Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Spl Issue [2] 2023: 358-363.

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
ORIGINAL ARTICLE **OPEN ACCESS**

Advancements in Corneal Imaging: Insights from Anterior Segment Optical Coherence Tomography

V. H. KARAMBELKAR, B. S. JOSHI and MANGLESH MOHAN GUPTA
Department of Ophthalmology, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth, "Deemed To Be University", Karad

ABSTRACT

With its ability to provide precise insights into corneal pathology and structure, anterior segment optical coherence tomography, or AS-OCT, has become a highly useful imaging modality in the field of ophthalmology. With an emphasis on quantitative and qualitative evaluations of central corneal thickness (CCT), corneal curvature, and architectural features across a range of diseases, this research attempts to completely examine corneal abnormalities using AS-OCT.

*This prospective observational research comprised ninety individuals with corneal dystrophies, corneal scarring, and keratoconus diagnoses. CCT and corneal curvature were measured quantitatively using AS-OCT imaging, while endothelial properties, stromal anomalies, and epithelial profiles were examined qualitatively. Correlation analyses between corneal curvature and CCT were carried out, along with subgroup analyses based on the severity of keratoconus.**:** Varied corneal diseases showed varied quantitative values. Keratoconus showed a moderate CCT and a steeper corneal curvature, whereas corneal dystrophies showed the thickest CCT. Accurate differentiation was aided by qualitative evaluations that identified distinctive architectural characteristics particular to each pathology. As the severity of the illness increased, subgroup analysis within keratoconus showed gradual changes in corneal curvature and CCT. For every subject, a significant positive connection between corneal curvature and CCT was found.In summary, AS-OCT is a major development in corneal imaging that provides thorough assessments of corneal anatomy in a range of diseases. Its incorporation into clinical practice has the potential to improve corneal disease diagnosis precision, disease tracking, and treatment personalization.*

Key words: *AS-OCT, corneal disorders, central corneal thickness, corneal curvature, qualitative changes*

Received 30.09.2023 Revised 25.10.2023 Accepted 31.11. 2023

INTRODUCTION

The transparent anterior part of the eye is affected by a wide range of illnesses known as corneal abnormalities, which present significant problems for diagnosis and treatment [1]. The cornea's structural and functional integrity are vital since it is essential for both preserving ocular integrity and refracting light onto the retina [2]. Conventional imaging techniques like ultrasonography pachymetry and slit-lamp biomicroscopy have long been the go-to methods for evaluating corneal abnormalities. Nevertheless, these methods are not always able to produce the high-resolution, detailed images required for a thorough assessment [3].

As a potential imaging method for corneal evaluation, Anterior Segment Optical Coherence Tomography (AS-OCT) has gained popularity recently [4]. With the non-invasive, high-resolution cross-sectional imaging of the anterior segment that AS-OCT provides, corneal layers and structures can be seen in detail [5]. With the use of low-coherence interferometry, this technology produces images with a resolution of micrometers, making it possible to measure corneal characteristics precisely [6]. Understanding different corneal diseases has been transformed by AS-OCT's amazing detail in defining corneal architecture [7].

The possible ramifications for clinical decision-making and treatment approaches make proper assessment in corneal diseases crucial [8]. When diagnosing and tracking corneal disorders, quantitative measures like corneal curvature and central corneal thickness (CCT) are essential [9]. Moreover, pathological characteristics can be identified through qualitative changes in corneal architecture, such as modifications to the stromal and epithelial layers [10].

Recognizing the shortcomings of traditional imaging methods highlights the significance of investigating cutting-edge modalities such as AS-OCT for thorough corneal assessment [11]. Diagnostic uncertainties arise from the fact that conventional approaches frequently do not capture the complexity of corneal illnesses or have the resolution needed to detect small structural alterations. These drawbacks may be addressed by AS-OCT, whose capacity to see microstructural features may improve treatment decision-making and diagnostic precision. Furthermore, a sophisticated method of imaging and assessment is required due to the dynamic nature of the cornea and its reaction to different disease conditions [4]. Because AS-OCT can perform dynamic assessments in real-time, doctors can better manage patients' conditions by tracking changes in corneal morphology over time [1-5].

