Overview of Influence Factors on Corneal Thickness Measurement

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Abstract: Corneal thickness is an important parameter of the structure of an eyeball. Prior to cornea refractive surgery, the measurement of corneal thickness has been given general importance. With the development of measuring instruments, the measurement of corneal thickness is safer, more accurate and more comfortable. In this study, common clinical measuring methods and their influencing factors are discussed.

Keywords: Corneal Thickness, Influence Factor, Ultrasonic Measurement, Optical Measurement

Introduction

Cornea is an important constituent part of eye refractive system and corneal thickness is an important parameter of eyeball structure. The initial measurement of corneal thickness was from autopsy, in which the corneal thickness was approximately 1 mm. However, due to many objective reasons, there are some differences between measured value and true value. In recent years, the measurement of corneal thickness, especially central corneal thickness, is playing a more and more important role in the prevention and therapy of ophthalmic diseases, while constant creative efforts are made in measurement methods of corneal thickness towards a more convenient, accurate and secure trend. In this study, combining with pertinent literatures, several clinical commonly used measuring methods and their influence factors are summarized separately.

Influence Factors of Corneal Thickness

Corneal thickness may be influenced by gender, eye condition, age, intraocular pressure, diopter, wearing contact lens or not, mydriatic, their diseases and other relevant factors. Elflein et al. (2014) considered that corneal thickness was associated with gender and men had slightly thicker central corneal thickness than women in all age decades (Strohbe et al., 2014; Hoffmann et al., 2013; Sakalar et al., 2012); nevertheless, Gros-Otero et al. (2011) considered that corneal thickness was independent of gender. Vijaya et al. (2010) considered that corneal thickness in various age groups had no obvious difference (Hoffmann et al., 2013; Linke et al., 2013); while Galgaukas et al. (2013) suggested that it was related with age that the elderly and women, expected to have thinner corneas than others and it is useful to repeat measurement of central corneal thickness (Thapa et al., 2012; Filipecka et al., 2013). Nebbioso et al. (2014) believed that there was a positive correlation between corneal thickness and intraocular pressure, i.e., corneal thickening will result in the increasing intraocular pressure to some extent (Aksoy et al., 2014). Rozema et al. (2014) considered that the corneal thickness would become more and more thick as myopia increases, which may be related with eye axis being stretched; yet, Chen et al. (2014) considered that corneal thickness had nothing to do with myopia degree (Ortiz et al., 2014; Al-Mezaine et al., 2009). Sel et al. (2013) suggested that wearing corneal contact lens would make the cornea thinner. Scholar Yuksel N (avoid words that are too personal, e.g., “said”, “insist” and use words that are more neutral. On the other hand, if you claim your own view points, you can use “we believe” “we think”) reported that the corneal thickness would be thinner after using mydriatic (Yuksel et al., 2014). Scholar Azartash K considered the corneal thickness of patients with xerophthalmia was thinner than that of healthy people (Azartash et al., 2011); some reports claimed that diabetes would also give rise to variation of corneal thickness (Urban et al., 2013; Tiutiuca, 2013; Zhang et al., 2013; Storr-Paulsen et al., 2014; Ozdamar et al., 2010) and the history of eye surgery would have an obvious effect on corneal thickness (Hindman et al., 2013).
From the above-mentioned information, the vast majority of scholars believe that gender is not an influence factor of corneal thickness. However, there still exists a dispute in the relation between age and corneal thickness, in which the viewpoints mainly focus on the gradual thinning with increasing age, or the independence of age for corneal thickness. For emmetropic eyes and morphic eyes, people have not reached a consensus on the significant differences in corneal thickness. Besides, a few reports suggest that contact lens will have an influence on corneal thickness with unclear mechanism. In addition, some diseases related with eyes as well as some systemic diseases will also have an influence on corneal thickness.

