



## The Impact of Using Modern Technology in the Field of Optics

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### Abstract

**Background:** Most of the modern technologies have their respective pros, and cons, but still the tools of modern technology are capable of dwelling with foreign threats, attacks from the dark web and many other concerned avenues. In KSA the medical field is determined to use the most appropriate tools to meet the demand of people at large, in the sector of health care. Optics or biomedical optics are also the integral part of this system and using the most advanced systems available. Though in KSA the application of these technologies is still in the development stage and need a loud and clear policy and strategic framework to deal with the situation. This present study will evaluate the scenario of use and application of modern technology in the field of optics in the Kingdom of Saudi Arabia (Makkah, Jeddah, Taif, Asir and Jazan and Albaha) (random samples), and the researcher will conduct a series of studies and obtain relevant information about the concerned point.

**Study Objectives:** The main objective of the study is to find the intervention of modern technologies in biomedical optics and the related applications. The researcher will also focus on the usage, valuation, industry approach and clinical settings.

**Materials and Methods:** Study is based on exploratory research design where the information is collected from various sources and presented in the form of a general discussion. Also, the researcher has contacted various hospitals in Saudi Arabia (Makkah, Jeddah, Taif, Asir ,Jazan



and Albaha) to find the preparedness for incorporating modern technology like IoT, AI and Nanotechnology in the field of optics or the biomedical optics.

**Keywords:** Role of modern technology, Optics, Biomedical optics, AI, nanotech.

## Introduction and Background

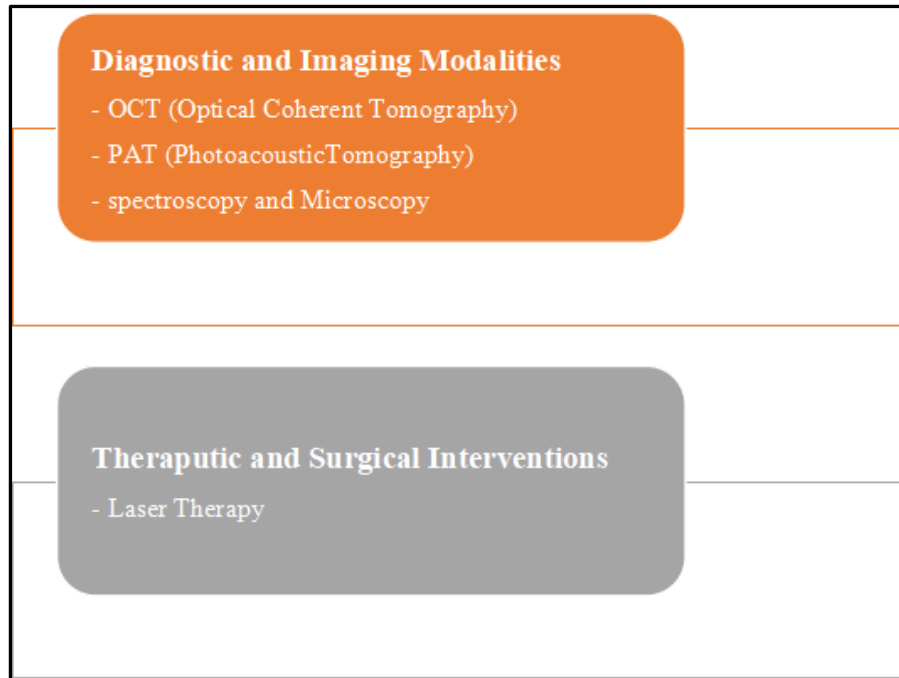
Healthcare reforms in Saudi Arabia are at the core of national development policy, this includes the economic development, social development, development of public services and above all the transformation of health care sector. Under this program the authorities are trying to restructure and modernize the healthcare system of the country. There are a number of components that are taken care of like, the population of the country is growing at a rapid pace i.e. by the end of 2030 it will touch the mark of 45 million, then the country is struggling to overcome the burden of non-communicable diseases (NCDs) such as diabetes, obesity and many others, then the need of developing a system of healthcare that is proactive and prevention focused rather than only reactive and treatment based. The authorities are committed enough to produce results in the above given areas in terms of allocating high finances in the areas of digital health infrastructure, joining hands with international agencies, working on Public private partnership to develop the sector and many other such initiatives are taking place. (Kalantan 2023), In such a scenario of development, optics or the biomedical optics is one field that works on emerging and enabling technologies. Here the process of diagnosis, imaging, treatment, etc. are based on light. To improve the process and take the system to next level the authorities have listed biomedical optics in major health targets in strategic formulations of Saudi Vision 2030. (Barakat et al 2023) This present study withholds both the national health agenda and capabilities of biomedical optics is a central theme. (Alqahtani et al 2023) As stated above, the focus of authorities is to bring down the burden of non-communicable diseases and develop the technologies that are capable of early diagnosis and that too a non-invasive one. As per the reports of WHO and related agencies the prevalence of diabetes in the KSA is high and hence there rises the need for monitoring diabetic retinopathy. Optics or biomedical optics is capable of offering high-resolution, three-dimensional imaging of living tissues without ionizing radiation and this is most suited process as per the needs. The directives of Saudi Vision 2030 has shown a high commitment level to obtain the required technologies and moving towards making Saudi Arabia as a potential hub for future developments and innovations. (Al Amro et al 2022)

