Refractive Errors and Astigmatism Presentation by Dr Ahmed Abass and Ms Lynn White

The annual Keratoconus Group AGM was bustling with members this year, and we were all waiting with bated breath to hear from Dr Ahmed Abass and Ms Lynn about their new research, development and testing of new glasses, which could be potentially extremely useful for Keratoconus patients in the future.

Dr Ahmed Abass started his presentation acknowledging colleagues working with him on the project at Liverpool University and collaborating organisations such as the NHS (Liverpool University Hospitals NHS Foundation Trust), Fight for Sight, **The Keratoconus Group** and St. Paul's Eye Unit.

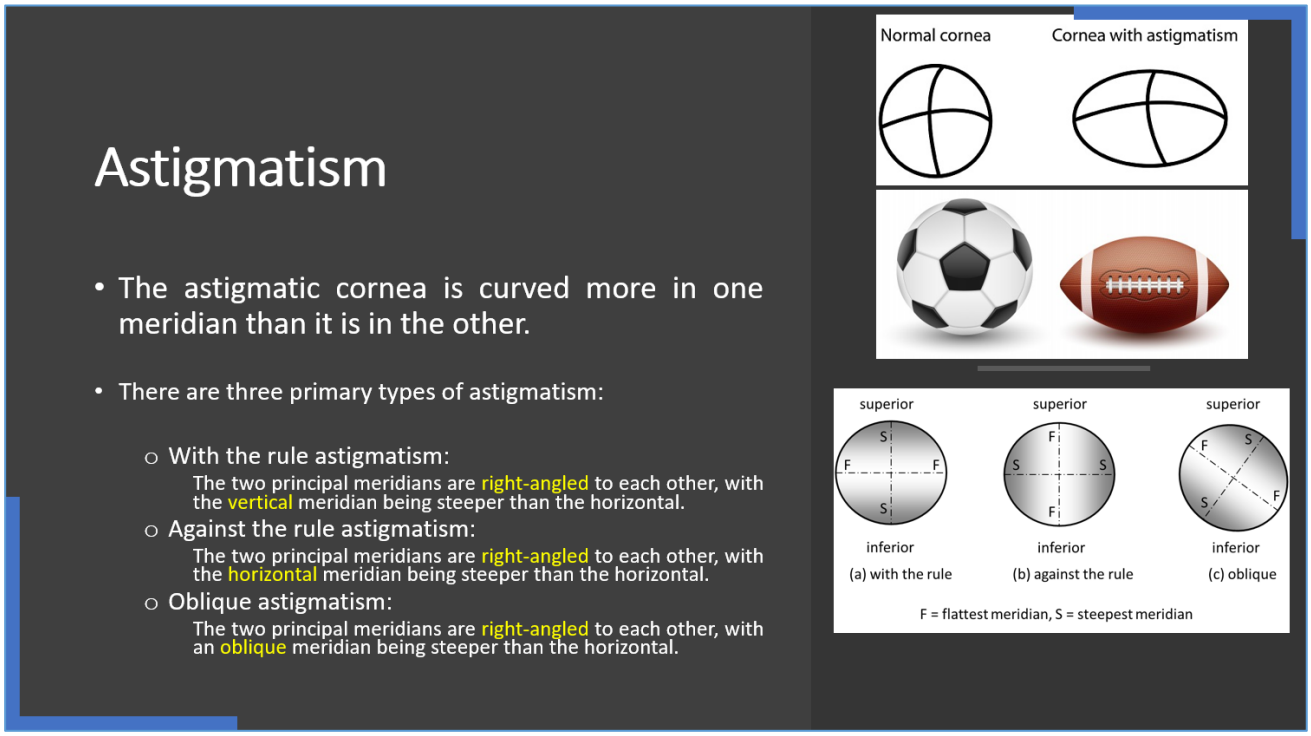
Refractive errors and **correction** were, in turn, explained. These two terms relate to problems with the eye's ability to focus light correctly on the retina, leading to blurred vision. The correction involves lenses or surgeries which help to bend the light correctly. This serves as the overall context for the specific condition of **astigmatism** that followed:

Astigmatism is a common type of refractive error that many Keratoconus patients face, where the cornea is curved more in one meridian than another, rather than being spherical. This causes light to focus **unevenly** on the **retina**, resulting in **blurred** or **distorted images**. In addition, there are three types of **astigmatism**: **with-the-rule astigmatism**, **against-the-rule astigmatism** and **oblique astigmatism**.

