes mellitus where retinal function is compromised. It is considered a public health disease and is the fifth leading cause of visual impairment worldwide. But although the worldwide prevalence is continually increasing, little is known about the frequency of this disease in Colombia, South America.

On the other hand, telemedicine is presented as a tool that has the potential to improve access to health care services, for remote or rural populations, and for those who have limited access due to physical or other disabilities. Recent technological advances in telecommunication and digital imaging, including fundus photography, telemedicine represents a valuable clinical aid for the documentation and diagnosis of ocular pathologies, and therefore helps to minimize adverse outcomes associated with chronic disease such as diabetes mellitus.

Objectives:

General Objective: To conduct a literature review to verify whether telemedicine can be a viable tool for the diagnosis and prevention of diabetic retinopathy in Colombia, based on case studies on the use of the non-mydriatic retinal camera supported by telemedicine for the diagnosis of this disease in countries such as Peru, Chile, Mexico, Argentina, Brazil, and Guatemala.

Specific objectives: To describe the status of the use of telemedicine for the diagnosis of DR in the world.

To analyze the progress and results of the use of the non-mydriatic retinal camera in Latin American countries.

Hypothesis: Could non-mydriatic retinal camera supported by telemedicine help to diagnose DR early and therefore reduce blindness caused by this disease in Colombia?

Method: A systematic bibliographic review of the last 12 years was carried out using academic search engines (Scielo, Elsevier, PMC-NCBI) that presented data and advances in the use of the non-mydriatic retinal camera in conjunction with telemedicine for the diagnosis of diabetic retinopathy; the VHL "Virtual Health Library" platform was also included specifically for Latin America and the Caribbean, to find specific studies on this region. Keywords used: "Diabetes mellitus, diabetic retinopathy, telemedicine, non-mydriatic retinal camera". Research in Spanish and English was included.

Results: Following the extensive electronic and manual search, 23 articles were selected from the 221 found (giving priority to studies conducted in Latin America) and after applying the inclusion criteria, 198 articles were rejected because they did not meet the required criteria.

Conclusions: According to the results obtained from the different studies used for this study, it was possible to conclude that telemedicine is a viable tool for the diagnosis of DR in primary care. On the other hand, taking into account the similar and uniform progress that countries such as Peru, Mexico, Brazil, Ecuador, and Colombia have had in recent years, in terms of the expansion of connectivity, infrastructure, new policies and technological developments, for the creation of new telemedicine projects, it could benefit that in a few years projects in the area of teleoptometry and teleophthalmology are finally implemented. Therefore, a proposal to carry out projects in Colombia, focused on developing a business model based on telemedicine with the support of the NMRC for DR screening, could prevent and reduce the prevalence of blindness caused by diabetes, as has been achieved in other Latin American countries.

Key words: Diabetes mellitus, diabetic retinopathy, telemedicine, non-mydriatic retinal camera.

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List of Abbreviations

DM	Diabetes mellitus
DR	Diabetic retinopathy
WHO	World health organization
ATA	American telemedicine association
NASA	National aeronautics and space administration
ISTP	Information system for telemedicine projects
ICT	Information and communication technologies
SRHP	Special registry of health care providers
IDF	International diabetes federation
NPDR	Non-proliferative diabetic retinopathy
PDR	Proliferative diabetic retinopathy
ETDRS	Early treatment diabetic retinopathy study
DME	Diabetic macular edema
NMRC	Non-mydriatic retinal camera
HCI	Health Care Institutions
FEDOPTO	Colombian federation of optometrists
DAWN	Diabetes attitudes wishes and needs
RACSS	Rapid assessment of cataract surgical service
RAAB	Rapid assessment of avoidable blindness
FA	Fluorescein angiography
NMR	Non mydriatic retinography
DHA	Department of health and assistance
NCTEH	National center of technological excellence in health
EyePACS	Eye picture archive communication system
CADx	Computer-Aided diagnosis
ADTR	Automated diagnosis for the acquisition of telematic retinography

1 Introduction

1.1 Justification

The prevalence and incidence of diabetes mellitus (DM) has suffered a strong increase at a global level, being one of the main problems in public health. The socioeconomic impact of diabetes includes direct and indirect costs: health care, disability, loss of productivity, and diminished quality of life (1).

In addition, the number of complications derived from diabetes that a person who does not treat it properly can suffer is high, and can affect several organs at the same time, including the retina, which, if compromised for long periods of time, can permanently impair vision. This complication is known as Diabetic Retinopathy (DR), and is the leading cause of blindness in the working age population, 25 and 75 years (2), which limits and/or worsens people-s quality of life.

The risk of blindness due to DR can be significantly reduced with timely and appropriate detection and treatment. For this purpose, there are multiple means of diagnosis, including non-mydriatic fundus photography, which is a simple, safe, and noninvasive examination for the patient. Additionally, fundus imaging can play an important role in the detection of other sight-threatening conditions, such as age-related macular degeneration, glaucoma, and other retinal vascular.

On the other hand, in Colombia, access to an integrated healthcare system, either because of geographical, socioeconomic conditions, and public awareness and education often serve as barriers to care. However, telemedicine offers the opportunity to improve access to health services (especially excluded populations), by breaking down these barriers and provide improved access for geographically dispersed populations (3).

Also with telemedicine applications, it possible to develop preventive programs through screening campaigns in large populations (4).

Telemedicine is a field that is still evolving and, thanks to technological advances in telecommunication such as smart phones, the internet, microphones, cameras, among others, have facilitated medical consultations in real time, providing tools that allow early diagnosis, and facilitating the monitoring of the disease.

1.2 Objectives

General objective:

To conduct a literature review to verify whether telemedicine can be a viable tool for the diagnosis and prevention of diabetic retinopathy in Colombia, based on case studies on the use of the non-mydriatic retinal camera supported by telemedicine for the diagnosis of this disease in countries such as Peru, Chile, Mexico, Argentina, Brazil, and Guatemala

Specific objectives:

To describe the status of telemedicine for the diagnosis of DR in the world.

To analyze the progress and results of the use of the non-mydriatic retinal camera for the detection of DR in Latin American countries.

1.3 Method

For this work, a systematic literature review of the last 12 years was carried out, starting from the following question:

¿Could non-mydriatic retinal camera supported by telemedicine help to diagnose DR early and therefore reduce blindness caused by this disease in Colombia?

The search was carried out using databases and academic search engines such as Scielo, Elsevier, PMC-NCBI; the VHL platform "Virtual Health Library" specific to Latin America and the Caribbean was also included, in order to find specific studies on this region. The following keywords were used: "Diabetic retinopathy, telemedicine, non-mydriatic retinal camera". In addition, research in Spanish and English was included.

After searching for articles related to the topic, they were filtered under inclusion and exclusion criteria.

Table 1: Inclusion and exclusion criteria for articles.

Inclusion criteria	Exclusion criteria
• Articles with relevant information for the development of the work, where data and advances in the use of non-mydriatic retinography and telemedicine for the diagnosis of retinopathy in diabetic patients are presented.	• Retinal Camera based studies with application of mydriasis in all patients.
• Articles published in the last 12 years	
• English and Spanish language.	

Selection of articles: The search for information article selection was delimited using the more specific keywords mentioned above, with emphasis on the term telemedicine. Approximately 221 publications were found from 2010 to 2022. Then, a global reading of each one was performed, and to reduce the number of articles and reviews found, those that were relevant to this research and provided reliable information were selected.

In the final search, 23 articles having to do with the research topic. Of these articles, I searched for the abstract and the full text, finding that 19 articles presented the full text, and 4 presented only the abstract.

These articles were then downloaded in full, and the titles organized in a table for easy reading, categorization, and reference. This table can be found in Results chapter 6.

2 Telemedicine

The following chapters will address the 3 most important components of telemedicine: the clinical part, in which diabetes mellitus and diabetic retinopathy will be discussed; the technical part, with the non-mydriatic Retinal Camera; and the business part, which involves the laws and regulations for the implementation of telemedicine projects, as well as the institutions that offer programs in optometry or ophthalmology.

2.1 A Brief History of Telemedicine

Telemedicine has existed for decades. Four great inventions created the foundations of modern telemedicine. The first was the telegraph, created in the 19th century, allowing almost instant communication over great distances (5). The was used during the American Civil War, facilitating the ordering of medical supplies (6). Later, during the First World War, it also made inroads in the transmission of electrocardiographic data (3)

The second important development was the telephone, patented at the end of the 19th century by Alexander Graham Bell. The telephone was key to medical communication for more than 50 years and still is to this day, and can *"be considered without doubt as the first and simplest form of telemedicine technology"* (7). It is said that, at the beginning of the 20th century, physicians were already talking by telephone with other colleagues in order to consult or exchange information.

The third event was the widespread use of radio broadcasting. In 1920 radio communication was used to assist ships at sea, for example, when there were medical emergencies, radio connections were established between the ship and doctors from shore stations to provide assistance and medical advice (6).

The last development was television, invented in 1927 by Philo Taylor Farnsworth. The television added visual communication to sound and allowed real-time broadcasting (5), of images and information simultaneously. In 1964, marked the first video-interactive link using television for a psychiatric consultation, becoming a great diagnostic tool (3), and initiating a new era of research and progress in healthcare.

The National Aeronautics and Space Administration (NASA) also played a key role in the early development of telemedicine. Concerned about the health of astronauts due to the effects of zero gravity, NASA saw an early opportunity to monitor the vital signs of its astronauts during space missions (8). Following the success of their early projects, NASA conducted a 20-year satellite-based communications program designed to provide both the reserve and astronauts with a wide range of medical services.

In 1988, NASA created the first international telehealth program, known as Space Bridge, to provide medical consultation to victims of the Armenian earthquake. Consultants used satellite communication to provide one-way medical care via video, voice and fax from four medical centers in the United States to a health center in Armenia. The disciplines they included were psychiatry, orthopedics, neurology, infectious diseases, and general surgery (8)

These programs demonstrated that telemedicine has the potential to overcome geographical, cultural, social, political and economic barriers to providing health care, and laid the groundwork for technical innovation, which would play an important role in the evolution and transformation of the healthcare system.

2.2 Telehealth and information and communication technologies (ICT)

It is important to clarify the term "*telehealth*" which refers to *the integration of communications systems in the practice of health protection and promotion*" (8). It links the remote use of information and communication technologies (ICT) in the field of healthcare to improve health outcomes and well-being of patients.

Telehealth effectively connects people with their healthcare providers when face-to-face care is not necessary or not possible (9)

2.3 What is telemedicine?

There are many definitions of telemedicine, as the field is expanding with many new applications and services. Telemedicine is constantly evolving, but it has been broadly defined as "distance medicine" (10) and as such includes diagnosis, management and treatment, as well as medical education.

The World Health Organization WHO, has adopted the following broad description: "*The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities*" (11)

The American Telemedicine Association describes it as: "*telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status. Telemedicine includes a growing variety of applications and services using two-way video, email, smart phones, wireless tools and other forms of telecommunications technology*" (9)

2.4 Types of Telemedicine

Telemedicine has two general applications: Medical practice and education.

In medical practice, the prefix tele- can be applied to any medical specialty or activity that uses information and telecommunications technologies. These include:

- Teleconsultation: Also known as video consultation or remote consultation. It makes possible the exchange of information between the physician and the patient using information and telecommunication technologies (12) (3). It is currently the most widely used telemedicine modality in primary care, representing approximately 35% of the total use of telemedicine networks (12).

Teleconsultation is classified into two types:

  - The synchronous modality, involve the exchange of information between doctor and patient in real time.

  - The asynchronous modality is those that are not performed in real time. Sometimes referred to as "store-and-forward", it takes some time for medical information to be sent and is received and is typically used in non-urgent situations. It constitutes the largest volume of telemedicine activity (13).

- Telemonitoring: The measurement and observation by the physician of one or several vital signs through electronic means and remote communication, which allows the provider to make remote decisions on

changes or adjustments in the patient's treatment. The physician can check physiological variables such as pulse, respiration, blood pressure, glucose, laboratory tests, imaging, among others. (3) (12).

- Teleurgencies: An option to access a medical evaluation that requires rapid guidance and management. It is carried out by professionals of the Emergency Department, and the transmission of vital signs is online from the means of transport where the patient is located, whether it is an ambulance, helicopter, etc. (14).

- Telesurgery: An aspect of telemedicine that combines elements of advanced technology such as robotics, state-of-the-art telecommunications and electronic devices, in which the physician can perform surgery without being present in the same physical location as the patient (12). The main objective of Telesurgery is to provide specialty health care to the most remote places, where it is not possible for the physician or the patient to move around. For this reason, it is necessary to perform this type of intervention from another geographical location.

- Telediagnosis: Consists of the electronic transmission of all the information in the patient's medical history between distant medical institutions, where the analysis is performed, tests are interpreted, tests are administered, and information considered complementary to the final diagnosis is shared (4).

- Teleconference: An "electronic" meeting between three or more people who are geographically separated. This is achieved through various technological devices in order to debate situations or discuss cases (4).

Among others.

In education it was found:

- Teleeducation: Defined as "the use of information and telecommunication technologies for distance medical education practice" (12). It can be done in real time or deferred. There are different categories that, depending on the purpose, provides opportunities for anyone who wants to expand and improve their knowledge, it is not only for medical staff or students, also for people who want to learn about their health status.

  In 2005 one of the largest studies on the psychosocial reality of patients with diabetes was published. The DAWN (Diabetes Attitudes Wishes and Needs), demonstrated the importance of improving the care of patients with diabetes, focusing on raising awareness about the challenges of living with diabetes, training people with diabetes through education programs focused on diabetes self-management and education health professionals about diabetes care centered on the individual (15). In addition, he recommended creating innovative tools to provide psychosocial support to persons with diabetes. Tele-education provides patients with the opportunity to achieve and maintain behaviors that lead to better outcomes through optimal management of their lives with the disease, in which the family and environment can play a part.

2.5 Benefits of Telemedicine

As a result of the application of telemedicine in various settings around the world, many potential benefits can be foreseen, which not only favor patients, who can receive timely care, but also healthcare organizations and/or

institutions, governments, healthcare professionals and citizens in general. The benefits focus on: (16), (11), (14), (12).

- Improving the quality of care: Equity and Universality are promoted.
- Scientific and technological support for professionals, with access to continuing education.
- Support for the development of a new healthcare model, centered on the patient.
- Optimization of administrative processes and resources.
- Increase in the population's health knowledge and promotion of self-care.
- Ability to transcend geographical and temporal limits.
- Ability to reduce costs.
- Ability to increase patient comfort, convenience and satisfaction. Waiting times in health care systems can be reduced.
- Access to and exchange of medical information.
- Provision of care that previously could not be rendered. With the help of ICT; isolation of seriously ill or disabled patients can be overcome.
- Quality control of screening programs.
- Improved quality and accompaniment by health services.

2.6 Latin American experience using telemedicine

Global telemedicine trends must be objectively differentiated between developed and developing countries, since advances in biomedical technology and telecommunications are not the same for all countries.

During the 1990s, many Latin American countries undertook several ambitious projects to reform their health and economic structures, which were intended to achieve decentralization in the public service network, improve hospital management capacity and adapt their financing sources and models. Most of the projects failed due to implementation errors, lack of political support or conflicts of interest between different corporate groups (17)

The present of telemedicine in Latin America has managed to expand and has had significant advances in the use of ICT. The expansion and offer of telemedicine platforms are growing to a great extent as a consequence of the pandemic. For example, Brazil has applications such as "Docway", Colombia with "doc-doc", Mexico with "Midoconline", Argentina with "Llamando al doctor" and Peru with "Smartdoctor". All these programs aim to provide online medical consultation, in addition to offering consultations in more than 50 specialties, avoiding the patient to move, and reducing the waiting time to get an appointment.

Chile and Uruguay are the leaders in the region in the implementation of telemedicine, thanks to significant investments in infrastructure, networks, fiber optics and connectivity.

Chile has significant experience in several areas of telemedicine application, with modalities in consultations in the specialties of dermatology, endocrinology, diabetology, nephrology, neurology, geriatrics, and psychiatry. It also has several digital health projects promoted by universities and directed by the Ministry of Health, such as the "Guidelines for the development of Telemedicine and Telehealth in Chile". For the covid-19 period, other specialties were authorized exclusively: psychology, phonoaudiology, nutritionist, traumatology, pediatric neurology, and kinesiology (18)

In Peru, the type of telehealth projects is very varied. Most of the projects correspond to telemedicine (58%). Most interventions use live interactive sessions (59%), followed by deferred interactions (32%), and to a lesser extent, remote monitoring, and monitoring of patients through text messages. The most frequently used channel or means of communication is the Internet (95%), which, thanks to alliances between non-governmental

organizations, universities, and development banks, provided part of the Peruvian Amazon jungle with broadband services, as well as rural health centers, providing care for more than 3,000 inhabitants in eight isolated communities (19).

