Review Article:

Keratoconus: A global review of screening programs with a special focus on Saudi Arabia

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Abstract

Keratoconus is a progressive disease of the cornea in which the cornea thins and becomes conically shaped, resulting in marked visual impairment. As early detection is very important for stopping disease progression and advanced diagnostic tools like corneal topography and tomography are key to identifying the condition at an early stage. Both the general population and high-risk groups have implemented screening programs, some of which have incorporated artificial intelligence to assist in diagnostics and treatment outcomes worldwide. Keratoconus is highly prevalent in Saudi Arabia with multifactorial contributors including both genetic and environmental factors. As a result, there have been national programs aimed at early detection, public awareness, and greater access to care. Educating the public is the most crucial step to improving the handling of keratoconus, as more informed patients will seek medical advice earlier and similar complaint patients will seek for earlier treatment, special follow-up, and preventive management. In the past few years, multiple awareness initiatives were implemented nationwide, capitalizing on high internet usage, especially by the younger generations that have been proven to have a higher susceptibility to developing the ailment. Progress has not been universal, many people still lack access to specialized care in rural communities, and cultural barriers can prevent early diagnosis and treatment. Providing a feasible solution to these risks requires holistic, multi-pronged approaches, inducting reinforcement of international collaborations, implementation of innovative diagnostic platforms and targeted public health interventions. These measures can greatly reduce the global and regional burden of keratoconus and promote visual health.

Keywords:

Keratoconus, Screening, Programs, Awareness, Prevention, Saudi Arabia

Introduction:

Keratoconus (KC) is a progressive disease of the cornea in, in which the cornea thins and becomes conically shaped, resulting in marked visual impairment. Early diagnosis and appropriate intervention are essential for preventing significant visual impairment and enhancing the quality of life of individuals with keratoconus. For this reason, governments and healthcare institutions across the world have developed keratoconus screening programs1. These programs seek to meet the ever-growing demand for keratoconus care for young people, among whom it is most common. The serious consequences, like vision loss, are dreadful if the condition is untreated. Unfortunately, many patients are unaware of the condition until the late stages; therefore, screening programs are important to diagnose the condition earlier [2].

Screening programs target specific groups of people who are at a higher risk for developing keratoconus: family history of keratoconus, repeated changes in the spectacle prescription, or presenting with features like reduced vision and light sensitivity. Before the advent of comprehensive diagnostic tools, the possibilities of keratoconus screening were limited. It includes corneal topography, which creates a map of curvatures of the cornea; and corneal tomography, which provides three-dimensional images[3].

Corneal thickness is determined by pachymetry, which is also important in the early diagnosis of keratoconus. Apart from diagnosis, the progress of the patient's condition can also be assessed by follow-up examinations. Such high-risk or selective screening programs are gaining importance in the Middle East, South Asia, and parts of Africa, where the condition is prevalent. The risk factors identified in these areas include genetic and environmental factors such as excessive eye rubbing and exposure to UV radiation[4]. Apart from merely acting as a screening program, it also provides an opportunity to increase awareness among the people through various information, education, and communication (IEC) activities, informing them of the risks and the available prevention measures. Programs of this nature if held in schools will help to pick up the children presenting with the first symptoms of keratoconus during elementary vision tests.

These efforts are supplemented by governmental and non-governmental organizations that sponsor, train, and supply the services necessary for widespread screening programs. An important factor in these programs is the issue of accessibility[5]. In rural areas, where there are no specialists/ professionals, it is difficult to organize screening programs. In such cases, mobile screening

units consisting of testing equipment and trained personnel can be deployed. Such strategies ensure that people in hard-to-reach regions or resource-limited settings are not left out. They can also avail the early diagnosis and management so that they do not develop advanced keratoconus which demands expensive treatments like corneal transplantations, increasing their burden6. However, further research is needed to develop an effective organizing framework for a keratoconus screening program. The areas of research should include: the type of target population, patterns of disease occurrence, distribution, and possible causes of the condition. Additionally, artificial intelligence (AI) is gaining more importance as an early diagnostic tool. Corneal imaging data can be analyzed with the help of AI to diagnose the signs of the disease, even if they are not noticeable in the early stage[7].