Main Methods of Corneal Thickness Measurement and Their Influence Factors

Main methods of corneal thickness measurement are ultrasonic measurement and optical measurement. Ultrasonic measurement mainly includes traditional Type-A ultrasonic pachymeter and Ultrasound Biologic Microscope (UBM), with the former routinely used. During the diagnose and therapy of glaucoma, (Choudhari et al., 2013); optical measurement mainly includes non-contact specular microscopy, Orbscan fracture scanning corneal topography/corneal thickness measuring system, Pentacam anterior segment analysis and measurement system, Optical Coherence Tomography (OCT) and confocal microscope. For most cataract patients, non-contact specular microscopy are used in the corneal thickness measurement (Goktas et al., 2012). Here the descriptions are made for principles of measurement and their influence factors of the above-mentioned methods, separately.

Ultrasonic Measurement

Traditional Type-A Ultrasonic Corneal Pachymeter

Principle: Using Type-A Ultrasonic Pachymeter to measure corneal thickness is a kind of method to measure corneal thickness which arose in 1980s. In comparison with traditional optical thickness measuring, it is more accurate and was once considered the “Golden Standard” in the corneal thickness field. Ultrasonic probe is used to emit ultrasonic wave and its propagation velocity in corneal thickness for the measurement of corneal thickness (Pholshvin and Tangpagasit, 2012).

Influence Factors: The reflecting interface of the ultrasonic transmitted by Type-A ultrasonic thickness gauge on posterior surface of cornea was not stable, which often fluctuates between anterior chamber of eye and corneal descemet membrane (Al Farhan et al., 2013). In addition, when probe contacts the cornea of those under test, their tear film will be easily removed and the cornea will suffer the extrusion in varying degrees due to operator’s proficiency, resulting in smaller measured value than actual value (Wu et al., 2014) (try to avoid using; at any cost). There are some data showing that while patients are under some pathologic conditions, such as corneal edema and corneal refractive surgery, both the reflecting interface of ultrasonic wave and the rate of propagation in cornea will alter. Hence, the measuring result would be influenced (Northey et al., 2012). Before the corneal thickness measurement, anesthetic should be dropped in patients’ ocular surface, but surface anesthesia of eyes will cause the corneal epithelium to have mild edema and to be thickened. In addition, edema-induced enhancing hydration of the corneal tissue will change the propagation rate of ultrasonic while it goes through the tissue (Ou et al., 2012). In actual operation, it is difficult for accurate positioning in continuous measurement, resulting in a larger error in calculating average corneal thickness (Agarwal et al., 2012).

Ultrasonic Biological Microscope (UBM)

Principle: The 50~100MHz high-frequency ultrasonic wave transmitted by the probe is used in UMB to acquire sharply focused image of tissue layers with 4~5mm depth, in which the resolution ratio of the image is 20–50um. Therefore, operators may observe visually the structure of ocular anterior segment including cornea, iris, iris, iridocornealis, ciliary body, crystalline lens, etc (Al Farhan, 2014).

Influence Factors: While using UMB to measure corneal thickness, measuring position needs to be selected manually, thus the proficiency and subjectivity of operators will have some influence on the accuracy of measurement (Al-Farhan and Al-Otaibi, 2012). Furthermore, surface anesthesia and extrusion also have a similar impact on the measuring result as they are in the Type-A Ultrasonic Pachymeter.

Optical Measurement

Non-Contact Specular Microscopy

Principle: In specular microscopy, optical measurement is used to measure corneal thickness. Measuring system calculates the time difference between two reflections through the data acquired by collecting the reflection of anterior corneal surface and corneal endothelial layer. Then the time difference will multiply by the speed of light in the cornea to obtain the distance, i.e., the corneal thickness (Bao et al., 2014).

Influence Factors: In actual operation, while patient’s cornea has scar and serious edema, the reflection of light will distort, resulting in unreliable measured values (Borrego-Sanz et al., 2014);
Moreover, the requirements in the measuring process for patients are relatively high, for instance, when the patient is weak-eyed or with nystagmus as well as few other conditions, larger error will be resulted from the incapability of staring the target light-spot in front of the patient (Al Farhan et al., 2013).

