https://doi.org/10.48047/AFJBS.6.2.2024.3089-3100

AFJBS

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Brief Overview about Corneal topographic changes after ptosis surgery

Hatem Amin Abdallah Ahmad Khattab, Eman Fahmy Ahmed Mohamed Ali, Atef Mohammad Hussein Khalifa, Hala Kamal Mattout

Ophthalmology Department, Faculty of Medicine, Zagazig University, Egypt

Corresponding author: Eman Fahmy Ahmed Mohamed Ali

Email: Emyrose399@gmail.com

Article History

Volume 6, Issue 2, Apr-Aug 2024

Received: 5 August 2024

Accepted: 15 August 2024

Published: 15 August 2024

doi: 10.48047/AFJBS.6.2.2024.3089-3100

Abstract: The cornea plays a crucial role in visual acuity due to its contribution of approximately two-thirds of the eyes total optical power. The anterior surface curvature of the cornea is primarily responsible for corneal refraction. Given that this surface is in direct contact with the eyelids, alterations in eyelid shape and function can result in changes to corneal refraction, steep and flat corneal meridians, refractive error, and corneal astigmatism. Various theories propose that upper eyelids cause a “band like pressure” on the cornea and may cause With the Rule astigmatism due to altered corneal shape. Several studies have recorded the refractive error, astigmatism and corneal topography changes produced by the ptotic eyelid on the cornea. Amblyopia has also been reported as a result of upper eyelid ptosis in children. Dry eye symptoms, an important post-eyelid surgery observation, may also worsen after blepharoptosis surgery as a result of various factors, including post-operative inflammation, chemosis, lagophthalmos, excessive orbicular denervation and resection, lid retraction, and dysfunction of the lacrimal pump system. It is known that these symptoms may be transient in the first few weeks and will likely resolve within 2–3 months after surgery

Keywords: *Corneal topographic changes, ptosis surgery*

Introduction

The healthy central cornea is aspheric and prolate (the central curvature is steeper than the periphery). Attempts to measure the corneal parameters were made as early as the 1600s by Scheiner, who compared reflections produced by glass spheres whose diameters were known to the reflections from the anterior surface of the cornea. The central keratometric values vary between 40 D to 47 D (mean 43D). The standard keratometry device measures two points at a 2.25-4 mm zone in the central cornea [1].

The radius of curvature of the central part of the anterior surface of the cornea is measured by the size of the reflection of an image projected by the keratometer using the formula r=2uI/o or the radius of curvature= 2 x distance between the reflective surface and the object x image size /object size (r=radius of curvature, u=distance between the reflective surface and the object, I=image size, and o= object size) [2].

The different keratometers, such as the Javal Schiotz and the Bausch and Lomb keratometer, were adequate to calculate the dioptric power of the cornea for intraocular lens power calculation and contact lens fitting.

However, with increased keratorefractive procedures, the evaluation of paracentral and peripheral cornea is of increased significance [3].

The term "topography" is derived from the Greek words "topos" (place) and "graphein" (to write) and refers to the study and representation of forms, being used especially in geography and astronomy. In ophthalmology, the term "corneal topography" is improperly used in order to characterize the shape of the corneal surface and its radii of curvature. A topographer analyzes only the front surface of the cornea. Tomography is derived from the word "Tomos" (Greek for cut or section) in which a 3-dimensional image of the anterior and posterior surface of the cornea and corneal thickness is measured as opposed to topography, where only the anterior surface of the cornea is mapped [4]. The Placido ring was the first instrument used to analyze the anterior surface of the cornea. Then, computerized videokeratography (CVK) was developed to map the corneal power and shape [5].

Principles of topography:

A luminous object is projected onto the cornea, and its reflection is analyzed. The methods of topography include:

- Placido method.
- Slit scanning technique.
- Schiempflug method [6].

The Placido method analyzes only the anterior surface of the cornea, whereas the other two methods also map the posterior corneal surface and measure the corneal thickness. The Placido method involves projecting a series of concentric black and white rings onto the cornea and capturing their reflection by a camera placed in the center of the rings [7].

This is the first Purkinje reflex. The power of the central 3 mm of the cornea is extrapolated, resulting in the Sim (simulated) K (keratometry) values. The rings are centered on the visual axis and not the pupil. The distance between the visual axis and the center of the pupil is the angle kappa (K) [4].

Algorithms calculate the power of the cornea at each point depending on the deformation of the mires. The Placido-based topography measures the refractive status of the cornea accurately but does not, however, reflect the true shape of the cornea [8].

The Slit scanning technology is based on measuring the dimensions of a slit scanning beam projected on the cornea. Orbscan initially was only a slit scanning technology to measure corneal thickness as well as curvature of the anterior and posterior surfaces of the cornea [1].

Elevation information was acquired directly, and curvature information was derived from this. Orbscan II incorporated a Placido disc attachment to get curvature measurements directly. The Orbscan IIz is a further improvement because it incorporates the Shack-Hartmann aberrometer in the Zyoptix workstation [9].

The reflection of the illuminated Placido disc onto the cornea is stored, followed by the projection of 40 slits, 20 from the right and the left (each slit 12.5 mm high x 0.30 mm wide) at an angle of 45 degrees to the instrument axis. The backscattered images are captured by the device's video camera [3].

Acquisition of images is followed by assessment of images and compensation for eye movements by a proprietary technique. Processing of the data is done by the machine to construct the anterior and posterior elevation maps and the curvature maps [10].

The Schiempflug technology uses a rotating camera to capture the reflection of a bright slit beam that sweeps across the cornea. A 3-D reconstruction of the anterior and posterior elevation is done, and the pachymetry is calculated. The Schiempflug principle is credited to Theodore Schiempflug, who devised a method to correct distortion in aerial photography. A single rotating camera and static camera are present in the Pentacam device [10].

