

Keratoconus Disease Prediction through using Machine Learning and Deep Learning

Abstract:

Keratoconus is a non-inflammatory disorder marked by gradual corneal thinning distortion and scarring. Vision is significantly distorted in advanced case, so an accurate diagnosis in early stages has a very importance and avoid complications after the retractive surgery. Using Machine Learning and Deep Learning can help identify Keratoconus at an early stage when intervention is most effective.

Machine learning models is used to gain insight. into how much the risk factors of a patient contribute towards the progressive stages of keratoconus, as well as how significant these factors are in the creation of an accurate prediction model. Several machine learning algorithms are used to classify the patients' stage of keratoconus using clinical information, such as measurements of the cornea's topography, elevation, and pachymetry.

Keywords: Keratoconus, machine learning, risk factors, Deep learning

Introduction:

The Cornea is the outer layer of the eye, so the structural and repair properties the inner contents, maintaining the shape of the eye and achieving light refraction. Keratoconus (KCN) is a non-inflammatory ectatic corneal disorder characterized by progressive thinning of the cornea that may lead to reduced vision or even vision loss.

In recent years, we have observed an increase in the use of machine learning (ML) and artificial intelligence for the diagnosis and monitoring of diseases. It has established itself as an indispensable resource for detecting and assessing trends in medicine and research.

1. Keratoconus is one such condition within the ophthalmic industry that ought to be examined using ML approaches. Keratoconus is a non-inflammatory corneal disease that can affect both eyes and is present in 1 out of every 2,000 patients globally. It is the deformation and thinning of the cornea into a conical shape, leading to optical aberrations and progressive vision loss.
2. The disease frequently manifests itself in adolescence and progresses to a state of stabilisation by the time the patient reaches their forties, resulting in a significant reduction in quality of life. The most common diagnostic procedures for keratoconus are corneal topography and corneal tomography. This, in conjunction with clinical evaluation parameters and a systematic classification approach, such as the Amsler-Krumeich Grade 1–4 keratoconus classification system, has been standard practice in the diagnosis of keratoconus and other corneal illnesses over the past several decades.
3. The pentacam illustrates several parameters, such as corneal curvature, thickness, and elevation data, through the use of colour-coded maps via corneal imagery, as shown in Fig. 1. The maps are displayed along with the corresponding numerical assessment of the patient's cornea.

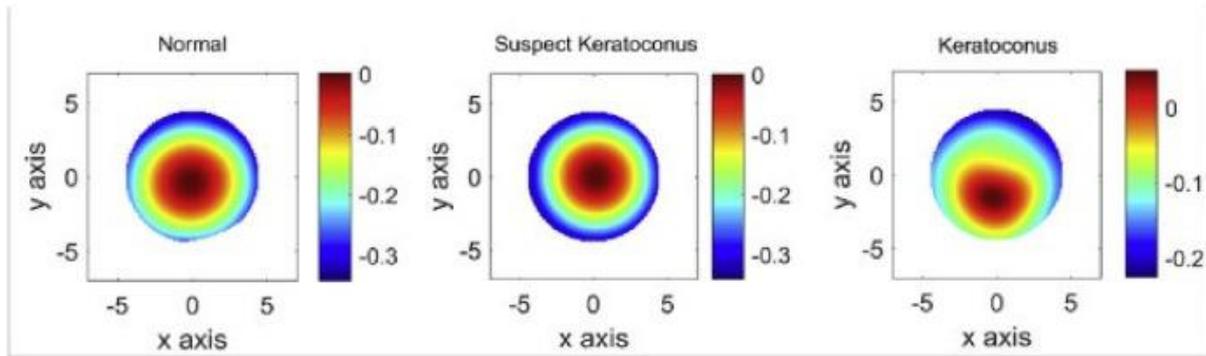
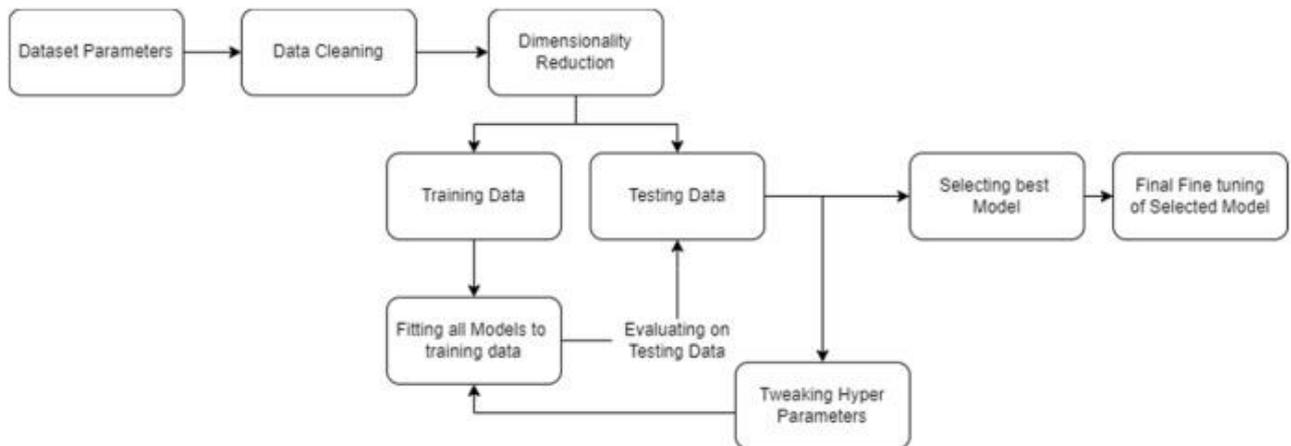


