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The Importance Of The Role Of Optics In The Presence Of Modern Technology In Health Facilities

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Abstract

Background: The role of modern technology is increasing on all the dimensions of present-day healthcare systems and the application and usage of optics is one of the major dimensions. Saudi Arabia is already considering the fild of optics in healthcare sector so as to meet the prevalence of Saudi Vision 2030. Optics in healthcare sector has become very important for timely diagnosis, treatment processes and even supervision of patients. In this present study the researcher had tried to touch all the related dimensions of usage, application, role, and significance of Optics in system of healthcare, that is governed by modern technologies.

Study Objectives: The main objective of the present research is to explore the current level of utilization of optical-techniques for diagnostic imaging, laser-based therapy, and fiber optic based medical communication systems, within the context of the healthcare setting in the country of Saudi Arabia.

Materials and Methods: Study is a narrative based review study and uses exploratory research design where the data is gathered from various sources on the basis of pre decieded criteria of inclusion and exclusion. PRISMA is used to segrigate and screen the collected studies. The results are presented in theoritical and chronological manner to give the clear picture of point in question.

Results: This review underscores the need for continued research, capacity building, and strategic planning to ensure that optical innovations benefit all segments of the population and contribute meaningfully to national health security.

Keywords: Optical technologies in healthcare, Biomedical optics in Saudi Arabia, Laser therapy in Saudi hospitals.

Background

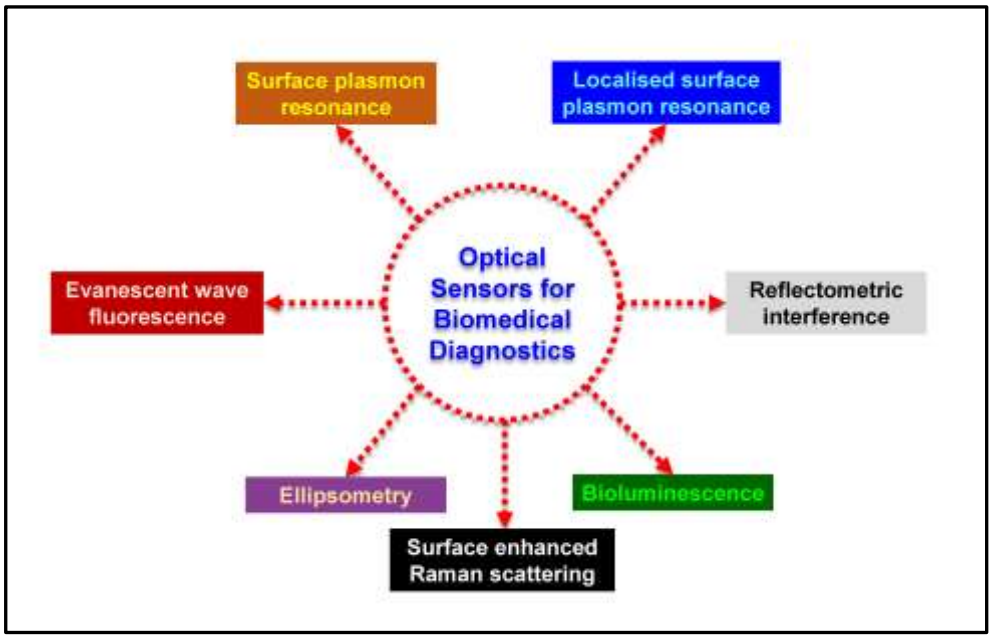
In the rapidly evolving domain of health, the application of technologies is fundamentally important for diagnosis, treatment, and quality of care. Of the many technological advancements occurring, with a number of these advancements coming from optical technologies, optics has become foundational for many of the health sciences innovations. [1] Optics is ubiquitous within health services, from high-resolution imaging systems to therapeutics requiring laser performance and fiber optical communications. In the context of Saudi Arabia, where health reform is underway as part of Vision 2030, implementing optical technology into health services is not only a technical imperative, but a national imperative.