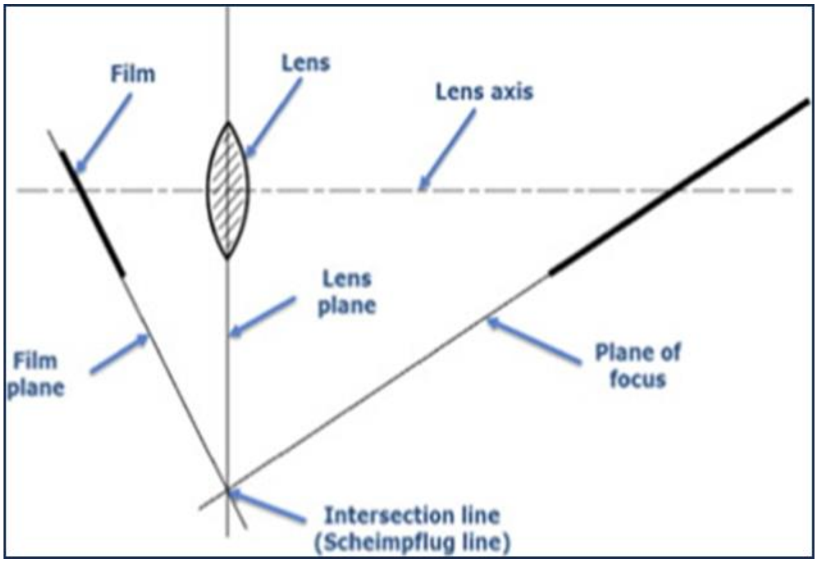


Figure (1): Principal operation of Scheimpflug imaging system [11].

The Schiempflug and the Placido-based technologies are combined in machines like the Sirius, TMS 5, and Galilei. The Galilei machine uses two rotating cameras (dual Schiempflug analyzer), whereas the pentacam has a single rotating camera [2].

Procedures:

Corneal topography, whether Placido based or slit scanning, or a combination of the two techniques, involves placing the patient's chin on the chin rest of the machine, asking the patient to focus on a fixation light, and capturing the image of the Placido mires and /or the slit beam by means of a camera and the machine automatically calculates the dioptric power across the corneal surface [7].

Tear film abnormalities and contact lens wear can alter corneal topography maps. In addition, the patient's eye movements, ptosis, and improper placement of the patient's head on chin rest can cause problems in data acquisition. Comparison between topography maps of the same patient cannot be made between devices. K1, K2, and sim K astigmatism may not be the same across all devices [8].

The Placido-based devices calculate the radius of curvature and, thereby, the dioptric power of the central and paracentral cornea and extrapolate the data in the peripheral cornea [8].

The slit scanning devices such as Orbscan and the Schiempflug-based devices such as the Oculus pentacam have faster acquisition times which means lesser problems with the eye movement of patients during acquisition. The tear film has a major role to play in corneal topography maps. It is preferred to remove soft lenses a week before and rigid gas permeable lenses two weeks before doing corneal topography to avoid contact lens-induced warpage [6].

Figure [2] Oculus pentacam [12]

Schiempflug-based Corneal Tomography:

Four maps are displayed together in a Pentacam image. Four Map Refractive is the most commonly used display. One map displays the front axial or sagittal curvature, similar to the Placido display. The second map in this four-map display is the pachymetric map. Anterior and posterior elevation maps are the remaining two maps. The anterior and posterior elevation maps are based on the best-fit sphere. [3].

Axial or sagittal map:

It is a two-dimensional image that shows the dioptric power/radius of curvature of the cornea in the central, paracentral and peripheral cornea up to 9 mm. Warm colors like orange and red denote steepening, and cooler colors like blue and green suggest flattening. Corneal power (keratometry) can also be shown as the radius of curvature. The axial or sagittal map is similar to the maps seen on Placido-based systems. Normal corneas are green throughout, with gradual flattening from center to periphery [1].

Pachymetry map:

Pachymetry map shows corneal thickness in various areas up to 9 mm. The thicker areas are depicted in cooler colors, and the thinner areas in warmer colors [4].

Elevation maps:

The difference between the examined anterior or posterior corneal surface and a standard reference shape 8 mm best fit sphere (BFS) or best fit toric ellipsoid (BFTE) is depicted as the elevation map. Areas above the BFS and BFTE are represented by warmer colors and the areas below by cooler colors. The anterior and posterior elevation of the cornea is mapped relative to a standard reference shape such as a sphere or a toric ellipsoid. [5].

Topographic indices of CSO Sirius topographer®:

Root mean square (RMS) is defined as the deviation in regularity/aberrations (characterized rf, rs, asphericity and Ax) of the corneal surface being examined from the best fit asphero-toric surface. RMS/A is defined as root mean square per area. Low values of RMS in the area signify that surface of the cornea is regular. Higher values denote irregular corneal surface.

Symmetry index of curvature The Symmetry Index of the curvature is defined as the difference of the mean anterior tangential curvature (expressed in diopters) of two circular zones centered on the vertical axis in the inferior and superior hemispheres. The two circular zones are centered in ($x = 0$ mm, $y = \pm 1.5$ mm) and their radius is 1.5 mm. SIf is an index which measures the vertical asymmetry: positive values indicate an inferior hemisphere steeper than the superior one, vice versa negative values indicate a superior hemisphere steeper than the inferior one. SIb is also expressed in diopters and the index jump has opposite sign respect to the case air-stroma, the sign of the difference is changed to keep the compatibility with SIf [13].