In the case of Argentina, during the crisis of 2001 and 2002, and thanks to ICT, the first virtual branch was created in Buenos Aires, achieving the first videoconference to be able to follow up surgical patients from a distance. Now the country has a *National Telehealth Plan* and has created the *Telehealth Network,* made up of institutions whose objective is to promote programs that facilitate the use of ICT, to create good practices and to meet the demands and expectations of patients (20).

Cuba, has set the objective of obtaining and exchanging images between the institutions integrated into the network for imaging diagnoses, using the Health Telematic Network as a transmission support, and complying with the established requirements of medical ethics and confidentiality. Between 2010 and 2011, telemedicine was used to improve accessibility to specialized consultation for 187 patients, located in primary care centers, with vision disorders requiring attention in the neurophthalmology service (21).

On the other hand, Mexico created the first national telemedicine network in 2005, based mainly on teleconsultation and tele-education. At the beginning of 2014, the Ministry of Health and Assistance (SSA) together with the National Center of Technological Excellence in Health (CENETEC) had 335 telemedicine medical units distributed in different departments. Among the specialties served are psychiatry, internal medicine, dermatology, surgery, pediatrics and obstetrics and gynecology (22).

During the pandemic, telemedicine was consolidated in Latin America. It is now seen as an everyday and common tool. Even so, its proper implementation requires overcoming several challenges that can limit the success of its application, including public policies, adequate legislation, support for health institutions with adequate infrastructure (connectivity), communication equipment and economic resources.

2.7 Telemedicine in Colombia

The country has a telehealth policy that aims to improve health conditions and is aimed at the entire Colombian population, especially those living in remote, remote, and isolated areas. It also emphasizes people in conditions of social and economic vulnerability and seeks to promote the development and use of ICT in order to improve the quality of care.

National experiences:

One of the pioneers in research, development and innovation of medical software was the National University of Colombia, who in 2001 through a cooperative agreement with Telecom, established the first telemedicine network Bogota - San Andres and Providencia.

Around 2004, the University together with the Technological Institute of Electronics and Telecommunications, associated with Colciencias, led a project called "telemedicine pilot project Apaporis-Leticia-Bogota", where consultations in different specialties were offered, and where patients from remote areas were trained (23).

In 2008, the Ministry of Health and Social Protection, in coordination with a public health promotion entity, managed to ensure that 141 health service institutions had the trained personnel and equipment necessary to provide telemedicine services. A total of 7,531 teleconsultations were provided to Colombians in remote areas of departments such as Guajira, southern Bolivar, Chocó, Vichada, Vaupés, Guaviare, Guainía, Caquetá, Putumayo, and Amazonas. As for specialized medicine, 806 patients were attended and remained connected through the telecare modality.

Within the framework of this program, in 2009, 1,140 specialized medical consultations were attended, 2,250 basic telemedicine consultations, 501 patients were attended in the telecare unit (20).

In 2011, a project called Tele-pediatric Emergency was created. It was carried out in the 13 first level hospitals in the city of Bogota. Its objective was to attend more than 720 patients hospitalized in emergency rooms in the most vulnerable areas of the city (24).

Today, the telemedicine center of the National University of Colombia conducts research especially towards imaging, management, and communication of medical informatics. It has provided specialized telehealth services to more than 35,000 patients in more than 40 municipalities and outlying areas of the country, in the following specialties: Internal Medicine, Radiology, Dermatology, Toxicology, Pediatrics, Psychiatry, Gynecology, Orthopedics, Cardiology, Infectious Diseases, Urology, Otolaryngology, Neurology and Nutrition (24).

The Distrital Francisco José de Caldas University has also played an important role in the development of telemedicine, in 2007 it developed a project called "Information System for Telemedicine Projects SITEM", creating a web portal, which allows them to organize the information that, in health matters, has a confidential nature. (25).

The Pontificia Bolivariana University of Medellín also developed an interface for remote monitoring of data obtained by a computer, with the aim of remotely assessing vital signs in cases of elective consultations, emergencies or emergencies (23).

In recent years, the Ministry of Health and Social Protection has held several events related to telemedicine and teleeducation to publicize national and international experiences in the use of ICT, human resource training and research, management and implementation of electronic medical records, export of services and advances in the ICT industry in the health sector.

2.8 Colombian Telemedicine Legislation

In order to facilitate access to services for the Colombian population, especially those with limited access to basic services in remote areas of the country, the National Government, through the Ministry of Health and Social Protection, implemented the following regulations:

- Law 1122 of 2007: Article 26, paragraph 2. "The Nation and the territorial entities will promote Telemedicine services to contribute to the prevention of chronic diseases, training and to the reduction of costs and improvement of the quality and timeliness of the provision of services such as diagnostic imaging" (26).

- Law 1341 of 2009: Article 40. Telehealth. "The Ministry of Information and Communication Technologies (ICT), will support the development of Telehealth in Colombia, with resources from the ICT Fund and bringing connectivity to strategic sites for the provision of services by this modality, to the remote territories of Colombia" (27).

- Law 1419 of 2010: "Establishes the guidelines for the development of Telehealth in Colombia". The purpose of this law is to develop TELEHEALTH in Colombia, as a support to the General System of Social Security in Health, under the principles of efficiency, universality, solidarity, integrality, unity, quality and the basic principles contemplated in this law" (28). This law allows the use of information and telecommunication technologies for the remote provision of health services, or telehealth.

Also under this law, article 2 defines Telemedicine as: "The provision of health services at a distance, in the components of promotion, prevention, diagnosis, treatment or rehabilitation, by health professionals using information and communication technologies, which allow them to exchange data with the purpose of

facilitating the access of the population to services that present limitations of supply of access to services or both in their geographic area" (28).

- Decree 3039 of 2007: "Whereby the National Public Health Plan 2007-2010 is adopted". Whose intention is to promote the telemedicine service for the prevention of risks and the recovery and overcoming of health damages (29).

- Decree 538 of 2020: "Technological platforms for telehealth activities". During the health emergency derived from the Coronavirus COVID; it became necessary to implement accessible digital platforms that allow the diagnosis and follow-up of the patient (30).

- Resolution 1448 of 2006: "Whereby the Qualification Conditions for the institutions that provide health services under the Telemedicine modality are defined. This norm seeks to guarantee and regulate the provision of health services under the telemedicine modality and to establish the enabling conditions of mandatory compliance for all institutions that provide this service" (31).

- Resolution 5521 of 2013. Article 13: In order to facilitate timely access to the benefits defined in this administrative act and in accordance with the quality standards in force in the country, the POS includes the telemedicine modality when it is available, allows the purpose of the provision of the service or guarantees greater opportunity, if in-person care is limited by geographical access barriers or low availability of supply (32).

- Resolution 2654 of 2019: "Whereby provisions are established for telehealth and parameters for the practice of telemedicine in the country". Its objective is to regulate and modernize the current regulations on Telemedicine and Telehealth, promoting greater and better access to health services in the most distant populations in the country (33).

Considering the above legislation, it is evident that the country is in fully committed to the development and implementation of Telemedicine. Progress has been made to the regulatory framework but, even so, it is necessary to develop and implement protocols with clear and simpler structured processes that allow the comprehensive provision of the essential health service.

2.9 Existing challenges to telemedicine in Colombia

Previously mentioned were the laws and regulations that have been incorporated in recent years, in which it is evident that Colombia has the potential to apply Telemedicine as an alternative solution to healthcare. However, it is not the only variable to consider, as there are several factors that limit its implementation. These are:

- *Social problems:*
  - Decrease in trust between "the patient and the professional". Patients are afraid and distrustful of having to assist the physician through technological tools. At the same time, there is a fear or concern about privacy and confidentiality with the treatment of their personal data (12) (34).

  - Decrease in the inter-professional relationship amongst health care providers. It may exist with the imposition to the use of telemedicine among professionals, some of them may refuse to adopt the new modalities of medicine and focus on traditional practices (12) (34).

    A 2017 a study on the application of telemedicine in Colombia, medical professionals' surveys, showed that in cities such as Medellin, Cali, Bucaramanga and Bogota, some type of

telemedicine is being practiced, with the participation rate of 58.33%. On the contrary the other 41.67% claimed not to make use of practicing distance medicine (35).

- Threat to the help professionals. In which the fear of an increase in the workload stands out. In addition to the need for additional training to meet the demand required for the use of telemedicine. It is important to emphasize that many health professionals in Colombia have had no experience or lack knowledge regarding the use and applications of telemedicine. And, last but not least, fear of rapid equipment obsolescence (12).

- Organizational and bureaucratic difficulties:
  - Underdeveloped infrastructure and lack of technical knowledge: This is likely the main reason why telemedicine projects have failed in remote areas of the country. To start a project, high costs are required for the acquisition and updating of equipment, as well as the need for wireless communication channels and/or storage media, fiber optics, among others, which are necessary to maintain the transmission of information (12).

- Legal challenges:
  - The lack of transparency and incomplete laws are a major obstacle to the adoption and incorporation of telemedicine. Although Colombia has laws that accredit the use of telemedicine and guarantee the training of professionals in the use of telemedicine technology, there are still large legal gaps in resolutions and regulations. It is important to have a wide range of regulations for the development of this modality (35).

  - The rule regulating telemedicine services *limited the use of telemedicine services to the care of the populations living in dispersed areas*. *In addition, it establishes that personal attention (face to face) will prevail over telemedicine whenever possible.* (34).

  - The Colombian legal framework restricted tele-medical service centers located abroad, which must enter into agreements with institutions in order to be able to provide their services in the country. Therefore, the absence of international legislation that allows health professionals to provide services in different jurisdictions and countries is evident (34).

  - Difficulty in developing protocols. Another limitation is the existence of unbiased, imprecise, confusing and erroneous information that can be provided to both professionals and patients (12).

  - Lack of clear national and regional telehealth commitment strategies on the part of governments.

- Economic problems:
  - Lack of financing: It is necessary for the country to give more economic support to research groups in order to be able to work more on telemedicine. Developed countries such as Germany, the United States and Japan invest 20 times more in the development of information technology, which shows the great difference in the development of these countries (36)

- Lack of knowledge of the benefits.

- Resistance to change.

2.10 Recommendations for improving telemedicine in Colombia

- Work on the formulation of policies, promoting the regulation of standards, creating strategies, plans and goals that help to clarify the legal framework for the implementation of telemedicine. In addition, consideration should also be given to cross-border consultations in which the health professional is in another country (37) (38)

- Clarify clinical protocols to explain what can and cannot be done in remote consultation.

- Allocate resources optimally.

- Workers/employees are an important part of the development of this type of project; therefore, it is advisable to study the regulations and if necessary, make changes in order to support the health professional, without affecting the patient. It is also necessary to establish policies and protocols to clarify the vacuum that exists regarding the ethical responsibility of the workers (37) (38)

- Prior training of the practitioner before the direct use of technologies with the patient is essential, but it is also important that they remain capable of using their own skills, judgment and knowledge within a new context (37) (38)

- Ensure that mechanisms are in place to document and track past exchanges and decisions made during consultations (37) (38)

- Equity, gender and human rights considerations for those with low literacy, access barriers, limited use of technology, minority language speakers or people with disabilities: These are people who in most cases do not have equal access to health care, or even access to basic health services (38) (37)

2.11 Teleoptometry in Colombia

One of the areas of visual health that are entering the field of telemedicine is tele optometry, a profession that has existed in Colombia for more than 60 years. Regulated by Law 0825 of 1954 and Law 372 of 1997, its activity includes: *Prevention, promotion, diagnosis, treatment and rehabilitation of diseases of the eye and the visual system through examination, diagnosis, treatment and management that lead to visual efficiency and eye health, as well as the recognition and diagnosis of systemic manifestations related to the eye that allow preserving and improving the quality of life of the individual and the community* (39)

Tele optometry in Colombia has been poorly explored. Even so, there are some fields in which Optometry has ventured. One of them is the creation of a "Telemedicine platform for Diabetic Retinopathy Follow-up" by La Salle University. This program contains data such as patient profile, physician profile, medical history, diagnosis, among others, which allows and facilitates the monitoring and care of people with diabetic retinopathy who are in remote areas or where care centers are very distant (40).

Also, La Salle University, together with the National Research and Education Network, held a teleconference on "Hypertensive Retinopathy in the context of Teleoptometry", where they were responsible for connecting and

integrating the National Science, Technology and Innovation system, resulting in a breakthrough for the development of Tele optometry in Latin America (41)

Taking advantage of the fact that Tele education is a field that favors Tele optometry, the Colombian Federation of Optometrists (Fedopto), developed a virtual learning platform that offers diploma courses on different topics such as dry eye and ocular allergy (42)

Likewise, there are now virtual courses or websites such as Optonet, which allow the Optometry professional to work while studying at a distance, thus allowing the professional to develop new skills, improve their skills, be more competitive and increase their knowledge (43)

Colombia has been introducing telemedicine for two decades, but it has been a very slow process. For this reason, there are limitations in terms of the scarce literature that addresses the term Tele optometry, even so, there are studies that support Tele optometry as an effective, innovative, fast, and very useful tool that can improve health equity.

2.12 Evolution of Tele optometry against COVID-19 in Colombia.

Healthcare workers around the world have been affected by the pandemic because of the difficulties they have encountered in continuing to provide service. Optometrists, of course, have been no exception to this situation. For this reason, Colombia has had to accelerate the process of integrating telehealth into its general health system in order to respond to the Covid-19 pandemic.

On April 23, 2020, the Ministry of Health and the National Government regulated and modernized the existing legislation for the exercise of clinical practice in Optometry against the backdrop of the pandemic. Among the most relevant conclusions are:

1. *Providers of visual health services that are in the Special Registry of Providers (REPS), in the intramural modality, may request authorization from the territorial entities to offer the home modality, in order to serve the population that has restriction of movement, as is the case of adults over 70 years of age, if they request priority care* (44).

2. *Qualified providers may also offer tele-guidance services without the need for authorization* (44).

3. *Due to the pandemic, authorized Optometry service providers may offer telemedicine, interactive tele-optometry or tele-expertise services* (44).

This has facilitated in some cases the contact with the patient and the follow-up of their visual health problems. The fact of not requiring special authorization for its use (at least in the case of tele-orientation) has been an ally to be able to maintain the provision of the service in a safe manner.

In addition, thanks to the experience gained, the eye care professional could later provide complete telehealth services not only referred to tele-consultation but perhaps using other types of diagnostic aids, which would generate a greater benefit for patients and increase health coverage.

3 Diabetes Mellitus (DM)

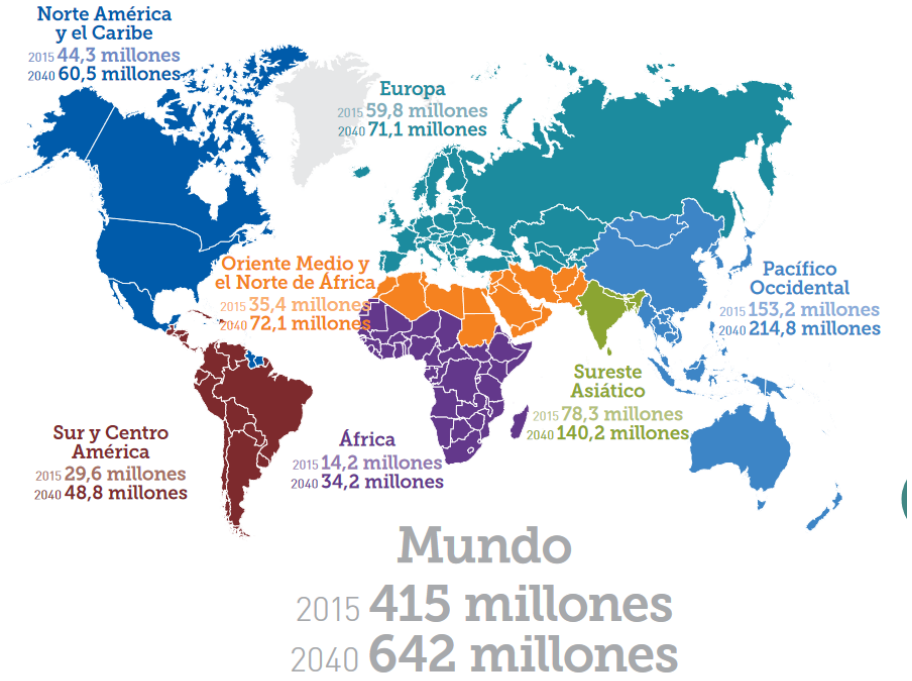
3.1 Epidemiology

The prevalence of diabetes mellitus is progressively increasing everywhere, due to the increase and aging of the population associated with changes in sedentary lifestyles and the existing obesity epidemic (45). This problem is causing governments and health systems to act and implement preventive measures against this condition. As a chronic disease, the importance of timely diagnosis, control and prevention is vital to avoid disabling and costly health complications.