Optics is broadly defined as the study of light and how light interacts with matter, and optics has many potential applications for medicine. Biomedical optics, in particular has made available a range of imaging modalities that have all been described as non-invasive imaging, including Optical Coherence Tomography (OCT), fluorescence microscopy and laser scanning confocal microscopy. [2], [3] These technologies will facilitate the early detection of diseases, real-time monitoring, and targeted interventions, primarily focused on preventing irreversible conditions in patients, especially within the areas of ophthalmology, oncology, dermatology, and cardiology. There are also therapeutic optics, including laser ablation, photodynamic therapy, and light-based wound healing, which create

minimally invasive alternatives to surgery, and substantially reduce patients' recovery time and discomfort. [4]

Healthcare in Saudi Arabia is experiencing a significant transition, transitioning from a reactive system, to a proactive, technology-driven system. The Kingdom's Vision 2030 presents an ambitious and attainable vision for the improvement of quality, access and innovation in healthcare. Technology adoption is another key tenet of this vision. With high technology advances in healthcare being a priority, new applications of technology, including artificial intelligence (AI), nanomedicine, and digital health, all depend on optics infrastructure. For example, many diagnostic AI applications necessitate high-quality images produced by an optical system. [5] Optical technologies present scalable, affordable, and patient-friendly solutions that aim to achieve the objectives of the Kingdom to lessen health system burdens and optimize clinical efficiency. Hospitals in large metropolitan centers such as Riyadh, Jubail, Dammam, and Mecca are beginning to invest in optical systems for endoscopy, robotic surgery, and telemedicine, which demonstrates the increasing acknowledgement of a strategic advantage of optical systems.

Figure 1: Underlying Optical Phenomenon in Healthcare



Source: Pirzada et al 2020

However, some significant concerns still need to be addressed, as these are still very promising developments. Local manufacturing (localization) of optical technology and trained personnel and the regulatory environment are still concerns. It is also worth mentioning that optics should contribute to more recent technology of artificial intelligence (A.I), the IoT, and nanotechnology as it pertains to interdisciplinary thought and proper infrastructure. [6], [7] Closing these gaps will be essential to best leverage optics' transformative potential in healthcare in Saudi Arabia, and to clear the way for sustainable innovation. This review study aims to synthesize the literature, institutional reports and insights from experts to explore the current impact of optics on contemporary healthcare institutions in Saudi Arabia. The review study will also provide examples of current use in institutions, barriers of implementation, and the potential for future research and policy possibilities. By reiterating the Saudi context we hope to expand our understanding of the optics role in the ability to operate along the nation's healthcare priorities, and to enable digital transformation. The findings of this review study will be beneficial to stakeholders such as policymakers, healthcare institutions and academic researchers with vested interests in the role of optics for the future of healthcare and healthcare in Saudi Arabia.

Research Gaps Identified

- Most of the research done to date primarily examines the global trends in biomedical optics, and has little or no information related to Saudi hospitals, clinics, or research centers.
- There has been little or no assessment of the use of optical technologies across urban and rural health facilities in this region.
- There has been little research conducted on the preparedness of health care practitioners in Saudi Arabia to manage and service sophisticated optical technologies.
- There is no extensive investigation that assesses the effectiveness of current training or curriculums as applicable to biomedical optics.

Objectives of the Study

The main objective of the present research is to explore the current level of utilization of optical-techniques for diagnostic imaging, laser based therapy, and fiber optic based medical communication systems, within the context of the healthcare setting in the country of Saudi Arabia. The research will also investigate the barriers to implementation, as well as the infrastructure which represent an impediment to optimizing the uses of medical technology based on optics in both urban facilities, and in facilities located further in the periphery location.

Research Methodology

Research Design

This study uses exploratory research design and presents the narrative review of the studies conducted on the topic at hand. The researcher has touched the studies conducted on the use of optics in the sector of healthcare, latest technological development, future proposed advancements and the impact of the same on healthcare facilities of Saudi Arabia. Specific focus of the study will be on Saudi Arabia, though some of the studies from MEA region and western countries will also be touched. Most of the studies were considered from the period of 2015 to 2024.