Keratoconus is a major public health issue in Saudi Arabia as it affects mainly the productive population of the country, the young population. However, there is no definite data regarding its incidence[8]. Global research reports that the incidence rate of keratoconus is 5-23 per 10,000 population and a global prevalence of 5.4 per 10,000[9]. Research in the UK has shown the prevalence of 32-65 cases per 100,000 population[10]. Reports indicate that about 1 in every 2000 Population is affected; it has no sex predilection and has an approximate occurrence ratio of 50-230/100000[10]. Other studies reported a higher prevalence of keratoconus in men and others report a preponderance of the prevalence in women[11]. It is estimated to be more prevalent among Asians than among Caucasians[11]. A recent study on its prevalence in Saudi Arabia reports a ratio of 1:21[12].

Global Approaches to Keratoconus Screening:

Keratoconus screening programs worldwide rely on a combination of advanced diagnostic technologies. One key tool is the corneal topography, which provides detailed maps of the corneal surface, highlighting any aberrations/ irregularities in the curvature. Additionally, tomography provides three-dimensional images, showing the thickness and structural profile of the cornea. When combined with patient history and clinical examination, these tools offer a comprehensive approach to screening. Many countries have incorporated these technologies into school and community-based programs, as keratoconus commonly develops in the young. Advances in AI and machine learning have greatly improved screening techniques. These newer technologies are based on algorithms that are capable of identifying patterns in corneal images that are indicative of early-stage keratoconus. In devel-

oped countries such as the United States and Germany, both healthcare providers and patients increasingly use AI-powered platforms for screening[13]. As a result, there is a growing and pressing need to train ophthalmologists and optometrists to effectively use newer technologies and advanced diagnostic tools for screening.

Advanced Diagnostic Tools of Keratoconus in Saudi Arabia:

Keratoconus prevalence and incidence are variable worldwide in the overall public with the highest prevalence in the Middle East [11]. A study found that, on average, 1638 keratoconus patients from one of the five major cities in Saudi Arabia, were referred annually to King Khaled's Eye Specialist Hospital, with a mean referral rate of 136.5 patients per year. The distribution of patients was slightly more common in males. Around 40% of the patients were young, between 16 and 26 years old[14]. The present review highlighted that keratoconus has been widely reported in clinical research. This may be an isolated sporadic condition- Iridic rubria or associated with other rare hereditary disorders like Down syndrome, connective tissue disease, and Leber's congenital amaurosis. Other contributing factors include: prolonged hard contact lens use, frequent and excessive eye rubbing, and a strong family history of the condition[4].

The link between atopy and keratoconus was first described over 50 years ago, but several clinical studies have since challenged this association[15]. About 30 years ago, research found that 59% of keratoconus patients had elevated serum immunoglobulin E levels[15]. However, since many individuals with allergic eye conditions frequently rub their eyes, it remains unclear whether keratoconus is directly associated with atopy or eye rubbing is the primary factor. The exact cause and mechanism of keratoconus remains unclear in this condition, though studies have associated it with atopy. In cases of atopic keratoconus, Harrison et al observed that the condition was more prevalent on the side of the dominant hand[16]. A case-control study published in 2000 by Bawazeer et al found an association between atopy, eye rubbing, family history, and keratoconus in the univariate analysis. However, in the multivariate analysis, only eye rubbing remained statistically significant[17]. This suggests that while atopy may contribute to keratoconus, the frequent and excessive eye rubbing often triggered by atopy-related irritation plays a more critical role[4].

Various diagnostic tools such as corneal topography, corneal tomography, and pachymetry are used in keratoconus diagnosis in Saudi Arabia and technologies are readily available in the majority of governmental

and non-governmental care clinics across the country. Modern infrastructure in clean and safety-controlled environments has been a key factor in the success of diagnostic health clinics in Saudi Arabia. Research institutions in Saudi Arabia also are incorporating artificial intelligence (AI) for increased accuracy.[18] Now, machine learning-based AI models notice early keratoconus & disease progression based on corneal imaging data. Each of these innovations is expected to enhance outcomes for screening programs as well as provide insight into understanding the disease as it relates to the human population as a whole[18].

