

# The Arrangement of a Framework, Scheimpflug Imaging and the Modern Treatment of the Ectatic Corneal Disorder: Keratoconus

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## Abstract

**Objective:** To review recent advancements in the understanding, diagnosis, and management of keratoconus, emphasizing the role of Scheimpflug imaging and the Belin ABCD classification in early detection and treatment planning. **Design:** Systematic review conducted in accordance with PRISMA 2020 guidelines. **Methods:** Electronic searches were performed using PubMed, Scopus, and Google Scholar (2010–2025) with keywords “Scheimpflug imaging,” “keratoconus,” and “corneal tomography.” Out of 178 identified records, 23 studies met inclusion criteria and were analyzed qualitatively for diagnostic precision, epidemiology, and treatment outcomes. **Results:** Scheimpflug-based imaging significantly enhances diagnostic accuracy by generating 3D corneal tomography and evaluating both anterior and posterior curvatures, pachymetry, and biomechanical indices. Epidemiological data reveal higher keratoconus prevalence in Asia and the Middle East. Management strategies—ranging from contact lenses and corneal collagen cross-linking (CXL) to DALK, PK, ICRS, and CAIRS—demonstrate improved stabilization and visual outcomes. The Belin ABCD classification outperforms traditional Amsler-Krumeich grading for progression monitoring. **Conclusion:** Integration of advanced imaging and modern classification systems has revolutionized keratoconus management. Scheimpflug imaging, when combined with personalized therapeutic approaches, allows earlier intervention, better disease stabilization, and enhanced visual prognosis.

**Keywords:** *Belin ABCD classification, Corneal-Allogenic-Ring-Segments (CAIRS), Corneal-Collagen-Cross-Linking with Riboflavin (C3R/CXL/CCL/KXL), Deep-Anterior-Lamellar-Keratoplasty (DALK), Ectasia, Penetrating-Keratoplasty (PK), Intrastromal-Corneal-Ring Segments (ICRS), Keratoconus, Scheimpflug Imaging & Topography.*

## Introduction

Burchard Mauchart (1748) named it Staphyloma Diaphanum. The name tapered cornea was presented in 1854 by the English doctor John Nottingham. At long last, John Horner (1869), the Swiss doctor, authored the term Keratoconus <sup>[1]</sup>. It is defined as a corneal ectatic disorder showing prolonged thinning and steepening of the central or paracentral cornea to cause high irregular astigmatism.

Keratoconus (Greek; kerato means cornea and konos means cone) is the forward protrusion of the cornea. Morphologically, if the collagen fibres of the cornea lose their elasticity, hence convert into a cone-like shape instead of their natural dome shape <sup>[2]</sup>.

Usually, Keratoconus is a bilateral, asymmetric, non-inflammatory, idiopathic ocular disorder characterised by thinning and steepening of the cornea. It can affect all the tissue layers of the cornea to cause high myopia with irregular astigmatism, often, and the visual potential gets lower. Corneal thinning most commonly occurs at the inferior-temporal site, but it can also be central or

paracentral. Various studies indicate associations between keratoconus, systemic disease, and ocular inflammation <sup>[3-10]</sup>.

The cornea is a transparent tissue covering the anterior chamber of the eye and borders the limbus, where it joins the sclera. It refracts light and contributes to two-thirds of the eye's resolution power. Its parabolic structure measures 11.5 mm horizontally and 11.0 mm vertically. The cornea becomes thickened at the periphery (660 µm) compared to the central zone (515 µm) <sup>[11,12]</sup>.

The corneal tissue consists of five primary layers, with the addition of Dua's layer. From anterior to posterior, these layers are: <sup>[13-18]</sup>

1. Corneal Epithelium: A non-keratinised, delineated squamous epithelium is persistent with the conjunctival epithelium, keeping up with the air/tear-film interface.
2. Bowman's Layer: Anterior limiting membrane composed of collagen fibres protecting the corneal stroma.
3. Corneal Stroma: The thickest middle layer is made up of collagen fibres.