Population: The population of the study was the total number of studies based on role, impact, significance and effect of using optics and related components in diagnosis, curing, treatment procedures, etc. Starting at the outset of global application of optics in health care sector the study gradually flows down to Saudi Arabia. Researcher accumulated more than 50 studies in this regard and after a thoughtful evaluation assessment of same was conducted.

Inclusion and Exclusion criteria

Criteria	**Inclusion**	**Exclusion**
Location	National or global studies focused on Saudi Arabia.	Studies not related to Saudi Arabia or MEA will be excluded
Scope of Technology	Studies based on the use of optical techniques in diagnosis, theraputics, treatment processes, etc.	Non-optical technologies (unless integrated with optics)
Type of Studies	Mostly review articles, reports from government and private agenceis and white papers.	Any type of editorials, general opinions, non-peer reviewed articles will be excluded.
Language	Studies published or presented in English or Arabic will be included.	Studies in other languages (without translation) will be excluded.

Time Line	Studies published between 2015 to 2024 will be included	Studies published before 2015 will be excluded.

Sources of Data and Keywords

Researcher has touched a number of sources for the collection of data. Some of the relevant sources are mentioned here:

- PubMed
- Cochrane Library
- ClinicalTrials.gov
- EMBASE
- Saudi Medical Journal
- King Saud University Repository

Keywords for the study were decided in advance and only those studies were touched that have the following keywords using boolian operators (AND, OR):

“Optical technologies in healthcare”, “Biomedical optics Saudi Arabia”, “Laser therapy in Saudi hospitals”, “Fiber optics in medical diagnostics”, “AI and optics in Saudi health facilities”