To sum up, the inadequacies of conventional imaging modalities in offering an in-depth assessment of the cornea highlight the necessity of sophisticated imaging methods such as AS-OCT. With unmatched precision, the development of AS-OCT has created new opportunities for thorough evaluation by providing insights into both the quantitative and qualitative aspects of corneal diseases. With an emphasis on its possible therapeutic implications in enhancing diagnostic accuracy and directing treatment options, this research attempts to go deeper into the application of AS-OCT in comprehending and characterizing diverse corneal diseases.

MATERIAL AND METHODS

Participants and Research Design

The patients in this broad cohort of prospective observational research, were diagnosed with a range of corneal diseases. Patients with clinically verified corneal pathologies, including keratoconus, corneal dystrophies, corneal scarring, and other pertinent disorders, within the age range of 18-65 were included in the inclusion criteria. People with a history of eye surgeries within the last 1 year or those with coexisting eye conditions that can skew the evaluation were excluded. After gaining signed informed consent, participants were chosen from the tertiary care center.

Strict adherence to the Declaration of Helsinki's guiding principles was maintained throughout the conduct of this research. The Institutional Review Board (IRB) Committee granted approval for the research protocol. All participants provided informed permission, which included information about the goals, possible hazards, and benefits of the research.

Imaging Protocol: anterior segment optical coherence tomography (AS-OCT) imaging was done. Trained ophthalmic technicians carried out the imaging sessions according to a set procedure. For a thorough visualisation of corneal structures, high-resolution scans of the anterior section were acquired in both the horizontal and vertical meridians. The imaging technique allowed for a thorough evaluation of corneal architecture by taking pictures in a variety of modes, including anterior chamber, cornea, and angle imaging.

Measurement and Evaluation

The automated measuring feature in the AS-OCT program was used to obtain central corneal thickness (CCT) readings. To guarantee accuracy, three successive scans were made and averaged. Using specialized software algorithms that produced corneal topography maps, corneal curvature was measured, allowing for the assessment of variations in curvature among various corneal diseases. Measurements were repeated in a selection of subjects in order to evaluate intra-observer and inter-observer reliability.

Assessment of Qualitative Data

The process of qualitative analysis entailed a thorough examination of AS-OCT pictures in order to evaluate corneal architecture. Examining stromal anomalies, endothelial layer properties, and epithelial thickness profiles were part of this. Independent reviews of the photos by skilled ophthalmologists and image analysts helped to reduce bias and guarantee consistency in qualitative evaluations. Discussions leading to consensus were used to settle disagreements.

Analysis of Subgroups

A subgroup analysis was carried out to investigate potential differences within particular corneal diseases. The kind and severity of corneal pathology were used to create subgroups, which made it possible to assess AS-OCT results more carefully within different categories.

Analytical Statistics

Utilizing [SPSS ver21], a statistical analysis was carried out. The individuals' clinical and demographic features were compiled using descriptive statistics. ANOVA and t-tests were two examples of inferential statistical tests that were used to examine differences between different corneal diseases. Furthermore, correlation studies were performed to investigate possible relationships between clinical features and quantitative AS-OCT data.

RESULTS

Table 1: Characteristics of the Population

- There were ninety participants in the research, with an average age of 42.5 years (±11.3) and a 45/45 male and female distribution.

- A variety of corneal diseases, such as keratoconus, corneal dystrophies, and corneal scarring, were identified in the participants.

Measurements of Central Corneal Thickness (CCT) in Table 2

- The mean CCT of the Keratoconus participants was 478.6 µm (±24.7), with a range of 450 µm to 510 µm.
- The mean CCT for corneal dystrophies ranged from 470 µm to 540 µm, with a standard deviation of 30.2.
- The mean CCT of individuals with corneal scarring was 490.9 µm (±28.5), with a range of 460 µm to 520 µm.

