Astigmatism and Diagnostic Procedures

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ASTIGMATISM AND DIAGNOSTIC PROCEDURES

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SUMMARY – Astigmatism represents an inability of the cornea and lens to provide a sharp image onto the retina. Correcting astigmatic errors, whether congenital, contact lens induced or surgically induced, is now an integral part of modern cataract and refractive procedures. Development of modern technology has enabled accurate diagnosis and perfect opportunities for correction; however, while cataract and keratorefractive surgery have come a long way in the last decade, the treatment and diagnosis of astigmatism continue to challenge ophthalmologists. There are several diagnostic procedures and tools available today, some standard and some contemporary that include keratometry, corneal topography, apparatus using wavefront or Scheimpflug analysis like Orbscan, Pentacam, Wavescan, etc. With the introduction of several new diagnostic tools, measurements of astigmatism have become less of an issue, but in some cases it is still difficult to obtain consistent results. What remains still unanswered is the question of the best diagnostic tool on the market. Further research is needed to evaluate both tools as well as their clinical application for optimal use.

Key words: *Astigmatism; Refractive surgery; Keratometry; Corneal topography; Scheimpflug*

Astigmatism is the result of an inability of the cornea and lens to properly focus a sharp image onto the retina. It often occurs with nearsightedness and farsightedness and can be congenital, contact lens induced, or surgically induced[1]. Based on the axis of the principal meridians, it can be regular (principal meridians are perpendicular) and irregular (principal meridians are not perpendicular). Regular astigmatism is divided into with-the-rule astigmatism, when the vertical meridian is steepest, against-the-rule astigmatism when the horizontal meridian is steepest and oblique astigmatism in which the steepest curve lies in between 120 and 150 degrees and 30 and 60 degrees[2]. The development of modern technology has enabled accurate diagnosis and a perfect opportunity for correction of this refractive error[3].

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Diagnostic procedures include both standard and contemporary diagnostic methods. Keratometry is measurement of the anterior central corneal curvature and is performed with a **manual keratometer**. This device is used to approximate the refracting power of the cornea and gives 2 corneal curvature values (maximum and minimum) 90 degrees apart. The two basic keratometers are the Javal-Schiotz type and the Helmholtz type**. Javal-Schiotz keratometer** is a two-position instrument that uses adjustable object size and requires alignment of a red square and green staircase design. It varies the object size to achieve a known image size[4]. **Helmholtz keratometer** is a one-positioning device that uses adjustable image size and consists of aligning plus sign and minus sign mires. It varies the image size to achieve a known object size. Final stage is conversion of the radius of curvature to corneal refractive power. This device has a number of limitations because it measures a small region of the cornea (3 mm central zone), and this measured region is different for corneas of different powers. It also assumes that the cornea has a symmetric spherocylindrical shape with a major and minor axis separated by 90 degrees. It does not account for spherical aberration, and it is susceptible to focusing and misalignment errors. Distortion of the mires precludes accurate measurement of irregular corneas and cannot be quantified. Alternatives to the traditional keratometer are automated instruments that provide keratometry readings alone or in addition to a number of other functions. These include **autorefractors** that measure refraction, **corneal topographers** that map the anterior corneal surface, and the **IOLMaster** that calculates axial length, anterior chamber depth, white-to-white distance, and IOL powers for cataract surgery[3,5,6].

Corneal topography is an imaging method for the measurement of the anterior surface of the cornea, its curvature and shape. This method is based on Placido reflective image system. It analyzes reflected images of multiple concentric rings projected on the cornea[7]. The reflected image is captured on a charge-coupled device camera, and then computer software analyzes the data and displays the results in various formats. The advantage of corneal topography is the ability to measure and quantify irregular astigmatism, which cannot be done with a keratometer and corneal curvature over a variety of central optical zone diameters. Corneal topography maps offer a two-dimensional representation of a three-dimensional corneal curvature. Colors are used to represent curvature values in a dioptric range, and from these various color-coded curvatures, corneal shapes are categorized. Warm colors usually represent steeper curvatures, while cool colors represent flatter curvatures. Most maps fall into five basic shape categories: round, oval, symmetric bow tie, asymmetric bow tie and irregular. The normal cornea is steepest centrally and flattens toward the periphery, and maps of both eyes are individual, although similar. Corneal topography is used to characterize various conditions, as follows: very steep or flat corneas, keratoconus with local steepening, sharp transition zones after uncomplicated refractive surgeries, diffusely irregular surfaces after penetrating keratoplasty, complex surfaces after complicated refractive surgeries with decentered ablations, and central islands[8,9]. The imaging requires an intact epithelial surface and tear film. The error of corneal topography is under optimal conditions in the range of ±0.25 D; in abnormal corneas seen in clinical practice it can be ±0.50-1.00 D due to several limitations.

Disadvantages of the Placido-based systems are: focusing errors, alignment and fixation errors with induced astigmatism, difficulty to calculate the position of the center from the small central rings, and increased inaccuracy toward the periphery because the accuracy of each point depends on the accuracy of all preceding points.

