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ORIGINAL ARTICLE

Influence of different types of astigmatism on visual acuity

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Abstract
Purpose: To investigate the change in visual acuity (VA) produced by different types of astigmatism (on the basis of the refractive power and position of the principal meridians) on normal accommodating eyes.
Methods: The lens induced method was employed to simulate a set of 28 astigmatic blur conditions on different healthy emmetropic eyes. Additionally, 24 values of spherical defocus were also simulated on the same eyes for comparison. VA was measured in each case and the results, expressed in logMAR units, were represented against of the modulus of the dioptric power vector (blur strength).
Results: LogMAR VA varies in a linear fashion with increasing astigmatic blur, being the slope of the line dependent on the accommodative demand in each type of astigmatism. However, in each case, we found no statistically significant differences between the three axes investigated (0°, 45°, 90°). Non-statistically significant differences were found either for the VA achieved with spherical myopic defocus (MD) and mixed astigmatism (MA). VA with simple hyperopic astigmatism (SHA) was higher than with simple myopic astigmatism (SMA), however, in this case non conclusive results were obtained in terms of statistical significance. The VA achieved with imposed compound hyperopic astigmatism (CHA) was highly influenced by the eye's accommodative response.
Conclusions: VA is correlated with the blur strength in a different way for each type of astigmatism, depending on the accommodative demand. VA is better when one of the focal lines lie on the retina irrespective of the axis orientation; accommodation favors this situation.

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PALABRAS CLAVE
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Defecto esférico;
Estado de acomodación;
Eje

Influencia de los diferentes tipos de astigmatismo en la agudeza visual

Resumen
Objetivo: Investigar el cambio en la agudeza visual (AV) producido por los diferentes tipos de astigmatismo (sobre la base del poder refractivo y la posición de los principales meridianos) en ojos con acomodación normal.
Métodos: Se utilizó el método de desenfoque inducido con lentes para simular un conjunto de veintiocho situaciones de desenfoque astigmático en diferentes ojos emetrópicos sanos. Además, se simularon veinticuatro valores de defecto esférico en los mismos ojos, a fines comparativos. Se midió la AV en cada caso, representándose los resultados, expresados en unidades logMAR, frente a los módulos del vector de potencia dióptrica (desenfoque).
Resultados: La escala LogMAR para AV varía de manera lineal, incrementando la distorsión astigmática, dependiendo la inclinación de la línea de la demanda acomodativa en cada tipo de astigmatismo. Sin embargo, en cada caso, no hallamos diferencias significativas entre los tres ejes analizados (0°, 45°, 90°). No se hallaron diferencias estadísticamente significativas en cuanto a la AV lograda con el defecto miópico esférico (MD) y astigmatismo mixto (MA). La AV con astigmatismo hipermetrópico simple (SHA) fue más elevada que con astigmatismo miópico simple (SMA). Sin embargo, en este caso se obtuvieron resultados no concluyentes en términos de significancia estadística. La AV lograda con astigmatismo hipermetrópico compuesto (CHA) se vio altamente influenciada por la respuesta acomodativa del ojo.
Conclusiones: La AV guarda relación con el desenfoque de modo diferente para cada tipo de astigmatismo, dependiendo de la demanda de acomodación. La AV es mejor cuando una de las líneas focales está en la retina con independencia de la orientación del eje; la acomodación favorece esta situación.

Introduction

Visual acuity (VA) is one of the standard parameters by which the outcome of most clinical trials is judged. Particularly important is the relationship between VA and the refractive state of the eye.[1–4] However, VA is affected by different extrinsic parameters, such as the design of the optotype chart, its luminance and contrast, since these factors can affect the chart readability.[5,6] Moreover, under the same experimental conditions, intrinsic parameters such as the subject's higher-order aberrations,[7,8] pupil size,[9] accomodation,[10] the level of neural adaptation[11–13] and the subjective perception of blur[14] have been demonstrated to influence the results. More specifically, several studies have investigated the effects of the astigmatism on near and distance VA and/or subject's reading performance. Raasch[15] proposed that the single parameter that better correlates refractive errors with VA is the strength (norm) of the vector that represents the refractive error.[16,17] According to this theory the cylinder axis of the astigmatism should have no influence on the expected VA. This hypothesis was supported by Oechsner and Kusel using numerical simulations[18] and later experimentally in different studies.[19–23] On the contrary, Miller et al.[10] and Wolffsohn et al.[24] suggested that with-the-rule astigmatism (WTR) has a less negative influence on VA compared with against-the-rule (ATR) or oblique astigmatism. Trindade et al.,[25] found that, after cataract and intraocular lens (IOL) implantation surgery, patients with ATR astigmatism had better uncorrected near VA than those with WTR astigmatism. On the contrary, in the description of a surgical method for optimizing the outcomes of refractive surgery, Alpins[26] also assumed that WTR astigmatism has a greater optical tolerance than ATR or oblique astigmatism. Kobashi et al.[27] reported that oblique astigmatism had lower VA and reading performance than those with uncorrected 0° and 90° axis of astigmatism. Atchinson et al.[8] found that subjective blur-limits for cylinder at 0° axis, were greater (about 20%) than those for oblique axes. However, in a recent study[28] the same main authors found that VA was affected significantly by the axis of the cylinder, with better VA for 90° than for any other orientation (45°, 135°, and 180°). Therefore, one issue that is still a matter of controversy is the impact of the astigmatic axis orientation on the near and distance acuities.

Moreover, the role that the accommodation plays in this context, has not been investigated in detail in anyone of the above mentioned studies. Recently, by measuring the accommodative response objectively, Stark et al.,[29] found that astigmatism led to increased accommodative variability in certain individuals. Bradley et al.[6] found that, contrary to what happens with spheres, both positive and negative cylindrical lenses at 90° and 180° located in front of an accommodating eye results in a similar VA; indicating that this effect is due to the fact that the human eye cannot selectively accommodate to one meridian. Singh et al.[30] explored the relation between uncorrected simple myopic and simple hyperopic astigmatism and VA in pseudophakic eyes. They found that VA is deteriorated significantly with