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LETTER TO THE EDITOR

Howland brothers: Pioneers of clinical aberrometry

Hermanos Howland: Pioneros de la Aberrometría Clínica

Aberrometers are now present in most of the research laboratories in Visual Science, and refractive surgery clinics, but the basis of the science behind the clinical applications of such instruments and the pioneers who first described the relevance that higher order aberrations of the eye have on the optical quality of the human visual system are not well known to most of us. Furthermore, despite this subject has been the object of review,[1] we believe that very often the credits to the pioneers have not been adequately addressed.

Recalling Helmholtz's quotation that ''...the aberrations of the eye would not be tolerated in any other optical system...''[2] and despite the fact that they are, in fact, quite well tolerated in the normal eye, their expression in disease and post-surgical eyes, can reach values that severely affect the quality of vision and quality of life of millions of patients that cannot be explained by the clinical refraction obtained as a combination of sphere, cylinder and axis.

The first to point out this relevant feature of the optical system, and computing such aberrations in a normal population were the brothers Bradford and Howard Howland (Fig. 1), an electrical engineer working at the Massachusetts Institute of Technology (MIT, Boston, USA) and a biologist appointed to Cornell University (Ithaca, NY, USA), respectively. These pioneers used a quite simple but smart principle to compute for the first time the monochromatic high-order aberrations up to the fourth order in 55 eyes of 33 subjects using an aberroscope.[2] They did so by asking the patients to draw the subjective images they observed when looking at a point source of light through a nearly square rhomboidal grid embedded between two cross-cylinders (Fig. 2). From those drawings, they were able to expand the terms of the wavefront error using Taylor series up to the 4th order, thus being able to evaluate relevant aberration terms such as spherical aberration and comatic aberration (Fig. 3).

As with many big discoveries, this also has been not made by purpose. Indeed, the cross-cylinder aberroscope was initially designed by Bradford Howland to evaluate the optical quality of cameras at MIT lab and published in Applied Optics journal in August 1968[3] and soon his brother Howard thought about the possibility of applying the instrument to the human eye. The design of this instrument was somewhat based on the Tscherning's spherical aberroscope.[4] Tscherning was the first to use the term ''aberroscope''. However, Tscherning's aberroscope was not developed until the end of the twentieth century since the criticism received from Allvard Gullstrand, which in the words of Howland, was a very sad story for Tscherning's discovery but that left the field ''untouched'' for them to tackle this topic almost 100 years later. It is also to be acknowledged that Howland brothers were aware at that time of the work of Smirnov in trying to obtain also the quality of vision of the human eye.[5] However, Smirnov's approach was different since a two channel vernier subjective ray tracing method took a lengthy exam and 10–20 h of computation at the time to obtain the results of 1 eye.

But the story behind the early ''quite simple'' beginnings of the technologically complicated aberrometers we have today is also linked to the highest technological advances of the human race. The need for excellent optical quality of the lenses Bradford Howland was interested in evaluating was related to his work at MIT in stabilizing satellites orbiting around Earth. For this purpose he designed optical sensors that used the light of the sun as guides for stabilization purposes.

Technological advances such as the introduction of the WATFOR software compiler from the University of Waterloo (Canada) allowed the Howland brothers to compute their clinical data much faster. WATFOR was one of the faster computer languages in 1965. Today, a standard affordable computer can be used to compute aberrations up to the 10th order or even higher in clinical setting in time scale of milliseconds.

Back to the application of this technology to the human eye, which was described in a paper published in Science in August 1976[2] the most surprising thing was the tremendous deviation from the predictions previously done from the schematic eye and the clarity with which many subjects described qualitatively their experience in viewing the grid that, after computing the deviations of the original patterns from a square grid, resulted in the discovery of comatic aberration in several eyes, particularly in diseased eyes such as keratoconic eyes. Despite the fact that refractive surgery was flourishing in the following two decades, the application to this field came with the interest of Raymond Applegate

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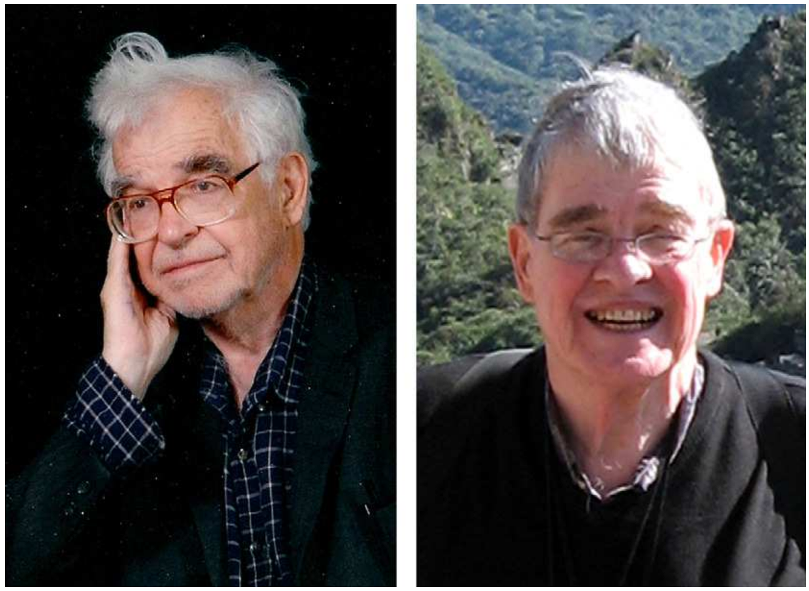