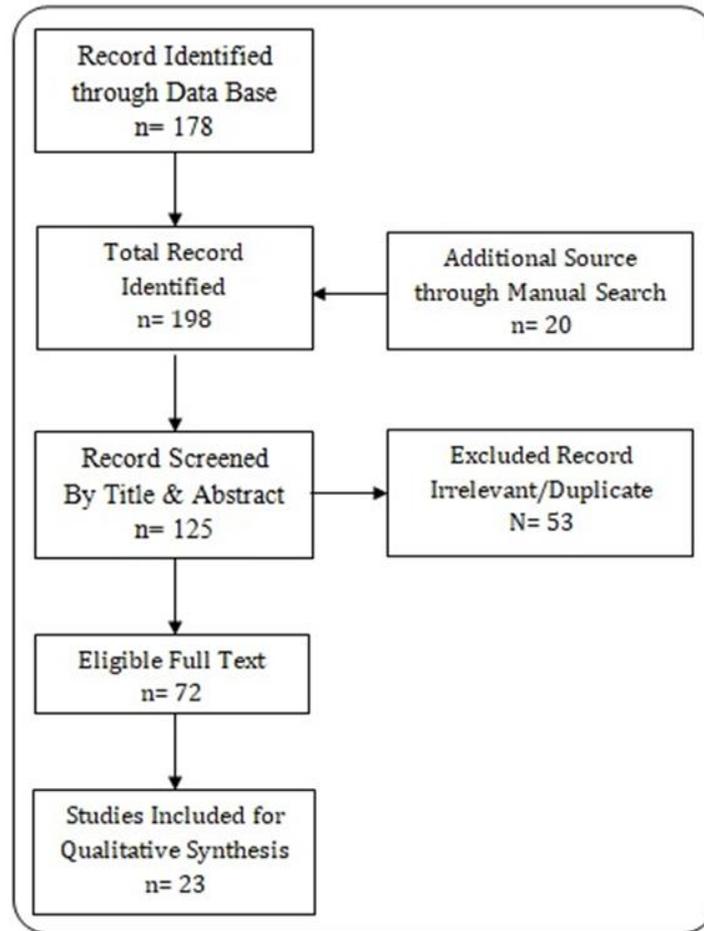
4. Descemet's Membrane: A thin acellular collagen fibre limiting membrane over the corneal endothelium.
5. Dua's Layer: A thin and strong layer between the stroma and Descemet's membrane.
6. Corneal Endothelium: It is a squamous cell layer anterior to the aqueous humour. Instead of growing back to replace lost cells, endothelial cells elongate, and the density of cells decreases overall.

**Methodology**

This systematic review adhered to PRISMA 2020 guidelines. Electronic searches were conducted via PubMed, Scopus, and

Google Scholar for English-language studies (2010–2025) using terms such as “Scheimpflug imaging”, “keratoconus”, “Pentacam”, “Galilei”, “Sirius”, and “Corvis ST”. Duplicates were removed, and full-text articles were screened based on predefined criteria. To ensure thoroughness, additional sources including books and chapters were identified through Google searches using combinations of “keratoconus”, “corneal ectasia”, “pellucid marginal degeneration” with keywords like “aetiology”, “pathophysiology”, “oxidative stress”, and “inflammation”.

In total, 178 records were identified through database searches. After duplicate removal (n = 53), 125 records were screened. Of these, 72 full-text articles were assessed and, 23 studies were included in the qualitative synthesis (**Fig- 1 & Tab-1**).



**Figure 1: Prisma Flow Chart**

**Table 1: Studies Included in Qualitative Synthesis**

	Author (Year)	Study Design / Device	Sample Size	Focus Area	Key Findings
1	Vinay B Agrawal et al., <sup>[34]</sup> (2011)	Single-centre, retrospective cohort	274	Topographic findings	Younger patients had more severe KC than Western populations
2	Millodot M et al., <sup>[20]</sup> (2011)	Cross-sectional study	981	Videokeratography	High KC prevalence in Jerusalem, similar to India
3	A.S. Jun et al., <sup>[7]</sup> (2011)	Questionnaire + Pentacam	18	Corneal biomechanics	IL-17 linked with stromal degeneration in KC
4	Xu L et al., <sup>[23]</sup> (2012)	Population-based study	3468	OCT biometry	48+D corneal power seen in 0.9% of Chinese >50 yrs
5	Henriquez MA et al., <sup>[56]</sup> (2012)	Prospective study	9	Topographic mapping post-CXL	FR implantation after CXL is safe and effective
6	Dua HS et al., <sup>[17]</sup> (2013)	Clinical/ experimental	25	Corneal anatomy	Described new pre-Descemet's strong stromal layer
7	Kamiya K et al., <sup>[50]</sup> (2014)	Prospective + Pentacam HR	126	Elevation difference	Useful for early KC detection