Fig. 1. Keratoconus topography maps showing normal, keratoconus suspect, and moderate keratoconus

Staging method

In addition to identifying keratoconus eyes as a discrete category, several research studies classified keratoconus eyes into clinical phases and employed machine learning (ML) methods to identify each stage independently. The study reveals a variety of classification criteria for keratoconus eyes. Kamiya et al., used the Amsler-Krumeich (AK) classification technique for Grades 1–4, which strongly emphasises keratometry but also often combines refraction and pachymetry measures. Using a distinct classification method, dubbed RETICS, Blazquez et al., and Bolarin et al.. The physical representations of keratoconus staging are illustrated here.



Dataset

Most of the research in this field is concerned with image datasets for the prediction of keratoconus, such as this publicly available dataset provided by Al-Timemy et al., But the data used for this research is numerical. Between 2014 and 2017, data on 124 keratoconus patients was gathered at the Vision Eye Institute Chatswood (VEIC) in Sydney, Australia. Table 1 and Table 2 contain information that has been extracted to be used as variables of consideration for the training process. Based on clinical expertise, all patients were classified using the AK classification, which takes into account the presence and severity of scarring, mean central keratometry (MCK), minimum corneal thickness (MCT), myopia, and astigmatism (MA). Table 3 illustrates how patients are classified using the AK categorization system [1]. Table 4 shows the distribution of cases for each grade.

Table 1. Risk Factor Data [1].

Variable
Atopy Ethnicity
Primary optical aid Gender
Eye history Diabetes Family history Allergy Hypertension General Health Eye rubbing

Table 2. Pentacam and clinician data [1].

Variable
Steep keratometry
Flat keratometry Thinnest pachymetry Sphere
Cylinder Refractive axis X-axis
y-axis Pachymetry
Amsler-Krumeich (AK) classification

Table 3. Amsler–Krumeich (AK) classification scheme [1].

Grade	Characteristic
1	Eccentric steeping
	MCK 48.00D
	MA 5.00D
2	Absence of scarring MCT 400 μ m
	MCK 53.00D
	MA 5.00–8.00D
3	Absence of scarring MCT 300–400 μ m MCK 53.00D
	MA 8.00–10.00D
4	Central corneal scarring

Grade	Characteristic
	MCT 200 μm
	MCK 55.00D
	Refraction not measurable

Table 4. Number of cases.

Grade	Cases
1	140
2	51
3	24
4	22
Total	237

Dataset manipulation and delimitation

The collected dataset contains metrics that are collected according to the assessment of the clinician. For this paper, these data points are not advisable and were removed from the analysis as they do not fall in line with the goal of using data readily available from the patient and the Pentacam (or any other appropriate topography device). The dataset was also split into two sections for the training and testing of the model, with the training section comprising 90% of the entire dataset and the test section 10%.

Data analysis

Quantitative analysis was carried out on the dataset to assess the correlation between the various attributes within it. These correlations will be separated according to the source of the data to provide a useful analysis of the significance of each attribute. The dataset will be analyzed in three different sections: the risk factor data readily available from the patient, the pentacam data readily available from the device, and the dataset comprising both parts to see the relative effect of the dataset sections on their own. Within this field of research, the sample size of data for applications of this nature is usually much larger to make the predictive model more generalizable. However, this project works on a relatively small dataset with the assumption that the ML techniques will offset this drawback. In addition, the demographic characteristics of the dataset are evaluated to give richer interpretations of the data and opportunities for development.

Significance:

Corneal disorders are the world's second leading cause of blindness. Keratoconus (KC) is a progressive corneal ectasia characterized by a thinning and protrusion of the cornea. The development of KC is influenced by both genetic and environmental factors such as eye rubbing and nocturnal ocular compression appearing to play a more significant role.

Research Aim:

Machine Learning and Deep Learning in diagnosing and managing corneal disorders is increasingly significant, offering improved diagnostic accuracy, efficiency, and potential for personalized patient care. Future research should focus on further refining Machine Learning and Deep Learning models, validating their effectiveness in clinical settings, and exploring their integration into routine ophthalmic practice to enhance patient outcomes.

Conclusions:

This research highlights the importance of machine learning methods and risk factor data in the diagnosis of keratoconus and highlights the patient's primary optical aid as the strongest risk factor. The goal of this research is to support the work of ophthalmologists in diagnosing keratoconus and providing better care for the patient through using Machine Learning and Deep Learning.

References:

1. Zorto, A. D., Sharif, M. S., Wall, J., Brahma, A., Alzahrani, A. I., & Alalwan, N. (2023). An innovative approach based on machine learning to evaluate the risk factors importance in diagnosing keratoconus. *Informatics in Medicine Unlocked*, 38, 101208.
2. Ambrósio Jr, R., Machado, A. P., Leão, E., Lyra, J. M. G., Salomão, M. Q., Esporcatte, L. G. P., ... & Lopes, B. T. (2023). Optimized artificial intelligence for enhanced ectasia detection using Scheimpflug-based corneal tomography and biomechanical data. *American journal of ophthalmology*, 251, 126-142.