DESIGN AND IMPLEMENTATION OF AN INTERACTIVE SIMULATOR OF CORNEAL TOPOGRAPHY AS A LEARNING TOOL

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Abstract

Introduction: Corneal topography is a technique that analyses the geometry of the cornea. It is used to detect ocular pathologies, fit contact lenses, and assist in refractive surgery. Learning the interpretation of corneal topographies is a complex task and highly depends on the availability of data from real subjects. The aim of this study was to develop an interactive simulator of corneal topography and evaluate its implementation as a learning tool for university students.

Methods: The development of the interactive simulator of corneal topography was divided into two parts. First, we generated images that simulated corneal topographies, covering the ranges of normal corneas, by using trigonometric formulas and RStudio. And second, we created a platform that enables interaction through buttons and slider bars. This functionality allows users to select the corneal radius, toricity, astigmatism axis, eccentricity, and scale type (absolute or relative) for each simulated corneal topography. The final version was made available to all third-year students at the Optometry degree of the University of Valladolid (30 students). Finally, an anonymous survey was conducted, composed of 8 questions with the Likert scale (from 1, “totally disagree”, to 5, “totally agree”) and 1 yes/no question. The questions involved the intuitiveness, concept and interpretation understanding, utility, satisfaction, and recommendation for future use.

Results: From the 30 students (8 males and 22 females, with a mean age of 21.1±1.0 years), 25 students anonymously answered the survey. The Likert type question with the lowest score was “The simulator has helped me correct some misunderstanding errors in concepts that I thought I had understood”, whose median and interquartile range was 3.0 [3.0-4.0]; the question with the highest score was “The simulator is a useful learning tool to complement the rest of the tools used in class”, whose result was 5.0 [4.0-5.0]; and the 6 remaining Likert type questions obtained the same result, 4.0 [4.0-5.0]. The 25 students answered “yes” to recommending the use of the simulator for future students.

Conclusions: The developed interactive simulator of corneal topography is a valuable tool for teaching corneal topography within university specialties, such as Optometry and Ophthalmology. The positive feedback from the Optometry students, highlighting their positive experiences at all levels, strongly supports its implementation as a learning tool.

Keywords: Simulator, cornea, topography.

1 INTRODUCTION

Corneal topography is a technique that analyses the geometry of the cornea (Fig. 1). This procedure has become indispensable for detecting corneal pathologies, fitting specific contact lenses, and assisting in refractive surgery [1-3]. At the university level, the basics of corneal topography are typically explained through real patient examples. However, this method has some limitations, such as the dependence on varied examples and the inherent noise of real patients. Consequently, explaining concepts not visible in real examples or eliminating patient-specific noise becomes a verbal task for the teacher and an imaginative task for the student, leading to confusion among the different topographical terms.

Nowadays, education must adapt to this changing world. New generations find the use of new technologies attractive [4]. Moreover, tools that promote an active role facilitate knowledge retention [5]. Therefore, to address the challenge of explaining corneal topography concepts effectively, this work aimed to develop a simulator for visualizing corneal topographies, whose parameters can be modified interactively by the teacher and/or the students. Additionally, the work aimed to assess the efficacy of implementing this tool in university education.