8	Mohammad Naderan et al., <sup>[32]</sup> (2015)	Prospective case-control	922	KC risk factors	Eye rubbing + family history linked with KC
9	Belin MW et al., <sup>[48]</sup> (2016)	Normative database	672	AK classification	Posterior curve/thinnest pachymetry more reliable
10	Lee R et al., <sup>[47]</sup> (2018)	Case report	1	Thyroid link	KC associated with thyroid dysfunction
11	Sashia Bak-Nielsen et al., <sup>[27]</sup> (2019)	Observational	National registry data	KC prevalence	KC 40 per 100,000 in Danish registry
12	Ritu Arora et al., <sup>[30]</sup> (2019)	CXL + Contact Lens	5	Pediatric KC	Rapid progression in 9–14 year olds
13	Grisevic S et al., <sup>[49]</sup> (2020)	Prospective	22	Topography/pachymetry	CXL stabilized KC progression
14	Mazharian A et al., <sup>[41]</sup> (2020)	Case-control	33	Questionnaire	Eye rubbing and sleep posture linked to KC
15	AlQahtani BS et al., <sup>[25]</sup> (2021)	Retrospective case series	29	CXL efficacy	CXL effective in halting KC
16	Chan E et al., <sup>[23]</sup> (2021)	Longitudinal cohort	1259	Pentacam	Early screening essential for progression control
17	Noor Alqudah et al., <sup>[45]</sup> (2021)	Retrospective	234	Topography	Higher prevalence of KC in young females
18	Mohan et al., <sup>[36]</sup> (2022)	Prospective	700	Tomographic classification	Screening essential in at-risk children
19	Jacinto SR et al., <sup>[4]</sup> (2022)	Review	-	Wavefront aberrometry	Highest prevalence in 20–30 year olds, Middle East
20	Hashemi et al., <sup>[19]</sup> (2023)	Case-control + Galilei	300	Socioeconomic risks	Poor hygiene and SES linked with KC
21	Susanne Marx-Gross et al., <sup>[5]</sup> (2023)	Cohort study + Scheimpflug	12,423	Risk factors	No correlation with atopy, diabetes, or smoking
22	Hina Kounsar et al., <sup>[26]</sup> (2023)	Retrospective	437	Regional risks	KC in Kashmir linked with VKC, UV, eye rubbing
23	Anthony V Das et al., <sup>[21]</sup> (2024)	Cross-sectional	2,384,523	Epidemiology	KC bilateral, common in males, 10% require surgery

## Results

A total of 178 studies were identified through database searches, of which 23 met the inclusion criteria under the PRISMA 2020 framework. The selected studies highlighted a consistent trend of increasing keratoconus prevalence globally, with the highest rates reported in the Middle East, India, and East Asia.

Scheimpflug-based imaging systems such as Pentacam, Galilei, and Corvis ST demonstrated superior diagnostic precision by providing three-dimensional tomography of both the anterior and posterior corneal surfaces. These modalities enabled early detection of subclinical ectasia, accurate pachymetric assessment, and biomechanical evaluation, facilitating stage-appropriate management.

The Belin ABCD classification system proved more reliable than the traditional Amsler-Krumeich grading for monitoring disease progression, incorporating anterior and posterior curvature, thinnest pachymetry, and visual acuity parameters.

Therapeutically, corneal collagen cross-linking (CXL) remains the cornerstone for halting disease progression, while adjunctive options such as intracorneal ring segments (ICRS), corneal allogenic ring segments (CAIRS), deep anterior lamellar keratoplasty (DALK), and penetrating keratoplasty (PK) further enhanced visual outcomes in advanced cases.

Collectively, these findings affirm that advanced imaging, refined classification, and personalized treatment have substantially improved the diagnostic accuracy and visual prognosis in keratoconus management.

## Epidemiology, Aetiopathogenesis, and Pathophysiology

Keratoconus shows marked geographical variation, with higher prevalence in Australia, China, India, and the Middle East<sup>[19-23]</sup>. The disease usually begins around puberty and progresses for 10-20 years, causing irregular astigmatism, corneal thinning, and visual deterioration<sup>[24]</sup>. Environmental and climatic factors contribute significantly hot, dry regions such as India and the Middle East report greater prevalence than cooler countries like Finland, Denmark, Japan, and Russia<sup>[6,34-38]</sup>. Ethnic differences are evident, with Asian populations showing 4.4-7.5 times higher risk compared with Western groups<sup>[40,41]</sup>. Genetic predisposition accounts for approximately 6-10% of cases, with frequent associations to eye rubbing, vernal keratoconjunctivitis, and atopy<sup>[26-28,37-43]</sup>.

The aetiology is multifactorial, involving genetic, biochemical, and mechanical factors. Associations with systemic diseases such as Down syndrome, Ehlers-Danlos syndrome, Leber's congenital amaurosis, hypothyroidism, and connective tissue disorders have been documented<sup>[44,45]</sup>.

Although traditionally described as non-inflammatory, growing evidence supports a quasi-inflammatory basis. Elevated levels of matrix metalloproteinase-9 (MMP-9), interleukin-6 (IL-6), and tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) suggest biochemical degradation and oxidative stress within the corneal stroma<sup>[8]</sup>. Structural changes include Bowman's layer fragmentation, collagen fiber disorganization, and stromal thinning leading to conical protrusion and scarring<sup>[3-10]</sup>.

Thus, keratoconus is best regarded as a biomechanical and oxidative degenerative disorder influenced by both genetic and environmental determinants.

**Classification**

The outmoded Amsler-Krumeich (AK) grading method for keratoconus, introduced by Marc Amsler (1947), is based on keratometry and optical pachymetry and solely measures central anterior curvature and central thickness. It was best to treat with rigid gas permeable lenses and Penetrated Keratoplasty, but its clinical utility is limited because current imaging allows for earlier diagnosis (Tab-2) [1,24,48,49]

The same kind of limitations are found in different keratoconus classification systems. The Belin ABCD characterisation framework for the Oculus Pentacam was intended

to address these lacks as well as the necessities recognised in the Worldwide Agreement on Keratoconus and Ectatic Illness. The ABCD parameters were originally supplied as a complete staging system with an additional Belin ABCD Progression Display.