There are visual analogies for **astigmatism** whereby a normal cornea is shaped like a football and an astigmatic cornea is shaped more like a rugby ball. Dr Ahmed Abass further provided some illustrative diagrams to show cross sections of the cornea with different steepest meridians.

A summary of the key implications of the information is presented below:

- **Astigmatism** causes blurred or distorted vision, impacting daily activities like reading or driving.
- **Glasses**, **contact lenses**, and **refractive surgery** (e.g., LASIK) can correct astigmatism by adjusting how light is focused onto the retina.
- **Early detection** through **routine eye exams** is essential, especially for children and those with symptoms of eye strain or headaches.
- **Knowing** the **specific type** of **astigmatism** is critical for prescribing accurate corrective lenses or performing surgery.

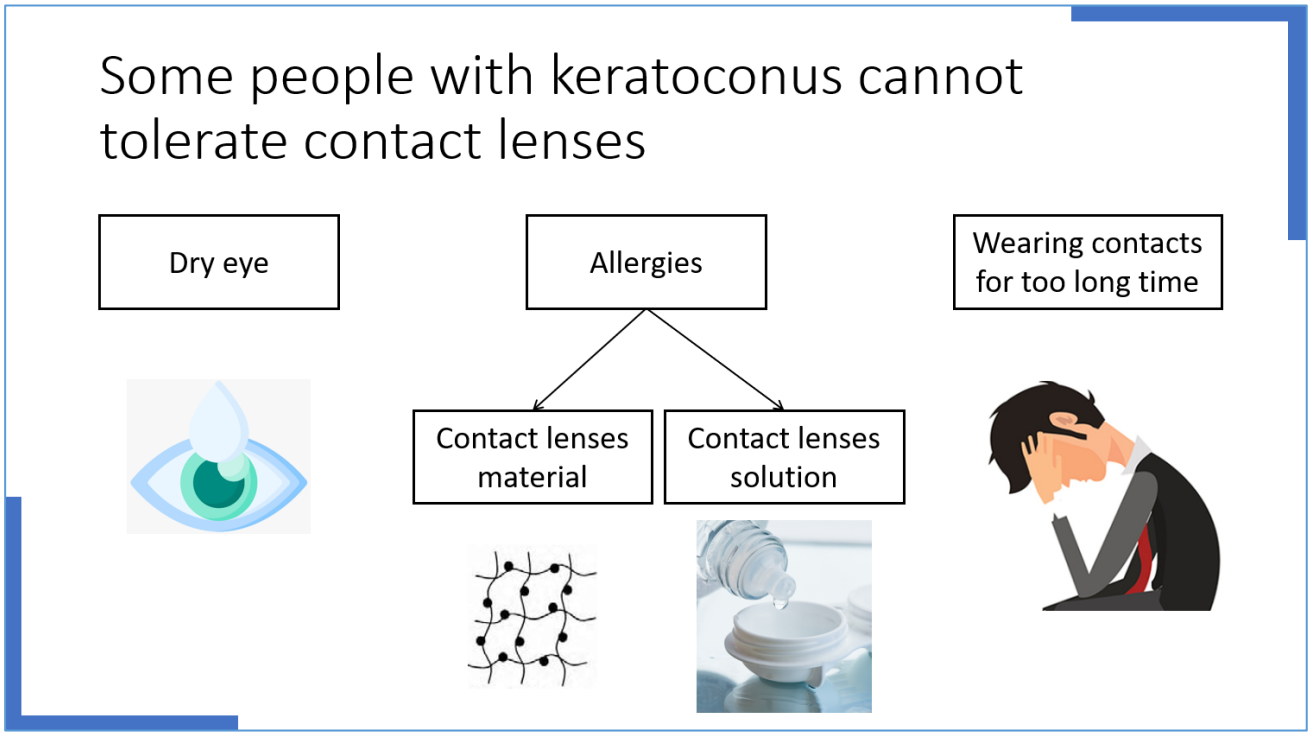


Ahmed continued his presentation by discussing contact lens intolerance in keratoconus**,** which many patients may have experienced. This may occur due to several factors such as:

Dry eye which is common in patients with keratoconus, where the eye does not produce enough tears or has poor tear quality, causing discomfort with the lenses.

Allergies to **contact lens material** - certain materials may trigger allergic reactions or sensitivities. In addition to **contact lens solutions** where **preservatives** are ingredients in the cleaning or disinfecting solutions that may also cause irritation or allergic responses.