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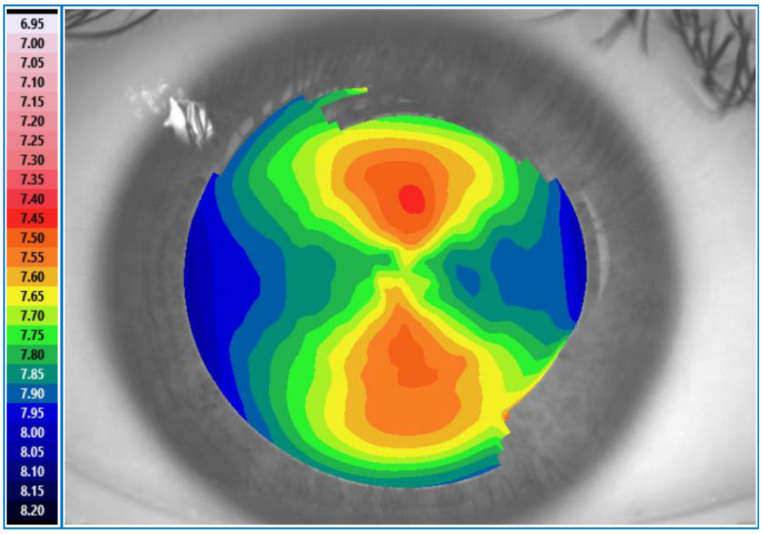

Figure 1. Image of a corneal topography (curvature map).

2 METHODOLOGY

The development of the interactive corneal topography simulator was divided into two parts: firstly, we generated images simulating corneal topographies, and secondly, we created a platform facilitating user interaction with visualization through buttons and sliders. Then, after the simulator was developed, an anonymous survey was conducted among students at the Optometry degree of the University of Valladolid. The details are explained in the following subsections.

2.1 Tool development

2.1.1 Images generation

Images simulating corneal topographies have been generated using R language.

The sagittal height for the principal meridians has been determined based on the shape of an ellipse [6,7], and from these, the intermediate meridians have been calculated by applying a square sinusoidal function [7,8]. The functions used are shown in Table 1. The axial / sagittal curvature was determined by calculating the tangential distance between each calculated point and the axis line (which is known as the axial or sagittal radius). Additionally, elevation was determined by calculating the best-fit sphere that fits each calculated point, and then determining the difference in sagittal height between the simulated cornea and the best-fit sphere at each point. All these calculations were performed for a 4 mm radius, in steps of 0.1 mm, over the entire 360º of the cornea, in steps of 5º. In addition, each graph has been created with two different scales: the absolute scale, which maintains the same maximum and minimum values for all simulations, and the relative scale, whose maximum and minimum values are adjusted to the values of each case.

In total, the following aspects have been combined: 11 radii of curvature (from 7.3 to 8.3 mm, in increments of 0.1 mm), 11 cylinders (from 0 to 5 D, in increments of 0.5 D), 19 cylinder axes (from 0 to 180°, in increments of 10°), 11 eccentricities (from 0.20 to 0.70, in increments of 0.05), and 2 types of scale (absolute and relative), resulting in a total of 50,578 different images.

Table 1. Functions applied to calculate the sagittal height of the principal and intermediate meridians.

Sagittal height of principal meridians	***Sagittal height of intermediate meridians***
$y\,(x) = \frac{r}{1-e^2} * \left(1 - \sqrt{1 - \frac{1-e^2}{r^2} * x^2}\right)$	$y_i\,(\alpha) = y_0 * cos(\alpha) + y_{90} * sen(\alpha)$
'x': radial distance to the centre 'r': central radius of the ellipse 'e': eccentricity of the ellipse	'α': angle formed with one principal meridian 'y_0' and 'y_{90}': sagittal height of the principal meridians

2.1.2 *Online publication: TopoVirtual*

The images were incorporated into an html platform, which enables the interaction. The developed simulator was made freely available online at https://topovirtual.uva.es.

The welcome page allows the user to select the language (Spanish or English), which redirects to the main page. The main page (Fig. 2) contains the interactive components and the topography simulations (numerical and visual results). The interactive elements include four sliders and two buttons allowing selection of corneal radius, toricity, astigmatism orientation, corneal eccentricity, and scale type. The numerical results of the simulations include keratometry, corneal astigmatism, corneal asphericity, and best-fit sphere radius, while the visual results include curvature and elevation maps, curvature and elevation profile graphs, and sagittal profile graph.