The new ABCD system is subdivided into four measurements, where Parameter "A" concerns the 3.0 mm area of the thinnest zone of the Anterior Radius of Curvature. In a 3.0 mm region around the most slender zone of the cornea, the back range of the curve is addressed by boundary "B". The most slender pachymetry in  $\mu\text{m}$  is boundary "C", and the user-entered "Distance Best Corrected Visual Acuity" is parameter "D" (Tab-3) [48-51].

**Table 2: Amsler Krumeich Classification System for Keratoconus**

Amsler Krumeich Classification	
STAGE I:	1. Eccentric steepening myopia/astigmatism < -5.00 D 2. Mean keratometry value < 48.0 D
STAGE II:	1. Myopia with or without astigmatism > -5.00 D but < -8.00 D 2. Mean keratometry value < 53.0 D 3. Lack of scarring 4. Minimum apical corneal thickness > 400 $\mu\text{m}$
STAGE III:	1. Myopia/astigmatism > 8.00 D but < 10.00 D 2. Mean keratometry value > 53.0 D 3. Absence of scarring 4. Minimal apical corneal thickness < 400 $\mu\text{m}$ but > 300 $\mu\text{m}$
STAGE IV:	1. Refraction not possible 2. Mean keratometry value > 55.0 D 3. Central corneal scarring 4. Minimum central corneal thickness < 300 $\mu\text{m}$

**Table 3: ABCD Classification System for Keratoconus**

ABCD STAGES	A Ant. Radius of Curvature and power (3 mm Zone of thinnest area)	B Post. Radius of Curvature and Power (3 mm Zone of thinnest area)	C Thinnest Pachymetry ( $\mu\text{m}$ )	D (Distance best corrected visual acuity)	Scarring
Stage 0	>7.25 mm (<46.5 D)	>5.90 mm (<57.25 D)	>490 $\mu\text{m}$	=20/20 (=1.0)	-
Stage I	>7.05 mm (<48.0 D)	>5.70 mm (<59.25 D)	>450 $\mu\text{m}$	<20/20 (<1.0)	-, +, ++
Stage II	>6.35 mm (<53.0 D)	>5.15 mm (<65.5 D)	>400 $\mu\text{m}$	<20/40 (<0.5)	-, +, ++
Stage III	>6.15 mm (<55.0 D)	>4.95 mm (<68.5 D)	>300 $\mu\text{m}$	<20/100 (<0.2)	-, +, ++
Stage IV	<6.15 mm (>55.0 D)	<4.95 mm (>68.5 D)	= 300 $\mu\text{m}$	<20/400 (<0.05)	-, +, ++

**Physical Examination:** [9,52,53]

A thorough eye exam is essential for assessing general eye health, using ancillary tests such as corneal curvature, astigmatism, corneal thickness, pre and post-refraction measurement of visual potential (with spectacles or RGP lenses), pinhole VA, retinoscopy for scissor shadow, slit-lamp examination, keratometry, computerized topography/tomography, ultrasound pachymetry, and tear film biomarkers for stability. Supportive tests include:

- [1] Rizutti's sign: A conical reflection on the nasal cornea is noted if a penlight is projected temporally.
- [2] The Fleischer ring is developed by a brown iron deposit in the cone's epithelium that may be viewed using a cobalt blue filter.
- [3] Vogt's striae are fine, vertically parallel striations in the stroma that vanish with strong pressure application over the eyeball.
- [4] Munson's sign refers to the bulge of the lower lid at the lower gaze.

**Signs**

Asymmetric refractive error with high and irregular astigmatism, retinoscopy scissor reflex, inferior steepening, skewed axis, higher keratometry readings, and corneal thinning at the most conspicuous region are all early symptoms of keratoconus. Later indications

include Bowman's membrane cracks, acute hydrops (aqueous entrance into the stroma that causes oedema, reduced vision, sensitivity to light, tearing, and discomfort), and stromal scarring after acute hydrops resolution.

**Management**

Initially, conditions such as atopic or vernal conjunctivitis and sleep apnea should be addressed. Management aims to maintain functional visual acuity and control progressive corneal changes. Spectacles and soft toric lenses can correct irregular astigmatism, but most cases require rigid gas-permeable lenses. Advanced options include Rose K, custom-designed lenses (based on topography and wavefront), semi-scleral, piggyback, scleral, PROSE, and hybrid lenses.

Patients intolerant to lenses or those with central scarring may need surgery. Corneal collagen cross-linking (CXL) using riboflavin (C3R/CXL/CCL/KXL) is a minimally invasive treatment effective in halting keratoconus progression, showing corneal morphological changes within 3-6 months. The FDA-approved Photrexa + KXL system (for epi-off CXL) has long been used in Europe under CE certification. The conventional method involves epithelial removal, riboflavin application, and UV light activation for 30 minutes. Variants include "epithelium-off", "epithelium-on", and accelerated cross-linking [50,54].

