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Subjective measurement of peripheral refraction

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Summary. — The quality of the peripheral image affects several visual aspects. In particular, eye shape, determined by peripheral refraction, has been shown to be an important factor associated with refractive error in children. For this reason, analysis of off-axis refractive error is one of the subjective measurements that should be performed during refractive procedures. Peripheral refraction refers to the position of the focal point of light radiation reaching the eye when horizontal rays are focused on fovea, outside primary visual axis. Recent studies have found that peripheral refractive error plays an important role in the development of myopia: myopic individuals show hyperopic defocus unlike emmetropes or hyperopes, who have myopic defocus at the peripheral level; thus, in order to focus objects located in the peripheral visual field on the retina, the bulb is prone to elongation. The aim of the study was to develop a method for measuring peripheral refraction, accessible to all clinicians without special instruments, and that can be performed during the refractive examination to obtain an additional finding in addition to the central refractive data.

1. – Introduction

In recent years, interest regarding peripheral refraction has seen an increase directly proportional to its correlation with myopia progression. The study of off-axis refraction has increased rapidly after the link between myopia development and peripheral refraction has been developed [1, 2]. Indeed, although it has always been thought that the foundation of refractive development was derived from central vision, the retinal periphery plays a crucial role in emmetropization. It turns out that myopic eyes corrected with spherical geometry tend to have relative peripheral hypermetropia [3]. Peripheral defocus appears to stimulate myopic progression, despite the fact that for every diopter of peripheral hyperopic defocus in children, myopia is increased by only 0.02 D per year [4]. Also contributing to refractive development are off-axis aberrations and their variation during the accommodative mechanism [5, 6].

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1·1. *Myopia progression.* – Myopia can consist of abnormal axial elongation of the eye; this causes images of distant objects to be focused not on the retina but in front of it. This can also result from excessive refraction by ocular structures such as cornea and lens. The level of myopia is usually quantified as refractive error but can also be expressed by measuring axial length in millimeters [7]. We are currently aware of several risk factors that predispose to this refractive condition that can be both environmental and genetic. Myopia is usually highlighted in childhood and tends to increase in adulthood [8]. Myopia represents a common and widespread condition in all areas of the world, so it is very important to implement strategies to reduce its prevalence globally [7]. People with myopia are indeed more likely to develop eye problems that damage vision or in some cases may result in permanent vision loss [9]. For centuries, it was thought that the onset of myopia and its development were mainly related to hereditary factors [10]. In this regard, myopia in Europe is increasing, and current research shows that a myopic parent triples the likelihood of their children being myopic; if both parents are myopic this risk is seven times higher [11]. This means that people do not inherit myopia but the tendency to become myopic. Measures to prevent and control myopic progression include various aspects including public health actions, pharmacological interventions, and optical solutions [3]. Among the public health actions, we find the indication of spending time outdoors, it was previously shown that there was an association between time outdoors and myopia [12], and more recently it was found that time outdoors does not affect progression in already myopic individuals but reduces its onset [13]. Pharmacological interventions that are effective and have fewer side effects include the use of low-dose atropine [14]. Instead, undercorrection with ophthalmic lenses appears among the optical strategies adopted for containment. Although still a widespread practice it has been found to be unproductive and even contraindicated, as it would increase the development of myopia [9, 15]. Bifocal and multifocal contact lenses are also used for myopic progression, especially multifocal lenses have the characteristic of having the central part of the lens for distance vision and peripheral areas with positive power that increases progressively [16]. One successful technique is orthokeratology. It involves the nighttime use of rigid gas-permeable lenses with reverse geometry for the purpose of shaping the cornea so that the subject is emmetrope during the day without the need for optical correction [3]. Orthokeratology is a reversible technique, and if the treatment is discontinued, the subject returns in a few days to the starting refractive condition and thus the cornea returns to the way it was before wearing these contact lenses [17]. Several optical solutions to myopia progression work on modifying the corrective parameters in the periphery, so in this study it was evaluated useful to investigate the mode of detection of peripheral refraction.

