Design, construction and test of a surgical keratometer

Desenho, construção e teste de um ceratômero cirúrgico

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SUMMARY

Objective: **The present study aims to draw, build and test a simple and low cost surgical keratometer.**

Methods: **The principle described by Plácido da Costa was used to construct the prototype. A circular ring of light was built and attached to a surgical microscope. The zoom system present in the microscope provided a bigger or smaller image of the ring to the observer. Its size would then be compared to a circular reticle located inside the ocular lens of the microscope. Numeric values were achieved by a graduated scale. The flattest and steepest meridians were also located.**

Results: **A precision between 0.29 and 0.62 D has been achieved in the evaluation of astigmatism. The meridian orientation showed a precision of about 10 degrees of inclination in astigmatisms greater than 1.60 D, and 6 degrees in astigmatisms greater than 1.96 D.**

Conclusion: **This device showed a slightly inferior precision in astigmatism measurement, when compared to conventional surgical keratometers (0.10 to 0.25 D). Equal to high precision was observed when evaluating meridian location (conventional precision = 10 degrees). It should also be mentioned that its low cost and easy use may render it a very useful device.**

Keywords: Cornea surgery; Instrumentation.

INTRODUCTION

Curiosity about the function and form of the cornea dates from the year 150 BC. Galen, at that time, already depicted the eye with a curved form of its external layer endowing it with optical properties [1]. However, refraction laws were only detailed and applied to vision by Kepler, in 1619, ten years after Christopher Scheiner had measured for the first time the curvature of the cornea when comparing reflections of a window, on a sphere of known size, with those produced by the cornea [2]. In 1854, Hermann von Helmholtz applied part of Scheiner's principles to the first device destined to measure the radius of the curvature of the cornea, or keratometer [3].

In the XIX century, measurements of the cornea were used in the attempt to determine the dioptric power of the eye and Alvar Gulstrand presented his schematic eye. With the universalization of the use of contact lenses, keratometry gained another impulse and the global form of the cornea started to be restudied.

As reported by Bicas [4], until 1941 there were only two general articles published, by Gama [5] and by Prado [6], on this matter in the Brazilian literature. However, in 1967, a device able to measure the curvature of the cornea, the depth of the anterior chamber and the visual field was presented.

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The device, designed and constructed by Bicas represented a landmark in the history of biomedical engineering applied to ophthalmoloqy in Brazil [4].

After 1970 refractive corneal surgery was introduced in the US and showed to be a decisive advance in the search for the form of the cornea in view of its possible surgical modification.

The determination of the corneal curvature during ophthalmologic procedures was introduced in 1962 in Colombia by Ignacio Barraquer [7] and from then on several instruments for this purpose proliferated. Surgical keratometers have wrongly been divided into quantitative and qualitative. Wrongly, because the word *kerato* (from the Greek cornea), *meter* (from the Greek measure) implies quantitative measurement and therefore, "qualitative keratometers" should be called keratoscopes.

While precision obtained with a keratoscope regarding evaluation of the corneal curvature at its different meridians (astigmatism) does not exceed 2.0 D [8], keratometers present a precision up to 0.10 D [9]. The simple use and low cost lead to proliferation of surgical keratoscopes but their limited precision opens the way for a simple and low cost surgical keratometer.

The purpose of this study is to design, construct and test a simple low cost keratometer.

METHODS

According to the principle described by Plácido [9], a circular illuminating system was idealized and attached to the objective lens of a surgical microscope presenting a focal distance of 175 mm. Fluorescent light was used for the illumination (25 W daylight, Osram, USA), coupled to a metal support. The lower plate of the support was hollowed and covered with a transparent mask where a circular ring was printed. The illuminated ring had a 133 mm diameter and an approximately 1 mm width.