In corneal hydrops, treatment focuses on symptom relief using cycloplegics, 5% sodium chloride, and pressure patches, followed by topical therapy for several weeks. Patients are advised to avoid eye rubbing.

Surgical options include DALK, PK, ICRS, and CAIRS. Some non-FDA-approved procedures include CXL with excimer laser, conductive keratoplasty, and ICRS [55].

ICRS come in various designs and are used in mild to moderate cases intolerant to lenses. Implantation requires >450 microns central corneal thickness at 7 mm zone. Though non-invasive, refractive correction is still needed with spectacles or lenses [56,57].

CAIRS, introduced by Dr. Soosan Jacob (2018), is a safe and effective option, especially when combined with CXL. Dr. Awwad refined its customisation. It is minimally invasive and supported by studies for treating mild to moderate keratoconus [57-62].

To reduce graft rejection, DALK replaces the anterior cornea while preserving deeper layers. It offers faster recovery and lower rupture risk, though it may be technically challenging and require conversion to PK [63].

Penetrating keratoplasty (PK), though effective, carries risks like infection, graft rejection, and wound rupture, and may necessitate optical correction with rigid lenses [63].

**Pachymetry vs Topography**

Pachymetry accurately measures corneal thickness to within 1–5 micrometres, with thicker areas shown in cool colours and thinner areas in warm colours on its map. It helps determine intraocular pressure and can indicate corneal oedema. Topography measures the cornea's front and back surfaces, producing graphical displays that

assess corneal health, calculate astigmatism, detect thinning, and aid in fitting customised contact lenses [64].

Traditional devices for diagnosing keratoconus use Placido-based corneal topography and are still widely used. However, the demerit is that it only measures the anterior corneal surface at a high false-positive rate. The anterior segment, encompassing the anterior and posterior corneal surfaces with close limbus-to-limbus coverage, can be imaged using more modern tomographic equipment such as anterior segment ocular computer tomography (OCT) and spinning Scheimpflug devices [64].

**Scheimpflug Devices**

Several instruments that make use of Scheimpflug imaging with corneal tomography are: the Pentacam system, Galilei, Corvis ST, TMS-5 and Sirius. The Pentacam system has a rotating Scheimpflug camera to make it competent to create a 3D map of the cornea [64].

Only a tiny portion of the subject is in focus when using a standard camera when it is unparallelled to the picture plane. The Scheimpflug principle connects with the geometry of the plane of focus, focal point and the image in an optical framework, with the condition when the lens plane doesn't resemble the image plane. The Scheimpflug principle bears the name of Austrian army Captain Theodor Scheimpflug. Initially, he used it to fix perspective distortion in photos taken from above (Fig-2).

This principle can be understood with an example: when the object and image planes are parallel, the image is sharp and focused. The unparallel object and image planes will not produce an image-focused entirely. By turning the picture plane as indicated by the Scheimpflug rule, the whole picture can be brought into concentration, in any event, when the article and picture planes are not equal [65-67].

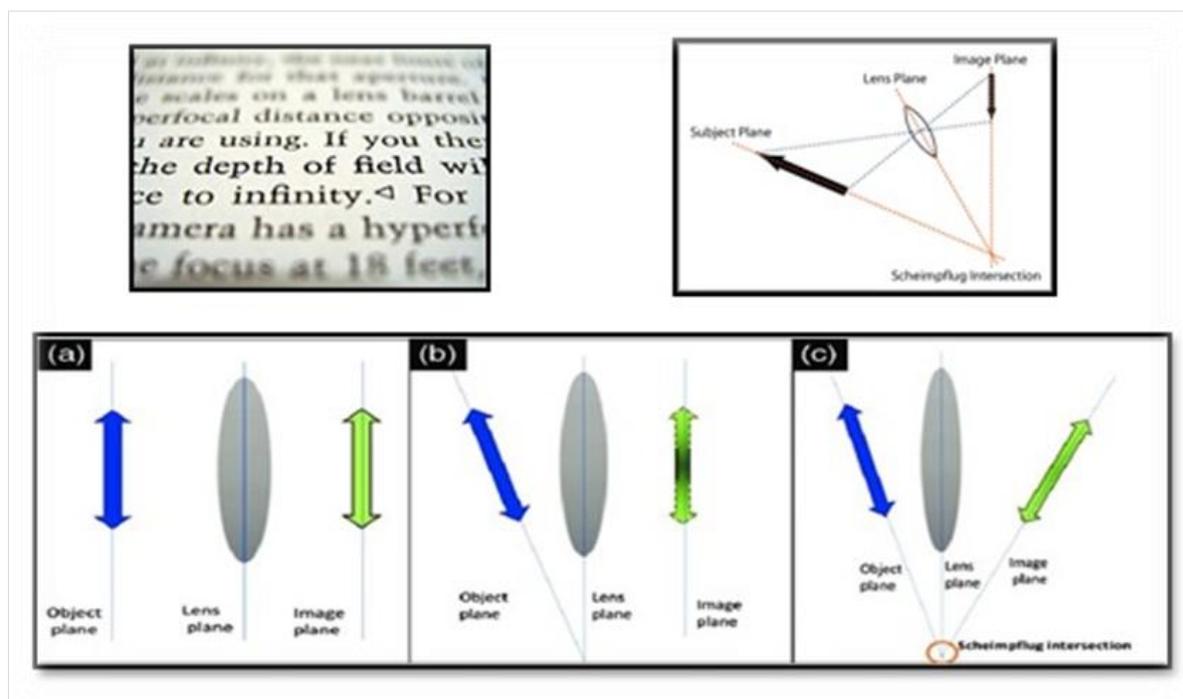


Figure 2: Concept of Scheimpflug Imaging [64]