1·2. *Peripheral refraction.* – To discuss peripheral refraction, it is essential to consider the limitations of the peripheral retina resulting from its non-uniform resolution capacity. The central fovea provides maximum visual acuity, while moving toward the retinal periphery, visual acuity progressively decreases. This implies that retinal images, depending on position, will have different degrees of sharpness. Specifically, blurring will reach 90% compared to the central image at around 40° from the fovea [18]. When talking about peripheral refraction, we refer to all those light rays converging on the retinal plane outside the primary visual axis, this axis consists of the rays reaching the retina horizontally, focusing on the fovea [19]. In addition to retinal anatomical composition, affecting the quality of peripheral vision are aberrations [20] and the Troxler; these can be an obstacle in the study of peripheral vision [20]. Although the scientific literature has interesting content about peripheral vision, historically, it was believed that the refractive state was determined by foveal stimuli. However, since early experiments conducted on animals, it has been demonstrated that foveal vision is not the sole foundation. On the contrary, the peripheral retina alone is capable of effectively regulating the emmetropization mechanism. Moreover, in cases where there are conflicting signals between the periphery and the retinal center, peripheral vision can represent the dominant stimulus in the evolution of refractive status [9]. These statements could be particularly significant in the context of myopia progression. When corrected with spherical ophthalmic lenses, myopic eyes exhibit relative peripheral hyperopia, this is defined peripheral defocus [3]. This connection between peripheral refraction and myopia development, recently identified, has led many researchers to analyze off-axis refraction in horizontal and vertical meridians and for a range of angles using various techniques. The diversification of these techniques occurs not only in terms of the instruments used but also by varying the subject's posture [20]. Most studies on peripheral refraction are objective and instrumental [21]. Aberrometers, such as the Hartmann-Shack wavefront sensor, aim to simultaneously measure the aberrations of rays entering the eye at various points in the pupil [22]. The results of open field aberrometry in several studies have indicated emmetropic or slightly myopic peripheries in emmetropes and low myopes, and hyperopic peripheries in moderate and high myopes [23]. Although some studies report that there is no evidence that a longer axial length is associated with a greater peripheral hyperopic shift of the refraction [24]. In contrast, several studies have been performed using the open-field auorefractometer [25]. Peripheral refraction performed with the autorefractometer has a repeatability that decreases the more we move to the periphery, however it is very good at the extreme periphery [26]. Retinoscopy can also be used for objective detection, despite, a small part of the test is subjective as the practitioner has to personally assess the retinal reflex. However, the Reliability of retinoscopy will be better during on the axis measurement [27]. Regarding peripheral refractive techniques, some require the subject to rotate the head or eye to a peripheral fixation point, others consist of keeping the head and eyes in the primary position of gaze and rotating the instrument to peripheral angles [20]. Regarding subjective detection techniques in the literature there are some articles investigating their methodology. In some cases, contrast detection is applied. Peripheral contrast sensitivity varies with refractive error and can be affected by uncorrected refractive errors [28]. In contrast, it is rare to find studies that illustrate subjective methods that are easily applied and assess whether there are different peripheral responses in myopic or nonmyopic subjects; instead, this is a topic that needs to be addressed and was the purpose of this study.

2. – Materials and methods

Fifty-three participants between the ages of 20 and 72 were examined in this study. Each subject received two separate data collection procedures, both conducted for distance and in monocular vision. Sex, age, central refraction of the right eye (defining the type of ametropia present) and peripheral refraction of the right eye were recorded for each participant.

Procedure 1: the initial procedure involved measuring central refraction for distance. Using a phoropter, the spherical and cylindrical components of the right eye were evaluated. Measurements were made at 5.20 meters using a digital optotype. The goal was to determine the refraction for each subject's maximum visual acuity. Because binocular vision was interrupted, it was not considered necessary to balance the two eyes.

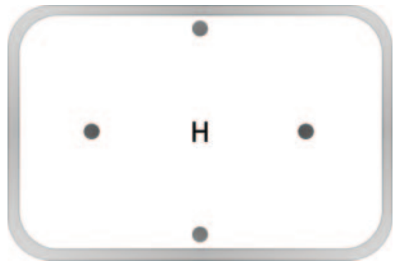

Fig. 1. – Use of central target (H) and peripheral targets (circles) for Procedure 2.

Accurate assessment of central refraction involved three basic steps: fogging, duochrome test, and cross cylinders.

Procedure 2: The second procedure aimed to assess peripheral refraction for distance. Only the spherical component was taken, simplifying the measurement because of complications due to astigmatism and other aberrations. The aim of the study was to provide a highly simplified method for understanding the refractive change response of the subject in the periphery. The sphere measurement was performed on the right eye, using a trial frame to improve the lateral visual field involved in the measurement. Subjects were placed in front of a screen at a distance of 5.20 meters, where an isolated central target was presented with an H or N (letters conventionally used to evaluate the spherical component in Humphriss' method), corresponding to a visual acuity of 2.5/10 or 0.6 logMAR. Small black circular targets were placed on the 4 sides of the screen at distance of 25 cm from central target, allowing assessment of peripheral refraction both horizontally and vertically as in fig. 1. Wearing the full correction obtained from procedure 1, subjects observed the black circles one by one, reporting changes in contrast of the central image. The candidate was evaluated under two different conditions: with the addition of a positive lens (+0.25 D) and with the addition of a negative lens (−0.25 D). The attention was on maintaining fixation on the central target while observing peripheral changes. A critical instruction repeated to the subjects was to never look away from the black circles, but to focus on the peripheral changes, effectively engaging the retinal periphery. This comprehensive examination attempts to understand the refractive change response of the subjects, considering both central and peripheral aspects.