Due to the high prevalence of this disease, it is considered a worldwide epidemic with a significant morbidity, mortality and high economic and social costs. According to the WHO in 2019, it was the ninth leading cause of death: with 1.5 million deaths that were a direct consequence of this condition (46).

According to the International Diabetes Federation (IDF), there were 415 million people worldwide affected by diabetes in 2015, which will increase to 643 million in 2030 and 783 million in 2045 (47).

Figure 1: Estimated number of people with diabetes in the world and by region in 2015 and 2040 (20-79 years).



Source: Based on (48)

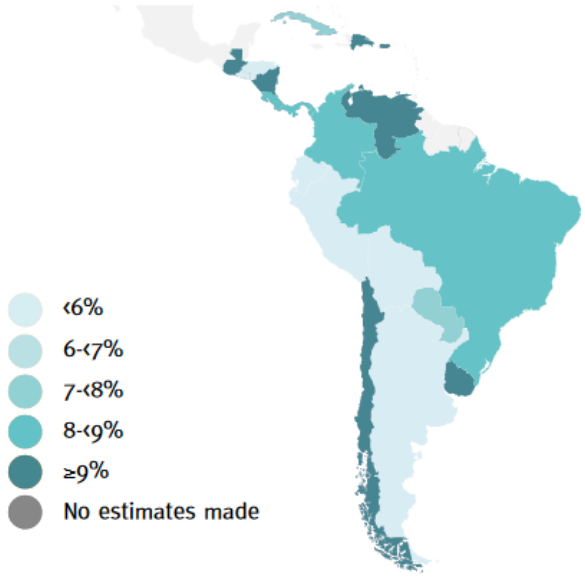
The increase of DM in developing countries also shows a worrying trend due to several factors, among them is poverty, which is undoubtedly one of the main reasons due to its complications, such as a poorly varied diet, rich in carbohydrates (these products are cheaper to produce and buy) and low in protein. Another important factor is the lack of education and awareness, the lack of knowledge causes that in many cases the symptoms are not recognized when they occur, leading to a late diagnosis. There is also the low adherence to treatment, not only because of the great economic difficulty to access treatment but also because of the lack of knowledge

of the possible consequences of not treating diabetes correctly, as well as a poorly prepared health system and finally the westernization of some developing countries, has also led to changes in dietary patterns (48).

In the South and Central America region, 31.6 million adults aged 20-79 years, or 9.4% of the regional population in this age group, were estimated to have diabetes in 2019. Of these, 13.3 million (41.9%) are undiagnosed and approximately 85.5% of adults with diabetes live in urban settings (48).

In 2021, $65.3 billion was spent on diabetes in this region, representing 6.7% of the total spent worldwide. In addition, IDF forecasts that the number of people with diabetes in the region will increase by 48%, reaching 49 million by 2045 (47).

Figure 2: Age-adjusted comparative prevalence of diabetes (20–79 years) in the IDF South and Central America Region.



Source: Based on (47)

Mexico and Brazil are the countries with the highest percentage of people with diabetes in Latin America. Mortality in these patients could increase by 80% in the next ten years. The situation is so critical that, by 2002, diabetes in Mexico was the leading cause of mortality (12.8%), being the country with the highest rate of related deaths (48).

Table 2: Top 5 countries for number of people with diabetes (20–79 years) in million.

COUNTRY	YEAR 2011	YEAR 2021
Mexico	10.3 m	14.1 m
Brazil	12.4 m	15.7 m
Colombia	2.6 m	3.4 m
Venezuela	1.7 m	2.3 m
Argentina	1.5 m	1.8 m
Chile	1.2 m	1.7 m

Source: : Own elaboration base on (47)

Colombia, according to the Ministry of Health, reports from the High-Cost Account indicate that 3 out of every 100 Colombians have diabetes mellitus. However, it is estimated that the real number is much higher and that one out of every 10 people in Colombia suffers from this disease. The reason for this is because approximately half of the population does not know that they suffer from this disease (49).

Likewise, according to estimates from the 2017 Global Burden of Disease Study, it moved to place 6 as the most frequent cause of death in 2017 after having been in position 7 in 2007, with a mortality rate of 28.98 per 100,000, a difference of 32.4% between 2007 and 2017 (50).

On the other hand, diabetes mellitus as a metabolic pathology, in its evolution affects different organs, including the eyes. The most important visual sequela is Diabetic Retinopathy (DR). The prevalence of DR increases with the duration of the disease, after 20 years 90% of cases of type I diabetes and 60% of type 2 will have some form of retinopathy and of these 5% would require treatment to avoid irreversible blindness (51)

3.2 Diabetic Retinopathy (DR)

Diabetic retinopathy (DR) is a microvascular complication of DM, which affects the retinal vasculature and causes progressive retinal damage that can lead to vision loss and in more severe cases to blindness. The main risk factors are duration of diabetes, impaired glycemic control and the presence of hypertension (51).

It is the leading cause of blindness in people of working age in developed countries. The WHO estimates that DR is responsible for 4.8% of the 37 million cases of blindness worldwide (46)

Studies have shown that early detection combined with appropriate treatment can prevent vision loss in up to 95% of cases. (51). However, screening compliance rates are below recommended and despite advances in diabetes management, and the availability in treatments such as laser and intravitreal injections, associated visual loss is still very common, for reasons such as:

- Late attendance for screening examinations and/or treatment.
- Poor participation in diabetes care.
- Not all cases of DR respond to treatment.(52)

3.2.1 Classification of diabetic retinopathy

DR can be classified into two main stages: non-proliferative and proliferative. The International Clinical Diabetic Retinopathy classification allows macular edema and diabetic retinopathy of the posterior pole to be evaluated separately and, with this, to define the management, treatment, and controls of a patient.

1. *Non-Proliferative Diabetic Retinopathy (NPDR):* This is the early stage of the disease and there is no presence of neovascularization, but some classic signs of DR such as microaneurysms are present. This category is divided into mild, moderate, and severe (53) (54).

2. *Proliferative Diabetic Retinopathy (PDR):* This is the most advanced stage of DR and is characterized by the presence of retinal or iris neovascularization; secondary to retinal ischemia (53) (54).

3. *Diabetic macular Edema:* Is a significant complication. It can occur in isolation or at any stage of DR and is the most frequent cause of visual loss in a patient with type 2 DM, so it should be managed by the specialist (53) (54).

Table 3: Classification of diabetic retinopathy, with its clinical characteristics according to the International Clinical Diabetic Retinopathy Disease Severity Scale.

	CATEGORY	CLINICAL CHARACTERISTICS	CONTROL (RECOMMENDED)
Non-proliferative diabetic retinopathy (NPDR)	Normal	• No observable abnormalities	Type 1 diabetes: 5 years after diagnosis of diabetes. Type 2 diabetes: 1 year after the diagnosis of diabetes.
	Mild	• At least one microaneurysm • No macular edema present	Annual
	Moderate	• More than microaneurysms, but less than severe NPDR • No macular edema present.	Every 6 months
	Severe	Any of: • >20 intraretinal hemorrhages in each of 4 quadrants • Definite venous beading in >2 quadrants • Prominent intraretinal microvascular abnormalities in >1 quadrant and no signs of proliferative DR	Every 3-4 months, according to the ophthalmologist's criteria

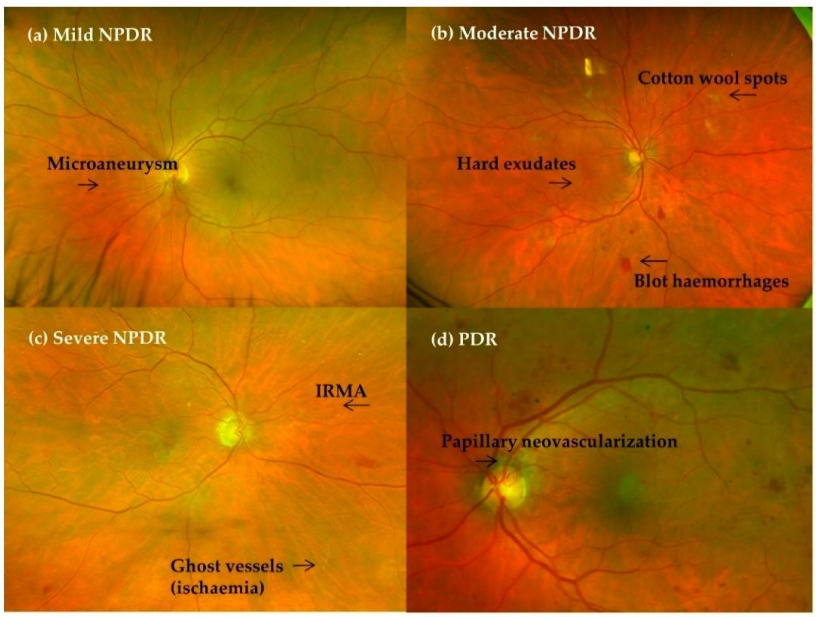
Source: : Own elaboration base on (53) (54).

Table 4: Classification of diabetic retinopathy, with its clinical characteristics according to the International Clinical Diabetic Retinopathy Disease Severity Scale.

	RESULTS OBSERVED IN RETINOGRAPHY	CONTROL (RECOMMENDED)
Proliferative diabetic retinopathy (PDR)	• Neovascularization • NVD • Severity of neovascularization – NVD > ¼ disc area in size – NVE > ½ disc area in size • Preretinal or vitreous hemorrhage	Use of treatments within a month or month and a half.

Source: : Own elaboration base on (53) (54).

Figure 3: Clinical DR progression. (a) Mild nonproliferative diabetic retinopathy (NPDR), (b) moderate NPDR, (c) severe NPDR and (d) proliferative diabetic retinopathy (PDR) with papillary neovascularisation.



Source: Based on (55)

Diabetic macular edema

It can occur at any stage of DR and is the most common cause of vision loss in a patient affected by the disease. The Early Treatment Diabetic Retinopathy Study (ETDRS) defined diabetic macular edema (DME) as a "thickening of the retina at the center of the fovea or within a diameter of disc. (56)

In addition, this study defined clinically significant macular edema (CME) as:

1.Retinal thickening at or within 500 µm of the centre of the fovea.

2.Hard exudates at or within 500 µm of the center of the fovea if associated with thickening of the adjacent retina.

3. A zone or zones of retinal thickening 1DD or larger, any portion of which is within 1DD of the center of the macula (53) (56)

3.2.2 Diagnostics and treatment

Diabetic retinopathy is a progressive pathology that goes through different stages during its development. Hence the importance of early detection and treatment to avoid deep damage to the retina.

Methods for diagnosing DR:

- ✓ Imaging Techniques for Diabetic Retinopathy Screening: These include:
  Fundus Photography, ultrawide-Field Imaging for Diabetic Retinopathy Screening, optical Coherence Tomography for Diabetic Macular Oedema Screening, OCT Angiography in Diabetic Retinopathy Screening, smartphone Function in Diabetic Retinopathy Screening, and automated DR Image Evaluation Systems Used for Teleophthalmology (55).

- ✓ Optical Coherence Tomography: It is a non-invasive and non-contact method that allows obtaining an optical slice of the retina and macula with a resolution of approximately 10 µm. It provides qualitative and quantitative data, therefore, it is able to detect any thickening in the retina (53).

- ✓ Fluorescein angiography: It is an invasive method that presents adverse effects ranging from mild to severe, such as nausea in 5 to 10% of patients, and severe adverse effects such as severe allergic reactions. For this reason it is a test that should not be performed routinely, but only when indicated (53).

Treatment:

- ✓ Laser treatment (photocoagulation): Pan retinal laser photocoagulation is effective in preserving central vision, but may be associated with exacerbation of macular edema, visual field loss, deterioration of night vision and loss of contrast sensitivity. Nevertheless, laser photocoagulation has long been considered the mainstay of PDR treatment (55).

- ✓ Intravitreal anti-VEGF drug injection: Can prevent vision loss, stabilize vision and in some cases even improve vision if performed early. Especially for DME, anti-VEGF therapy showed rapid regression of retinal neovascularization and has become an alternative treatment for PDR (55) (54).

- ✓ Vitrectomy: It is performed in the most advanced cases, in which after laser treatment, hemorrhages and PDR persist and progress. The use of vitrectomy to treat DME remains controversial. Even so, it remains the only way to eliminate fibrous proliferation and alleviate tractional detachment (53).

- ✓ Intravitreal steroid injections: Indicated for EDM, it can stabilize the blood-retinal barrier, reduce exudation and regulate down-regulating inflammatory stimuli (54).

- ✓ Vitreoretinal surgery.

3.3 Epidemiology of diabetic retinopathy in Latin America

The increase of DR in developing and underdeveloped countries translates into a major public health problem, as more patients are diagnosed with DM every day.

In Latin America, there are population-based studies specifically designed to estimate the prevalence of blindness, but they are not specific for DR, however, the Clinical Guide of Diabetic Retinopathy for Latin America published in 2016 by the Pan American Association of Ophthalmology shows that up to 40% of diabetic patients have some degree of DR, 17% require treatment and 5% of them are at high risk of blindness (57).

In Chile, as of 2005, 30% of diabetic patients evaluated had DR and of these cases, 5 to 10% required treatment with photocoagulation due to risk of visual loss (57).

In Costa Rica, the prevalence of DR in diabetic patients is 15%; 5.8% of patients have mild Non-proliferative DR, 3.9% have moderate DR, 4.7% have severe DR, 0.6% have proliferative diabetic retinopathy and 2.6% have macular edema. (58).

In Mexico 8% of blindness is caused by DR (58). In October 2010, a DR workshop held in Queretaro, Mexico, was attended by 1840 patients of which 13 were type 2 diabetics; 309 patients had DR (17 %); and 91 % had diabetic

retinopathy in the non-proliferative phase, 9 % had DR in the proliferative phase, and 11 % had macular edema. (59).

In Ecuador for 2013, a study was conducted in patients with type 2 DM during the period 2010 to 2011, where 62 prevalent cases of diabetic retinopathy (17.1 %) were diagnosed (59).

The RACSS Rapid Assessment of Cataract Surgical Service and the RAAB Rapid Assessment of Avoidable Blindness are studies that aim to estimate the prevalence of blindness, its causes, age, among others. They included seven studies carried out in Latin America, which yielded results of the percentage of blindness attributable to DR, with Brazil being the country with the highest prevalence of blindness due to diabetes (15.9%), followed by Cuba (9.2%) and Chile (8.5%), while in Colombia the figure is 1.4% (60) (57).

Table 5: Prevalence of diabetes and estimated cases of diabetic retinopathy.

COUNTRY	POPULATION	DIABETES	DM FID	DR
Brazil	190 M	10.1%	8.7%	7,6%
Mexico	118 M	16.0%	12.6%	30%
Colombia	42 M	7.1%	7.2%	18%
Argentina	41 M	7-9 %	6.0%	30%
Venezuela	30 M	6.6 %	6.8%	25%
Peru	19 M	5.5%	6.5%	30%
Chile	16 M	9.6%	11.2%	18%
Ecuador	16 M	6.0%	5.7%	10%
Bolivia	11 M	7.2%	7.2%	-
Cuba	11 M	5.8%	6.7%	20%
Dominican Republic	10 M	5.0%	10.7%	5%
Paraguay	7 M	10.0%	7.0%	30%

Source: : Own elaboration base on (57).