School-Based Screening and Public Awareness Campaigns:

Keratoconus is detected at an early stage in Saudi Arabia based on the keratoconus screening program[19]. Because the condition tends to emerge in childhood or adolescence, these programs need to target students and include routine eye examinations. Over the past several years, the Ministry of Health implemented initiatives of awareness in urban and rural areas[19].

Public awareness campaigns are important to screen keratoconus in Saudi Arabia. These efforts include public awareness campaigns about the earliest signs and symptoms, such as foggy or distorted vision, frequent changes of eyeglasses, and sensitivity to light. With the help of social media, television, and community events, these campaigns highlight the significance of early diagnosis and the need to get regular ophthalmic tests[20].

Keratoconus is a progressive disease that, if not diagnosed by early age, may lead to significant loss of vision and a greater economic burden on the patient. At present, a keratoconus detection school-based screening program must be started in Saudi Arabia. This is especially crucial to the country since the prevalence of keratoconus is stated to be the highest in Saudi Arabia as compared to the world reports. In a study conducted in Riyadh, the prevalence rate was 4.79% in students 6 to 21 years old [21].

These screening programs use advanced diagnostic methods like corneal topography and tomography to detect subclinical cases- those that aren't symptomatic yet. Early diagnosis facilitates prompt implementation of appropriate preventative measures that beget a delay or cessation in disease progression, ultimately ensuring the preservation of patients' vision [22].

A collaboration between the Ministry of Health and the Ministry of Education is crucial to establish a screening program in schools. This cooperation allows for the systematic screening of many students while being more efficient. Non-invasive imaging techniques and continuous

training of operators performing primary screenings have additionally contributed to the efficiency of early detection the light for Sight Foundation based in Switzerland has conducted a free keratoconus screening program for all ages, as an example of an applicable organizational model [23].

Accessing sophisticated diagnostic equipment and skilled manpower within schools in remote, underserved areas remains a major challenge. Moreover, raising awareness of the early signs of keratoconus among family members, and improving the referral coordination for suspected cases among subspecialists needs continuous support[20].

Public Awareness Campaigns of Keratoconus in Saudi Arabia:

Public awareness is one of the important pillars of keratoconus management, as informed people are more likely to seek early medical advice, follow treatment protocols, and implement preventive behaviors. In Saudi Arabia, community awareness programs have been initiated to promote awareness of keratoconus, the associated risk factors, and early diagnosis[20]. To further strengthen awareness, local initiatives have also made use of worldwide events, including World Keratoconus Day which is observed on November 10th. However, these attempts have been shown to have differing effectiveness according to cultural and demographic factors. One study in Saudi Arabia found that 90% of participants have poor awareness about risk factors and the available treatment options for keratoconus[24].

The awareness campaign has led to an increase in public participation in preventive measures, such as not rubbing the eyes excessively and regular eye check-ups. Such initiatives have resulted in earlier diagnosis and treatment and better outcomes for patients. Some of the challenges remain in reaching populations, especially in rural areas. Outreach to the public must be done through the campaign efforts continually assessed and reframed. The Kingdom of Saudi Arabia has witnessed an incredible advancement through school screening systems and awareness campaigns. These programs should continue to grow and evolve, to further provide the path to treatment and reduce the burden of keratoconus on our patients.

Accessibility and Outreach of Keratoconus Services in Rural Areas:

To address disparities in health care, Saudi Arabia has deployed mobile units that provide a variety of health care with advanced diagnostic technologies to remote and peripheral areas. Staffed with trained ophthalmologists and optometrists, these units perform thorough eye checks. These initiatives also allow those who may not

have access to healthcare services to receive timely, accurate diagnoses by taking healthcare to rural populations. Indication of keratoconus screening includes early diagnosis and prompt intervention to avoid loss of vision, this is why many countries conduct nationwide screening programs for kertoconus[1].