## Major Technologies Used and their Applications

The area of biomedical optics makes use of various technologies across the medical domains, where the applications use to range from diagnosis, imaging to providing therapies and performing surgeries. Here it is important to note that the usage and adoption of these technologies is not uniform i.e. some of the applications have reached large area of service



and prominently used across the domain. Some of the such technologies are stated below, as observed in major eye hospitals or the multi-specialty general hospitals. (Lee et al 2021)



Source: Made by the researcher based on Information from various sources

### Figure 1: Technologies used in Biomedical Optics

As stated in the above figure 1, the biomedical optics is based on various technologies of different purposes. Like in case of Diagnostics and Imaging modalities it makes the use of OCT (Optical Coherence Tomography), PAT (Photoacoustic Tomography) and Spectroscopy or Microscopy. Then for Therapeutic and Surgical Interventions Laser Therapy is being used.

In order to present a clearer picture, glimpses of these processes are given below.

**OCT** is a basically a non-invasive imaging technique that makes the use of reflected light to create cross sectional and high-resolution images of tissues that are structured on a micron scale, also named as optical biopsy. Generally used for diagnosis of various ailments related to retina and also includes diabetic retinopathy, macular edema, and glaucoma. (Gulshan et al 2016), **PAT** is also related to biomedical imaging, this makes the use to hybrid modalities using the high-resolution optical imaging, here deep penetrations are made by using ultrasonic waves. Here the biological tissues are lightened with the help of a pulsed laser, causing a transient temperature rise and subsequent thermoelastic expansion that generates a detectable ultrasonic wave. (Ipp et al 2021), **Spectroscopy and Microscopy** these are the two most advanced technologies used for chemical imaging, this technology is based on vibrational spectroscopy (Infrared and Raman micro-spectroscopy) and multi-photon



processes. Keeping in mind the above structural details this present study will also focus on the identification of specific bio-chemical signatures of diseases and understanding the lipid metabolism of cancer stem cells. (Kang et al 2019), Then at the next level comes the **Therapeutic and Surgical Interventions** where prominently the laser therapy is used. These therapeutic lasers throw coherent and intense light to targeted tissues, this is very popular process for cosmetology which is generally consumer driven and also marketed accordingly. This present study includes the usage and application of modern technology tools in the field of optics, as this is one of the important aspects to be covered under the gamete of overall development of healthcare sector. Then on the other hand the use and application of AI and nanotechnology has raised the level of diagnosis, observation and even technology.