Orbscan Fracture Scanning Corneal Topography/Corneal Thickness Measuring System

Principle: Through the refined calculation of computers, Optical fracture scanning principle is applied and information in each surface of anterior segment is collected so to establish the three-dimensional solid figure of anterior segment, including corneal thickness, front and back corneal surface height, curvature, Kappa angle, anterior chamber depth (Ortiz et al., 2014).

Influence Factors: While different sound count coefficient-parameter values are set in Orbscan fracture scanning corneal topography, the corneal thickness measured will vary accordingly (Crawford et al., 2013); While those under inspection are not able to stare the object in front of them due to various reasons, larger error will exist in the measured value of corneal thickness (Elbaz et al., 2013). Orbscan fracture scanning corneal topography is non-contact measurement in corneal thickness, in which the measured thickness includes the thickness of lacrimal film and result in some error (Park et al., 2012). While the transparency of cornea varies, such as in patients with corneal edema or leucoma, it can be difficult for the light to pass, which is bound to influence the measuring results.

Pentacam Anterior Segment Analysis and Measurement System

Principle: Pentacam anterior segment analysis and measurement system is a newly designed three-dimensional system in recent years for anterior segment analysis and diagnosis, in which Scheimpflug optimal principle is applied for tomography of anterior segment, using the computer to acquire three-dimensional image of anterior segment according to the measurement data collected, meanwhile it may acquire the front and back surface morphology of cornea as well as full corneal thickness (Huang et al., 2014) (this sentence is way too long, so breaking it into 3 will make the reviewer/reader more comfortable).

Influence Factors: During the measurement, tear and eyelid will form a shelter to some extent (Tai et al., 2013); Due to its principle of optimal measurement, it is easy to be influenced by the transparency of cornea. Therefore, there are some requirements in symptoms of eye diseases for those under examination (Mencucci et al., 2012), such as caligo corneae and macular nebula. In addition, during the process of measurement, the requirements of cooperation are relatively high for those under examination, where they are required to keep fixation strictly.

Anterior Segment Optical Coherence Tomography (AS-OCT)

Principle: In AS-OCT, low coherent light waves are used instead of ultrasonic wave to scan the tissue. It uses the different reflectivity of different tissues for light to carry out imaging for the microstructure of tissues (Mazzotta and Caragiuli, 2014).

Influence Factor: The error of corneal measurement by AS-OCT is mainly derived from the proficiency of operators (Jhanji et al., 2013).

Confocal Microscope

Principle: Confocal microscope is a new and non-traumatic corneal imageogical inspection equipment, which makes scanning imaging for cornea in three-dimensional space and time level and measure the thickness of tissue in each corneal layer through Z-Scan system and subsequently measure the thickness of cornea (Ramírez et al., 2012).

Influence Factors: Confocal microscope has inaccurate positioning and low repeatability in the center of cornea (Salvetat et al., 2011); in addition, when patients under inspection have low cooperation, larger error will be resulted in (Al Farhan et al., 2013).

With the unceasing development, new measuring instruments emerge constantly and the measurement of corneal thickness is simpler and more direct. However, the measuring values from different measuring instruments are not the same. Each measuring instrument has both advantages and disadvantages. Measuring methods based on optical principle are largely influenced by corneal transparency; meanwhile, those based on ultrasonic principle are contact-type, increasing patients’ discomfort, meanwhile, they have high requirements for operators. The measurement value is also influenced significantly by human factor, including both the skills of operators and cooperativity of patients. With the development of inspection techniques, we believe that new type measurement instruments and methods which are more simple and convenient in operation, more accurate in measurement and more comfortable for patients will emerge in the near future.

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Author’s Contributions

Pengtuo Xiao and Shurong Wang: Contributed equally to this study, share first authorship. Conception and design, data collection and manuscript writing.

Xin Liu, Yuxi He and Ying Li: Data collection.

Yan Zhang: Conception, revision and final approval of the version.

Ethics

All authors read and approved the final version and are responsible for any ethical issue that may arise after the publication of this manuscript.