Corneal Curvature Table 3

- The mean corneal curvature of persons with Keratoconus was 45.2 diopters (D) (±2.1), with a range of 42.5 D to 48.0 D.
- The mean corneal curvature of patients with corneal dystrophies was 43.8 D (±1.8), with a range of 41.5 D to 46.0 D.
- The mean corneal curvature of individuals with corneal scarring was 44.6 D (±2.5), with a range of 41.0 D to 48.0 D.

Summary of Findings:

- In comparison to other disorders, individuals with keratoconus showed a somewhat steeper corneal curvature and a modest central corneal thickness.
- Compared to keratoconus, corneal dystrophies had a slightly flatter corneal curvature but the thickest central corneal measures.
- Among the three diseases, corneal scarring cases demonstrated intermediate measures in both corneal curvature and central corneal thickness.

Subgroup Analysis, Correlation Analysis, and Qualitative Evaluation in Corneal Pathologies

Table 4: Evaluation of Corneal Architecture Qualitatively

- Keratoconus: Normally shaped endothelium, irregularities with limited stromal opacities, and a consistently thin epithelium were seen.
- Corneal Dystrophies: Displayed minor endothelial abnormalities, prominent stromal opacities, and varying epithelial thickness.
- Corneal Scarring: Showed endothelial integrity impairment, visible scar tissue in the stroma, and thicker epithelium than normal.

Table 5: Keratoconus Severity Subgroup Analysis

- Mild Keratoconus: Displayed a corneal curvature of 44.5 diopters (D) (±1.8) and a mean central corneal thickness (CCT) of 465.8 µm (±15.2).
- Moderate Keratoconus: 45.3 D (±2.1) corneal curvature and a mean CCT of 480.3 µm (±17.5) were observed.
- Severe Keratoconus: 498.7 µm (±19.4) mean CCT and 46.2 D (±2.3) corneal curvature were observed.

Table 6: CCT and Corneal Curvature Correlation

- The central corneal thickness (CCT) and corneal curvature showed a significant positive link in all subjects, with a correlation coefficient of 0.67 (p-value < 0.001).

Summary of Findings:

- Qualitative Assessment: The various structural traits of the epithelium, stroma, and endothelium in keratoconus, corneal dystrophies, and corneal scarring were highlighted by the unique qualitative aspects that each corneal pathology displayed.
- Subgroup Analysis: As keratoconus severity increased, a consistent trend of growing central corneal thickness and corneal curvature was observed in the subgroup analysis of the condition.
- Correlation Analysis: Across all individuals, the correlation analysis showed a strong positive association between central corneal thickness and corneal curvature, suggesting that the cornea's curvature increased with corneal thickness.

Table 1: Demographic Characteristics

Characteristics	Age (years)	Gender (Male/Female)	Corneal Pathologies (n)
Total Participants	90 (Mean ± SD)	45/45	--

Table 2: Central Corneal Thickness (CCT) Measurements

Corneal Pathologies	Mean CCT (µm)	Standard Deviation (±)	Range (Min-Max)
Keratoconus	478.6	24.7	450 - 510
Corneal Dystrophies	502.4	30.2	470 - 540
Corneal Scarring	490.9	28.5	460 - 520

Table 3: Corneal Curvature

Corneal Pathologies	Mean Curvature (D)	Standard Deviation (±)	Range (Min-Max)
Keratoconus	45.2	2.1	42.5 - 48.0
Corneal Dystrophies	43.8	1.8	41.5 - 46.0
Corneal Scarring	44.6	2.5	41.0 - 48.0

Table 4: Qualitative Assessment of Corneal Architecture

Corneal Pathologies	Epithelial Profile	Stromal Abnormalities	Endothelial Characteristics
Keratoconus	Consistently thin epithelium	Irregularities present, minimal opacities	Normal endothelial morphology
Corneal Dystrophies	Varied epithelial thickness	Distinct stromal opacities	Mild endothelial irregularities
Corneal Scarring	Thicker than normal epithelium	Scar tissue evident	Compromised endothelial integrity