## Review of Literature

Research institution in Saudi Arabia like, King Abdullah University of Science and Technology is having a well-established lab of photonics and optoelectronics. They focus on device-level and system research. (Alkhazragi et al 2020) This includes semiconductor lasers, photonic integrated circuits, optoelectronic security primitives, and integrated sensing. (Alshaibani et al 2023) The lab pages, publication lists, and recent pre-prints highlight ongoing projects in integrated photonics, laser devices, and sensor development. KAUST labs combine device fabrication using molecular beam epitaxy (MBE) and nano-fabrication with applications in communication, sensing, and environmental monitoring. This local research capability provides skilled personnel and prototype infrastructure for clinical and industrial projects. Current academic work excels in demonstrating devices and lab innovation. However, there are relatively few studies on large-scale field deployments or systematic links to Saudi industry or health systems. (Ooi et al 2016), However, concerns remain about how these tools fit into current workflows, regulations, and legal responsibilities. Large-scale tele-retinopathy screening projects and reports from the field in 2023 and 2024 show ongoing efforts and interest in expanding programs that combine fundus imaging, cloud services, and AI triage. (Mhanna et al 2023) The clinical evidence is strongest for screening-type cases, such as diabetic retinopathy. However, thorough health-economic evaluations and studies on long-term outcomes, like cost-benefit analyses for preventing blindness in Saudi Arabia, are still limited. There is a growing amount of research on teleophthalmology in Saudi Arabia and globally. Reviews and studies highlight how teleophthalmology programs help with screening, including diabetic retinopathy, postoperative care, and remote consultations. Research from Saudi Arabia and surrounding regions shows promising accuracy for remote image-based screening when trained graders or AI tools are used. Surveys of clinicians in Saudi Arabia also show that acceptance of AI tools for diabetic retinopathy screening is on the rise, as mentioned earlier in the above given matter. (FASTer 2021-24)



Working on laser-based sensing has been the focus of recent studies and their project updates. These new optical sensors aim to keep a watch on the environment, which is something that covers the whole area of the sensing of trace gases and the tracking of pollution. Along with the local researchers, the students of KAUST are involved in scientific research(local) adjunctured in membrane optical sensors and printed sensor technology types. On top of that, reports indicate that there is rising market interest in optical sensors, especially for applications in the smart cities and industrial monitoring sectors. **(IMARC Group 2024)** These developments are indicators that while scholars are advancing the frontiers, they are also acknowledging the market demand for the use of optics in environmental sensing. Nonetheless, there is a large number of sensor prototypes that are still at the laboratory stage or are only in their prototype phase. In addition, there is very little research on how these sensors can be recalcitrant to length and their performance in the difficult Saudi climate comprising high temperatures and dust. **(TechSci 2025)**

## Research Gaps

Going through the trail of literature review the researcher has identified some prominent gaps in the available literature. Some of such gaps are given below:

- Some of the systematic reviews on mapping of photonics prototypes and other related aspects have not considered the role of AI and Nanotechnology on the process and respective benefits thereof.
- Only a few studies have included the health-related economic aspects and social impact evaluation of teleophthalmology including optical sensor programs in Saudi contexts.
- Then the field testing and performances of sensors enabled by nanotechnology were not included in only a few studies.

## Research Objective

The main objective of the study is to find the intervention of modern technologies in biomedical optics and the related applications. The researcher will also focus on the usage, valuation, industry approach and clinical settings.

## Research Methodology

### Research Design

This present study rests on the pillars of secondary data, this is evident that most part of the study will apply exploratory research design. This is one different type of research design that is based on discussion outcomes of various studies conducted in the recent past. The information is collected in chronological order and the respective developments are presented in the same format. In this present study, optics or biomedical optics and the modern or advanced technology related to the same is being discussed.



The respective sources of data will be as follows:

- Studies conducted by Saudi and international authors in the recent past,
- Some of the reports and articles published by different government and private agencies.
- Authentic medical publications in the form of white papers, articles, presentations, etc.
- The researcher has also touched some of the online sources with a caution that all the respective sources are trusted.

### **Study Area and Population**

The main focus of this present study will be on the eye hospitals, multi-specialty hospitals in Saudi Arabia (Makkah, Jeddah, Taif, Jazan, Asir and Albaha) that are actually working towards the usage and application of modern technologies like AI, IoT, Nanotechnology, etc. Specifically, with the patients and research activities. There are certain other technologies of the modern times that are being used in the process and will be detailed in the present study. The researcher will present the collected information general perspective, so as to present the current scenario and future prospects.

### **Statistical Analysis**

The data collected from various sources will be evaluated & interpreted using basic tabulation formats, charts, diagrams, etc. Wherever required.