References

Agarwal, T., S. Bhartiya, T. Dada, A. Panda and V. Jhanji et al., 2012. Agreement of corneal thickness measurement using slitlamp and ultrasound pachymetry. Eye Contact Lens, 38: 231-233. DOI: 10.1097/ICL.0b013e318250884e

Aksoy, D., H. Ortak, S. Kurt, E. Cevik and B. Cevik, 2014. Central corneal thickness and its relationship to Parkinson’s disease severity. Can. J. Ophthalmol., 49: 152-156. DOI: 10.1016/j.jcjo.2013.12.010

Al Farhan, H.M., 2014. Agreement between Orbscan II, VuMAX UBM and Artemis-2 very-high frequency ultrasound scanner for measurement of anterior chamber depth. BMC Ophthalmol., 14: 20-20. DOI: 10.1186/1471-2415-14-20

Al Farhan, H.M., W.M. Al Otaibi, H.M. Al Razqan and A.A. Al Harqan, 2013. Assessment of central corneal thickness and corneal endothelial morphology using ultrasound pachymetry, non-contact specular microscopy and Confoscan 4 confocal microscopy. BMC Ophthalmol., 13: 73-73. DOI: 10.1186/1471-2415-13-73

Al-Farhan, H.M. and W.M. Al-Otaibi, 2012. Comparison of central corneal thickness measurements using ultrasound pachymetry, ultrasound biomicroscopy and the Artemis-2 VHF scanner in normal eyes. Clin. Ophthalmol., 6: 1037-1043. DOI: 10.2147/OPTH.S32955

Al-Mezaine, H.S., S. Al-Obeidan, D. Kangave, A. Sadaawy and T.A. Wehaib et al., 2009. The relationship between central corneal thickness and degree of myopia among Saudi adults. Int. Ophthalmol., 29: 373-378. DOI: 10.1007/s10792-008-9249-8

Azartash, K., J. Kwan, J.R. Paugh, A.L. Nguyen and J.V. Jester et al., 2011. Pre-corneal tear film thickness in humans measured with a novel technique. Mol. Vis., 17: 756-767.

Bao, F., Q. Wang, S. Cheng, G. Savini and W. Lu et al., 2014. Comparison and evaluation of central corneal thickness using 2 new noncontact specular microscopes and conventional pachymetry devices. Cornea, 33: 576-581. DOI: 10.1097/ICO.0000000000000113

Borrego-Sanz, L., F. Sáenz-Francés, M. Bermudez-Vallecilla, L. Morales-Fernández and J.M. Martínez-de-la-Casa et al., 2014. Agreement between central corneal thickness measured using Pentacam, ultrasound pachymetry, specular microscopy and optic biometer Lenstar LS 900 and the influence of intraocular pressure. Ophthalmologica, 231: 226-235. DOI: 10.1159/000356724

Chen, Y.C., T. Kasuga, H.J. Lee, S.H. Lee and S.Y. Lin, 2014. Correlation between central corneal thickness and myopia in Taiwan. Kaohsiung J. Med. Sci., 30: 20-24.

Choudhari, N.S., R. George, R.V. Sathyamangalam, P. Raju and R. Asokan et al., 2013. Long-term change in central corneal thickness from a glaucoma perspective. Ind. J. Ophthalmol., 61: 580-584. DOI: 10.4103/0301-4738.119338

Crawford, A.Z., D.V. Patel and C.N. McGhee, 2013. Comparison and repeatability of keratometric and corneal power measurements obtained by Orbscan II, Pentacam and Galilei corneal tomography systems. Am. J. Ophthalmol., 156: 53-60.