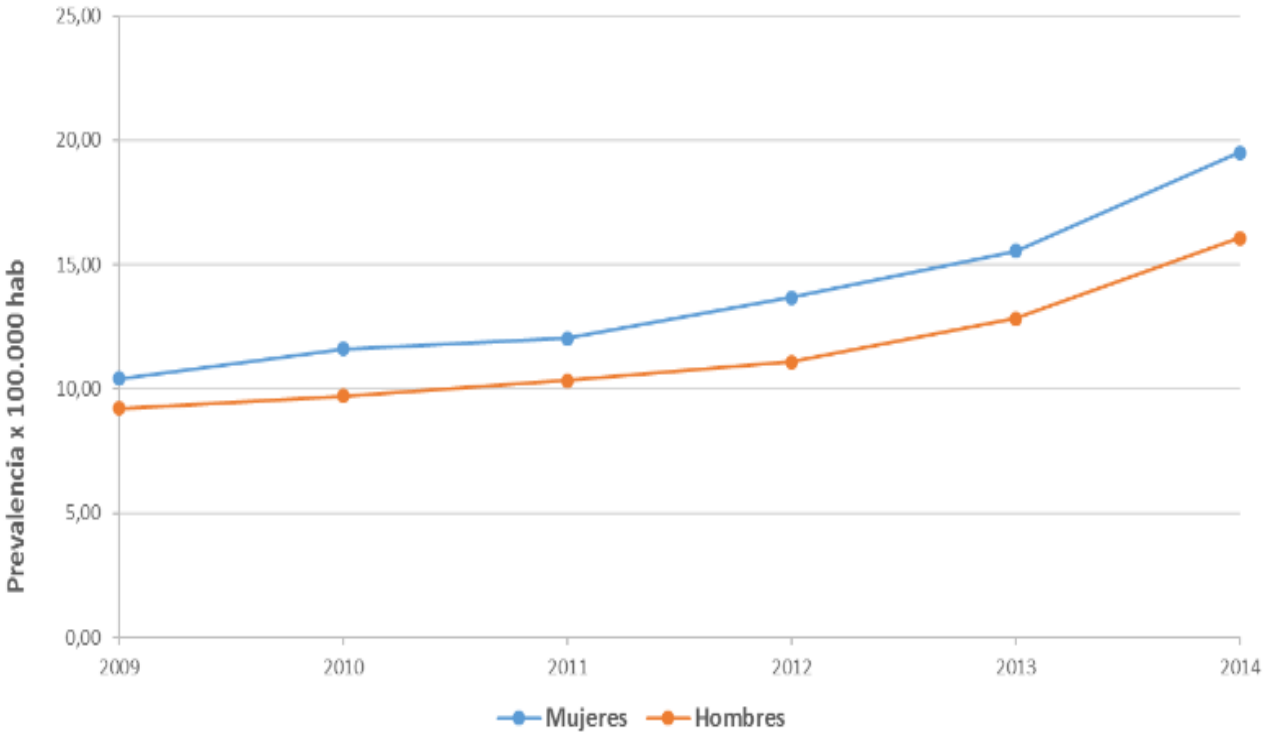
3.4 Emidemiology of diabetic retinopathy in Colombia

In Colombia, no epidemiological population study has been conducted to date to investigate the prevalence and causes of blindness throughout the national territory. The sociopolitical and topographical challenges of Colombia, make it difficult to have a consolidated information on the most updated data.

In 2016, the Colombian Ministry of Health and Social Protection, published a study on the Visual Situation in Colombia conducted between 2009 and 2014, where it was evident that DR cases have been increasing from one year to another, reporting a prevalence of 12.86% per 100,000 inhabitants in 2009 and 19.76% for 2014 (61).

In relation to the prevalence of DR by sex, inequality is evident. Women have a higher prevalence of DR than men. For women, the prevalence per 100,000 inhabitants increased from 10.41 to 19.51, and for men, the prevalence increased from 9.20 to 16.06 (61).

Figure 4: Prevalence of diabetic retinopathy by sex.



Source: Based on (61)

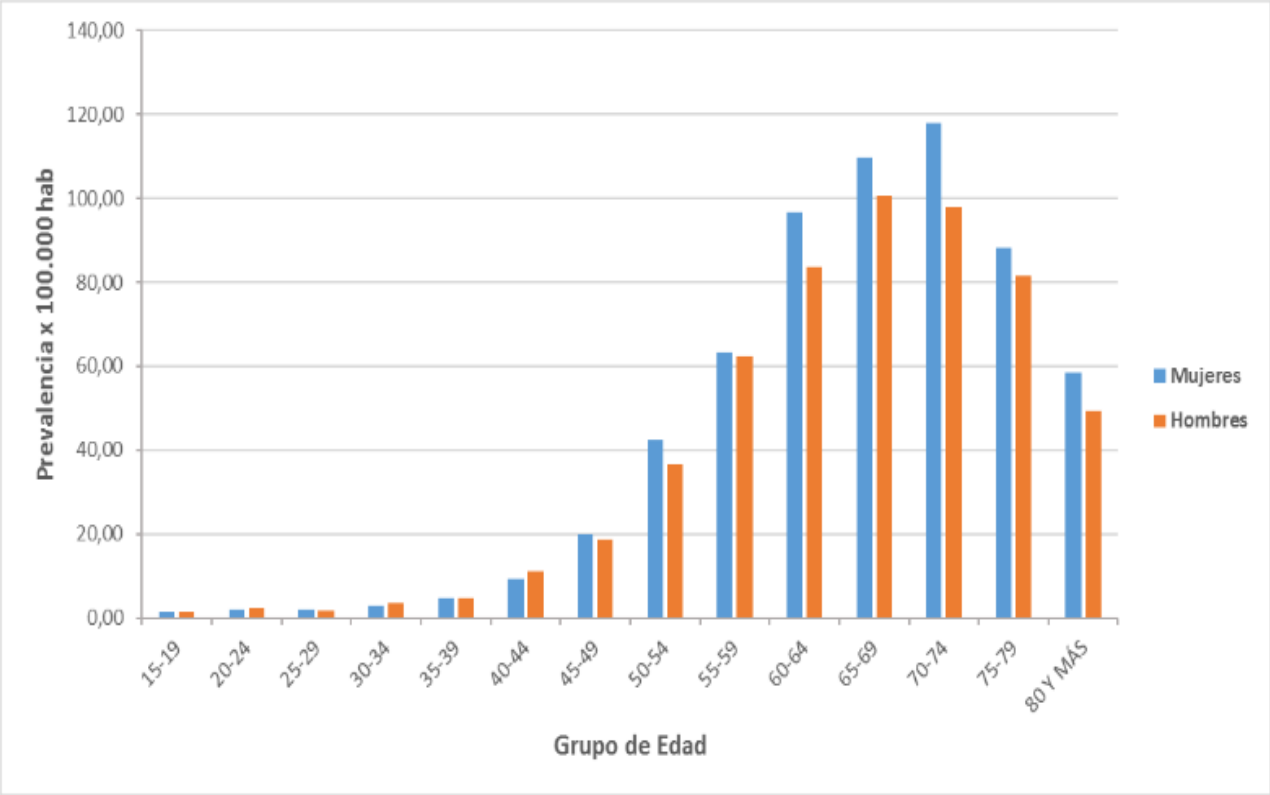
For the analysis of the prevalence of DR by age group, starting with women, it was found that the highest prevalence of DR present was in the group aged 70-74 years with an estimated prevalence of 117.82 per 100,000 inhabitants, followed by the group aged 65-69 years with an estimated prevalence of 109.60/100,000. In the case of men, the prevalence was similar to that of women; the age group with the highest prevalence was 65-69 years with an estimated prevalence of 100.53/100,000 (61)

In general, this disease affects to a greater degree the population over 50 years of age, in which the prevalence per 100,000 inhabitants is above 38.00 and reaches a maximum of 117.82 according to sex.

Considering the impact of DR on patients' quality of life, early and appropriate intervention is necessary to reduce the burden of comorbidity. DR significantly limits function-ability in both basic activities and work, with psychological and social repercussions.

In India, a study was conducted on the quality of life in people with diabetic retinopathy, which concluded that the quality of life was significantly lower in diabetics with DR compared to those without DR, and the maximum effect was observed in general health, general vision and mental health (62).

Figure 5: Prevalence of diabetic retinopathy by age groups and sexes.



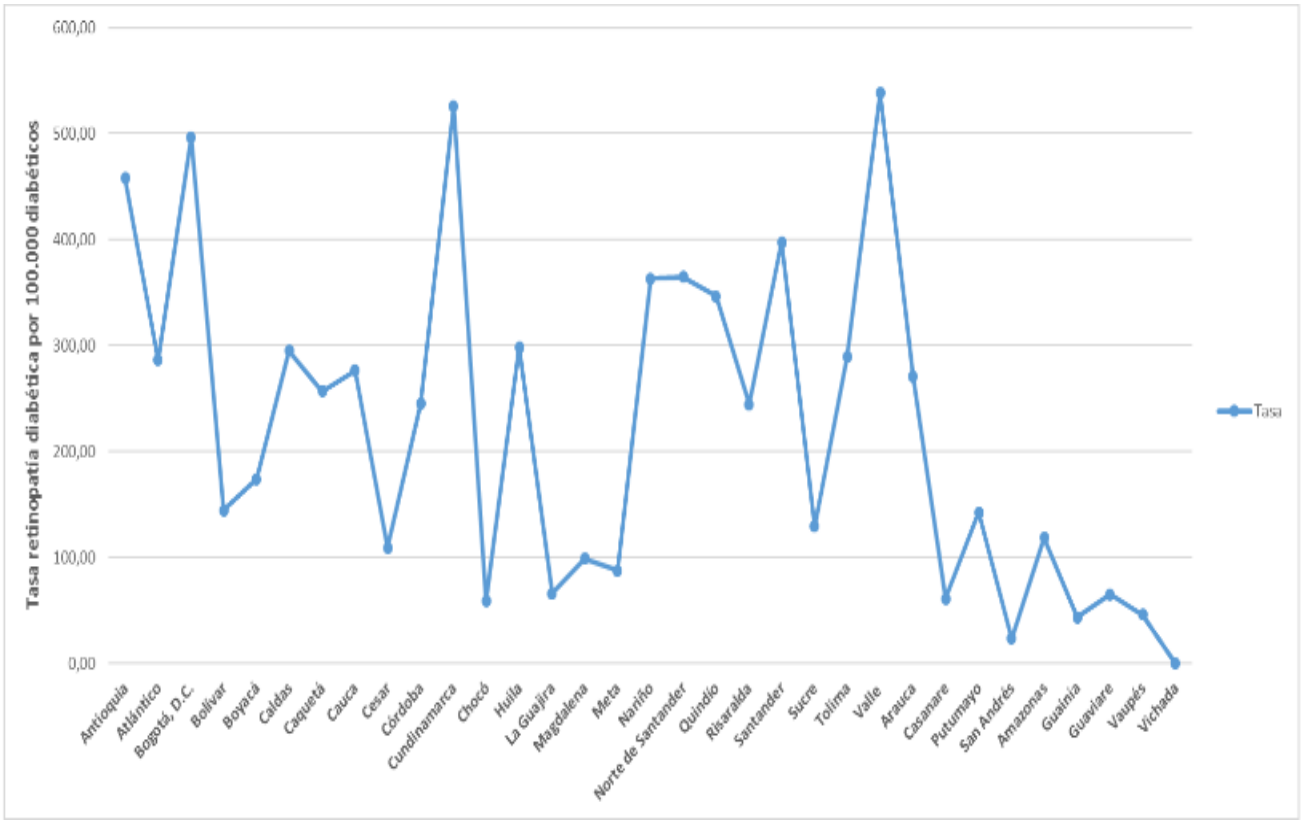
Source: Based on (61).

In relation to the prevalence by departments for 2014, it was found that those with a higher prevalence of DR, are the departments headed by Valle with 30.09/100,000 inhabitants; Cundinamarca with 29.54/100,000; Bogotá D.C. with 27.84/100,000; Antioquia with 25.65/100,000; Santander with 22.11; Norte de Santander with 20.36/100,000; and Nariño with 20.34/100,000. Of all these departments, Bogotá D.C., Antioquia, and Santander have maintained the prevalence of the disease between 2009 and 2014, while the others have shown an increase of up to 150% in prevalence.

In contrast, the departments reporting the lowest prevalence's for the same period are Vaupés 2.31; San Andrés 1.32, Vichada 0.00. per 100,000 inhabitants.

Among the departments with a higher prevalence of diabetic retinopathy per 100,000 diabetics for 2014 are Santander with 397.84, Antioquia with 458.24, Bogota with 496.92, Cundinamarca with 526.03, and Valle with 538.57 (61).

Figure 6: Rate of diabetic retinopathy in patients with diabetes. Colombia, 2014.



Source: Based on (61)

Figure 7: Prevalence of diabetic retinopathy by state. Colombia 2009-2014

Departamento	Año 2009	Año 2010	Año 2011	Año 2012	Año 2013	Año 2014
Antioquia	23,28	23,00	12,18	18,90	24,32	25,65
Atlántico	6,60	10,54	7,54	7,73	11,91	16,04
Bogotá, D.C.	27,77	25,67	26,08	19,73	17,97	27,84
Bolívar	2,78	5,07	4,82	4,63	3,93	8,09
Boyacá	4,05	3,86	5,50	5,97	10,48	9,63
Caldas	1,63	4,11	4,82	7,14	11,59	16,35
Caquetá	4,38	6,82	7,17	5,74	7,85	14,39
Cauca	10,36	11,95	9,18	10,64	14,37	15,44
Cesar	4,31	2,29	3,63	2,63	3,11	6,12
Córdoba	4,30	2,01	2,29	3,04	7,54	13,76
Cundinamarca	6,94	8,30	14,92	19,79	21,89	29,54
Chocó	0,65	1,29	1,48	1,05	1,04	3,28
Huila	3,08	6,07	8,82	14,82	15,28	16,73
La Guajira	0,79	0,89	2,46	2,02	2,76	3,78
Magdalena	2,16	1,78	2,45	3,36	3,50	5,54
Meta	4,93	5,18	5,40	5,85	4,50	4,94
Nariño	4,53	5,07	8,62	14,23	13,80	20,34
Norte de Santander	11,82	9,45	19,44	33,90	34,47	20,36
Quindío	6,44	11,66	8,37	13,67	24,24	19,29
Risaralda	2,99	4,45	6,87	6,58	9,21	13,60
Santander	24,74	15,21	19,16	13,86	8,72	22,11
Sucre	3,79	2,58	6,48	8,28	8,32	7,22
Tolima	15,56	15,30	14,17	16,51	13,49	16,04
Valle	11,75	14,82	17,18	24,19	39,26	30,09
Arauca	2,07	1,63	8,86	11,94	6,29	15,15
Casanare	2,22	0,62	1,53	0,90	1,18	3,46
Putumayo	1,57	0,93	1,23	2,43	4,20	8,00
San Andrés	0,00	4,11	0,00	0,00	2,67	1,32
Amazonas	0,00	1,39	1,38	2,72	1,34	6,65
Guainía	2,66	0,00	2,57	2,53	0,00	2,45
Guaviare	0,99	1,95	0,00	1,89	4,65	3,67
Vaupés	0,00	0,00	0,00	0,00	0,00	2,31
Vichada	0,00	0,00	0,00	1,50	2,92	0,00

Source: Based on (61)

Given the worrying results, obtained in the study conducted from 2009-2014, and in order to perform a timely detection and treatment in patients with visual diseases, Colombia developed the "National Program of Comprehensive Care in Visual Health 2016-2022", in the specific case for DR; the diabetic patient independent of age is entitled to:

Promotion/Prevention:

- *Education on self-care and seeking care at home, work, social activities, educational institutions, senior groups.*

Timely Detection:

- *DR screening performed by an ophthalmologist for all patients diagnosed with type 1 diabetes, 5 years after the diagnosis is confirmed regardless of age, and thereafter an annual exam must be performed.*
- *Diabetic retinopathy screening by ophthalmologist to all patients diagnosed with type 2 diabetes from the time of diagnosis an annual exam.*

Treatment:

- *Laser Photocoagulation access strategies for patients with DR.*

Rehabilitation:

- *Strategies for accompanying families and caregivers on the evolution of existing pathologies and the required home and institutional care* (63).

4 Retinal camera

Retinal imaging has a long and impressive history. The observation and evaluation of the inside of the human eye dates to 1847, when Charles Baggage, an English mathematician and scientist, invented the first ophthalmoscope. It was later rediscovered in 1852 by the German physicist Hedrmann von Helmholtz, who, using a system of mirrors as his main observation tool, was able to see the inside of the human eye. Around 1886, Dr. Howe made, with not very good quality, the first photograph of the human retina. In 1905, Zeiss, together with Dr. Dimmer, designed a new ophthalmoscope with a built-in camera. In 1926 the first fundus camera that could provide a 20-degree view of the retina is invented, allowing ocular fundus structure documentation. Many years later, a camera with the capability of a 30-degree view would be the new standard and by 1961 Novotny and Alvis made the first photographs with filters (64) (65).

Since then, there have been major advances for fundus photography and recording, with many of these new cameras now featuring electronic illumination control, automatic eye alignment, high-resolution digital image capture, non-mydriatic widefield options and, improved portability (66) (64).

4.1 Retinal Camera Types

The use of the retinal camera is a very valuable clinical tool and is considered a key element in the clinical care and treatment of patients with retinal and systemic diseases.

The standard method used for DR detection is 7-field stereoscopic fundus photography, first, because of its high prevalence, and second, because DR affects both the posterior pole and the periphery. However, currently the cost of these devices is high, and their availability is low. Thanks to the development of new technologies, photographs can be taken without pharmacological mydriasis, and even by smartphone, with a sensitivity and specificity of about 90% (53) (64).

Nowadays, cameras used for fundus photography can be classified into two main groups: non-mydriatic and mydriatic retinal cameras.

4.1.1 Non-mydriatic retinal camera

They are small cameras that have the theoretical advantage of avoiding pupillary dilation thanks to the infrared focusing system that does not stimulate pupillary contraction. Most of these cameras have software that automatically detects the posterior pole of the eye, and they also have a flash that is triggered once the retina is well aligned and in focus (65).