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### **Discussion**

#### **Role of AI in diagnostics**

AI is transforming healthcare in Saudi Arabia and will significantly improve biomedical optics. The Saudi Data & AI Authority (SDAIA) oversees AI adoption in all sectors, including healthcare. AI can analyze large medical datasets from scans, lab results, and patient histories to improve the diagnostic abilities of imaging techniques like OCT and PAT. For example, AI combined with OCTA can diagnose and track the progression of diabetic retinopathy with greater accuracy. A survey of 34 large hospitals in the Kingdom revealed that only three, or 8.82%, have gone on to incorporate AI solutions in patient care. (LiDAR 2025) , The gap between policy and practice is quite huge. The number one reason for the non-negotiable part of AI in biomedical optics is not the shortage of foresight and funds, rather the question of whether healthcare organizations are operationally and culturally ready or not. The initiation of these technologies is overcoming the systemic barriers like people



resistance to new digital systems and the need for new policies to manage data privacy and ethics. **(Butt et al 2017)**

SDAIA has set up a Center of Excellence for AI applications in healthcare and the Ministry of Health has been using telepresence robots for remote consultations during the Hajj season. This is a clear indication that they are very much on their way with these technologies. Yet, the discrepancy between the grand-scale projects and the limited daily use of AI in hospital departments suggests that the core problem is a complex combination of the healthcare professionals; conservative mindset, lack of skills, and technical issues resulting from the integration of new systems into existing workflows. **(Kong et al 2022)** The full breakthrough of the transformation of the healthcare sector in the Kingdom brought by AI will depend on the ability to overcome these organizational and human-related barriers.

### **Research and Development Activities**

Universities with the best reputations in the world are the primary agents of the highly disruptive process. In particular, the Royal Science and Technology University of King Abdullah (KAUST) boasts a very robust Bioengineering curriculum that takes a holistic view, basically combining the concepts of electrical and mechanical engineering, materials science, and biology. This program matches the global impact research under Vision 2030 and is virtually entirely based on the development of the next generation of biodevices and application of bioinformatics and machine learning.

The VIBRA Lab of these universities with its focus on advanced spectroscopy and micro-optics is an example of basic research aiming at generating value and intellectual property for a very long time. **(Alghamdi et al 2018)** Similar to that, King Saud University (KSU) is the center of this network with its Optical Instrumentation Lab and academic staff who are always willing to take part in research work on advanced optical imaging techniques. The appearance of these specially built laboratories and the arrival of Saudi researchers are the signs of a deliberate strategy of assembling a pool of locally trained specialized scholars. This is the first and most important step in achieving the "Saudization" goal i.e. the expatriate healthcare professionals will be replaced by the highly qualified Saudi nationals, thus the sector's long-term sustainability will be assured. **(Rasha 2019)**

Also, as far as the university and research programs are concerned, their formation is the really crucial step in the opening of the era of the most highly-trained healthcare professionals who are the key players in the process of biomedical technologies implementation and spreading.



## Challenges

### Regulatory issues

The Saudi Food and Drug Authority (SFDA) has established a stringent regulatory framework for medical devices. A major challenge for foreign manufacturers is the absence of regulatory harmonization with international standards. The SFDA now requires a Technical File Assessment (TFA) and no longer accepts authorizations from Global Harmonization Task Force (GHTF) member countries like the EU or USA. This necessitates that manufacturers appoint an in-country Authorized Representative and maintain a Quality Management System (QMS) compliant with Saudi standards. **(Bhaskaranand et al 2022)**

### Infrastructure Issues

The effective integration of advanced technologies like AI with biomedical optics requires a robust digital infrastructure. While the government has allocated funds for healthcare IT, challenges persist in establishing high-performance computing systems and secure data networks. A significant hurdle is the need for large-scale data collection to train AI algorithms, which poses considerable risks to patient privacy and requires the development of clear ethical guidelines and regulations. **(Ting et al 2021)**

## Conclusion

The impact of modern biomedical optics technology in Saudi Arabia is a complex and multi-faceted phenomenon, deeply intertwined with the nation's ambitious Vision 2030. This exploratory study reveals that the technology's influence extends far beyond the clinical setting, serving as a critical driver of economic diversification, a catalyst for human capital development, and a tangible expression of the Kingdom's strategic pivot towards a knowledge-based economy. KSA is on the cusp of a profound transformation in its healthcare sector, with modern biomedical optics at the forefront of this change. The combination of a powerful strategic vision, dedicated financial investment, and a growing domestic ecosystem positions Saudi Arabia to not only meet the health challenges of its population but to become a significant force in the global health technology landscape. By effectively navigating its current challenges, the Kingdom is poised to transition from a leader in technological adoption to a leader in technological creation.

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