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Literature Reviews

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 1mm. 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 (Strobbe *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 Galgauskas *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 Microscopy (UBM), with the for mer routinely usedDuring 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, to detect the echo reflected from posterior surface of cornea by ultrasonic pulse. It uses the time difference received from cornea by ultrasonic wave and its propagation velocity in corneal thickness for the measurement of corneal thickness (Pholshivin 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 corner 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 20~50 um. Therefore, operators may observe visually the structure of ocular anterior segment including cornea, iris, angulus iriddocornealis, 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 leukoma, 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 imageological 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.

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