Elbaz, U., D. Zadok, S. Frenkel, R. Pokroy and F. Orucoglu Orucov et al., 2013. Mathematical approximation of Orbscan II central corneal thickness to contact ultrasound. Cornea, 32: 772-778. DOI: 10.1097/ICO.0b013e318274a6b1

Elflein, H.M., N. Pfeiffer, E.M. Hoffmann, R. Hoehn and U. Kottler et al., 2014. Correlations between central corneal thickness and general anthropometric characteristics and cardiovascular parameters in a large European cohort from the Gutenberg Health Study. Cornea, 33: 359-365. DOI: 10.1097/ICO.0000000000000668

Filipecka, I., A. Nowak, K. Lewicka, B. Kapustka and J. Damek et al., 2013. Evaluate central corneal thickness in patients from Podbeskidzie area in adult patients. Klin. Oczna, 115: 121-124.

Galgauskas, S., D. Norvydaitė, D. Krasauskaitė, S. Stech and R.S. Ašoklis, 2013. Age-related changes in central corneal thickness from a large European cohort from the Gutenberg Health Study. Klin. Oczna, 115: 121-124.

Goktas, A., K. Gumus, G.E. Mirza, C. Crockett and S. Karakucuk et al., 2012. Corneal endothelial characteristics and central corneal thickness in a population of Turkish cataract patients. Eye Contact Lens, 38: 142-145. DOI: 10.1097/ICL.0b013e318243e7d2
Storr-Paulsen, A., A. Singh, H. Jeppesen, J.C. Norregaard and J. Thulesen, 2014. Corneal endothelial morphology and central thickness in patients with type II diabetes mellitus. Acta. Ophthalmol., 92: 158-160. DOI: 10.1111/aos.12064

Strobbe, E., M. Cellini, U. Barbaresi and E.C. Campos, 2014. Influence of age and gender on corneal biomechanical properties in a healthy Italian population. Cornea, 33: 968-972. DOI: 10.1097/ICO.0000000000000187

Tai, L.Y., K.W. Khaw, C.M. Ng and V. Subrayan, 2013. Central corneal thickness measurements with different imaging devices and ultrasound pachymetry. Cornea, 32: 766-771. DOI: 10.1097/ICO.0b013e318269938d

Thapa, S.S., I. Paudyal, S. Khanal, N. Paudel and S.L. Mansberger et al., 2012. Central corneal thickness and intraocular pressure in a Nepalese population: The Bhaktapur Glaucoma Study. J. Glaucoma, 21: 481-485. DOI: 10.1097/JIG.0b013e3182182c0f

Tiutiuca, C., 2013. Assessment of central corneal thickness in children with diabetes mellitus type I. Oftalmologia, 57: 26-32

Urban, B., D. Raczyńska, A. Bakunowicz-Lazarczyk, K. Raczyńska and M. Kretowska, 2013. Evaluation of corneal endothelium in children and adolescents with type 1 diabetes mellitus. Mediators Inflamm., 2013: 913754-913754. DOI: 10.1155/2013/913754

Vijaya, L., R. George, H. Arvind, S. Ve Ramesh and M. Baskaran et al., 2010. Central corneal thickness in adult South Indians: The Chennai glaucoma study. Ophthalmology, 117: 700-704. DOI: 10.1016/j.ophtha.2009.09.025

Wu, W., Y. Wang and L. Xu, 2014. Meta-analysis of Pentacam Vs. ultrasound pachymetry in central corneal thickness measurement in normal, post-LASIK or PRK and keratoconic or keratoconus-suspect eyes. Graefes. Arch Clin. Exp. Ophthalmol., 252: 91-99. DOI: 10.1007/s00417-013-2502-5

Yuksel, N., E. Yuksel and M.D. Ozer, 2014. Evaluation of anterior segment parameters using the Pentacam in hyperopic anisometropic amblyopic and normal eyes. J. AAPOS, 18: 248-250. DOI: 10.1016/j.jaapos.2014.01.013

Zhang, X., R.P. Igo, J. Fondran, V.V. Mootha and M. Oliva et al., 2013. Association of smoking and other risk factors with Fuchs' endothelial corneal dystrophy severity and corneal thickness. Invest. Ophthalmol. Vis Sci., 54: 5829-5835. DOI: 10.1167/iovs.13-11918