Keratoconus Vertex front and back (KVf and KVb), Anterior & Posterior keratoconus vertex: Highest point of ectasia on the Anterior and Posterior Elevation Maps of anterior and posterior corneal surface respectively.

Baiocchi-Calossi-Versaci front and back index (BCVf) and (BCVb) evaluates the presence of an ectasia through analysis of the coma and trefoil components of Zernike's decomposition of elevations in the zones where keratoconus statistically arises. Based on the presumption that ectasia statistically develops in a preferential direction (infero-temporal) and it mainly manifests in coma, trefoil, spherical aberration. The index BCV or vectorial BCV is the vectorial sum of BCVf and BCVb.

Symmetry index front & back (SIf, SIb) measures vertical asymmetry, positive values indicate an inferior hemisphere steeper than the superior, negative values indicate superior hemisphere steeper than the inferior.

Keratoconus Vertex front& back (KVf and KVb): highest point of ectasia on the anterior and posterior elevation maps.

Baiocchi-Calossi-Versaci front & back (BCVf) and (BCVb): presence of ectasia through analysis of coma and trefoil components of Zernike's decomposition of elevations in zones where keratoconus statistically arises.

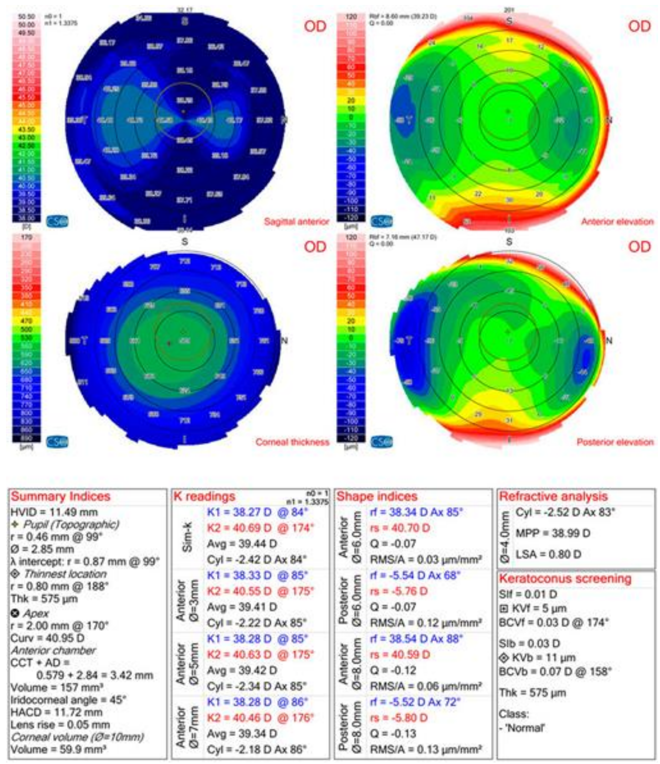


Figure [3] CSO Sirius scan image of a normal eye [14]

Corneal topographic changes after ptosis surgery

The cornea plays a crucial role in visual acuity due to its contribution of approximately two-thirds of the eyes total optical power. The anterior surface curvature of the cornea is primarily responsible for corneal refraction. Given that this surface is in direct contact with the eyelids, alterations in eyelid shape and function can result in changes to corneal refraction, steep and flat corneal meridians, refractive error, and corneal astigmatism [15].

In a normal person, the corneal topography of the two eyes is like mirror images. The eyelid pressure causes flattening of the peripheral cornea and steepening of the central cornea of the ptotic eye, leading to higher incidence of corneal astigmatism and loss of symmetry. Corneal topography of ptotic eye also shows more surface irregularity and asymmetry as compared to the normal eye [7].

Various theories propose that upper eyelids cause a "band like pressure" on the cornea and may cause With the Rule astigmatism due to altered corneal shape. Several studies have recorded the refractive error, astigmatism and corneal topography changes produced by the ptotic eyelid on the cornea. Amblyopia has also been reported as a result of upper eyelid ptosis in children [2].

Severe ptosis correction has been found to induce significant changes in corneal spherical and cylindrical power, corneal aberrations, and contrast sensitivity. Also, upper eyelid blepharoptosis repair can lead to varying degrees of dry eye that may persist for several months after surgery. So, performing orbital and cosmetic surgery prior to intraocular surgery is advisable to achieve more predictable results with less manipulation [16].

Dry eye symptoms, an important post-eyelid surgery observation, may also worsen after blepharoptosis surgery as a result of various factors, including post-operative inflammation, chemosis, lagophthalmos, excessive orbicular denervation and resection, lid retraction, and dysfunction of the lacrimal pump system. It is known that these symptoms may be transient in the first few weeks and will likely resolve within 2–3 months after surgery [17]. However, it should be noted that gland orifice migration or subclinical gland inflammation could also contribute to this pathophysiology. Also, it could be due to the increase in the MG area of loss postoperatively. The tarsal sutures and other manipulations on the tarsus may affect the MGs through direct trauma or by triggering inflammation [9].

Gullstrand's hypothesis suggests that the induced corneal astigmatism is caused by pressure from the eyelid on the vertical meridian, leading to with-the-rule (WTR) astigmatism [18]. This pressure flattens the corneal periphery while steepening the central region [17]. Consequently, elevating the eyelid causes central flattening and peripheral steepening. Assadi et al. in their study reported significant flattening of the inferior cornea six months after levator resection or sling surgery [11].

Agrawal and Ravani studied the changes in astigmatism after ptosis correction surgery in children at one week, six weeks and three months post- operatively. Surgical techniques for ptosis correction were fasanellaservat surgery, levator resection and frontalis sling surgery. They found that there is a significant astigmatic change following ptosis surgery in children [13].