Figure 1 Photograph of Bradford (left) and Howard Howland (right).

(now at Houston University) in computing together with Howard Howland and his associate, Jan Buettner, the aberrations for the front surface of post-surgical corneas. These were analyzed with the first corneal topographers coming out during the late 1980s and early 1990s. It is noteworthy that today, every single corneal topographer describes the corneal surface not only in terms of curvature, power or elevation but also as a wavefront map, and the mathematics that was initially developed to analyze the aberroscopic images was 10—15 years later transferred to the description of corneas and now available in every instrument of the kind. This fact also made people realize the future potential of wavefront aberration calculation in post-surgical eyes.

But as in happened with Gullstrand regarding the criticism to Tscherning's instrument, not everyone appreciated at first glance the developments that might come from the investigation of the optical quality of the eye. Professor Howland recalled some comments such as: ''Howie, there is not much in this, as even some of the worse cases of aberrations have 20/25 visual acuity''; today, we perfectly understand that quantity and quality of vision are quite different things and even 20/20 or 20/15 visual acuity as

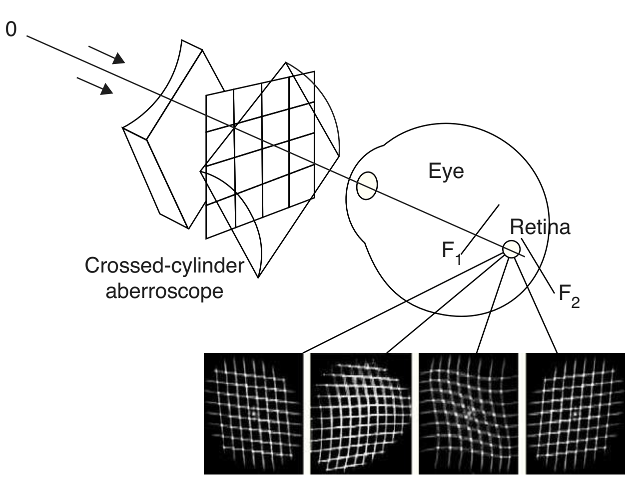

Figure 2 Schematic representation of the cross-cylinder aberroscope and some of the retinal images that can be formed in the retina with different amounts of single aberrations.

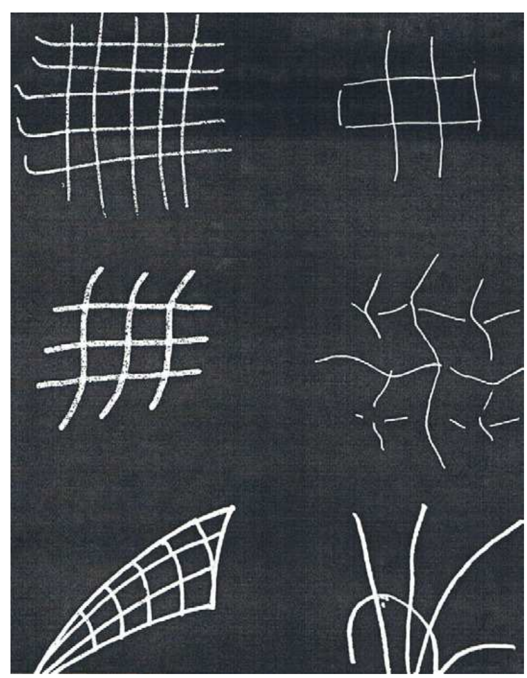

Figure 3 Drawings of the images of 6 patients evaluated with the cross-cylinder aberroscope published in the cover of Science issue, in August 1976. Up-right drawing corresponds to one of the eye of Dr. Howland which is a normal aberrated eye (note the difference in the distortion of the lines when comparing it with a keratoconic eye with a much larger comatic aberration corresponding to the down-left drawing).

measured in a clinical setting might not rule out a significant amount of aberrations.

The contributions of the Howland brothers are to be acknowledged in this and many other fields in Visual Science, including their contributions to the development of photo-refraction, and Howard Howland's work in vision in animal models and the emmetropization mechanism of the eye.

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