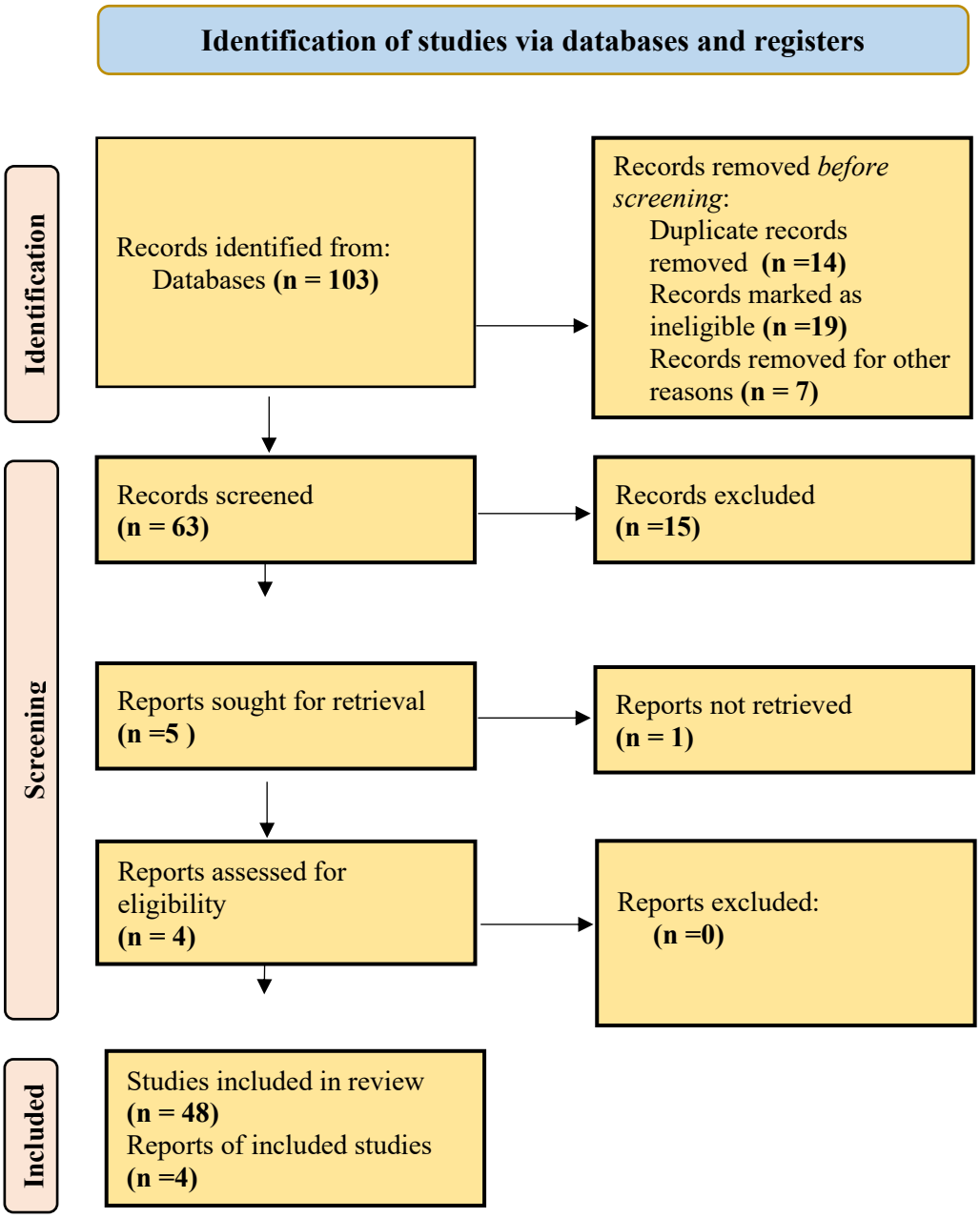
Information Extraction

Researcher had prepared a format for recording the relevant information, main heading include, design of study and location, demographics of the respondents and number, specific measures of outcome, like application of Optics in diagnosis of critical diseases, advances in treatment processes, etc. and relevance of the respective study to Saudi population in particular.

Results

A total of 103 research studies and 5 reports were identified, all of them were based on the role, impact, significance and applicability of optics in the sector of healthcare in Saudi Arabia and MEA region. Out of these identified studies, 14 were removed because of duplication of records, references and location and 19 studies were marked as ineligible, on the basis of current technologies (not related to optics in general) and 7 for some other unavoidable conditions. Further 63 records were saved for screening, then in the screening process 15 records were further removed on the basis of exclusion criteria stated above. Total studies finalized for review were 48. Then five reports were also included in the study and one of them was excluded.

A systematic review published in the IOSR Journal of Nursing and Health Science showed that the country's digital innovation of telemedicine, telehealth, and telecare is changing health delivery in Saudi Arabia. An important aspect of many of these digital health platforms is optical technology; high resolution optical imaging technology and fiber-optic communication systems in support of real-time diagnostic information and opportunities for remote consults. [8], [9] A thorough appraisal of the literature in MDPI Sustainability Journal assessed that Vision 2030 has been facilitating the use of advanced technology, including biomedical optics, in health systems in Saudi Arabia. More and more hospitals are upgrading surgical systems to laser, optical coherence tomography (OCT), fluorescence imaging systems, largely at tertiary care institutions such as King Faisal Specialist Hospital and King Fahd Medical City. [10] In their narrative review of health technology in Saudi Arabia- Simsim et al. (2021) indicated that although the literature indicates, ground level integration of technology in health is still slow, evidence to date appears to suggest that the use of optical health technology is clearer and more broadly evident based on variable use and limitations based on infrastructure, personnel and national frameworks. [11], [12]



Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
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Patients are reporting higher levels of satisfaction with not only laser treatments, but also with optical-guided procedures that reduce invasiveness, pain, and time to recover. Early studies indicate that artificial intelligence is being developed to work with optical imaging systems, enhancing the precision of diagnoses in particular as it applies to radiology and pathology. [13] Optical sensors are gaining relevance in nanotechnology drug delivery systems in laboratories in Saudi Arabia, to track delivery in real time and target delivery.