Zinkernagel et al. reported significant changes in corneal astigmatism within a central 3-mm zone after ptosis correction [15]. Pressure exerted by the eyelid on the periphery of a ptotic eye's cornea causes a flat periphery and steep center resulting in astigmatism. Ptosis surgery corrects this condition, with the greatest effect being observed at the center of the cornea [15].

Preoperative ptosis severity predicts postoperative corneal astigmatism change. Severe ptosis induces steepening of the inferior meridian, which subsequently experiences the greatest flattening after surgery [11]. On the other hand, mild ptosis causes steepening of the superior meridian, which then has the most significant flattening postoperatively [16].

Aydemir and Aksoy Aydemir studied the effect of ptosis on IOL power calculation. The results showed that only patients with ptosis more than 4 mm experienced significant decrease in corneal curvature and astigmatism after surgery. Hence, for patients with severe eyelid ptosis and cataracts, it is essential to consider changing their lens power choice if cataract surgery is followed by ptosis repair [22].

Corneal biomechanical properties reflect the capacity of the cornea to respond to applied mechanical forces [19]. The properties are characterized by parameters such as corneal hysteresis and corneal resistance factors. Corneal hysteresis is the difference between the air pressure on the cornea during deflation and inflation [28], while corneal thickness plays an essential role in determining corneal resistance factors. Li et al., in their study of the corneal biomechanical parameters of ptotic and fellow eyes in patients with congenital blepharoptosis, they reported that these parameters differed significantly and these differences remained unchanged six months postoeratively. They also noted that the ptotic eyes had thicker and less deformable corneas and the CCT was the most crucial factor that changed in ptotic eyes, and subsequently affected the other parameters [20].

Human corneal tissue is considered a viscoelastic material with measurable properties. The corneal stroma is composed of type 1 collagen and an extracellular matrix mainly represented by proteoglycans and glycosaminoglycans, which are secreted by corneal stromal cells [32]. Previous studies found that a symmetrical arrangement of corneal collagen leads to symmetrical corneal biomechanical parameters in both eyes of healthy people [33]. The biomechanical properties of the cornea are modified by metabolic and lifetime environmental factors, especially UV exposure, so the CH and CRF mean values are significantly lower in subjects exposed to higher UV radiation than in a reference group [33]. Chronic corneal disturbances induced by UVB rays may include apoptosis of corneal cells, inhibition of cell proliferation, and cell autolysis of central layers of the epithelium, leading to thinning of the corneal epithelium [34].

Liu et al in their study to investigate the difference in refractive status and ocular parameters between ptotic and fellow eyes in patients with unilateral congenital ptosis reported that The BCVA of the ptotic eyes was significantly lower than that of the fellow eyes. The incidence of myopia and astigmatism did not differ significantly between ptotic eyes and fellow eyes. However, the prevalence of amblyopia in the ptotic eyes was higher than that in the fellow eyes, The CCT was greater in the ptotic eyes than in the fellow and mean corneal power of ptotic eyes were lower than those of fellow eyes, which means that the corneas of the ptotic eyes were thicker and flatter [21].

Brown et al found that after ptosis repair, repositioning of the upper eyelid causes visually significant astigmatic change [25]. Holck et al. studied the corneal topography 6 weeks after ptosis repair in patients with unilateral ptosis, they found an increase in with-the-rule astigmatism. But 12 months after ptosis surgery the increased WTR astigmatism at 6 weeks decreased [26].

Uğurbaş and Zilelioğlu in 1999 studied the effect of congenital ptosis on corneal topography of 22 patients. They found that Ptotic eyes had an increased incidence of astigmatism and bow tie pattern on corneal topography. Lack of mirror-image symmetry with the fellow eye was higher in amblyopic eyes

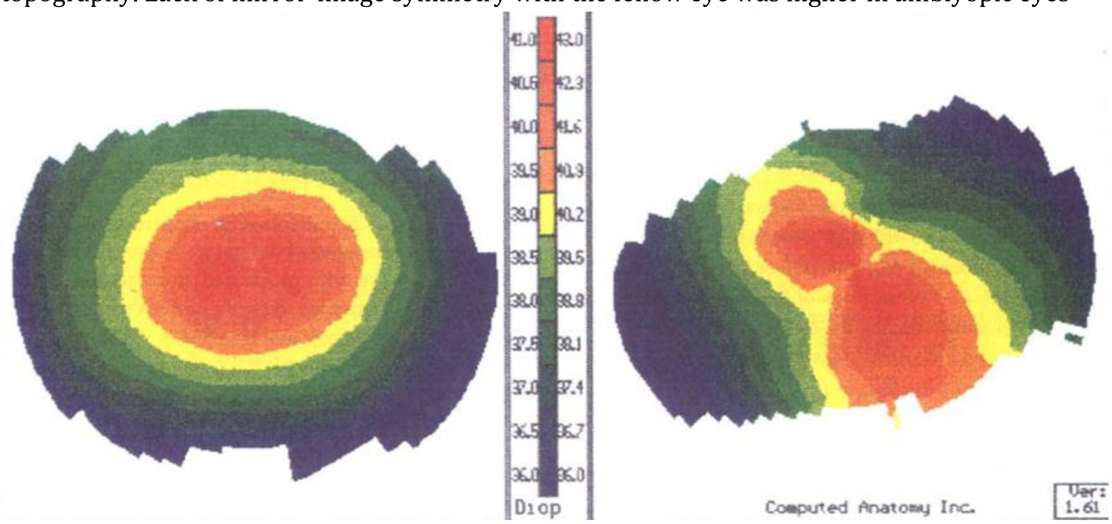


Fig.(4) Round corneal pattern in normal right eye and bow tie pattern in ptotic left eye of a patient

In 2016 Savino et al reported that corneal topography demonstrated a reduction in average keratometry and in corneal astigmatism. Significant differences were found in apical keratometry front and in best-corrected visual acuity in the postoperative examinations. Central corneal thickness did not show significant differences between preoperative and postoperative examinations. Postoperative topographic maps showed a reduction of symmetry index front [14].