**Interpretation of Pentacam**

The Oculus Pentacam uses Scheimpflug technology to generate topographic reports, including a cross-sectional image showing the cornea, anterior chamber, iris, and lens, as well as a 3D detail of the corneal shape. Corneal density is assessed using densitometry, with values below 30 considered normal. Conditions like corneal oedema increase the densitometry value. The overview and four maps report

include keratometry, pachymetry, and other values, a colour map illustrates corneal thickness, and an axial map shows the anterior corneal surface's curvature in diopters. Anterior and posterior float images, also referred to as elevation maps, use a best-fit sphere to depict the cornea's form rather than the cornea's refractive power [64].

Accurate patient identification, including age and eye type, is crucial at the beginning of the procedure. The quad or multi-map

option provides the best visual comparison of the data, so before evaluation, it should be taken care of. It is frequently helpful to utilise a tiny zone of absolute scale at a constant interval of 0.5 D, correcting the greenish colours to near-normal levels, to prevent mistakes from lost details or suspicious patterns. A brief examination of the scan is helpful since green colours, when seen as absolute values, reflect normative data. Usually, too much red is unnatural<sup>[64]</sup>.

The Pentacam Overview report is separated into four windows. A cross-sectional Scheimpflug picture of the cornea, anterior chamber, iris, and lens is seen in the top left window. Densitometry readings are shown in the top right window. Values over 30 suggest decreasing corneal clarity. A 3D picture of the cornea is shown in the lower left window, representing blue for the iris, green for the posterior cornea, and red for the foremost corneal surface. A pachymetry map, with a numerical scale, is displayed in the lower right window. This colour map shows corneal thickness, with warmer colours denoting thinner areas and cooler colours representing thicker parts<sup>[64]</sup> (Fig-3).

The numerical details for thinning, central-corneal thickness, and apical keratometry with anterior and posterior corneal elevations. The specific details of any measure can be assessed by taking a cursor on that point, to appear chart display and statistics boxes of the Scheimpflug topography. Useful information such as SimK, minimum corneal thickness, 3,5,7 mm zone irregularity, kappa angle, pupil diameter, and white-to-white may be found in the statistics box (Fig-4)<sup>[64]</sup>.

All findings should be cross-checked with slit lamp findings because corneal topography decreases its interpretative value by corneal artefacts, as in cases of nebulo-macular corneal opacities, dry eye, corneal neovascularisation, and corneal scars.

A sagittal map, sometimes referred to as an axial curvature map, may be seen in the top left section of the Pentacam 4 Map

Report. A colour scale indicates the power in diopters, and this map shows the anterior corneal surface curvature at each place in terms of dioptic values. Cooler hues denote flatter regions of the cornea, whereas warmer hues show a steeper corneal curvature. The top and lower left regions correspond to the elevation maps (anterior and posterior float). Warmer colours on these maps indicate corneal elevation above the best-fit sphere, while cooler colours indicate corneal depression below it (Fig-5).

The anterior axial map often shows different bowtie patterns. The top-left pattern indicates Pellucid marginal corneal degeneration with high against-the-rule astigmatism in a "crab claw" shape (Fig-6) while the top-right pattern shows inferior steepening in keratoconus. Topography frequently reveals astigmatism from keratoconus progression, eventually developing a skewed radial axis and further inferior steepening (Fig-6).

The anterior axial map of Pentacam defines a considerable inferior paracentral steepening in the keratoconus. The anterior and posterior floats display a paracentral bulge, suggesting focal elevation in comparison to a completely spherical surface, and the pachymetry map indicates thinning in this location (Fig-7).

The lower left pachymetry map is a colour-coded representation of corneal thickness, with cooler colours indicating thicker areas and warmer colours indicating thinner areas. The ocular surface disorder can be evaluated in the cases of pterygium, corneal scars, and Salzmann nodules (Salzmann's nodular degeneration or SND, a slowly progressive condition characterised by bilateral grey-white to bluish nodules measuring 1-3 mm, located anterior to Bowman's layer near the limbus or in the mid-peripheral cornea can induce irregular corneal astigmatism. Corneal topography can assess the refractive impacts of these circumstances, supporting infection observation and careful preparation (Fig-7)<sup>[69-72]</sup>.