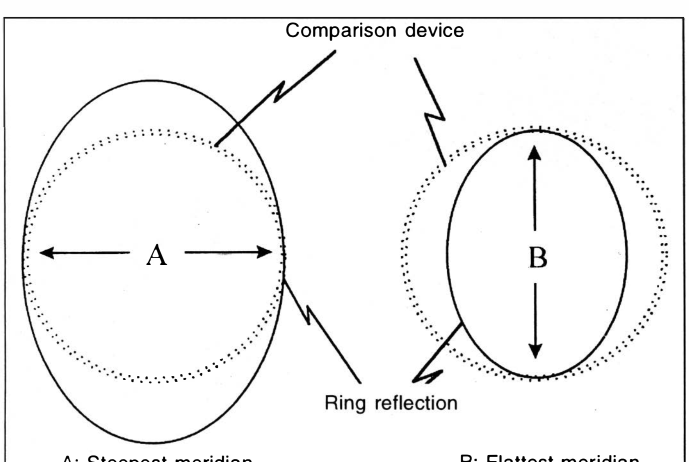


Fig. 1 - Increase or decrease of the size of the image produced by the convex surface in order to coincide with the reticle (double dotted line) present in the microscope.

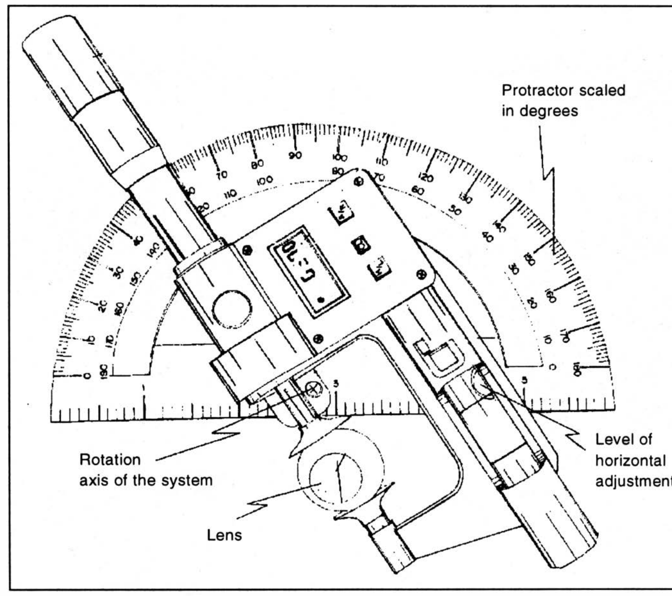


Fig. 2 - Model of inclination of the optical lenses in order to evaluate the meridian of their astigmatism.

The purpose of such an illuminating system was to present a circular image to a polished convex surface, thus producing a virtual, direct and smaller image, located at approximately 2 mm from its posterior surface. The image would be observed and compared with a reticle located at the ocular lens of the microscope. Such reticle presented a double circular line (360 degrees) circled by a semi-compass subdivided into 5 arc degrees.

With the varifocal magnifying (zoom) system present in the microscope, the observer could increase or decrease the observed field and, consequently, the image produced by the surface. The purpose of magnifying, or decreasing, the image was to make the image of the surface coincide with the circular reticle of the microscope. If there is no astigmatism, the image produced would be circular and the superposition complete. If there is astigmatism two points of coincidence would that required in order to define the most steep and flat meridians of the surface (Fig. 1).

A scale was coupled to the manual (zoom) magnifying system for the determination of the numerical values. This scale was empirically constructed measuring the curvature radii of steel spheres of known size.

The device was tested by means of evaluation by three observers of the astigmatism present in eight toric plastic lenses (with astigmatism at the anterior face) oriented in three different positions (90, 180 and 45 degrees). The lenses presented respectively 0.74, 0.98, 1.22, 1.60, 1.96, 2.76, 3.86 and 5.64 D mean astigmatism as measured by the corneal videokeratograph (EyeSys, TX, USA).

In order to determine precision of the astigmatism meridian, five toric lenses (with 0.74, 1.22, 1.60, 1.96 and 3.86 D mean astigmatism) were inclined in preestablished positions and measured by three observers (Fig. 2). Orienta-