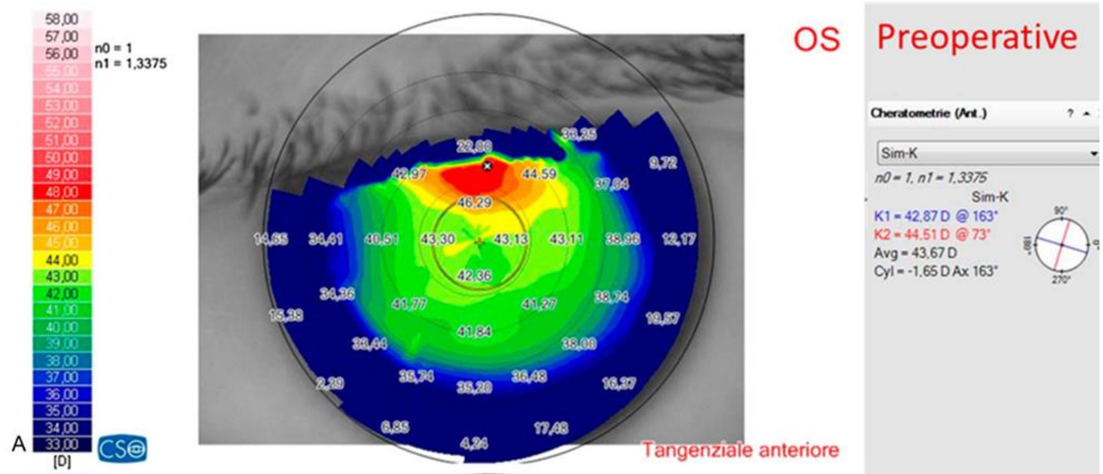


Fig. (5) preoperative topography showing irregular anterior corneal surface with focal steeping in the superior corneal hemisphere [14].

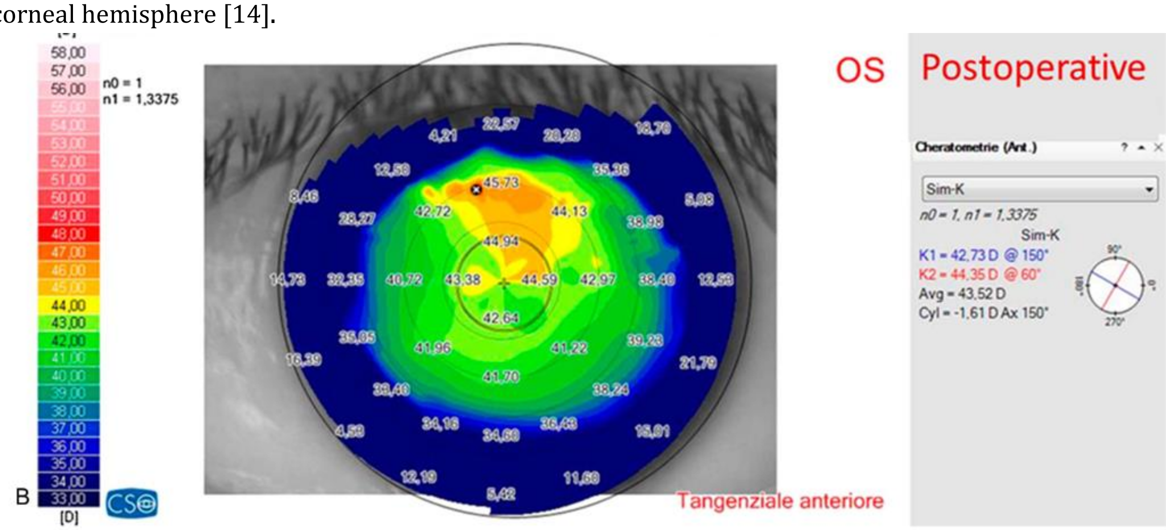


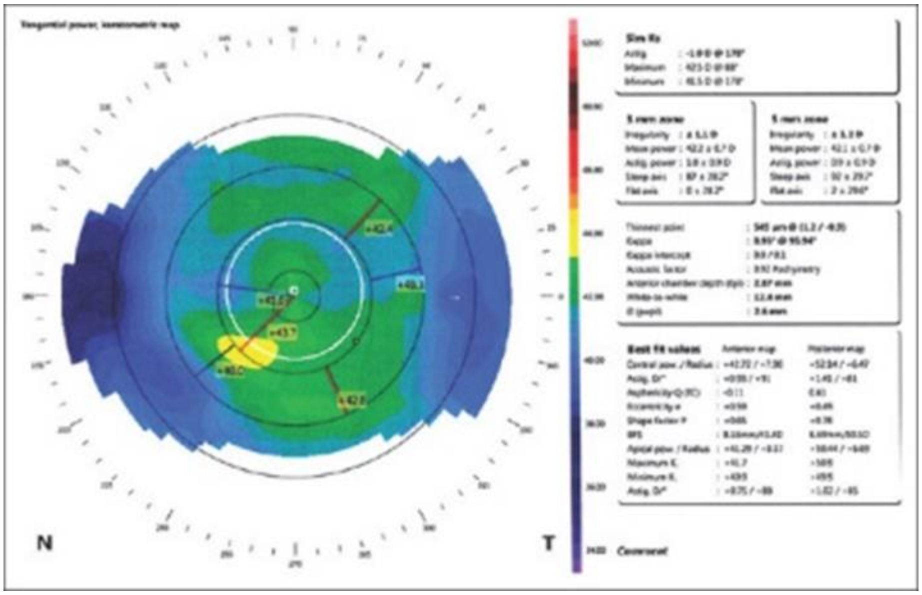
Fig. (6) postoperatively, mild flattening of the superior cornea [14].