One of the great advantages of using non-mydriatic cameras is that they require less time and less light (a single flash) as opposed to 7 standard fields, and as mentioned above, they do not require mydriasis in most patients, therefore, since they do not require the instillation of drugs, they have the advantage of not requiring the presence of an ophthalmologist or optometrist, but rather the retinography can be performed by any technician or professional who is properly trained. It also benefits patients with angle-closure glaucoma or suspected angle-closure glaucoma.

It is a simple, cost-effective, safe, and very comfortable test for the patient. Currently there are high quality non-mydriatic cameras that allow photographing images through 3.3 mm pupils and a field of approximately 50-60º in the horizontal plane (65):

A limitation of non-mydriatic fundus photography is that it requires cooperation from the patient, who must be able to follow commands and be able to remain still. In addition, the cost of the equipment is high, ranging from $25,000 to $30,000 depending on the model.

It is also important to take into account the room illumination. Depending on the brightness, this could affect the pupil diameter and therefore the image acquisition. In addition, they also do not provide a dynamic fundus view, which means that assessment of spontaneous venous pulsations, or subtle abnormalities of visual fixation such as nystagmus, must be assessed later through an ophthalmoscope (65) (67).

4.1.2 Mydriatic retinal camera

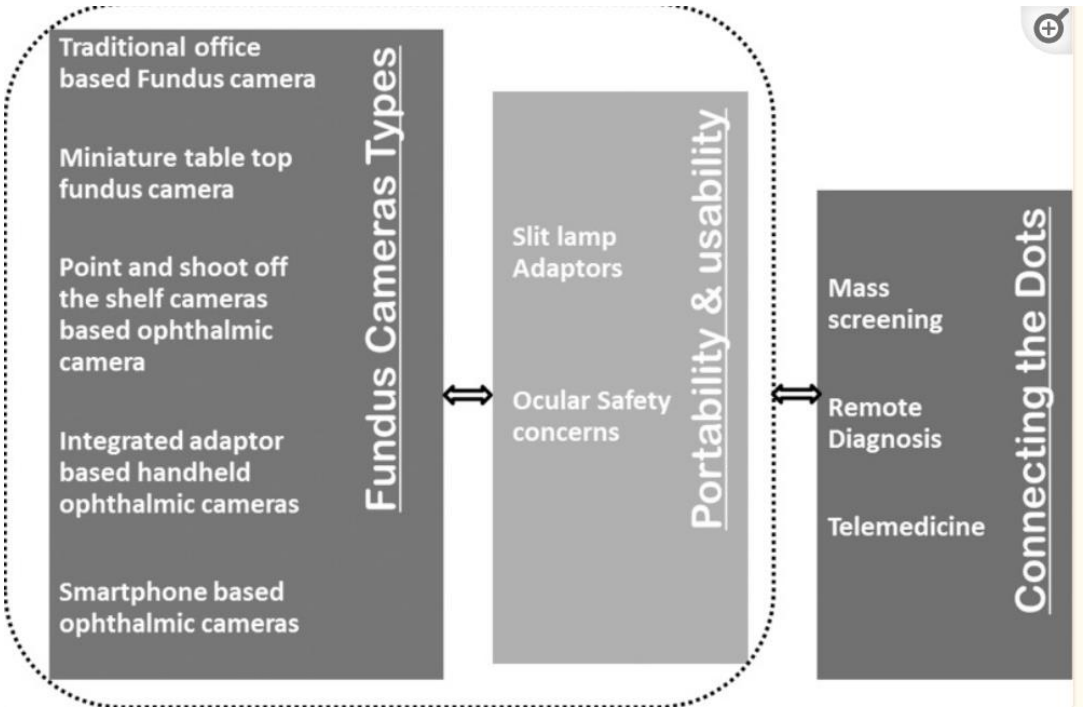
They are more specialized and use visible light, so it is necessary to dilate the patient's pupil, requiring the presence of an ophthalmologist or optometrist. The test lasts approximately 30 minutes, it is a very simple, fast, useful and painless test (65).

It is a test that benefits those who present media opacity such as cataracts or diabetic patients whose pupil is not very reactive and that with the use of non-mydriatic cameras it was not possible to obtain good results.

The advantage of this type of cameras is that they allow obtaining images of a larger area of the retina and with greater detail (stereoscopic capture as well as visualization of the peripheral retina from 75º to 90º of the fundus). Therefore, it provides very important information about the state of the retina, helping to diagnose pathologies.

Their disadvantages, from the patient's point of view, are those presented at the moment of applying the drug, which include itching, stinging, photophobia, headaches and double or blurred vision, which usually last between 4 and 24 hours depending on the type of drug used.

Figure 8: Flowchart depicting evolution and scope of retinal screening and fundus photography.



Source: based on: (66)

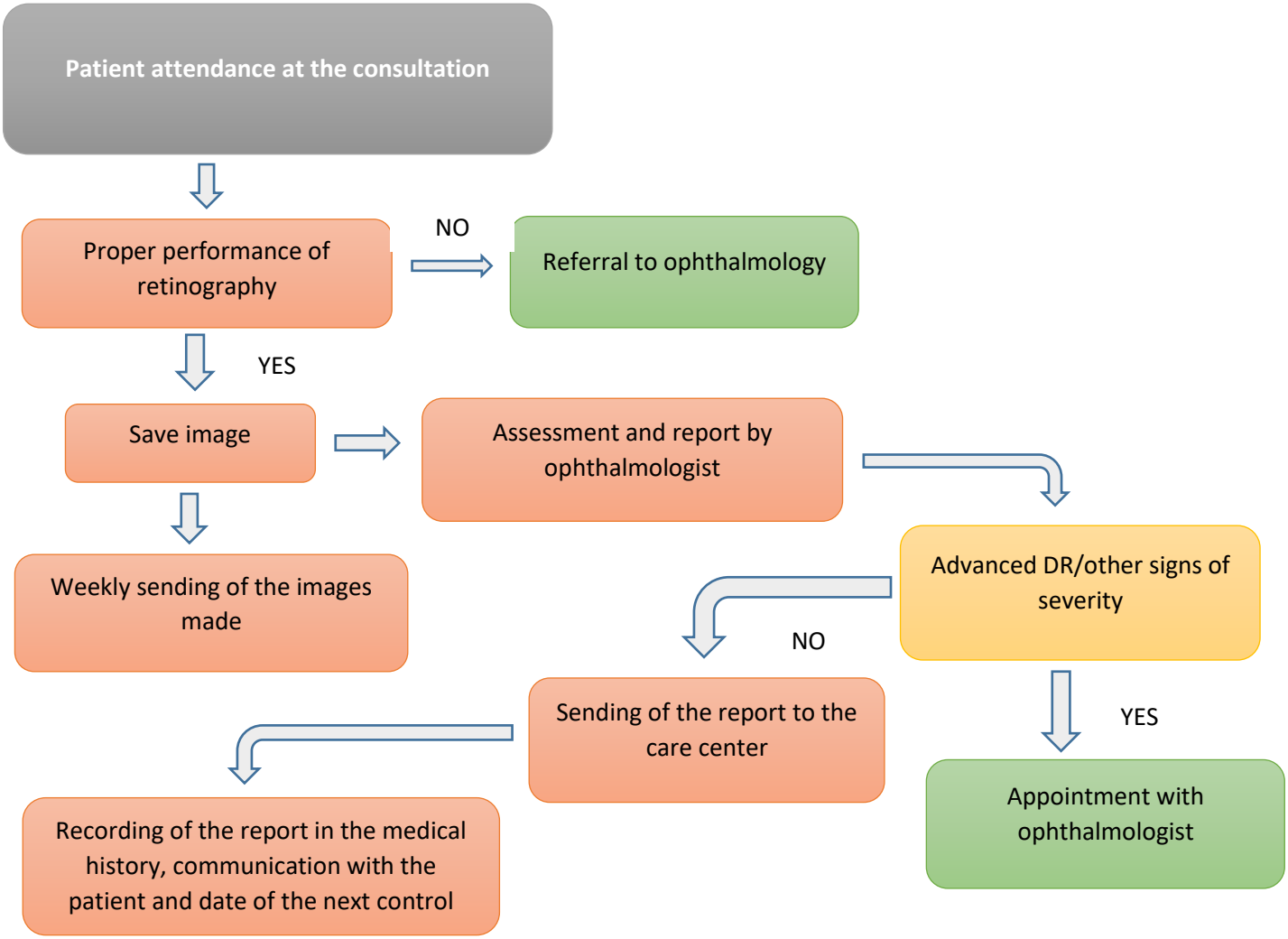
4.2 Use of non-mydriatic retinal camera for DR diagnosis in telemedicine

The type of retinal camera most commonly used for telemedicine projects is the NMRC. Numerous studies support the impact and usefulness of this type of camera in the implementation of screening systems for diabetic retinopathy (DR) (68).

To perform, evaluate and record retinography, it is necessary to have human and material resources, among which are: qualified personnel to take the images, computer technicians, a room adapted for retinography, a non-mydriatic retinography and a computer with access to a software program remotely connected to the hospital concerned (68).

The following diagram shows the technique for referring patients from primary care to the ophthalmologist using a teleophthalmology program with the aid of non-mydriatic retinography.

Figure 9: Technique for referring patients from primary care to the ophthalmologist using a teleophthalmology program.



Source: : Base on (68)

4.2.1 Image analysis methods in teleophthalmology.

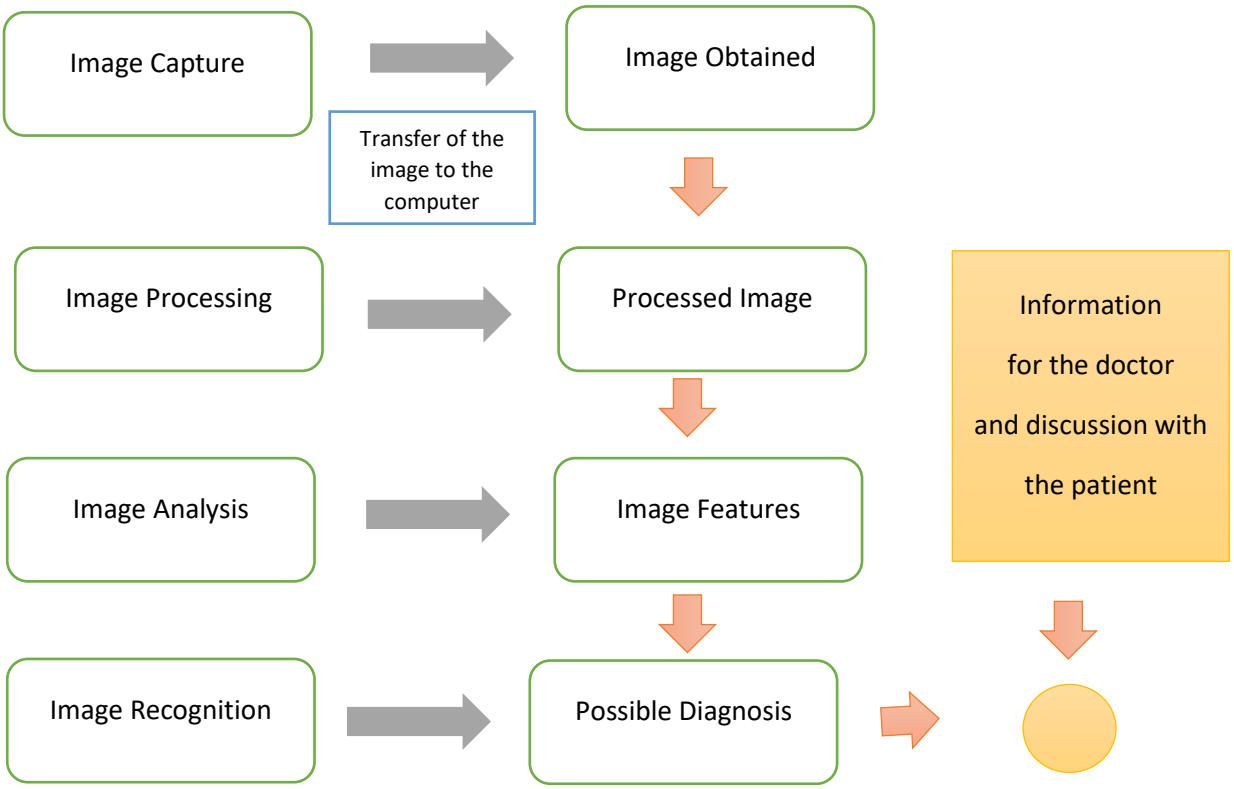
To perform image analysis, there are traditional systems and automatic systems. Traditional analysis requires software that performs the transmission and storage of the image, which is then evaluated and analyzed by an ophthalmologist. A great example of this method is the Eye Picture Archive Communication System (EyePACS), which was developed in 2001 by the University of California to use telemedicine to implement diabetic retinopathy screening programs in community clinics (69). This program uses an "electronic store-and-forward" system, which allows digital retinal images to be captured and uploaded to the EyePACS website for interpretation by a trained physician located elsewhere. Currently, the EyePACS system has been implemented in much of the United States and in many other countries, where it has served more than half a million people, preventing and reducing the risk of blindness in the diabetic population (69).

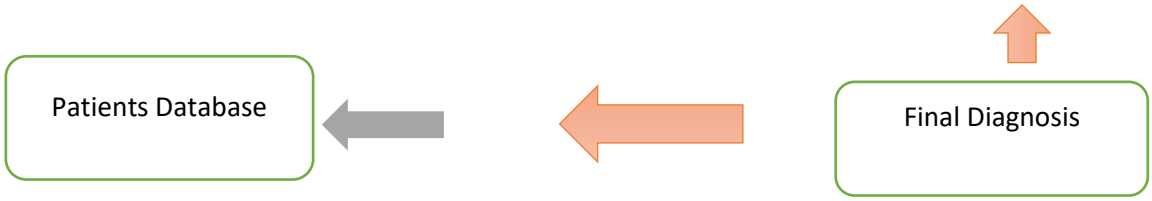
On the other hand, there are the automatic analysis systems, which have been designed by interdisciplinary groups of experts in computer science and ophthalmology, in order to identify changes in early stages of diseases. The operation depends on the design, but they are focused on the same goal. The first step in order to carry out the automatic analysis is to recognize and separate the fundus structures (optic nerve, macula, and blood vessels) and then the images must go through a recognition process, where the ability to detect the presence of any signs of disease is measured and thus classify whether the evaluated retina is "healthy or diseased". When images are classified as "diseased" they go through a more detailed analysis to identify the degree and stage of the disease, this is achieved through the creation of a "visual dictionary" that contains the general patterns and characteristics of each alteration that may be present in the retina (70) (71) (72).

For the development of this type of analysis, there are tools such as Computer Aided Diagnostic Systems (CADx), which were developed with the aim of improving the accuracy of examinations, increasing consistency in the interpretation of images, assisting in the evaluation of prognosis and supporting the therapeutic decision-making process (70) (72).

The following diagram depicts image processing through Computer Aided Diagnostic Systems.

Figure 10: Image processing through software.





Source: Based on (72)

On the other hand, both for the analysis and for the diagnosis of retinal images under the telemedicine method, standardized protocols must be carried out. Some general aspects are listed below*:*

- Collection of patient data (name, medical history, etc).
- Storage of the images obtained of each person in a database.
- All the images must pass a quality process, in which they can be improved in contrast or color, and sharpness.
- At the end of the process, the definitive diagnosis is determined by the specialist physician, who evaluates the images and relates the personal history and data from the clinical history of each patient*.*
- All the results, notes, treatment and controls must be stored in the database, separated in personalized files for each patient (72)

4.2.2 Transmission of images in telemedicine.

To carry out the transmission of images in a telemedicine service, an information storage space is required, a recording and image capture equipment and communication systems such as computers, telephones, cell phones, etc., which must be capable of capturing, digitizing, and transmitting the information.

In the ophthalmology area, high quality digital images are required, so their transmission is slower and requires more storage space. The English National Screening Programme for diabetic retinopathy sets a minimum specification for cameras in patients known to have specific features of diabetic retinopathy. The camera must be capable of providing a minimum field of view of 45 horizontally and 40 vertically at the specified resolution (at least 30 pixels/degree). In addition, the "field of view" of the fundus camera must be capable of capturing images as defined in the protocol used in the Early Treatment Diabetic Retinopathy Study(73) (56).

4.2.3 Challenges in taking fundus images using telemedicine

The final result of the data collection depends on several factors; therefore, it is important and recommended to have protocols to reduce the risk of bias.

Clinical Factors:

- Miotic pupil
- Little collaboration on the part of the patient.
- Artifacts, spots, and halos that produce unusual images.
- Brief discomfort and alteration of vision caused by the flash, resulting in patient discomfort.

- Presence of some opacity in the cornea, such as scars, or opacities in the lens (64).

Technical Factors

- Personnel in charge of taking the photograph and handling the equipment. Hence the importance of being operated by qualified and trained health personnel for this purpose.
- Price of fundus cameras, they can have high prices, so obtaining the equipment is not always possible/feasible (64).