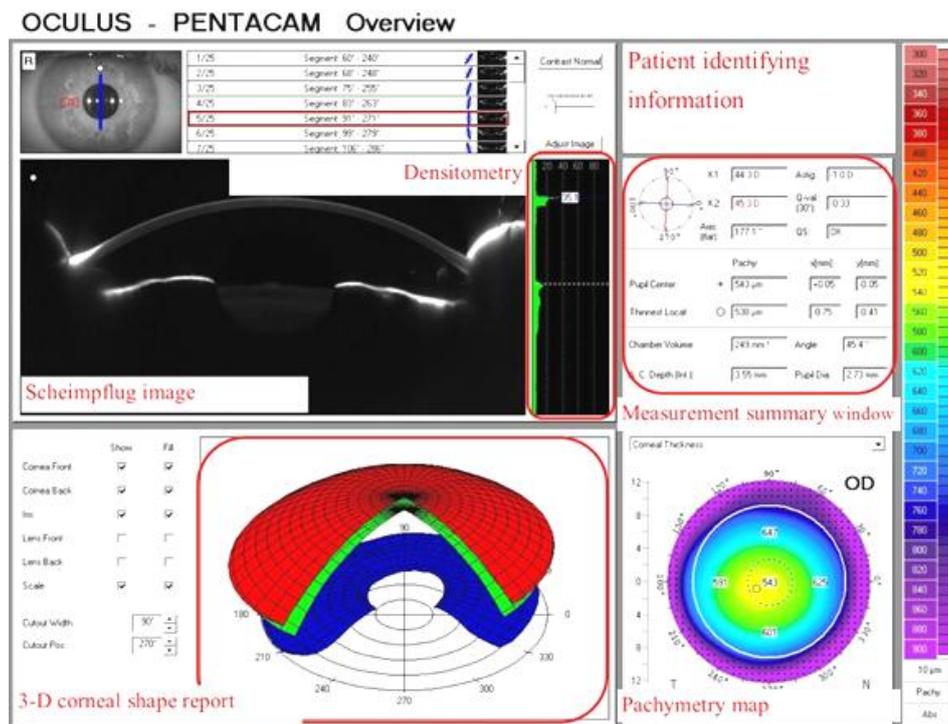


Figure 3: Pentacam Overview Window<sup>[67]</sup>



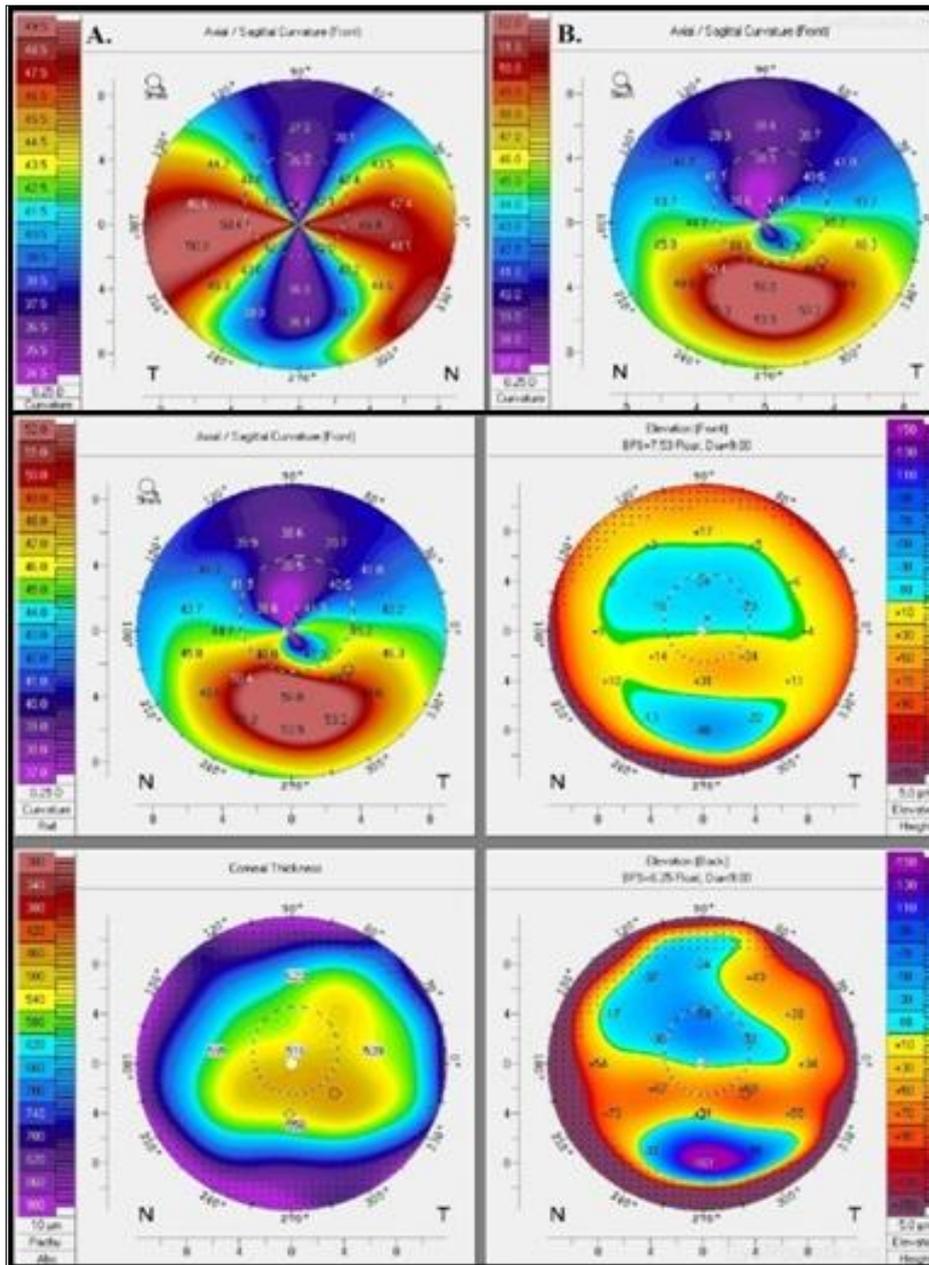


Figure 7: Pachymetry with Anterior Axial Map <sup>[67]</sup>

## Discussion

Ectatic corneal disorders, such as keratoconus and post-LASIK ectasia, are progressive conditions involving corneal thinning and steepening, leading to irregular astigmatism and visual deterioration. Early detection and accurate staging are essential for preventing progression and optimising outcomes.

The Amsler-Krumeich classification, once standard, is limited by its reliance on anterior curvature. In contrast, the Belin ABCD system integrates anterior/posterior curvature, thinnest pachymetry, and best-corrected visual acuity, offering more precise staging and earlier diagnosis.

Advances in imaging have improved diagnostic capabilities. While Placido-based topography assesses only the anterior surface, Scheimpflug imaging provides 3D tomography of both corneal surfaces, pachymetric data, and biomechanics—crucial for detecting subclinical ectasia, pre-surgical screening, and tracking progression.

Management has also evolved. Corneal Collagen Cross-Linking (CXL) is the primary treatment to stabilise the cornea. In mild-to-moderate cases, Intracorneal Ring Segments (ICRS) and

topography-guided PRK with CXL improve vision and corneal shape. Phototherapeutic Keratectomy (PTK) plus CXL can help in cases with anterior stromal opacity.

For advanced disease with scarring or thinning, surgery is necessary. Deep Anterior Lamellar Keratoplasty (DALK) preserves endothelium and lowers rejection risk, while Penetrating Keratoplasty (PKP) remains essential in full-thickness scarring, despite higher complication rates.

In conclusion, innovations in imaging and treatment have improved outcomes in ectatic corneal disorders. However, challenges remain in early detection, accessibility, and standardised care. Future research should focus on improving diagnostic tools, expanding minimally invasive options, and developing predictive models for disease progression.

## Limitations

This review highlights significant advancements in the diagnosis and management of ectatic corneal disorders. Much of the evidence is derived from observational studies, clinical reports, and region-