Sharifi et al stated that following anterior levator resection for unilateral congenital ptosis, the amount of astigmatism decreased. Regarding tomographic indices, the change in minimum keratometry was significant. The amount of change in total higher-order aberrations (HOAs) was not significant. However, there was a decrease in the amount of third-order aberrations (vertical coma and vertical trefoil) which was most for vertical coma [17].

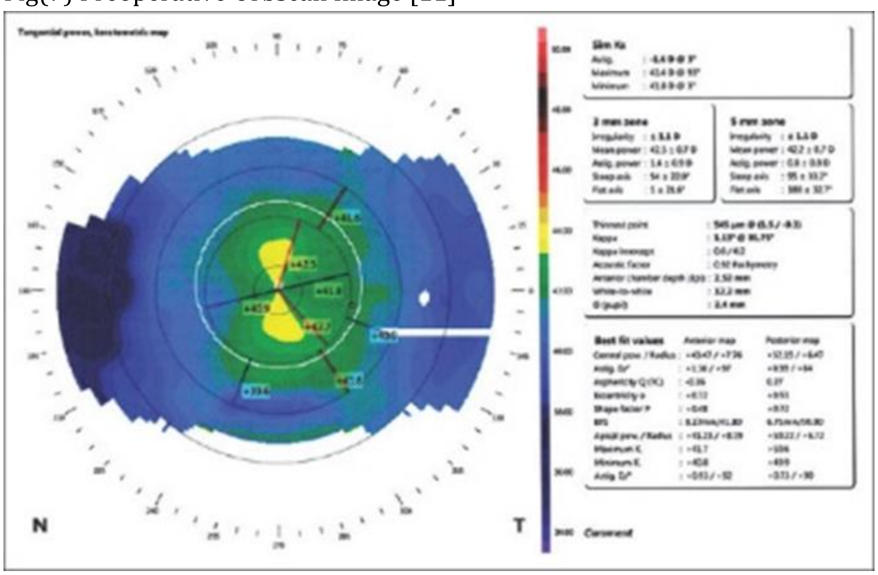
Kim et al reported that at 6 weeks after levator resection, 50% of the eyes showed an increase in corneal power, 34.6% showed a decrease, and 15.4% showed no change. The corneal astigmatism in 50% of eyes with levator resection decreased, increased in 19.2% of eyes, and showed no change in 30.8% of eyes. [27].

Ceylan and Yeniad assessed corneal topography after ptosis surgery. There was a significant change in K2 value at one month postoperatively. In there study they follow the patients up until 6 months postoperative. Although there was astigmatic change at 1 month, they observed no astigmatic changes at subsequent visits [18].

Assadi et al showed a significant decrease in Steepest K postoperatively was noted. Superior K and Inferior K also decreased, but the decrease in Inferior K was statistically significant. Variation in BCVA, and cycloplegic sphere and cylinder was minimal. Sim K astigmatism, Surface Regularity Index, Central Corneal Thickness did not show significant variation [11].



Fig(7) Preoperative Orbscan Image [11]



Fig(8) postoperative Orbscan Image [11]

Gandhi et al reported that in their attempt to assess the effects of frontalis sling surgery for congenital ptosis on corneal topography, three months post-operatively, significant reduction of cylindrical power was observed by refraction with corresponding improvement of mean BCVA. Corneal topography showed reduction in astigmatism; however, the average keratometry did not undergo a significant change. There was significant steepening of the previously flatter meridian while the steeper meridian remained relatively unchanged. A greater reduction in astigmatism was noticed in children in the age group of 5–10 years. [12].

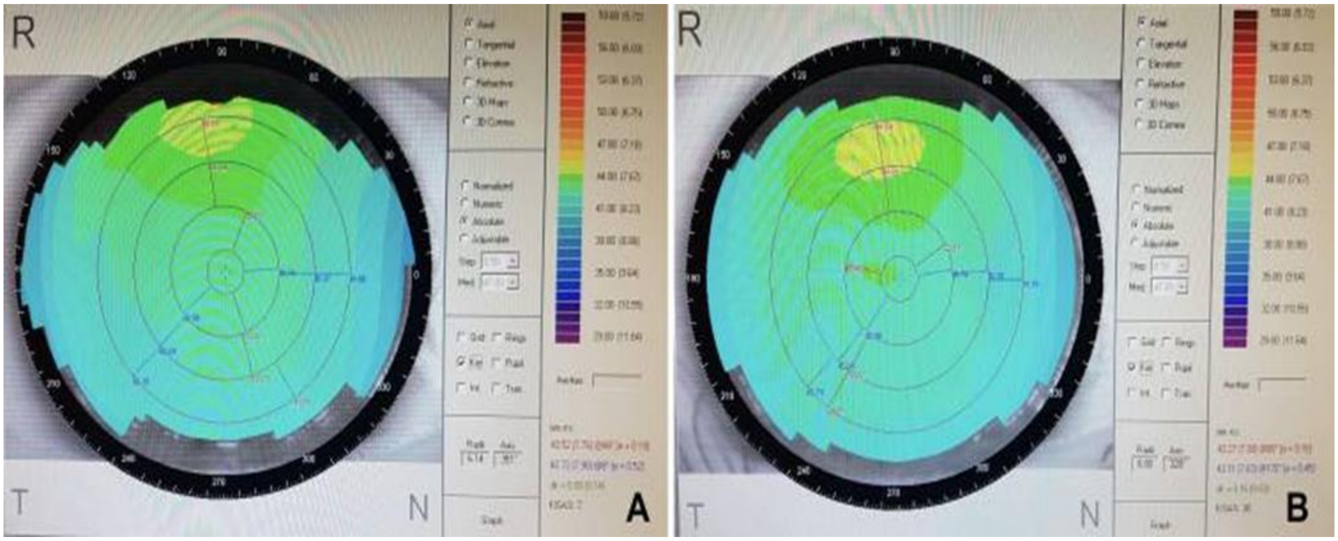


Fig. (9) (A) Pre-operative corneal topographic map of the right eye of a patient showing with the rule astigmatism. (B) Corneal topography of the same patient 3 months post-operatively, demonstrating reduction in astigmatism, steepening of K1 while the K2 remains relatively unchanged [12].