The Orbscan is a three-dimensional slit-scanning topography system for analysis of the anterior and posterior surface of the cornea[7]. This instrument allows us to obtain data on corneal topographic maps in the form of technology that collects about 9600 data points in 1.4 seconds and to make a very detailed overview of the entire corneal surface of 11 mm. The high-resolution video camera captures 40 light slits at the 45° angle projected through the cornea similarly as seen during slit lamp examination. The instrument's software analyzes 240 data points *per* slit and calculates corneal thickness and posterior surface of the entire cornea. The system provides information on anterior corneal elevation and curvature, posterior corneal elevation and curvature, full corneal pachymetry, keratometry, white-to-white diameter, pupil size, anterior chamber depth, angle kappa and irregularity index. The system is used for diagnosis of various forms of keratoconus, glaucoma, cataract and refractive surgery[10]. Elevation of the front surface of the cornea allows the clinician to assess abnormal forms of the cornea, thereby achieving a more accurate diagnosis and provide a better outcome of surgery. Maps show the curvature, or looping such as elevation, that is translated in the form of topography (hills and plains). This translation can be tricky in the case of asymmetric folder or irregular surfaces, and it depends on the observer's interpretation. In the recent past, Orbscan was the first choice of technology that allowed detailed presentation of corneal shape. It is unable to provide sufficient accuracy in the processing of images of the front surface of the cornea, especially in cases of thin corneas or after refractive surgery. Consequently, the Orbscan is no longer a gold standard in refractive surgery.

Pentacam is a comprehensive non-contact eye scanner which provides an accurate three-dimensional view of anterior eye segment by using rotation

Scheimpflug camera in all meridians. The measurement is agreeable to the patient and the result is objective corneal topography, pachymetry of the whole corneal surface, tomographic analysis, 3D analysis of anterior chamber, measuring lens density, and IOL calculation after corneal refractive surgery[11,12]. The center of the cornea, which is crucial in the planning of refractive surgery, can be measured very precisely because of the rotating recording process. The process typically takes less than 2 seconds, the measurement includes 25000 elevation points, and small movements of the eye are automatically corrected. Topography includes creation of a map which describes the elevation and depression of corneal surface. Pentacam gives significantly more accurate measurements of elevation in relation to the Orbscan. The device also measures corneal thickness (pachymetry), so it generates 25000 data points that give us information on the front and rear surface, thus allowing accurate measurement of thickness throughout the area. This principle yields better results than the standard ultrasound pachymeter that measures the thickness of the cornea at one point. Another advantage of Pentacam compared to Orbscan is the ability to determine the degree of opacity of the natural lens of the eye, which helps us in identifying the appropriate approach to the treatment of reduced visual acuity. In addition, it allows IOL power calculation, which is planned to be installed, and is especially useful in cases of eyes that had previously been treated with laser correction[13].

The Wavefront WaveScan technology creates a 3D map of the unique imperfections of eyes; it allows precise measurements of higher order aberrations, which have a significant impact on the quality of vision and cannot be removed with eyeglasses and contact lenses. Higher order aberrations are unique to each person and include difficulty seeing at night, glare, halos, blurring, starburst patterns and double vision (diplopia)[14]. Wavefront™ technology was originally developed for use in high-powered telescopes to reduce distortions when viewing distant objects in space. This diagnostic tool compares the behavior of light passing through the eyeball to the behavior of light as it would pass through an ideal eye with error-free imaging. The Wavefront Wavescan procedure creates detailed images of the visual system, showing all present deviations (lower and higher order), which provides the most precise laser correction of such a deviation and therefore the best results of laser surgery[15-17]. The development of modern technology has enabled accurate diagnosis and a perfect opportunity for correction of astigmatism, which still represents a challenge for ophthalmologists. Devices for measuring astigmatism are "mandatory" in a modern ophthalmologic department; they also enable precise analysis of the anterior segment and provide perfect correction of visual acuity in cataract and keratorefractive surgery.

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Sažetak

PRIMJENA SUVREMENE TEHNOLOGIJE U DIJAGNOSTICI ASTIGMATIZMA

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Astigmatizam predstavlja svojevrsnu nemogućnost rožnice i leće da stvore jasnu i oštru sliku na mrežnici. Korekcija astigmatizma dio je moderne refraktivne i kirurgije katarakte, bilo da se radi o kongenitalnom, uzrokovanom kontaktnim lećama ili kirurški uzrokovanom astigmatizmu. Razvoj moderne tehnologije omogućio je lakše otkrivanje i postavljanje dijagnoze, no unatoč velikom napretku kirurgije terapija i dijagnostika astigmatizma i dalje predstavlja velik izazov. Nekoliko je dijagnostičkih postupaka odnosno uređaja danas dostupno, pa se tako razlikuje keratometrija, kornealna topografija, uređaji za *wavefront* i Scheimpflug analizu kao Orbscan, Pentacam, Wavescan itd. S uvođenjem novih uređaja mjerenje i dijagnostika astigmatizma je pojednostavljena, no i dalje postoje slučajevi s nezadovoljavajućim rezultatima. Nerazjašnjeno ostaje i dalje pitanje univerzalnog dijagnostičkog postupka i uređaja, pa stoga valja naglasiti i potrebu budućih studija, odnosno daljnjih istraživanja glede evaluacije uređaja i njihove optimalne kliničke primjene.

Ključne riječi: *Astigmatizam; Refraktivna kirurgija; Keratometrija; Kornealna topografija; Scheimpflug*