5 Coverage of eye care professionals in Colombia

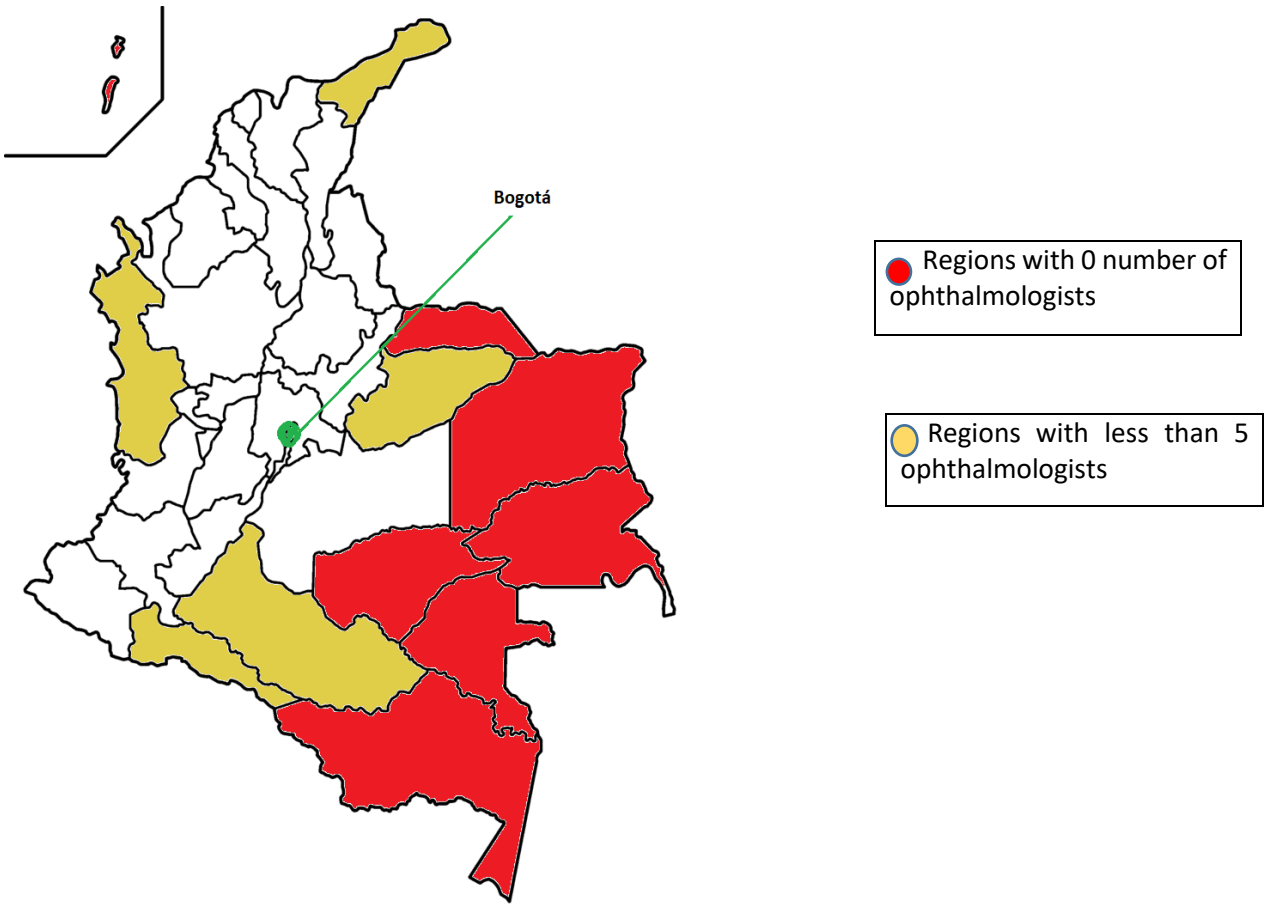
With the projected increase in diabetic patients, and the increase in visual impairment due to aging and lifestyle changes, there are numerous challenges to eye health, so it is important to consider the number of eye care professionals per number of patients.

5.1 Statistics

In Colombia, most of the images are read and analyzed by ophthalmologists. In 2013, a report was conducted in Bogota which determined that from 1982 to 2011, the number of doctors graduated in Ophthalmology was 868, for a total of 1,627 Ophthalmologists in the country (61).

Also, the Ministry of Health together with the Colombian Society of Ophthalmology and based on the population of Colombia, indicated that the number of ophthalmology specialists per total inhabitants for 2011, was 2 per 100,000 inhabitants (903 ophthalmologist /46,044,606 Colombian population). In addition, they concluded that the highest concentration of ophthalmology specialist physicians was in the departments: Santander, Casanare, Valle del Cauca, Antioquia, and Boyacá. In contrast, the departments of San Andrés, Arauca, Amazonas, Guainía, Guaviare, Vaupés, and Vichada, which are the most isolated regions of Colombia, lacked ophthalmologists in the report. (61).

Figure 11 Regions in Colombia with less than five ophthalmologists.



Source: Own elaboration based on (61) in collaboration with the Colombian Society of Ophthalmology.

In 2015, 1,370 ophthalmologists were registered. Of the total number of physicians, Bogota accounted for 38.4% (527 professionals), Antioquia with 17.3% (238 professionals), Atlantic Coast 18.0% (247 professionals), Eje Cafetero 4.6% (64 professionals), Santander 8.1% (112 professionals), South with 1.2% (17 professionals) and Valle del Cauca with 12.0% (165 professionals) (61).

Optometrists are also involved in image reading, although to a lesser degree. According to the Special Registry of Health Service Providers (SRHP), 1,836 optometrists are registered (with an estimate of 0.76 specialists per 10,000 inhabitants), of which 1,400 are women and 436 are men. Of the total number of optometrists, 12.69% practice independently and 36.47% rendering of services. Of these, 29.68% work in a private "Health Care Institutions" (HCI) and 22% in a public HCI. In addition, 20.88% of optometrists are not registered in the SRHP, so there is a significant underreporting of the actual number of optometrists in the country (61).

The Colombian Federation of Optometrists (FEDOPTO) reported that only 514 optometrists are federated. Most of them are in the city of Medellin with 11.6%, Bucaramanga with 8.7%, followed by Cali with 8.7%, Ibague with 7.0% and Cucuta with 5.0%.

5.2 Universities with professional Ophthalmic programs

5.2.1 Optometry

The education and practice of optometry has developed differently and at different rates around the world. In Colombia, the Optometrist is the one who has the first contact with the patient in primary care, playing an important role in the diagnosis of ocular pathologies.

In the country, there was only one faculty of Optometry for more than 28 years, but since 1996 the educational offer grew due to changes in legislation. Today there are 7 Optometry Faculties at a national level with 5 years of university training.

Table 6 Colombian Universities that offer Optometry Programs.

UNIVERSITY	CITY
La Salle	Bogotá
El bosque	Bogotá
Antonio Nariño	Bogotá y Medellín
Metropolitana	Barranquilla
Santo Tomás	Bucaramanga
Fundación Universitaria del Área Andina	Bogotá y Pereira
Del Sinú	Cartagena

Source: Own elaboration base on (61).

5.2.2 Ophthalmology

The ophthalmology program in Colombia has a duration of 6 semesters. This is an area that works at an interdisciplinary level within medicine since many human diseases have collateral effects on visual health.

Table 7: Colombian Universities that offer programs in Ophthalmology.

UNIVERSITY	CITY
Pontificia Universidad Javeriana	Bogotá y Cali
Universidad Pontificia Bolivariana	Medellín
Universidad Del Norte	Barranquilla
Universidad De La Sabana	Chía-Cundinamarca
Universidad Nacional de Colombia	Bogotá
Universidad El Bosque	Bogotá
Universidad CES	Medellín
Universidad del Rosario	Bogotá
Universidad Militar Nueva Granada	Bogotá
Universidad Simon Bolivar	Barranquilla
Fundación Universitaria Sanitas	Bogotá

Source: Own elaboration base on google information.

Analyzing the data presented by the Ministry of Health, the lack of eye care professionals, whether ophthalmologists or optometrists, is insufficient to cover the care of 50 million Colombians. There is also an unequal distribution of them in the national territory. Most professionals are concentrated in the cities with the largest populations and close to the country's capital, since the opportunities for professional growth or work are found in these areas, leaving the remote areas without health care coverage.

6 Results

6.1 Selected Studies

After the results of the electronic and manual search, 23 articles were selected from the 221 found, giving priority to studies carried out in Latin America, and after applying the inclusion criteria, 198 articles were rejected because they did not meet the required criteria.

To facilitate the analysis and review of the articles, they were divided by region and ordered by date from the oldest to the most recent.

Table 8: Studies performed in Latin American countries

ARTICLE	COUNTRY	AUTHOR	YEAR	TYPE OF STUDY	MAIN CONCLUSIONS
Prevalence of diabetic retinopathy in Peruvian patients with type 2 diabetes: results of a hospital-based retinal telescreening program	Peru	Jaime E. Villena et al.	2011	Prospective observational and intervention study.	- The prevalence of DR in these patients with type 2 diabetes was 23.1%. - A national screening DR program should be considered in order to detect this prevalent condition early and treat it in a timely fashion.
Detection of diabetic retinopathy by non-mydriatic digital retinography	Guatemala	Jose Luis Dominguez Paez.	2016	Cross-sectional descriptive study	In Guatemala, considering that it has one of the lowest diabetes investments in the region, it is necessary to have cost-effective programs for the control of diabetes and diabetic retinopathy. For this reason, telemedicine has been proven to be an ideal method to make services and specialized physicians available in areas and regions where it would not otherwise be possible to provide such service.
Program For Detection of Patients with Diabetic Retinopathy Through A Screening Program In Telemedicine	Mexico	Dra.Renata Garcia et al.	2018	Cross-sectional study.	With this type of screening program, cases that are susceptible to appropriate management can be detected early in order to prevent progression and reduce visual loss secondary to the complications of late stages of the disease.
Non-Mydriatic Fundus Retinography in Screening for Diabetic Retinopathy: Agreement Between Family Physicians, General Ophthalmologists, and a Retinal Specialist.	Brazil	Leonardo Provetti Cunha et al.	2018	Cross-sectional study.	It is recommended non-mydriatic fundus retinography as a complementary work-up for diabetic patients, helping in the diagnosis of DR and the setting of priorities for ophthalmic evaluations, making access to ophthalmologic care easier for severe patients and avoiding unnecessary testing of patients without DR

Model of network and telemedicine management of diabetic retinopathy in two municipalities of the Eastern Metropolitan Health Service.	Chile	Ricardo Flores et al.	2019	Retrospective descriptive study.	This model allowed a reduction of referrals to ophthalmologists, reducing the burden of secondary and tertiary health care systems.
P28 Implementation of non-mydriatic retinal photography and telemedicine strategy as tools for screening for diabetic retinopathy	Argentina	Andrea Lorena Morejón Barragán et al.	2020	Cross-sectional study.	This type of strategy in the management of patients with diabetes, would optimize detection coverage, evaluation times, timely referral to specialized consultation, geographical transfers, and healthcare resources.
Prevalence of diabetic retinopathy on a rural area of Argentina	Argentina	Tomás Ortiz-Basso et al.	2022	Observational cross-sectional study	The prevalence of DR in a rural region of Argentina is similar to that reported in other parts of the world. It is essential to implement and sustain tele-ophthalmology programs that work in an interdisciplinary manner to combat blindness due to diabetes.

Table 9 Studies performed in the rest of the world.

ARTICLE	COUNTRY	AUTHOR	YEAR	TYPE OF STUDY	MAIN CONCLUSIONS
Prevalence of diabetic retinopathy using non-mydriatic retinography	Spain	A. Gibelalde et al.	2010	Prospective and observational study	Use of non-mydriatic retinopathy in telemedicine plays an important role in the early diagnosis of diabetic retinopathy and it can be applied to other ophthalmic diseases.
Screening For diabetic retinopathy with a mobile non- mydriatic digital Fundus camera in southern Israel	Israel	Jaime Levy MD et al.	2011	Cross-sectional study.	Diabetic retinopathy screening with a mobile non-mydriatic fundus camera improved the quality of care for diabetic patients in southern Israel. This screening method identified patients requiring prompt referral to the ophthalmologist for further complete eye examination.
Diabetic retinopathy screening and teleophthalmology.	Spain	M. Martínez Rubio et al.	2012	Cross-sectional descriptive study.	We highlight the benefits of the tele-ophthalmology in screening diabetic patients to enable early diagnosis and treatment and improving the circuit of communication between primary and specialist care.
Implementation of screening for diabetic retinopathy using digital	Spain	Lidia Clara Rodríguez García et al.	2012	Prospective longitudinal	The implementing of DR screening is possible if an NMRC is available, along with

retinography in primary care.				descriptive study.	available resources, the motivation of the professionals involved and management commitment. A longer follow-up is required to determine its impact on referral rates to ophthalmology service, and to only refer those with dubious images
Ophdiat®: Five-year experience of a telemedical screening programme for diabetic retinopathy in Paris and the surrounding area	France	C.Schulze-Döbold et al.	2012	Cross-sectional study	Telemedicine is a screening method that is well adapted for diabetic patients. In view of the increasing number of such patients and the decreasing number of ophthalmologists, expansion of the Ophdiat® screening network is desirable.
Telemedicine and Retinal Imaging for Improving Diabetic Retinopathy Evaluation	USA	Seema Garg et al.	2012	Cross-sectional study	Telemedicine screening at the point of care of the primary care physician represents a potential paradigm shift in the management of DM, can improve screening, and may ultimately prevent vision-threatening DR
Diabetes Eye Screening in Urban Settings Serving Minority Populations Detection of Diabetic Retinopathy and Other Ocular Findings Using Telemedicine	USA	Cynthia Owsley et al.	2015	Cross-sectional study.	In a DR telemedicine screening program in urban clinic/pharmacy settings in the US serving predominantly minority populations, 1 in 5 persons with diabetes screened positive for DR. The vast majority of DR was background indicating high public health potential for intervention in DR's earliest phases when treatment can prevent vision loss.
The Nonmydriatic Fundus Camera in Diabetic Retinopathy Screening: A Cost-Effective Study with Evaluation for Future Large-Scale Application	Italy	Giuseppe Scarpa et al.	2016	Cross-sectional study.	Fundus images obtained with a nonmydriatic fundus camera could be considered an effective, cost-sparing, and feasible screening tool for the early detection of DR, preventing blindness as a result of diabetes.
Diabetic Retinopathy Screening Using Telemedicine Tools: Pilot Study in Hungary	Hungary	Dóra J. Eszes et al.	2016	Observational, Transversal study	Participants found digital retinal screening to be reliable and satisfactory. Telemedicine can be a strong tool, supporting eye care professionals and allowing for faster and more comfortable DR screening.