Few studies researched factors that influence changes in corneal astigmatism after eyelid surgery. Pimpha et al studied factors associated with corneal astigmatism change after ptosis surgery. They found significant postoperative corneal astigmatism change only in a subgroup of eyes with preoperative astigmatism of ≥1.5 diopters. They also reported no significant astigmatic change in group with severe ptosis as indicated by MRD1 [29]. On the other hand, Aydemir and Aksoy Aydemir reported that only patients with ptosis more than 4 mm experienced significant decrease in corneal curvature and astigmatism after surgery [22]. Younger patients tend to experience a greater reduction in corneal astigmatism following ptosis surgery. changes in astigmatism become more stable over time after eyelid surgery, particularly after 6 months [11, 15].

References

1. Al-Sharify, N., , Noor T.,, Ahmed, S. M., Weng, L. Y., See, O. H., Al-Sharify, Z. T., & Ghaeb, N. H. (2023). Review study of refraction error measurement methods of human cornea. AIP Conference Proceedings, 2787(1). https://doi.org/10.1063/5.0150148
2. Fan, R., Chan, T. C., Prakash, G., & Jhanji, V. (2018). Applications of corneal topography and tomography: a review. Clin Exp Ophthalmol, 46(2), 133-146. https://doi.org/10.1111/ceo.13136
3. Kanclerz, P., Khoramnia, R., & Wang, X. (2021). Current Developments in Corneal Topography and Tomography. Diagnostics (Basel), 11(8). https://doi.org/10.3390/diagnostics11081466
4. Roberts, C. J. (2019). Corneal topography. Refractive Surgery E-Book, 49.
5. Corbett, M., Maycock, N., Rosen, E., & O'Brart, D. (2019). Corneal Topography: Principles and Applications. https://doi.org/10.1007/978-3-030-10696-6
6. Ghemame, M., Charpentier, P., & Mouriaux, F. (2019). Corneal topography in clinical practice. J Fr Ophtalmol, 42(10), e439-e451. https://doi.org/10.1016/j.jfo.2019.09.001
7. Jalife-Chavira, J., Trujillo-Schiaffino, G., Mendoza-Villegas, P., Salas-Peimbert, D., Anguiano-Morales, M., & Corral-Martinez, L. (2019). Optical methods for measuring corneal topography: A review. Optica Pura y Aplicada, 52, 1-26. https://doi.org/10.7149/OPA.52.2.51016
8. Ucakhan, A. (2020). Corneal Topography. In StatPearls. StatPearls Publishing.
9. Bandlitz, H.-J., Dharwadkar, S., and Knorz, M. (2020): Orbscan IIz vs Pentacam: Which is better for keratoconus evaluation? Ophthalmological Sciences, 20(4): 166–169.
10. Dharwadkar, S., Knorz, M., and Bandlitz, H.-J. (2015): Tomography vs topography in keratoconus evaluation. Ophthalmological Sciences, 18(1): 18–24.
11. Ahmed, I. (2023): Scheimpflug Imaging. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 30844201.
12. Belin, M.W., and Azar, D.T. (2012): Clinical Ocular Surface Disease: Diagnosis and Management. New York, NY: Informa Healthcare, 2012.