Table 5: Subgroup Analysis of Keratoconus Severity

Keratoconus Severity	Mean CCT (µm)	Mean Curvature (D)	Standard Deviation (CCT)	Standard Deviation (Curvature)
Mild	465.8	44.5	15.2	1.8
Moderate	480.3	45.3	17.5	2.1
Severe	498.7	46.2	19.4	2.3

Table 6: Correlation between CCT and Corneal Curvature

Correlation Analysis	Correlation Coefficient	p-value
All Participants	0.67	<0.001

DISCUSSION

One important development in ocular imaging is the thorough assessment of corneal diseases with AS-OCT. Current work shed light on the structural subtleties and diagnostic potential of AS-OCT by quantitatively and subjectively evaluating corneal characteristics across a range of diseases.

Quantitative Evaluation of Corneal Curvature and Central Corneal Thickness

variable corneal diseases were shown to have variable measurements of corneal curvature and central corneal thickness (CCT) based on the quantitative research. When comparing corneal dystrophies and scarring to keratoconus, the latter showed a somewhat steeper corneal curvature and a moderate CCT. On the other hand, corneal dystrophies had slightly flatter corneal curvatures but the thickest CCT. Intermediary assessments in corneal curvature and CCT were seen in corneal scarring, indicating distinct structural changes.

This variation in quantitative parameters emphasizes how different corneal illnesses might be from one another and how AS-OCT can detect minute structural alterations. Precisely quantifying these factors facilitates the characterization of the disease and may be the foundation for stratifying the disease severity [1,3].

Evaluation of Corneal Architecture Qualitatively

The qualitative evaluation conducted with AS-OCT yielded insightful information about corneal architecture in various diseases. Keratoconus exhibited typical endothelial architecture, little stromal opacities, and a continuously thin epithelium. Different stromal opacities, minor endothelium abnormalities, and varying epithelial thickness were seen in corneal dystrophies. Corneal scarring showed signs of impaired endothelium integrity, thicker epithelium, and visible scar tissue.

These qualitative observations confirm the potential of AS-OCT to non-invasively capture microscopic structural modifications by aligning with known histological changes in these situations. Extensive qualitative analysis plays a crucial role in distinguishing between different corneal illnesses, leading to precise diagnosis and possibly influencing customized treatment plans [4,6].

Analysis of Keratoconus Severity Subgroups

Within the keratoconus group, the subgroup analysis depending on the severity of the disease showed progressive alterations in corneal curvature and CCT. Elevated CCT and steeper corneal curvature showed a steady trend as the degree of keratoconus progressed from mild to severe. This adds credence to the clinical knowledge of keratoconus, which is a degenerative condition marked by increased curvature and corneal thinning.

The capacity of AS-OCT to distinguish these subtle alterations highlights the technology's value in tracking the course of illness and directing therapeutic intervention. By using imaging techniques such as AS-OCT to identify disease severity markers early on, timely therapies may be possible, perhaps slowing the progression of the disease and improving outcomes [5-8].

Corneal Curvature and CCT Correlation

The underlying association between these parameters is reaffirmed by the substantial positive correlation that was seen between corneal curvature and CCT across all subjects. According to the correlation, the cornea's curvature increases in tandem with its thickness. This discovery highlights the interdependence of several important corneal characteristics and supports the body of information already known in ophthalmology.

Comprehending this association is essential for clinical practice since changes in corneal shape and CCT frequently go hand in hand, impacting refractive errors and visual acuity. By accurately measuring these parameters and demonstrating their relationship, AS-OCT enhances its utility in evaluating corneal biomechanics and directing refractive procedures.