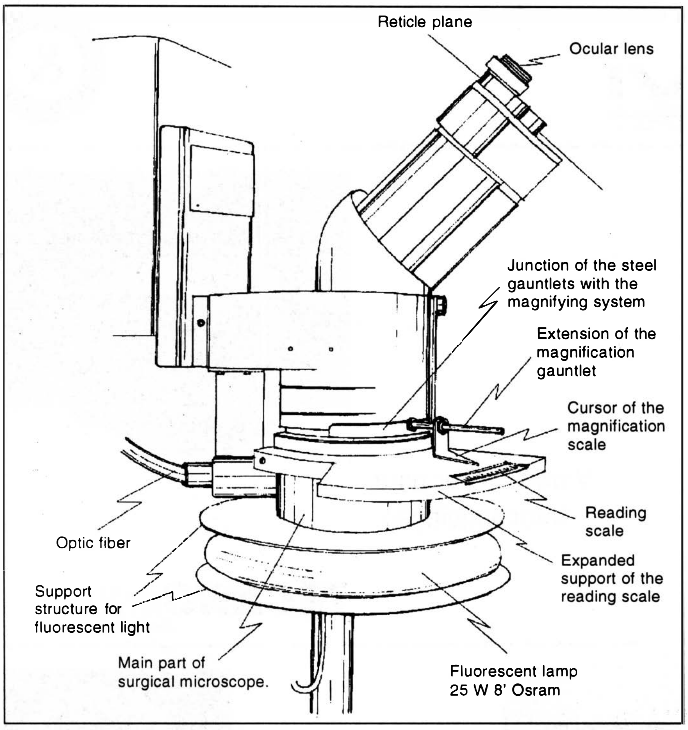


Fig. 3 - Lateral view of the surgical keratometer coupled to a microscope.

tions were measured with a precision of 5 arc degrees using the 180 circumference degrees, totalling 37 meridians. The 37 measurements were made at random by each observer in each lens.

RESULTS

The device was idealized, assembled and empirically calibrated (Fig. 3).

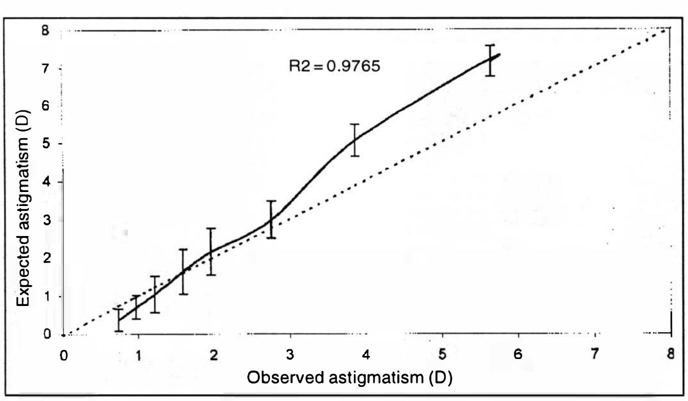
Regarding the quantification of astigmatism, there was a statistically significant reproducibility ($p < 0.005$) in the three tested positions. The astigmatism determined by the keratometer was underestimated by values of approximately 1.50 D and overestimated from this point on. Linear regression curve showed a correlation coefficient (R^2) of 0.9765. The measurements of the three observers were statistically concordant in the three positions of the lenses with 0.74, 0.98, 1.22, 2.76, 3.86 and 5.64 D. The observed standard deviations ranged from 0.29 to 0.62 D) (Graph 1).

A substantial value dispersion around the expected inclination value was observed on measuring the astigmatism meridian when low (below 1.60 D) astigmatisms were measured; mean values of error are between 16.0 and 20.0 degrees with a standard deviation between 11.0 and 16.0 degrees. On reaching 1.60 D, the error decreases to 9.1 degrees and the standard deviation to 6.3 degrees, and from 3.80 D on, the error is kept within 5.4 and 6.7 degrees with a standard deviation of approximately 4.0 degrees (Graph 2).

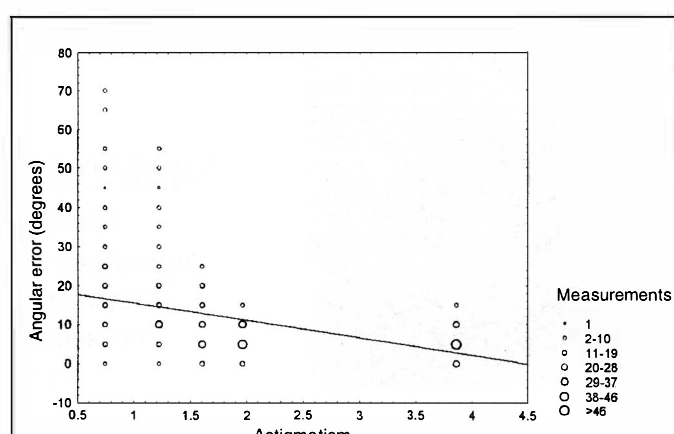
DISCUSSION

Simplicity of construction, using simple optical principles, and mechanisms already present in the microscope are reflected in cost and use of the prototype. The cost remained well below that of the conventional keratometers and its use was accepted by the three observers. In spite of its simplicity, and adjustments required for precision of the printed scale, the results shown are encouraging.