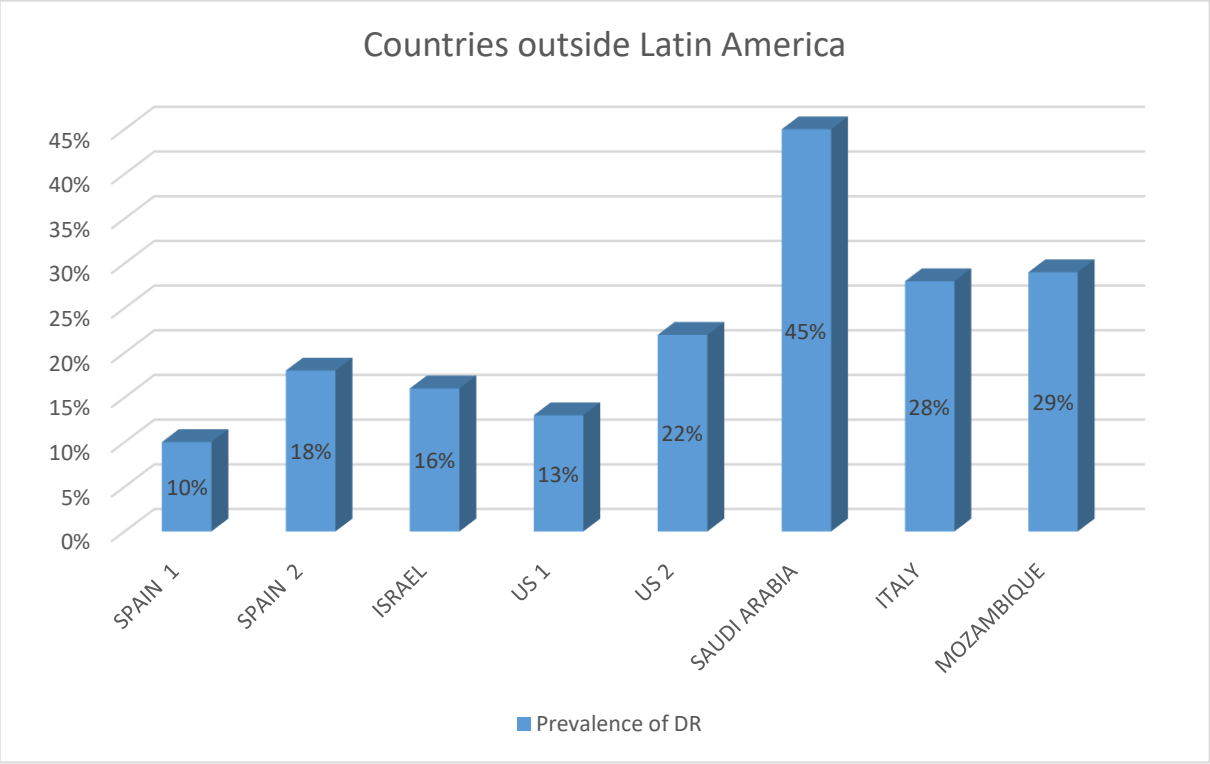
A decade-long telemedicine screening program for diabetic retinopathy in the north-east of Italy	Italy	Stela Vujosevic et al.	2017	Observational, longitudinal, cohort study	data from the present study are the most recent epidemiology data on DR in Europe and confirm the high value of telemedicine screening approach. Moreover, data from the present report show that screening for DR can be safely repeated in a two and a half year period in low risk patients with DM and no DR at first examination. However, in case of risk factors, a stricter follow-up is warranted.
Tele-ophthalmology for diabetic retinopathy screening: 8 years of experience.	Spain	A.Pareja-Ríos et al.	2017	Retrospectively study.	Diabetic eye disease screening by tele-ophthalmology has shown to be a valuable method in a growing population of diabetics. It leads to a regular medical examination of patients, helps ease the workload of specialised care services and favours the early detection of treatable cases.
Non-mydriatic fundus camera screening with diagnosis by telemedicine for diabetic retinopathy patients with type 1 and type 2 diabetes: a hospital-based cross-sectional study	Saudi Arabia	Maram Yaslam et al.	2019	Cross-sectional study.	Non-mydriatic funduscopic screening photography was practical and useful for the detection of DR in patients with type 1 and type 2 diabetes.
Diabetes mellitus in the Tamil Nadu State—Noncommunicable diseases nurse model in diabetic retinopathy screening	India	Rengappa Ramakrishnan et al.	2020	Cross-sectional study	This method of screening, diagnosis, and management of DR is a novel using the telemedicine platform. Through this, nearly 70% of the patients with DM were screened for DR from rural areas where there are no ophthalmologists and facilities to screen DR. Teamwork is necessary for the effective, efficient functioning of this project
The Efficiency of First Telemedicine Application of Fundus Photograph for the Diagnosis of Diabetic Retinopathy in Turkey	Turkey	Meltem Sertbas et al.	2021	Retrospectively study.	The study confirmed that the use of the retinal photographing intertwined with the telemedicine system should be used more widely into provide regular screening of diabetic retinopathy
A 15-month experience with a primary care-based telemedicine screening	USA	James E. Benjamin et al.	2021	Retrospectively study.	A successful telemedicine screening program must close the communication gap

program for diabetic retinopathy					between screening and diagnosis by reviewer to provide timely follow-up by eye care specialists.
Effectiveness of remote screening for diabetic retinopathy among patients referred to Mozambican Diabetes Association (AMODIA): a retrospective observational study	Mozambican	Mauro Rigato et al.	2022	Observational retrospective study.	Prevalence of DR among urbanized Mozambican patients was similar to that observed in Western countries. Telediagnosis might partially overcome the paucity of local ophthalmologists with experience in DR.

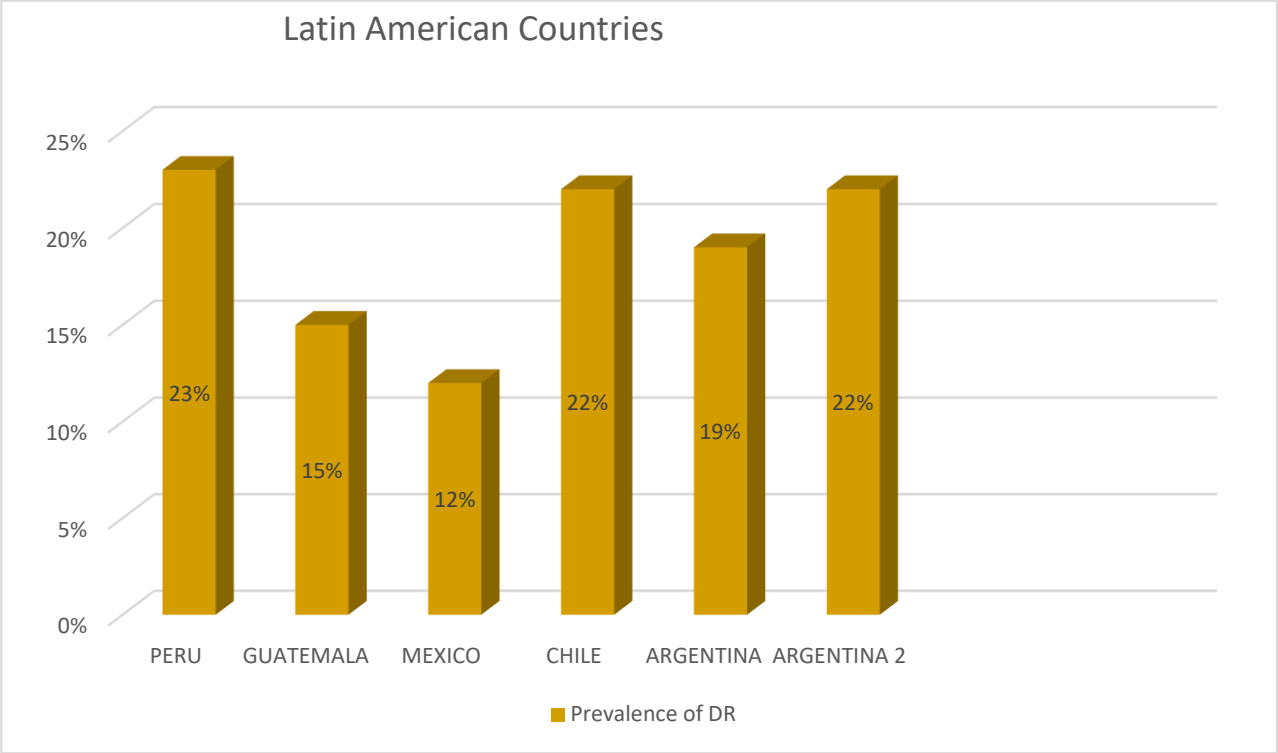
Then, the different articles were then regrouped in different ways according to their purposes: Prevalence and diagnosis of DR making use of telemedicine (15 articles), experiences making use of CRNM and telemedicine in DR screening (6 articles), concordance between physicians making use of CRNM in DR screening (1 article), degree of satisfaction by patients to the use of CRNM (1 article).

Prevalence and diagnosis of DR making use of telemedicine

Figure 12: Comparison of prevalence of DR in Latin American countries and the rest of the world.



Source: Own elaboration base on (74) (75) (68) (76) (77) (78) (79) (80) (81) (82) (83) (84) (85) (86) (87).



Source: Own elaboration base on (74) (75) (68) (76) (77) (78) (79) (80) (81) (82) (83) (84) (85) (86) (87).

Experiences using NMRC and telemedicine in DR screening

Table 10: Percentage of photos taken with good quality and attendance to controls.

COUNTRY	PERCENTAGE OF GOOD QUALITY PHOTOS TAKEN.	ATTENDANCE AT CONTROLS
ESPANA	93%	No data.
ITALIA	80%	95%
FRANCIA	90,06%	51,86 %
INDIA	68%	77%
USA	67,4%	55%
TURQUIA	No data.	96%-49,5%

Source: Own elaboration base on (88) (89) (90) (91) (92) (93).

The quality of the photos taken in the different studies showed that their validity averaged between 67% and 93%, depending on the country. The average patient attendance to control or consultation was between 49.5% and 96%. These studies confirm that fundus images obtained with a non-mydriatic fundus camera would aid in the early detection of DR, preventing blindness as a consequence of diabetes (88) (89) (90) (91) (92) (93).

Agreement Between Physicians using NMRC in DR screening

The results shown by Leonardo Provetti Cunha et al. in their 2018 study showed that general practitioners performed better than expected, considering the short training time. The agreement between retinologists and general practitioners was almost as good as that between retinologists and ophthalmologists (moderate to substantial in both diagnosis and disease severity). Also, evaluation of fundus images by trained general practitioners was effective, with results comparable to those of ophthalmologists (94).

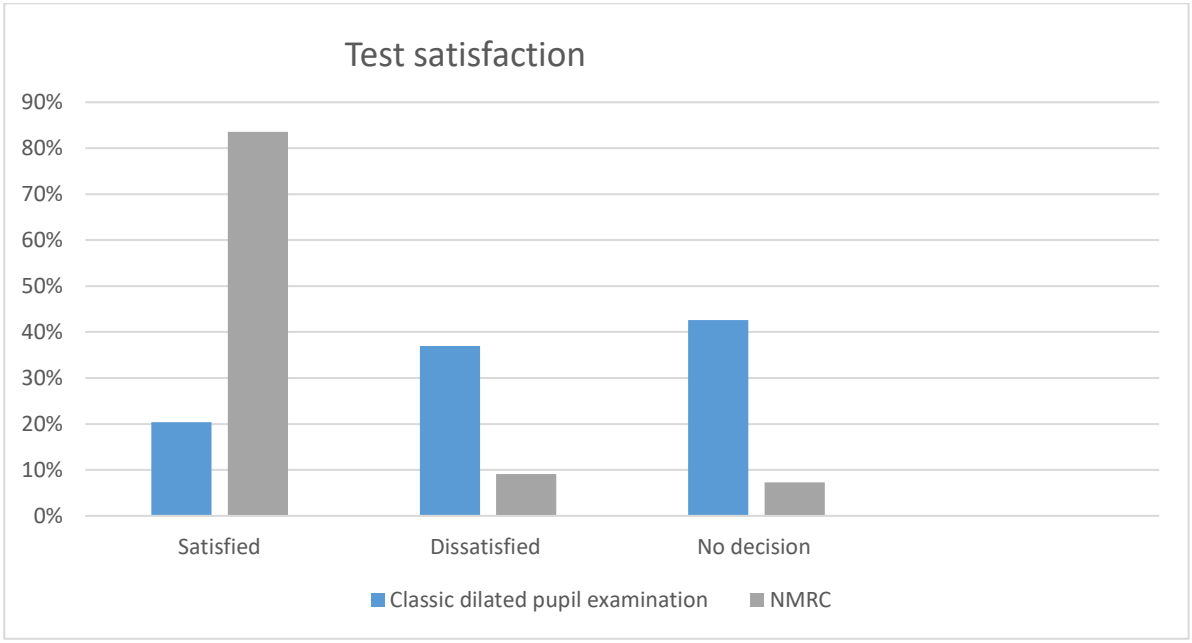
Degree of patient satisfaction with the use of NMRC

A pilot study, which reflected the experience of the participants during fundus examination with a traditional examination vs. telemedicine modality. Patient satisfaction with the classic dilated examination was 20.4%, 37% were dissatisfied and 42.6% could not decide. On the contrary, with the use of NMRC, 83.6% of the participants expressed satisfaction, 9.1% were dissatisfied and 7.3% were unable to decide.

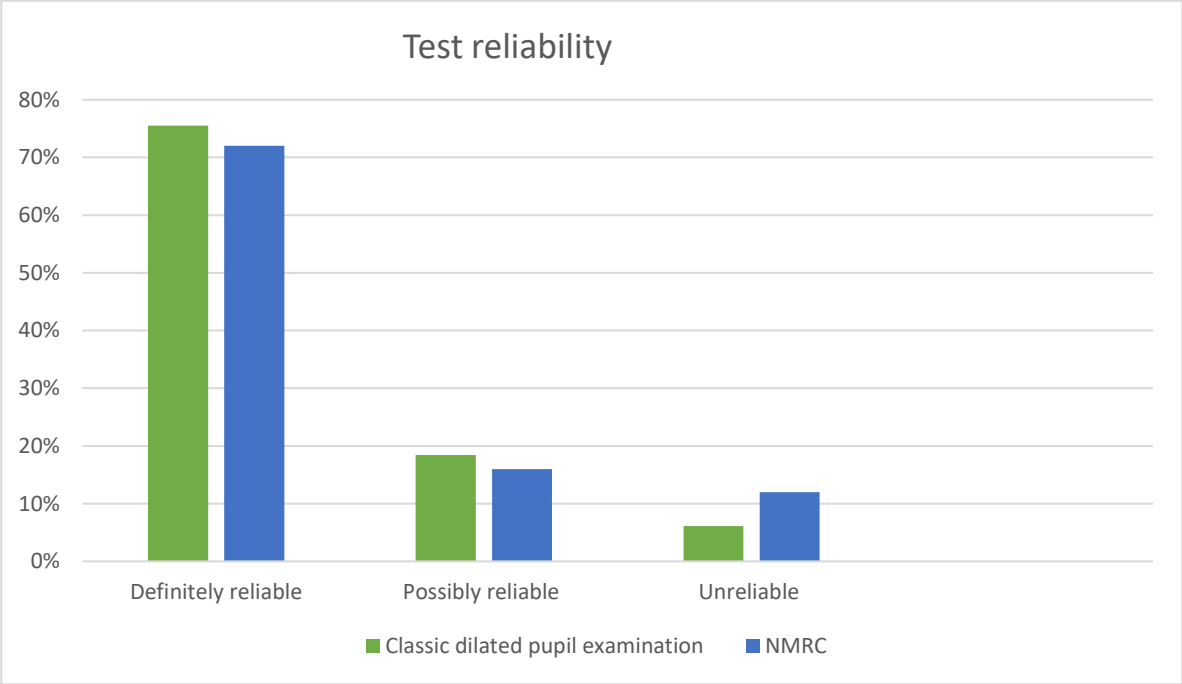
Regarding the reliability of the test, the classical pupil dilation test showed 75.5% to be definitely reliable, possibly reliable 18.4% and unreliable for 6.1%. With the use of NMRC, definitely reliable 72.0%, possibly reliable 16.0%, and unreliable for 12.0%.

The large majority of patients were satisfied with the scan and considered the consultation reliable under a telemedicine model. 67.3% were willing to undergo a non-mydriatic fundus camera examination again (95).

Figure 13: Comparison between satisfaction and reliability in Hungary.



Source: Own elaboration base on (95).



Source: Own elaboration base on (95).

7 Discussion

This research work shows the results obtained from different studies related to the use of non-mydriatic retinal camera, supported by telemedicine for the diagnosis of DR in Latin American countries and others outside the region. It was shown that the non-mydriatic retinal camera is an important and useful support for the diagnosis of diabetic retinopathy, since, with the help of these programs, it was possible to control and treat up to 50% of patients with PDR, in addition to increasing the annual rate of fundus checks performed in people with diabetes (between 20% to 96%, depending on the study), thus reducing the prevalence of risk of blindness, and providing the opportunity to care for people who have difficulty attending the doctor.

On the other hand, it was also observed that these studies had in common four key processes with respect to patient care: Taking the photograph (with NMRC), transmission of the image, reading and assessment, and report with possible referrals according to severity of the pathology. At the same time, important advances were reflected in the development and implementation of this screening method. In Latin America, many of these studies are an important basis for pilot testing, and a potential model of care for the government and health care providers.

Prevalence and diagnosis of DR making use of telemedicine

Variability was observed in relation to the estimated prevalence of DR in the different published studies. This is possibly due to the different methodologies used, which include: type of disease classification, treatments, age groups, and degree of training of the professional who took the photographs.

Spain is one of the countries that has been implementing Telemedicine in its different communities since DR is one of the most important causes of blindness in this country. Gibelalde et al. carried out a study on the prevalence of DR by screening with a non-mydriatic retinography, which showed that 10% of the sample taken for the study had some degree of DR (74). This prevalence is low when compared with other studies carried out in state areas, as was the case in the municipality of Alicante, where the prevalence found was 18% (75). Even so, the prevalence in both studies is still lower considering other studies where DR ranges between 17.2% and 30%. Although the prevalence was lower in the studies found, these studies emphasize that the use of telemedicine with a non-mydriatic retinal camera is an important tool for the early diagnosis not only of DR, but also for other ocular pathologies.

Analyzing the results found in Israel and the USA, similar prevalence were found (16-13% prevalence of DR respectively), this is possibly due to the high degree of development in these countries, and the high social investment (public health, prevention and infrastructure) (76) (77).

In Italy, no national data were found on the prevalence and incidence of legal blindness due to DR, and there is no national registry of patients with DM, however, several studies documented the prevalence and incidence of DR from studies conducted in geographically limited populations, as is the case of Vujosevic et al. who conducted a very comprehensive study in the metropolitan area of Padua (northeastern Italy) of telemedicine screening for diabetic retinopathy (DR), finding that the country has a significant prevalence of 28% (80) .