Prolonged wear of contact lenses for extended periods of time can lead to eyestrain, discomfort, or even ocular damage, especially in patients with keratoconic eyes that are already sensitive.



In addition, Ahmad explained non-orthogonal **astigmatism** in patients with **keratoconus**. He mentioned that keratoconus causes **irregular astigmatism**, particularly **non-orthogonal astigmatism**, where the steepest and flattest meridians of the cornea are **not exactly 90° apart**, unlike **regular** (orthogonal) **astigmatism**.
Additionally, he provided topography maps which illustrated the difference in optical power across the cornea.

Furthermore, in **orthogonal astigmatism**, the axes are cleanly aligned (e.g., 90° apart). However, in **non-orthogonal astigmatism**, the axes may deviate from this, resulting in more **complex visual distortions** that are harder to correct with standard lenses or glasses.

Moreover, Dr Ahmed Abass mentioned that there are **limitations** of **glasses** for **keratoconus patients**. This is because glasses are generally ineffective in fully correcting vision for keratoconus due to the complexity of the corneal distortion:

Standard glasses correct vision using a combination of:

- **A sphere** - For **near sightedness** (myopia) or **far sightedness** (hyperopia).
- **A cylinder** - for **astigmatism,** assuming **regular** and **symmetrical curvature** changes.

Nonetheless, in **keratoconus patients,** it is essential to consider:

- The **cornea's irregular** and **conical shape** which means that its **distortion** does not follow a predictable access-aligned geometry.
- This **misalignment** between the actual corneal shape and the lens design assumptions leads to **incomplete** or **poor correction** of **vision** with **glasses**.

The **key implications** of the above information are:

- **Contact lens intolerance** is a significant **challenge** in **keratoconus management**. Eye care professionals must consider alternative treatments such as scleral lenses or surgical options.

- **Non-orthogonal astigmatism** complicates both diagnosis and correction, requiring advanced imaging and customised lens design.
- **Glasses are often insufficient** for visual correction in keratoconus due to the **irregular nature** of the **cornea**; hence, reliance on speciality lenses (e.g. rigid gas permeable, hybrid, or scleral lenses) is common.
- **Personalised care** is critical - each **keratoconus** patient's eyes may vary in terms of **severity**, **progression**, and **tolerability** to correction methods.
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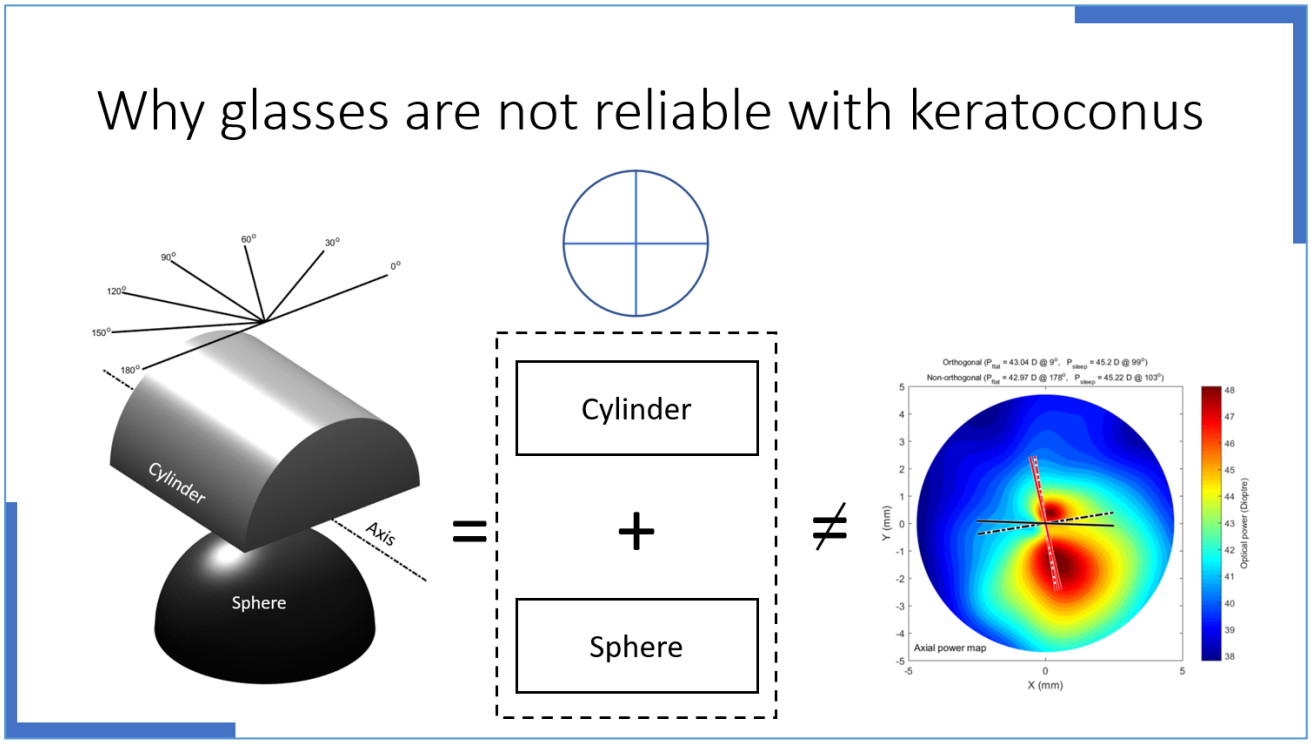
Comprehensive Overview