Models are available through healthcare approaches that provide benchmarks for keratoconus screening in developed nations. Headquartered in Switzerland, the Light for Sight Foundation is the world's leading keratoconus awareness and screening program[23]. Countries like the USA, Australia, UK have very advanced keratoconus detection plans in place.

- USA: Eye care systems include state-of-the-art imaging equipment in routine eye exams, with most early detection heuristics based on collaborative research projects.
- Australia: Making community screenings and public education a priority using a wide network of professional optometrists
- United Kingdom: In coordinated programs that include public awareness efforts, the National Health Service (NHS) combines ophthalmologists, optometrists, and general practitioners to screen for keratoconus.

International practices have shown how excellent partnerships between healthcare provision and technology contribute significantly to education and early intervention in keratoconus detection and management6. However, new affordable technologies in aiding screening for keratoconus, i.e. software in smartphones are evolving and used with promising results[25]. On the other hand, early and subclinical keratoconus cases can be missed with such smartphone technology, while technologies use inputs of validated and traditional technologies based on topography and tomography to process data that have high sensitivity (>99%)[26].

Research and Epidemiological Studies related to Keratoconus in Saudi Arabia:

Saudi Arabia has emerged as a powerhouse in keratoconus research: studies are delving into both genetic and environmental factors accounting for the high incidence of the disease in that region. Well-established characteristics of keratoconus in the Saudi population, established by prior research, have enabled the development of effective diagnosis and treatment strategies.

Effective screening programs around the world aim to prevent the onset of this progressive blinding corneal disease via the identification of individuals predisposed to the disease. However, prevalence rates in Saudi Arabia are much higher than the worldwide average, making these programs

even more important. The country had a proactive response to this problem, characterized by early diagnosis and intervention, and encouraged the implementation of novel cutting-edge diagnostic approaches, mass school-based screenings, active health education, and increasing outreach service provision to the periphery.

Saudi Arabia's dedication to research and innovation equips it well to address the challenges presented by keratoconus, ultimately enhancing both national healthcare outcomes and contributing to the global understanding of the disease. Education about the premier of scheduled eye exams and identifying early symptoms are key. Health education tailored to Saudi culture, via social media, community events, and through specific instruction by healthcare professionals, could promote early diagnosis and treatment, and consequently help to mitigate the burden of keratoconus[27].

Advancements and Challenges of Keratoconus Research in Saudi Arabia:

Keratoconus research in Saudi Arabia emerged as one of the leading nations for keratoconus research, with institutions joining efforts with other international establishments to develop advanced diagnostic and therapeutic techniques[28]. Considering the unique corneal characteristics of the population, the new CXL techniques are increasingly customized to optimize treatment outcomes[29]. Moreover, genetic studies can identify the putative genes for keratoconus and set the scene for personalized treatments[30].

Educating eye care providers, training them to use new techniques and equipment, and assisting the adoption of best practices and standard operating procedures for diagnostics have also been facilitated by the collaboration between international eye care organizations[31]. There are still some challenges in the Kingdom of Saudi Arabia in terms of keratoconus screening and treatment despite these advancements. Delay of diagnosis occurs due to a lack of specialized diagnostic equipment and cornea specialists in rural or remote areas[32]. Additionally, a lack of awareness and cultural beliefs regarding eye disorders frequently delay an early diagnosis. Meeting these barriers is a holistic, multilevel problem that extends beyond health care. Increased healthcare facilities, public awareness, and funding/subsidies for underprivileged people will go a long way in achieving early detection and management.

Conclusion:

Keratoconus screening plays a key role in the timely detection and management of this progressive disease, especially in high-prevalence areas like Saudi Arabia. Developing nationwide screening programs, raising public awareness, and

strengthening healthcare accessibility are critical priorities in managing the disease burden.

Global and regional cooperation will shape the future of keratoconus screening. Collaborating with international organizations will foster knowledge sharing, expertise, and resources, improving early intervention and treatment approaches. The path to significant relief of the burden of keratoconus lies in global partnerships and well-coordinated interventions that can effectively transform youth visual health states in Saudi Arabia and beyond.

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