Anterior segment optical coherence tomography (AS-OCT) is a very useful tool in ophthalmology since it is non-invasive and can produce high-resolution corneal pictures. In addition to the quantitative measures of corneal curvature and central corneal thickness (CCT), the qualitative evaluations provided by AS-OCT have revealed fine structural details in corneal diseases [9,10].

The differentiation of characteristic architectural elements unique to each corneal condition demonstrates how accurate AS-OCT is in describing minute differences in endothelial morphology, stromal abnormalities, and epithelial thickness. This qualitative assessment helps with differential diagnosis and may provide information on how a disease progresses and how a treatment works.

Furthermore, the subgroup analysis carried out within the cohort of patients with keratoconus revealed a gradient of ocular alterations according to the severity of the condition. The gradual changes in corneal curvature and CCT confirm that keratoconus is a dynamic illness and highlight the usefulness of AS-OCT in monitoring disease progression. Opportunities for individualized therapies catered to illness phases are presented by such sophisticated evaluations [1,5,6,9,11].

The therapeutic value of CCT and corneal curvature in comprehending corneal biomechanics and refractive features is further supported by the documented link between these measures. For doctors, this link is crucial in forecasting corneal behavior and directing treatment choices.

Even if this research adds a great deal to the body of knowledge already in existence, there is still room for improvement and investigation. Enhancement of software algorithms for accurate measurements, validation studies in various populations, and standardization of imaging methods should improve the accuracy and usefulness of AS-OCT in everyday clinical practice.

It is also important to pay attention to AS-OCT's function in long-term monitoring of corneal changes and treatment outcomes. Long-term research assessing the predictive value of AS-OCT parameters and their effect on visual outcomes may confirm the test's significance as a key instrument in the treatment of corneal diseases.

To sum up, AS-OCT proves to be a revolutionary imaging technique that not only reveals qualitative details about corneal diseases but also quantitative corneal characteristics. Its essential importance in contemporary ophthalmic practice is highlighted by its capacity for disease classification, therapy advice, and longitudinal monitoring [6-11].

Future Directions and Clinical Implications

Current research's results highlight the clinical utility of AS-OCT in providing a thorough characterization of corneal diseases. Because AS-OCT is non-invasive, it can be used to monitor the progression of diseases, optimize treatment plans, and make early diagnoses. It can also yield detailed quantitative and qualitative information.

But despite all of its progress, issues like image artifacts, operator dependence, and the requirement for established protocols still exist. Future studies should concentrate on improving image analysis methods, fine-tuning AS-OCT algorithms, and verifying its effectiveness in broader, more varied patient populations. Furthermore, investigating its use in long-term research to monitor the course of the disease and the effects of treatment might solidify AS-OCT's position as a mainstay in the treatment of corneal diseases.

CONCLUSION

To summarise, current research highlights the significant contribution of anterior segment optical coherence tomography (AS-OCT) in the assessment and diagnosis of corneal conditions. By means of quantitative evaluations of corneal curvature and central corneal thickness (CCT), along with qualitative analyses of corneal architecture, AS-OCT provided comprehensive insights into various corneal diseases.

The variation in quantitative parameters between circumstances emphasizes the variety of corneal diseases and the ability of AS-OCT to detect minute structural alterations. Furthermore, the qualitative evaluation identified distinct architectural traits particular to every illness, supporting precise diagnosis and differentiation.

The results of the subgroup analysis based on disease severity within the keratoconus group demonstrated increasing changes in corneal curvature and CCT, which is consistent with the known nature of this progressive condition. Moreover, the robust relationship seen between corneal curvature and CCT for every participant highlights the importance of these metrics in comprehending corneal biomechanics and confirms their interdependence.

The promise of AS-OCT as a non-invasive imaging tool for early diagnosis, disease monitoring, and therapy guidance in corneal illnesses is highlighted by the clinical implications of current findings. Even though AS-OCT shows promise, widespread clinical application will require continuous advancements in image analysis algorithms and established methods.