1. Why Glasses Are Not Reliable with Keratoconus

- Glasses are designed to correct **regular astigmatism**, assuming a consistent, orthogonal curvature of the eye.
- Standard lenses use a **combination** of **spherical** and **cylindrical corrections**, aligned along standard meridians.
- **In Keratoconus patients**, a condition where the **cornea thins** and **bulges** into a **cone shape**, introduces **irregular** and **non-orthogonal astigmatism**.
- The **optical distortion** caused by **keratoconus** does **not match the simple combination of sphere and cylinder corrections** offered by glasses.



2. Non-Orthogonal Astigmatism Prevalence

- Significant prevalence of **non-orthogonal astigmatism** has been found in:
    - **39% of Brazilian keratoconic eyes**
    - **26% of Chinese keratoconic eyes**
- These rates highlight the **limitation of conventional lens prescriptions**, which assume **orthogonality**.
- The **data and pie charts** provided showed a measurable proportion of both **normal** and **keratoconic eyes** deviating from **standard astigmatic** assumptions.

- This calls for re-evaluating **standard prescription methods**, recommending that prescriptions consider the **two power meridians independently**, rather than assuming they are at 90° to each other.

3. High-Order Aberrations (HOAs)

- **Wavefront-guided spectacles** (which correct HOAs) are theoretically **possible** but **difficult** to **implement** in practice.
- These **aberrations** include **irregularities in the eye's optics** that cannot be corrected by standard lenses.
- **Contact lenses offer better centring** and alignment with the **visual axis** compared to **spectacles**, **improving correction** of HOAs. This is because **contact lenses** sit directly on the **eye surface**, **moving** with the **eye** and providing a **wider**, **unobstructed field** of **vision**.
- Even with slight **decentration**, specially designed optics in **contact lenses** can offer a **reasonable level of vision correction**.
- Mathematical surface reconstruction shows that complete correction is **complex**.
- However, this approach is suitable for some daily activities, even if it does not provide the perfect correction.

Key Implications

1. **Limitations of Spectacles**: Glasses cannot adequately address the complex optical distortions caused by keratoconus due to their reliance on basic spherical and cylindrical corrections.
2. **Need for Updated Prescription Models**: The high prevalence of **non-orthogonal astigmatism**, especially in **keratoconic** eyes, underlines the need to possibly abandon the assumption of orthogonal meridians in vision correction.
3. **Superiority of Contact Lenses**: For keratoconus patients, specially designed contact lenses (e.g., rigid gas permeable or scleral lenses) offer better alignment and correction of both low and high-order aberrations.
4. **Role of Advanced Optics**: While wavefront-guided corrections present a promising future, current practical application in spectacles is limited. Clinical focus should be on **advancing lens design** and **fitting strategies** for **contact lenses**.
5. **Tailored Vision Solutions**: Future prescription systems should be more **dynamic** and **personalised**, incorporating measurements of **irregular astigmatism** and HOAs rather than relying on **standard cylindrical models**.