specific data, which may not fully represent global clinical practices. Additionally, while modern grading systems and imaging techniques like Scheimpflug imaging have enhanced early detection and disease monitoring, their availability and cost can limit their routine use, especially in resource-limited settings. The therapeutic approaches reviewed, including CXL, ICRS, and keratoplasty techniques, are supported by evolving clinical data, but standardised treatment protocols and long-term outcome studies are still limited. Furthermore, this review is narrative and does not include a systematic review or meta-analysis, which may affect the comprehensiveness of evidence comparison. Future research involving larger, multicenter, and long-term studies is needed to establish uniform guidelines and improve patient care strategies globally.

## Conclusion

Early diagnosis of corneal ectatic disorders significantly improves visual rehabilitation outcomes through timely non-surgical and surgical interventions. Diagnostic approaches have evolved from surface-based assessments to comprehensive tomographic analysis. The ABCD classification system, incorporating anterior/posterior curvature, thinnest pachymetry, and visual acuity, enables precise staging and personalised treatment planning.

The ABCD system is especially useful for monitoring progression and guiding outcomes after procedures like corneal collagen cross-linking (CXL) and refractive surgery. Scheimpflug imaging enhances diagnostic accuracy by providing detailed 3D corneal tomography, capturing key parameters such as elevation, pachymetry, and biomechanics. However, it is best used alongside tools like corneal biomechanics and epithelial mapping for a complete evaluation.

The integration of structured diagnostics and advanced imaging has transformed management strategies, allowing earlier intervention, better visual prognosis, and reduced complication risk. Emerging innovations—including biomechanical stabilisation, regenerative therapies, and AI-driven diagnostics—hold promise for further enhancing care.

In summary, combining advanced technologies like Scheimpflug imaging with refined systems such as ABCD, and applying them within modern treatment frameworks, has greatly improved outcomes in corneal ectasia. Continued innovation and accessibility remain crucial for optimising patient care and preserving vision.

## Declarations

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## Conflict of Interest

Nil

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## Ethical Clearance

Not Required

## Trial details

None

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