These data are consistent with other studies conducted in the country, where prevalence was found to be 26.2%. But significantly higher and alarming prevalence were also found in other regions, ranging from 34% to 59% (96). Hence the importance of early diagnosis of the disease. Implementing programs for DR screening by means of retinal cameras in primary care will facilitate the appropriate follow-up, treatment, and controls for the disease, benefiting patients and governments, with the optimization of resources, and at the same time giving patients affected by this disease the opportunity for a better quality of life.

In 2019 in Saudi Arabia; Yaslam et al, showed a significantly high prevalence of DR 45%, compared to other studies conducted in the same country (Hajar et al. found a prevalence of 27.8% (97)). This is because the sample selected was from a diabetic center, with the most complicated cases, and the patients used had a longer duration of the disease. These screening programs proved to be useful, effective and timely, as it was possible to detect that up to 30% of the cases had active disease, requiring urgent referral, either for laser or other therapeutic options, thereby reduce the risk of blindness (79).

Mozambique is one of the poorest countries on the planet. However, they managed to do a study where they released the results of a remote DR screening. In this study, retinal images were first evaluated by a local ophthalmologist and finally graded by an experienced reader in Italy. The overall prevalence of DR graded by the Italian ophthalmologist was 29%, significantly higher than the 12% recorded locally (81). These results show that, African countries face a chronic lack of equipment, trained health personnel and ophthalmologists. Therefore, identifying appropriate and cost-effective strategies such as teleophthalmology could represent an opportunity to improve DR screening in countries with limited resources and specialists.

In Latin America, there is currently a great disparity between the levels of progress in telehealth and telemedicine, when comparisons are made between the different Ibero-American countries, with Brazil, Argentina, Colombia, Chile, and Mexico being the ones that have achieved the most important advances in medical informatics, both at the private and state level (98). Therefore, making comparisons between the countries of the region is a challenge, due to the lack of clinical and scientific evidence.

Latin American data estimate that the prevalence of DR fluctuates between 20% to 40% of diabetic patients and that, of these, 5% are at high risk of blindness. The prevalence found in the different studies carried out in the area shows a similar trend, except for Mexico, where the study reported a prevalence of only 12% (84), these results differ from other studies conducted in this country, where a prevalence of up to 31.5% is estimated (99).

Adrianzén et al. wanted to know the frequency and severity of diabetic retinopathy in a specific population in Peru. For this study, they used non-mydriatic retinal cameras, with subsequent pupil dilation in all patients, and of all patients with DM, 25.9% showed DR (100). These results are similar to those found by Villena et al. but with the difference that in this study no drugs were used to induce mydriasis (physiologically dilated pupil only), the prevalence found was 23.1% (82). The second study presents advantages in terms of reduced time to be attended, in addition to the non-use of drugs, and timely referral to the ophthalmologist in case any significant sign was found. Also, it is emphasized that the presence of an ophthalmologist was not necessary (taking into account the shortage of specialized personnel) to explore the fundus, since a qualified technician was able to perform this work.

In Guatemala, prevalence rates of 15.3% were found. Of the total number of patients seen, 71.8% had not had an ophthalmologic evaluation in the year prior to this study (seven out of ten patients had not been evaluated by an ophthalmologist) (83). It can be seen that the majority of the diabetic population does not have adequate ophthalmologic coverage; not even those with a history of this disease.

Another study conducted by Lopez, in the same country, showed a higher prevalence of DR 51%, and also revealed that 51% of the diabetic population that went to the hospital had not been previously checked by an ophthalmologist (101). These results show the current limitations for the diagnosis of ocular pathologies in the population suffering from diabetes, the infrequency offered for the attendance to controls added to the deficit in number of professionals in visual health, makes it reasonable to think that the application of new study methods such as screening with telemedicine for DR would be very useful.

Chile and Argentina have several projects under the telemedicine care model. Argentina conducted a study with the objective of evaluating the annual rate of fundus examinations performed in people with diabetes before and after the implementation of a tele-ophthalmology program, showing that the implementation of the program in rural areas increased from 39.3% to 78.6%, being 22.9% higher than the examinations performed in urban areas. This program showed significant progress in the provision of services since it improved annual fundus checks in diabetic patients (102).

Regarding the prevalence of DR in this country, Basso et al, found a prevalence of 21.5% in their study (87), Morejon et al. found 18.7% (86). These results are similar to those found in other studies in the region, as it was, the "Diabetes Blindness Prevention Campaign" in 2018, which identified a prevalence of 23.4%, where it is still a lower prevalence than the one given by the DR Clinical Guide for Latin America, who mentions that in Argentina the prevalence can reach up to 30%, depending on the region (57). Therefore, these studies emphasize the value of implementing programs in tele-ophthalmology that work to prevent blindness caused by diabetes, in addition to the early and sustained implementation for as long as possible, so that the changes are really significant.

Due to the increasing prevalence of DM, and consequently of DR, Chile developed and validated an automated diagnostic software for telematic retinography acquisition (DART); which, is being used successfully since 2017. The prevalence found was 22% (85), higher data than those presented by Núñez et al., where values of 9,5% were found (103). These studies emphasized the importance of implementing this type of telemedicine programs, which allow the efficient optimization of specialized ophthalmologic resources for the treatment of DR.

Analyzing the global data presented in the articles chosen in this degree work, it was observed that, between developed vs. developing countries, the prevalence of DR was higher in developing countries, this is due to the fact that these countries experience a greater threat of collapse to health and social systems, and to some factors such as: A poorly prepared health system, lower health spending, shortage in health professionals, and very poor disease surveillance and monitoring systems (104).

It was also observed that, despite the high prevalence of diabetic patients in these developing countries, the coverage offered by health entities for retinal controls is insufficient. The worrying aspect of the situation is that, even knowing the consequences of this situation, such as severe visual loss, blindness, higher treatment costs, in addition to the social impact on this working population, programs have not yet been implemented to try to prevent this situation, therefore, it is of great importance to ensure patients timely referral for intervention and effective results.

Experiences using NMRC and telemedicine in DR screening

In this category it was intended to observe the effectiveness in the use of NMRC with the help of telemedicine, measuring the number of gradable photos that were sent to ophthalmologists located in hospitals or large cities.

Countries such as Spain, Italy, France, and Turkey had a very good level of evidence in terms of the number of gradable images and the time required for their transmission. The percentages found showed a sensitivity and specificity between 80% and 96% depending on the country (88) (89) (90) (93). According to The British Diabetic Association, a sensitivity of at least 80% and a minimum specificity of 95% is recommended for a good screening technique (105), therefore, it can be inferred that, with the use of telemedicine, results similar to traditional techniques are achieved, with a fairly good level of evidence, and the efficacy of this tool to diagnose eye diseases such as DR is confirmed.

However, the opposite occurred in the USA and India, where the results were below 70%. In the case of the USA, it was concluded that the main problem was the low training of the personnel in the handling of the fundus

camera, in addition, there was a deficit in identifying the photos that had good quality. In the case of India, the main reasons for non-graduable images were poor focusing of ocular structures, very small pupils, cataracts, among other factors (91) (92). These data show an important reflection, in which, for a telemedicine screening program to be successful, it is not only enough to identify the pathology, patient education, and treatment; there must be a correlation between all the factors involved for its proper development. Therefore, it is vital to have trained personnel to take good quality fundus photographs in order to avoid unnecessary referrals.

Another important point to mention is the controls that the patient must attend in order to follow up the disease. In France and the USA, it was found that not all patients attended a second check-up, however, as the years went by, with these studies, it was observed that the number of scheduled check-ups was increasing (92) (88). Because of this, a campaign led by the national health authorities is needed to encourage patients to attend screening centers.

Sertbas et.al in their study conducted in Turkey, wanted to compare the situation in follow-up consultation attendance in two different diabetes centers. One was managed under a telemedicine program and the other under traditional ophthalmology consultation. The results were evident, it was shown that, (96%) almost all patients who were referred to be examined by digital photography through telemedicine were evaluated by the ophthalmologist, while under the traditional method, only half of the patients had attended consultation with the ophthalmologist (49.5%) (93). India reported that thanks to the use of telemedicine platforms for DR diagnosis and management, 77% of patients at high risk of blindness attended consultations at the base hospitals for follow-up and treatment (91). Hence the importance of implementing this type of program in rural areas, and of using this screening method more widely.

Agreement Between Physicians using NMRC in DR screening

In Brazil, the aim was to determine the degree of agreement between general practitioners and specialists (ophthalmologists and retinologists) to diagnose DR with CRNM in a telemedicine program. The results were higher than expected, with good levels of concordance between the professionals, and adequate levels of sensitivity and specificity regarding the diagnosis and classification of the disease. Therefore, it can be deduced that non-mydriatic fundus retinography is a useful and reliable method for the detection of DR in patients with socioeconomic problems and living in rural populations. On the other hand, the importance of involving general practitioners in primary care (or appropriately qualified personnel) to perform fundus retinography is emphasized, as it is believed that this would significantly reduce the incidence of DR-related blindness (94)

In the USA, Andonegui et al, conducted a study similar to the previous one, where they wanted to evaluate the rate of DR diagnosis in patients who were considered to have a positive screening test by general practitioners. They concluded that, with proper training, general practitioners can screen patients for DR with a high level of accuracy using non-mydriatic retinography, at the same time, it will be able to help ophthalmologists decongest their schedules due to the filtration of photographs with pathologies vs. those considered normal (106).

Degree of patient satisfaction with the use of NMRC

The degree of patient satisfaction with the telemedicine consultation model found in this study showed that it was a very well accepted and satisfactory method. For patients, the fact of not using mydriatics, which caused discomfort and exposure to their side effects, meant that it was considered a reliable, easy and accurate examination compared to the traditional consultation (95). These results are an indication that telemedicine programs have been well received by both patients and physicians. Other similar studies, such as the one conducted by Garcia et al. in 2009, also confirmed that the retinography service is well valued by patients since it reduces travel, time and costs (107).

Although telemedicine cannot replace all face-to-face medical care services, there are many benefits of this tool, which is here to stay for good. With interesting promises of greater supply in terms of quantity and quality of healthcare services, but like any new procedure, it generates a series of ethical dilemmas, which depend on the judgments and values prevailing in the discussions of each society and the healthcare models chosen by the governments.

8 Conclusions

- According to the results obtained from the different studies used for this work, it was possible to conclude that telemedicine is a viable tool for the diagnosis of DR in primary care. This model makes it possible to improve health access and coverage in remote places or regions where the population does not have access to health care or where there is a shortage of professionals.
  Now, taking into account the similar and uniform progress that countries such as Peru, Mexico, Brazil, Ecuador, and Colombia have made in recent years in terms of expanding connectivity, infrastructure, new policies, and technological developments for the creation of new telemedicine projects, it could be beneficial to finally implement projects in the area of teleoptometry and teleophthalmology in a few years. Therefore, a proposal to carry out projects in Colombia, focused on developing a business model based on telemedicine with the support of the NMRC for DR screening, could prevent and reduce the prevalence of blindness caused by diabetes, as has been achieved in other Latin American countries.

- One of the most important limitations of this work was the lack of studies and/or evidence about the use of telemedicine for the diagnosis of DR in most Latin American countries, including Colombia, so reference studies from different countries around the world were taken into account, such as Spain, the United States, Saudi Arabia, Peru, Mozambique, among others, in which very varied situations and environments were reflected in the implementation of telemedicine projects, which suggests that at least one of these studies, or a mixture of them, could serve as a basis to be developed or applied to the conditions of Colombia.

- The potential success, reliability and opportunities offered by this type of program were also observed, but the difficulties and/or limitations that may arise, such as lack of infrastructure, lack of current health policies, among others, were also identified. Nevertheless, these studies revealed that telemedicine is a promising tool because of its usefulness and cost-effectiveness in the healthcare field. Furthermore, the different authors advise that future studies (with continuous follow-ups) should be carried out to determine the projected amount of vision that could be saved if a telemedicine program were implemented.

- It was noted that one of the greatest health challenges for Colombia is to ensure the coverage and provision of medical services for the entire population. The country does not currently have an integrated network or a support platform that can provide health services to all the most remote municipalities or towns in the country, so it has not been possible to carry out studies in all areas of telemedicine. However, the progress achieved so far makes it easier for any incursion in the area of visual health to be positive and to be taken into account as a baseline study.

- The existence of constitutional norms and laws that support the use and implementation of telemedicine in Colombia was confirmed. This provides the opportunity to initiate projects in more areas of health, including teleophthalmology and teleoptometry.

- This type of service, such as telemedicine, offers a great opportunity to reinforce the development of prevention programs in the diabetic population, with the objective of reducing irreversible visual loss due to DR. This would be possible with comprehensive programs of nutrition, exercise, metabolic control, and the use of appropriate medications according to the degree of severity of the disease.

- Currently, no DR prevalence data is available for Colombia. This 2021, research ca be taken as a reference, and analysis of the data to indicates that screening for DR by telemedicine can be used to project the number of people diagnosed with DR. According to this report, identified cases would increase between 11% and 25.1% between 2020 and 2024 (108).. Feasibility estimates show that that with the implementation of teleophthalmology programs, the risk of vision loss could be reduced by 10 to 15% and that these percentages could increase with time and with technical and human strengthening in this type of projects (108).

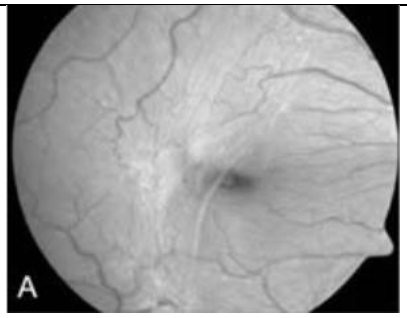
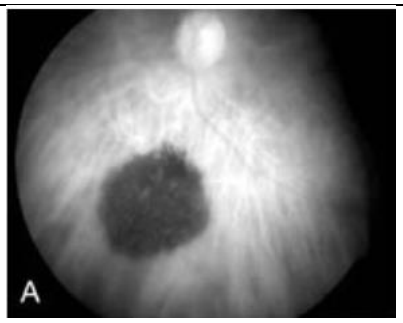
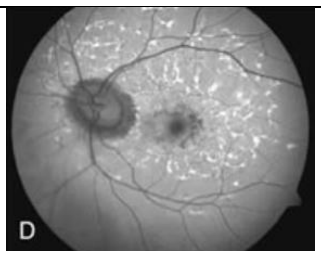
Appendix

Retinal Cameras: Types of filters and their uses

The use of filters independently of the retinal camera used, allows to know the location of possible retinal lesions, since each filter represents very different wavelengths. The most commonly used filters for monochromatic fundus photography are blue, green and, less frequently, red (109).

The following table describes the different types, their properties, and their clinical use.

Table 11: Filters: Types and properties.

FILTER	WAVELENGTH	PROPERTIES	IMAGES	APPLICATIONS
COBALT BLUE FILTER	Short wavelength (490nm, is the one that penetrates less into the retina)	This filter highlights the nerve fibers and the vitreoretinal interface.		Epiretinal membranes, and to assess optic nerve damage due to glaucoma or other optic nerve pathology.
ANERITRA GREEN FILTER	This is the medium wave filter (540 - 575 nm)	Distinguish areas where neovascularization, avascularization or vascular congestion can be seen in addition to the nerve fiber layer		Those whose signs affect the retinal vasculature, e.g. epiretinal membranes; aneurysms
RED FILTER	Wavelength 630-640 nm. (It is the least used filter because the images obtained are blurred and poorly contrasted)	It is responsible for highlighting choroidal details, especially pigmented lesions, tumors and choroidal vascularization.		Those affecting the choroid melanomas, nevus, choroidal inflammatory lesions.
AUTOFLUORES-CENCE (EXCITER FILTER + BARRIER FILTER):	Blue: 490 nm + barrier filter yellow-green: 525 nm.	Ocular tissues have the ability to emit light in the 520-530 nm range when using the excimer and barrier filter, in the absence of		It is very useful in the diagnosis of: o Papillary drusen (superficial and occult).

		fluorescein injection.		o Astrocytomas o Retinal dystrophies o Melanoma.

Source: : Own elaboration base on (109)

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Declaration

I declare that this thesis, which I submit to Aalen University for examination in consideration of the award of a higher degree M.Sc. Vision Science and Business (Optometry) is my own personal effort. Where any of the content presented is the result of input or data from a related collaborative research program this is duly acknowledged in the text such that it is possible to ascertain how much of the work is my own. I have not already obtained a degree at Aalen University or elsewhere on the basis of this work. Furthermore, I took reasonable care to ensure that the work is original, and, to the best of my knowledge, does not breach copyright law, and has not been taken from other sources except where such work has been cited and acknowledged within the text.

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Signed _____

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