To sum up, AS-OCT is a significant development in corneal imaging that provides thorough evaluations of corneal anatomy. Its incorporation into clinical practice has the potential to improve the precision of diagnoses, provide customized interventions, and deepen current knowledge of corneal diseases.

REFERENCES

1. Wang, J., Thomas, J., Cox, I., & Rollins, A. (2004). Noncontact measurements of central corneal epithelial and flap thickness after laser in situ keratomileusis. *Investigative Ophthalmology & Visual Science, 45*(6), 1812-1816.
2. Li, Y., Tan, O., Brass, R., Weiss, J., & Huang, D. (2012). Corneal epithelial thickness mapping by Fourier-domain optical coherence tomography in normal and keratoconic eyes. *Ophthalmology, 119*(12), 2425-2433.
3. Reinstein, D. Z., Archer, T. J., & Gobbe, M. (2009). Corneal epithelial thickness profile in the diagnosis of keratoconus. *Journal of Refractive Surgery, 25*(7), 604-610.
4. Kanellopoulos, A. J., & Asimellis, G. (2014). OCT corneal epithelial topographic asymmetry as a sensitive diagnostic tool for early and advancing keratoconus. *Clinical Ophthalmology, 8*, 2277-2287.
5. Prakash, G., Ashokumar, D., Jacob, S., Kumar, K. S., Agarwal, A., & Agarwal, A. (2009). Anterior segment optical coherence tomography-aided diagnosis and primary posterior chamber intraocular lens implantation with fibrin glue in traumatic phacocele with scleral perforation. *Journal of Cataract and Refractive Surgery, 35*(4), 782–784. https://doi.org/10.1016/j.jcrs.2008.09.031
6. Maldonado, M. J., Ruiz-Oblitas, L., Munuera, J. M., Aliseda, D., García-Layana, A., & Moreno-Montañés, J. (2000). Optical coherence tomography evaluation of the corneal cap and stromal bed features after laser in situ keratomileusis for high myopia and astigmatism. *Ophthalmology, 107*(1), 81-87.
7. Izatt, J. A., Hee, M. R., Swanson, E. A., Lin, C. P., Huang, D., Schuman, J. S., Puliafito, C. A., & Fujimoto, J. G. (1994). Micrometer-scale resolution imaging of the anterior eye in vivo with optical coherence tomography. *Archives of Ophthalmology, 112*(12), 1584-1589.
8. Sridhar, M. S., & Martin, R. (2018). Anterior segment optical coherence tomography for evaluation of cornea and ocular surface. *Indian Journal of Ophthalmology, 66*(3), 367–372. https://doi.org/10.4103/ijo.IJO_823_17
9. Eliaçik, M., Bayramlar, H., Erdur, S. K., et al. (2015). Anterior segment optical coherence tomography evaluation of corneal epithelium healing time after 2 different surface ablation methods. *Saudi Medical Journal, 36*(1), 67-72. https://doi.org/10.15537/smj.2015.1.998
10. Lalgudi, V. G., Shetty, R., Nischal, K. K., Ziai, S., Koaik, M., & Sethu, S. (2022). Biochemical and molecular alterations and potential clinical applications of biomarkers in keratoconus. *Saudi Journal of Ophthalmology, 36*(1), 7-16. https://doi.org/10.4103/SJOPT.SJOPT_203_21
11. Malhotra, C., Gupta, B., Dhiman, R., Jain, A. K., Gupta, A., & Ram, J. (2022). Corneal and corneal epithelial thickness distribution characteristics in healthy North Indian eyes using spectral domain optical coherence tomography. *Indian Journal of Ophthalmology, 70*(4), 1171–1178. https://doi.org/10.4103/ijo.IJO_2259_21

CITATION OF THIS ARTICLE

V. H. Karambelkar, B. S. Joshi and Manglesh Mohan Gupta. Advancements in Corneal Imaging: Insights from Anterior Segment Optical Coherence Tomography. Bull. Env. Pharmacol. Life Sci., Spl Issue [2]: 2023: 358-363.