Comprehensive Overview

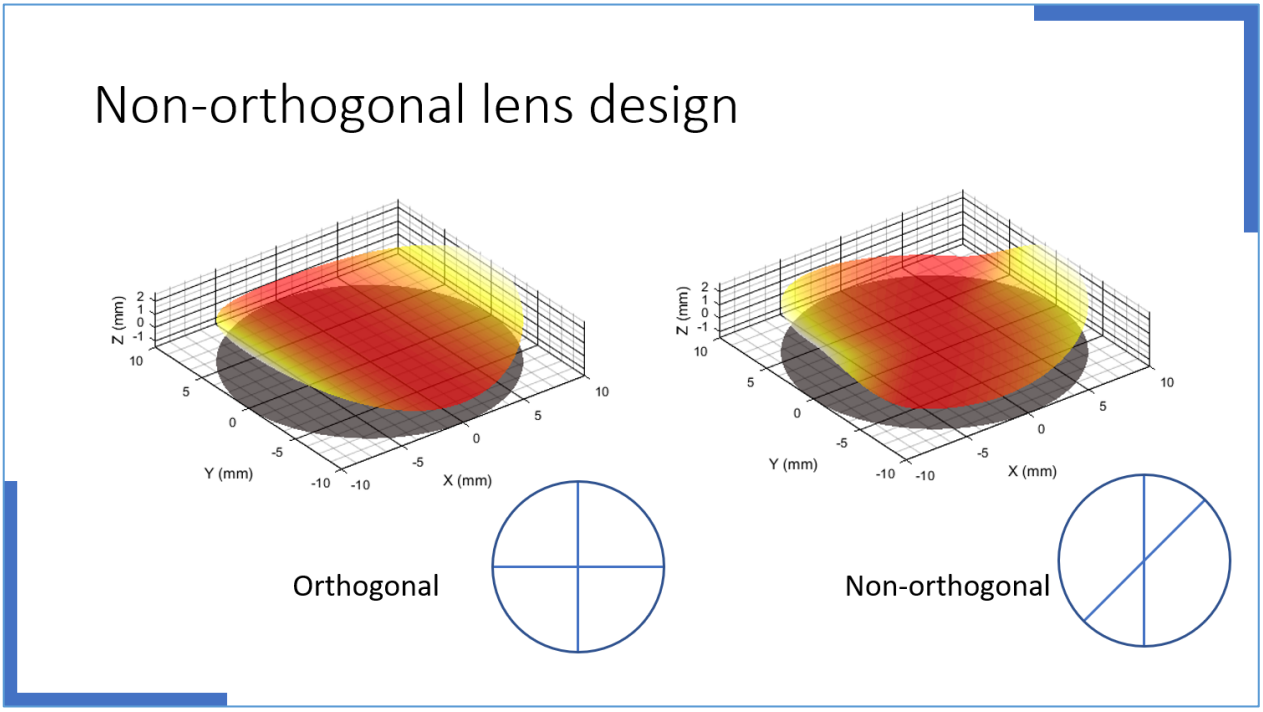
1. Spherical Aberration Elimination

- The slides presented by Dr Ahmed Abass showed that **spherical aberration** occurs due to the **inability** of **spherical lenses** to **focus** all **incoming light rays** to a **single point**.
- **Graphs** and **3D models** demonstrated special surface curvature, used to optimise lens design for improved focus.
- **Techniques** to correct spherical aberration involve **modifying lens curvature** to **align focal points** for **all incoming light**.

2. Orthogonal vs. Non-Orthogonal Lens Design

- The slide presented by Ahmed contrasted **orthogonal** and **non-orthogonal lens system**s using **power maps**:
  - **Orthogonal Design**: The **corneal** and **lens optical powers** are **complementary**, resulting in a **uniform** overall **power distribution**.
  - **Non-Orthogonal Design**: The **misalignment** of **corneal** and **lens axes** leads to **irregular power** maps and **less uniform** overall power.

- These designs affect how well light is focused across the eye, with orthogonal designs offering more consistent optical performance.



3. Fight for Sight & UK Keratoconus Study

A pioneering study funded by **Fight for Sight** and the **UK Keratoconus Self-Help and Support Association** tested whether correcting **non-orthogonal astigmatism** could improve vision in people with **keratoconus**.

Key findings from the **research** include:

- Improved visual acuity
- Reduced ghosting
- Better letter clarity

The small study indicates that specially designed lenses addressing non-orthogonal astigmatism can alleviate the visual challenges faced by keratoconus patients.

The results are encouraging. In this pilot study, many participants experienced clearer vision, reduced ghosting, and sharper letter recognition with these specially designed lenses.

“This is the first study of its kind,” Dr Abass said. “We’ve shown that the idea works. Now we need to focus on scaling it up, finding ways to mass produce these lenses and test them on a larger group.”