3. – Data collection and analysis

As indicated, 53 subjects between the ages of 20 and 72 were examined. To assess the normality of the age distribution, the chi-square test was employed. The data distribution was not-normal, primarily due to most subjects being around twenty years old. Given the preliminary nature of the study, the sample was mainly recruited from university students. Subsequently, the sample was diversified by recruiting subjects randomly, resulting in a partially more varied age distribution. After that, the distribution of refractive error data was evaluated. Subjects were classified according to their refractive state: emmetropia, myopia, hyperopia, astigmatism, and combinations such as myopia and astigmatism. All examined subjects were included in these categories and no exclusion criteria were assigned for the refractive value. To standardize the analysis, the distribution of central refraction data was evaluated by calculating the spherical equivalent using the formula $sph + (cyl/2)$. Once again, the data set does not exhibit a normal pattern. Finally contingency tables were created to assess the dependence between cat-

TABLE I. – *Lower verified correlation between myopes and negative lenses with a Cramer index of 17%. Table shows the number of myopic and myopic astigmatic subjects who preferred a specific lens in the peripheral field.*

peripheral variation	nasal −0,25	temporal −0,25	upper −0,25	lower −0,25	tot
myopia	9	9	8	9	35
myopia + astigmatism	19	11	14	17	61
total	28	20	22	26	96

egorical variables using the Cramer's test. This index measures the connection intensity between two qualitative variables, evaluating the dependence index and the degree of association between variables. When the index is less than 0.2, there is low dependence; if it is between 0.2 and 0.6, there is moderate dependence; if it is greater than 0.6, there is strong dependence.

In many cases was found a moderate dependence, in particular the identified correlations include:

- Low dependence in case of myopes with negative lenses, with a Cramer's index of 17%. (table I).
- Moderate correlation was observed regarding myopes with positive lenses, hypermetropes, presbyopes, and emmetropes, both with negative and positive lenses. A Cramer's index of 34% was observed for emmetropes with positive lenses and 41% in presbyopes with positive lenses (table II).
- In no case strong dependence was found.

4. – Conclusions

In recent years, the continuous expansion of myopia worldwide has become a growing concern. Due to its prevalence, interest in strategies to limit progression is increasing. Some scientific evidence correlates peripheral refractive error with the longitudinal growth of the eye, typical of myopic eyes. Therefore, peripheral refraction must be considered in the evolutionary mechanism of myopia. Peripheral refraction can be obtained through both objective and subjective methods. There are few references in the literature that discuss subjective methods. The aim of this study was to find out whether there is a simple method for subjective detection of peripheral refraction that allows easy implementation in any optometric setting, especially without the need of a specific instruments.

TABLE II. – *Highest verified correlation between presbyopes and positive lenses with a Cramer index of 41%. Table shows the number of presbyopic and presbyopic astigmatic subjects who preferred a specific lens in the peripheral field.*

peripheral variation	nasal +0,25	temporal +0,25	upper +0,25	lower +0,25	tot
presbyopia	2	2	2	3	9
presbyopia + astigmatism	4	4	2	2	12
total	6	6	4	5	21

In this preliminary study the central monocular refraction and the peripheral refraction were measured in the 53 examined subjects, using a trial frame and trial lenses in an open field. Central refraction was measured objectively and subjectively then for the peripheral one, it was assessed with which of the two lenses (+0.25 D, −0.25 D) the contrast of the central target increased while maintaining fixation on the peripherally placed target. This way, the examined retinal portions were temporal, nasal, superior, and inferior. From the analysis using the calculation of Cramer's index, expressing the degree of correlation between variables, a greater dependence was observed in myopes with the choice of positive lenses and hyperopes, presbyopes, and emmetropes with both negative and positive lenses. In contrast, myopes with negative lenses showed a low correlation.

Although the purpose of the study was to measure peripheral refraction subjectively, the response to negative and positive lens placement may represent a change in accommodative state; therefore, it is considered to have assessed the change in stimulus response and its correlation with the subject's ametropia. It should also be considered significant that although the peripheral angle was small, a lens preference was reported by the subjects and that this behavior, despite having a small sample, was manifested differently depending on ametropia. For future studies, subjective measurements could be correlated with objective measurements, and the sample size should be increased to achieve a greater distribution in age and, consequently, refractive error.

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