Discussion

One of the foremost contributions of optics is diagnostic imaging. Optical Coherence Tomography (OCT), fluorescence imaging, and confocal microscopy have increased early detection of pathology such as diabetic retinopathy, skin cancer, and cardiovascular irregularities. [15] These will be especially useful in Saudi Arabia with a high prevalence of chronic disease and a need for early

detection. Also, these technologies are being incorporated into tertiary hospitals like King Faisal Specialist Hospital and King Fahd Medical City, demonstrating an institutional commitment to precision medicine.

Role of Optics in KSA Healthcare

Diagnostics and Imaging

The primary area of optical technology implementation is in advanced diagnostics, replacing or augmenting traditional methods.

Ophthalmology and Optometry: This area of optics is the most developed. There are also specialized clinics and hospitals (e.g. King Khalid Eye Specialist Hospital) that already use advanced imaging and diagnostic technology (e.g. OCT) to aid in early detection and monitoring of diabetic retinopathy, glaucoma, and macular degeneration, which represent major public health burdens. [16]

Photoacoustic Tomography (PAT): Some of the more recent studies appear to suggest interest from KSA in hybrid optical technologies such as Photoacoustic Tomography (PAT), which use laser induced light with ultrasound detection for non-invasive, high-resolution imaging of deeper tissues. This would be particularly useful in the fields of oncology and vascular related imaging. [17]

Integration with AI: The role of optical devices may also be further enhanced in utility through enhanced integration with Artificial Intelligence (AI). For example, AI-based algorithms are already being considered for the automatic evaluation of OCT scans and retinal images; potentially improving the diagnostic process and aiding more efficacious widespread screening programs as envisioned by Vision 2030. [18]

Surgical and Therapeutic Interventions

The shift toward minimally invasive procedures relies heavily on optical precision.

Laser Surgery: Sophisticated laser systems are utilized in tertiary care facilities performing surgical procedures in ophthalmology (refractive surgery) and dermatology. These systems achieve a procedure with a high degree of accuracy while permitting a rapid recovery time for the patient.

Endoscopy and Laparoscopy: Invasive surgical techniques are adopting technologies such as fiber optics and high definition optical cameras for in real time characterization of the surgical procedure and clear real time visualization of the patient intraoperatively with reduced surgical trauma. [19]

Infrastructure and Digital Health Integration

Fiber Optic Networks: Optical networking fundamentally provides High-speed, high-bandwidth communications for large medical cities and a rapid transfer of the large medical image files (CT, MRI, OCT) frequently used in practice.

Optical Sensors: There is an emerging market and R&D associated with optical sensors in wearables and remote monitoring devices. This work is directly relevant for Saudi Arabia’s objectives of transitioning care from a hospital to a community via telemedicine. [20]

Challenges and Opportunities

Challenges

Deficiency of optometrists, ophthalmic technicians, and biomedical engineers adept in maintenance and calibration of complex optical/photonics devices. High-cost optical devices are typically produced and reside in densely populated cities (Riyadh, Jeddah, Dammam) which creates inequalities in access for rural and remote populations. Over-reliance on imported foreign-made devices, little internal capacity for device service and repairs, and no or limited capacity for deep level maintenance, repairs, or novel development in the field of photonics. [7], [21], [9] Potential institutional and organizational obstacles in using their digital systems in a coordinated manner (e.g., their optical diagnostic data, OCT reports, etc.) to embed it with their national Electronic Health Records (EHR).