Key Implications

1. **Clinical Relevance**: Eliminating spherical aberration and addressing non-orthogonal astigmatism can significantly enhance visual outcomes, especially for patients with complex corneal conditions like keratoconus.
2. **Lens Design Innovation**: Demonstrates the need for **precision engineering** in **lens geometry**. **Orthogonal alignment** of **corrective optics** yields **better results** than **conventional designs**.
3. **Evidence-Based Development**: Encouraging pilot results warrant expanded trials and investment in scalable production methods for next-generation contact lenses.
4. **Patient Impact**: Potential to vastly improve quality of life for individuals with previously uncorrectable or poorly managed visual impairments.

Anyone interested in collaborating with the University of Liverpool or learning more is welcome to contact Dr Abass at a.abass@liverpool.ac.uk.

Our second presenter, whom we invited to speak to The Keratoconus Group members, was Ms Lynn White, who discussed **Correcting Non-Orthogonal Astigmatism.**

Lynn discussed her study on correcting **non-orthogonal astigmatism** in **patients** with **keratoconus**, highlighting **improvements** in **visual acuity** and **reduction** in **ghosting** with **specialised lenses**.

Clinical Considerations for Keratoconus Patients
The study investigated the effects of non-orthogonal lenses on **visual acuity** and **ghosting** in **keratoconus patients**. It highlighted significant **improvements** in **vision quality** and patient satisfaction. Lynn provided examples of patients she had recently worked with below:

- Patient SR had **mild keratoconus** in the left eye with a prescription of 0.00/-2.50 x 90.
- **Vision improved** from 6/6 to 6/4 with **non-orthogonal lenses**, eliminating **ghosting**.

- 83% of patients reported **reduced ghosting**, with 35% noting **substantial improvement**.
- 87% reported **improved letter clarity**, with 52% stating it was **substantially better**.
- Preferred **angles** for **power meridians** were 85° (26.1%) and 80° (30.4%).

Study Protocol and Methodology

The study involved **18 keratoconus patients** and assessed the **impact** of **lens angles** on **vision quality**. **Topography** was used to classify **keratoconus severity**, and various **lens angles** were tested.

- 23 eyes from 18 patients diagnosed with **keratoconus** were included.
- **Topography** was performed using **Pentacam** data to classify **keratoconus severity**.

- Normal **refraction** was **conducted** with **standard lenses**, followed by testing with **non-orthogonal lenses**.
- Patients were asked about **letter clarity** and **ghosting** after each test.
- The **optimal angle** for lens correction was **determined** through **iterative testing**.

Visual Acuity and Lens Correction Outcomes
Lynn presented the data from her study on the correlation between **orthogonal** and **non-orthogonal lens corrections**, showing significant **improvements** in **visual acuity**.

- A **strong correlation** (R = 0.84) was found between **orthogonal** and **non-orthogonal** best-corrected visual acuity (BCVA).
- **Statistical significance** (p = 0.001) indicates a **meaningful difference** in **visual acuity outcomes**.
- **Non-orthogonal lenses** showed a frequency distribution **favouring improved vision** over **orthogonal lenses**.

Cylinder and Sphere Power Comparisons

The research compared **cylinder** and **sphere powers** between **orthogonal** and **non-orthogonal refractions**, revealing notable differences.

- **Cylinder power** comparison showed a **strong correlation** (R = 0.94) with no **significant difference** (p = 0.567).
- **Sphere power comparison** indicated a **correlation** (R = 0.92) with a p-value of 0.086, suggesting **no significant difference**.
- The **data supports** the **effectiveness** of **non-orthogonal lenses** in **improving vision**.

Implications for Quality of Life in Keratoconus Patients

The findings suggest that **improved vision** through **non-orthogonal lenses** can **enhance** the **quality** of **life** for **keratoconus patients**.

- **Significant improvements** in **letter clarity** and **reduction** in **ghosting** can lead to **better daily functioning**.
- The study indicates the **potential** for **developing new refraction routines** tailored for **keratoconus patients**.
- Find a simple method of **detecting** and **measuring non-orthogonal astigmatism**
- **Future trials** may focus on **testing binocular vision** and patient **trial lenses** in **normal environments**.

Anyone interested in collaborating with Lynn White or learning more is welcome to contact Ms Lynn White at lynn@lwvision.co.uk.

Finally, the Keratoconus Group would like to thank Dr Ahmed Abass and Ms Lynn White for taking the time to share their expertise and present this invaluable information to our members during the Annual General meeting at Moorfields Eye Hospital in March 2025.