Surgical keratoscopes which do not present an external reference are precise up to a maximum of 2.5 D [11]. We could speculate about the fact of using the Gestalt theory which considers that there is a tendency of the human being to turn irregular forms into regular forms, thus "nullifying" slightly elliptic forms, which would correspond to low astigmatisms [12]. On comparing an image with an external reference, a higher precision of the astigmatism value is attained, however without determining the absolute value of the steepest and flattest



Graph 1 - Behavior of the astigmatism measurements obtained using the keratometer (continuous line) as related to the expected measurements (dotted line). The measurements found below the dotted line denote underestimation while those above the line, denote overestimation. One standard deviation is shown for each measurement. The regression curve is not shown, but presented a regression coefficient of 0.9948.



Graph 2 - Angular error present on measuring lenses with increasing astigmatism. Astigmatisms higher than 1.6D showed standard deviations lower than 6.3 degrees.

meridians. Commercial keratometers cots between US$ 14,000 and 29,000 and present a precision ranging from 0.10 to 0.25 D [9], but more specific data on their performance are scarce, there being a literature regarding only clinical results obtained by their use. The tested model has a precision ranging from 0.29 to 0.62 D and an approximate cost of US$ 500,00. Clinical tests with anesthetized eyes are required for clinical comparison.

The lack of statistical significance regarding reproducibility of astigmatism reading in 1.60 and 1.96 D range in the three positions by the three observers is not easily explained. Technical limitations in the printing of the reading scale which would not reflect a correct curvature value, or imperfections of these lenses, could help but are not the last word regarding this fact. These factors should be accounted for when constructing a prototype for clinical use.

Concerning orientation of the meridians, comparison with commercial devices is again difficult, since values with a precision of 10 degrees, described by Frantz et al. [13], in regard to the keratometer produced by the Nidek company (Palo Alto, CA, USA), render implicit to the reader a constant precision in all astigmatism values. The keratometer presented in this study has a precision of approximately ± 10 degrees of inclination in astigmatisms higher than 1.60 D, and of approximately 6 degrees in astigmatisms higher than 1.96 D. Such a precision does not characterise the device as being useful, for example, in present-day photo-refractive surgeries, but in surgeries related to higher astigmatisms, such as extracapsular cataract extractions, corneal resections and cornea keratoplasty. In these cases there is detection and measurement of astigmatism with characterization of the steepest meridian.

RESUMO

Objetivos: *Desenhar, construir e testar um ceratômetro cirúrgico simples e de baixo custo.*

Métodos: *Para a montagem do aparelho foram utilizados os princípios descritos por Plácido da Costa. Um anel circular iluminado foi construído e acoplado a um microscópio cirúrgico. O sistema de "zoom" do microscópio era acionado pelo observador, que deveria aumentar ou diminuir o tamanho da imagem do anel, produzida pela superfície de teste, até a coincidência com uma retícula circular, presente na lente ocular do microscópio. Uma escala graduada foi montada para a obtenção de valores numéricos. A localização dos meridianos também foi realizada.*

Resultados: *O aparelho apresenta uma precisão de 0,29 a 0,62 D, na medida do astigmatismo. A precisão na medida da localização do astigmatismo é de aproximadamente 10 graus de inclinação, em astigmatismos maiores do que 1,60 D e de aproximadamente 6 graus em astigmatismos maiores do que 1,96 D.*

Conclusão: *O aparelho tem precisão pouco inferior aos ceratômetros convencionais (0,10 a 0,25 D) na determinação do valor do astigmatismo. A precisão na orientação do meridiano mais plano/curvo é igual ou superior aos aparelhos convencionais (precisão de 10 graus). Além disso, seu baixo custo e alta simplicidade de uso, devem torná-lo muito útil em nosso meio.*

Palavras-chave: *Córnea - Cirurgia; Instrumentação.*

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