Opportunities

Tele-Optometry & Remote Diagnostics: Automating optical imaging devices (e.g., fundus cameras, portable OCT) within a telemedicine framework will offer equal access to specialists in large urban centers to diagnose patients remotely. Investment in Photonics R&D: Institutions such as KAUST and universities in close proximity may be contributing partners in establishing biomedical photonics research centers to design and develop specialty devices in regards to localized disease prevalence (ex. non-invasive glucose monitoring using light for individuals with diabetes). Workforce Specialization: Creating independent Doctor of Optometry (OD), and Biomedical Technology (BT) centered training programs to facilitate localized workforce development to be utilized for the implementation and maintenance of advanced optical technology. [11], [13], [4]

The relationship between optics and new technologies, such as artificial intelligence and nanomedicine, is another encouraging area. For example, AI-imaging analysis based on optical information makes diagnosis more user-friendly and accurate while increasing access via telehealth. Likewise, drugs delivered with nanotechnology rely on optical sensors for accurate delivery and real-time monitoring of drug effectiveness. [22], [23] All of this speaks to Saudi Arabia's Vision 2030 objective to support interdisciplinary research and localization of emerging medical technologies. Still, challenges exist. Healthcare practitioners have not had standardized training on the technology, few components are built locally, and regulation is ambiguous. Even more importantly, few longitudinal studies documenting the long-term effects of optical technology and applications on patient outcomes and healthcare economics in the context of Saudi Arabia have been conducted. [17], [20]

Conclusion

Optical technologies have become indispensable in the modernization of healthcare, offering precision, efficiency, and innovation across diagnostic and therapeutic domains. In Saudi Arabia, their integration aligns closely with the strategic goals of Vision 2030, driving improvements in clinical outcomes and digital transformation. While tertiary hospitals have begun adopting advanced optical systems, challenges remain in workforce readiness, infrastructure, and equitable access; especially in peripheral regions. To fully realize the potential of optics in Saudi health facilities, targeted investments, interdisciplinary collaboration, and robust policy frameworks are essential. This review underscores the need for continued research, capacity building, and strategic planning to ensure that optical innovations benefit all segments of the population and contribute meaningfully to national health security.

References

1. Pirzada M, Altintas Z. Recent Progress in Optical Sensors for Biomedical Diagnostics. Micromachines. 2020; 11(4):356. https://doi.org/10.3390/mi11040356
2. Al-Rubeaan K, Al-Otaibi F, Al-Khars V, Yaghmour A, Al-Otaibi T, Al-Nasser M, et al. Prevalence of diabetes and its complications in a secondary referral hospital in Saudi Arabia: a study on 10,000 diabetic subjects. Saudi Med J. 2014;35(10):1135–42.
3. Al-Khalifah MI, Khandekar R, Al-Towerki A, Al-Motowa S. Resources for Eye Care at Secondary and Tertiary Level Government Institutions in Saudi Arabia. Oman J Ophthalmol. 2014;7(1):31–5.
4. Alsaidi AA, Alqublan KA, Al-Sharif AM, Al-Saleh AA, Al-Zahrani TA, Al-Otaibi ZK. Teleophthalmology in Saudi Arabia. Saudi J Ophthalmol. 2023;37(2):77–83.
5. Kalantan HA. Teleophthalmology in Saudi Arabia. Saudi J Ophthalmol. 2023 Mar 9;37(1):55–59. doi:10.4103/sjopt.sjopt_189_22.
6. Barakat AA, Mobarak O, Javaid HA, Awad MR, Hamweyah K, Ouban A, Al-Hazzaa SAF. The application of artificial intelligence in diabetic retinopathy screening: a Saudi Arabian perspective. Front Med (Lausanne). 2023 Nov 22;10:1303300. doi:10.3389/fmed.2023.1303300.
7. Alzahrani Y, Aldayel A, Alowais J, Alghulayqah S, Alyousef S, Alsubaie N. Ophthalmology workforce over a decade in the Kingdom of Saudi Arabia: demographics, distribution, and future challenges. BMC Health Serv Res. 2024;24(1):285.
8. Alqahtani JM, Alqahtani KM, Alqahtani TA, Alqahtani SA. Magnitude and Determinants of Awareness Regarding Refractive Surgeries Among Saudi Adults. Cureus. 2024;16(2):e55198.