13. Parisa, Atighehchian, M., & Farsiani, A. R. (2023). Comparison of corneal measurements using two different Scheimpflug analyzers in Sirius and Pentacam devices. Sci Rep, 13(1), 16956. https://doi.org/10.1038/s41598-023-44133-3
14. Sidky, M., Hassanein, D., Eissa, S., Mostafa, Y., & Lotfy, N. (2020). Prevalence of Subclinical Keratoconus Among Pediatric Egyptian Population with Astigmatism. Clinical Ophthalmology, Volume 14, 905-913. https://doi.org/10.2147/OPTH.S245492
15. Uğurbaş, S. H., & Zilelioğlu, G. (1999). Corneal topography in patients with congenital ptosis. Eye (Lond), 13 (Pt 4), 550-554. https://doi.org/10.1038/eye.1999.136
16. Fagien, S. (2004). Reducing the incidence of dry eye symptoms after blepharoplasty. Aesthet Surg J, 24(5), 464-468. https://doi.org/10.1016/j.asj.2004.07.001
17. Saadat, D., & Dresner, S. C. (2004). Safety of blepharoplasty in patients with preoperative dry eyes. Arch Facial Plast Surg, 6(2), 101-104. https://doi.org/10.1001/archfaci.6.2.101
18. Von Helmholtz, H. (1925). Helmholtz's treatise on physiological optics (Vol. 3). Optical Society of America.
19. Marinescu, M., Dascalescu, D., Constantin, M., Coviltir, V., Burcel, M., Darabus, D., Ciuluvica, R., Stanila, D., Potop, V., & Alexandrescu, C. (2022). Corneal Biomechanics - an Emerging Ocular Property with a Significant Impact. Maedica (Bucur), 17(4), 925-930. https://doi.org/10.26574/maedica.2022.17.4.925
20. Li, X., Liu, C., Mao, Z., Liang, X., Li, Z., Liu, X., Gong, R., & Huang, D. (2020). Effect of congenital blepharoptosis on corneal biomechanical properties and changes after ptosis surgery. Eye (Lond), 34(6), 1055-1062. https://doi.org/10.1038/s41433-019-0586-9
21. Liu, Y., Chen, T., Huang, J., Li, W., Chen, Y., & Huo, L. (2022). Refractive error characteristics and influence on ocular parameters in patients with unilateral congenital ptosis. BMC Ophthalmol, 22(1), 291. https://doi.org/10.1186/s12886-022-02511-x
22. Aydemir, E., & Aksoy Aydemir, G. (2023). Ptosis effects on intraocular lens power calculation. J Cataract Refract Surg, 49(2), 171-176. https://doi.org/10.1097/j.jcrs.0000000000001063
23. Sinclair, P. D. (2018). .Metabolic effects of bariatric surgery. Clinical chemistry, 64(1), 72-81.
24. Pearson-Stuttard, J., Zhou, B., Kontis, V., Bentham, J., Gunter, M. J., & Ezzati, M. (2018). Worldwide burden of cancer attributable to diabetes and high body-mass index: a comparative risk assessment. The Lancet Diabetes & Endocrinology, 6(6), e6-e15.
25. Brown, M. S., Siegel, I. M., & Lisman, R. D. (1999). Prospective analysis of changes in corneal topography after upper eyelid surgery. Ophthalmic Plast Reconstr Surg, 15(6), 378-383. https://doi.org/10.1097/00002341-199911000-00002
26. Holck, D. E., Dutton, J. J., & Wehrly, S. R. (1998). Changes in astigmatism after ptosis surgery measured by corneal topography. Ophthalmic Plast Reconstr Surg, 14(3), 151-158. https://doi.org/10.1097/00002341-199805000-00001
27. Kim, Y. K., In, J. H., & Jang, S. Y. (2016). Changes in Corneal Curvature After Upper Eyelid Surgery Measured by Corneal Topography. J Craniofac Surg, 27(3), e235-238. https://doi.org/10.1097/scs.0000000000002435
28. Del Buey-Sayas, M., Lanchares-Sancho, E., Campins-Falcó, P., Pinazo-Durán, M. D., & Peris-Martínez, C. (2021). Corneal Biomechanical Parameters and Central Corneal Thickness in Glaucoma Patients, Glaucoma Suspects, and a Healthy Population. J Clin Med, 10(12). https://doi.org/10.3390/jcm10122637
29. Pimpha, O., Mongkolareepong, N., & Mekhasingharak, N. (2022). Factors associated with corneal astigmatism change after ptosis surgery. Int J Ophthalmol, 15(4), 576-580. https://doi.org/10.18240/ijo.2022.04.08
30. Singer, M. E., Dorrance, K. A., Oxenreiter, M. M., Yan, K. R., & Close, K. L. (2022). The type 2 diabetes 'modern preventable pandemic'and replicable lessons from the COVID-19 crisis. Preventive Medicine Reports, 25, 101636.
31. Watkins, J. D., Carter, S., Atkinson, G., Koumanov, F., Betts, J. A., Holst, J. J., & Gonzalez, J. T. (2022). Glucagon-like peptide-1 secretion in people with versus without type 2 diabetes: a systematic review and meta-analysis of cross-sectional studies. Metabolism, 155375.
32. Espana, E. M., & Birk, D. E. (2020). Composition, structure and function of the corneal stroma. Exp Eye Res, 198, 108137. https://doi.org/10.1016/j.exer.2020.108137
33. Schweitzer, C., Korobelnik, J.-F., Boniol, M., Cougnard-Grégoire, A., Goff, M., Malet, F., Rougier, M.-B., Delyfer, M.-N., Dartigues, J.-F., & Delcourt, C. (2016). Associations of Biomechanical Properties of the Cornea With Environmental and Metabolic Factors in an Elderly Population: The ALIENOR Study. Investigative ophthalmology & visual science, 57, 2003-2011. https://doi.org/10.1167/iovs.16-19226
34. Glupker, C. D., Boersma, P. M., Schotanus, M. P., Haarsma, L. D., & Ubels, J. L. (2016). Apoptosis of Corneal Epithelial Cells Caused by Ultraviolet B-induced Loss of K(+) is Inhibited by Ba(2.). Ocul Surf, 14(3), 401-409. https://doi.org/10.1016/j.jtos.2016.05.001
35. Ruddick-Collins, L. C., Morgan, P. J., & Johnstone, A. M. (2020). Mealtime: A circadian disruptor and determinant of energy balance?. Journal of Neuroendocrinology, 32(7), e12886.
36. Pandey, S., Mangmool, S., & Parichatikanond, W. (2023). Multifaceted Roles of GLP-1 and Its Analogs: A Review on Molecular Mechanisms with a Cardiotherapeutic Perspective. Pharmaceuticals, 16(6), 836.
37. Wang, J. Y., Wang, Q. W., Yang, X. Y., Yang, W., Li, D. R., Jin, J. Y., ... & Zhang, X. F. (2023). GLP− 1 receptor agonists for the treatment of obesity: Role as a promising approach. Frontiers in Endocrinology, 14, 1085799.

38. Somm, E., Montandon, S. A., Loizides-Mangold, U., Gaïa, N., Lazarevic, V., De Vito, C., ... & Jornayvaz, F. R. (2021). The GLP-1R agonist liraglutide limits hepatic lipotoxicity and inflammatory response in mice fed a methionine-choline deficient diet. Translational research, 227, 75-88.