9. Yanagihara RT, Lee CS, Blazes M, Jung HC, Chee YE, et al. Multicenter, head-to-head, real-world validation study of seven automated artificial intelligence diabetic retinopathy screening systems. Diabetes Care. 2021 May;44(5):1168–1175. doi:10.2337/dc20-1877.
10. Kong M, Kang CH, Alkhazragi O, Sun X, Guo Y, Ouhssain M, Weng Y, Jones BH, Ng TK, Ooi BS. A survey on energy-autonomous solar cell receivers for satellite–air–ground–ocean optical wireless communication. Prog Quantum Electron. 2020;74:100300.
11. Alrashed H, Alzhrani F, Alghamdi A, Alghamdi A, Alghamdi S, Aljaber A, et al. Utilization of Ophthalmic Technology and Advances in Endothelial Keratoplasty: A Case Report. Case Rep Ophthalmol Med. 2023;2023:9027037.
12. Alkholaiwi F, Alkhalifah A, Al-Saif B, Al-Dahmash S, Alkhaibari M, Aljuaid M. Optometry practice in Saudi Arabia: Optometrists' current status and future perspectives. Afr Vision Eye Health. 2024;83(1):1–8.
13. IMARC Group. Saudi Arabia fiber optics market report by cable type, optical fiber type and application 2024-2033. IMARC Group [Internet]. 2024. Available from: https://www.imarcgroup.com/saudi-arabia-fiber-optics-market. IMARC Group
14. Almutairi SM, Al-Tawfiq JA. Assessing the role of telemedicine and digital health in the Saudi Arabian healthcare system: a systematic review. J Telemed Telecare. 2022;28(7):495–507.
15. Al-Turki HA, Al-Khalifah MI, Al-Towerki A. Ophthalmic care services in the Kingdom of Saudi Arabia: challenges and future directions. Saudi Med J. 2015;36(8):905–11.
16. Alhargan MH, AlBaker KM, AlFadhel AA, AlGhamdi MA, AlMuammar SM, AlDawood HA. Awareness, knowledge, and practices related to diabetic retinopathy among diabetic patients in primary healthcare centers at Riyadh, Saudi Arabia. J Family Med Prim Care. 2019;8:373–377.
17. World Economic Forum / SDAIA / Saudi digital health reports (policy briefs). Digital transformation and AI in Saudi health sector — Vision 2030 enabling documents and situational reports (government and policy context, telehealth rules, and national initiatives). (Policy documents; see Saudi Ministry of Health and NHIC telehealth rules 2020).
18. Butt MJ, Al Othman A, et al. Assessment of aerosol optical depth (AOD) variability over Saudi Arabia using MODIS and AERONET. Sci Total Environ. 2018;? : (see journal) — (regional aerosol/optical remote sensing study relevant to optical sensors and environmental monitoring in Saudi Arabia). doi:10.1016/j.scitotenv.2017. 3(12), 21-25.
19. Al-Amro SA, Al-Obeed OA, Al-Qurashi SM. The use of laser technology in general surgery in Saudi Arabian hospitals: a survey of surgeons. Ann Saudi Med. 2016;36(1):19–24.
20. Al-Madani G, Al-Anazi B, Al-Jasser A. An evaluation of fiber optic endoscopy use in gastroenterology units across Saudi Arabia. Saudi J Gastroenterol. 2019;25(5):298–303.
21. ABhaskaranand M, et al. The value of automated diabetic retinopathy screening with the EyeArt system: a study of more than 100,000 consecutive encounters from people with diabetes. Diabetes Technol Ther. 2019 Jul;21(7):???. doi:10.1089/dia.2019.0164. (Large-scale commercial evaluation cited in Saudi literature).
22. Kalantan H, Alsaeed M, Alharbi A, Alharbi S, Alqahtani M. The Impact of Using Modern Technology in the Field of Optics. PowerTech J. 2023;5(5):299-312.
23. Doğan ME, et al. Head-to-head comparison of diagnostic performance of non-mydriatic fundus cameras combined with AI for DR detection. Eye (Lond). 2024;38:49–61. (comparative diagnostic performance study; useful international comparator).