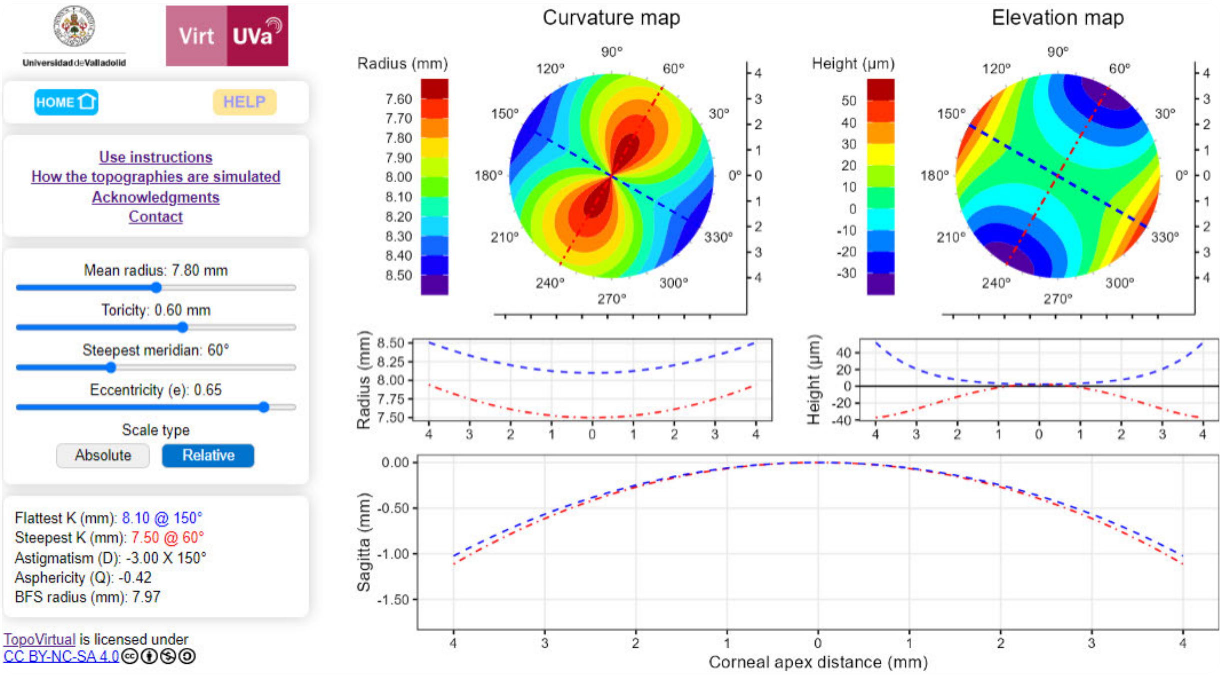

Figure 2. TopoVirtual: interactive simulator of corneal topography, available at: https://topovirtual.uva.es.

2.1.3 *Anonymous survey*

An anonymous survey was conducted among all students enrolled in the third year at the Optometry degree of the University of Valladolid. The survey was composed of 9 questions: the possible response of the first eight questions were based on the Likert scale (from 1, “totally disagree”, to 5, “totally agree”) and the last one was a yes/no question, as shown in Table 2.

Table 2. Questions of the anonymous survey.

No. question	*Questions*
1	The visual aspect is intuitive and understandable.
2	Interactive controls are user-friendly.
3	Help comments provide valuable support.
4	The simulator enhances my understanding.
5	The simulator enhances my interpretation.
6	The simulator helps correct misunderstandings.
7	The simulator is a valuable learning tool.
8	Overall, I am satisfied with the simulator.
9	Would you recommend its use as a learning tool?

3 RESULTS

From the 30 students (8 males and 22 females, with a mean age of 21.1 ± 1.0 years), 25 students anonymously answered the survey. The results of the Likert type questions are shown in Fig. 3. Regarding the yes/no question, the 25 students answered "yes" to recommending the use of the simulator for future students.

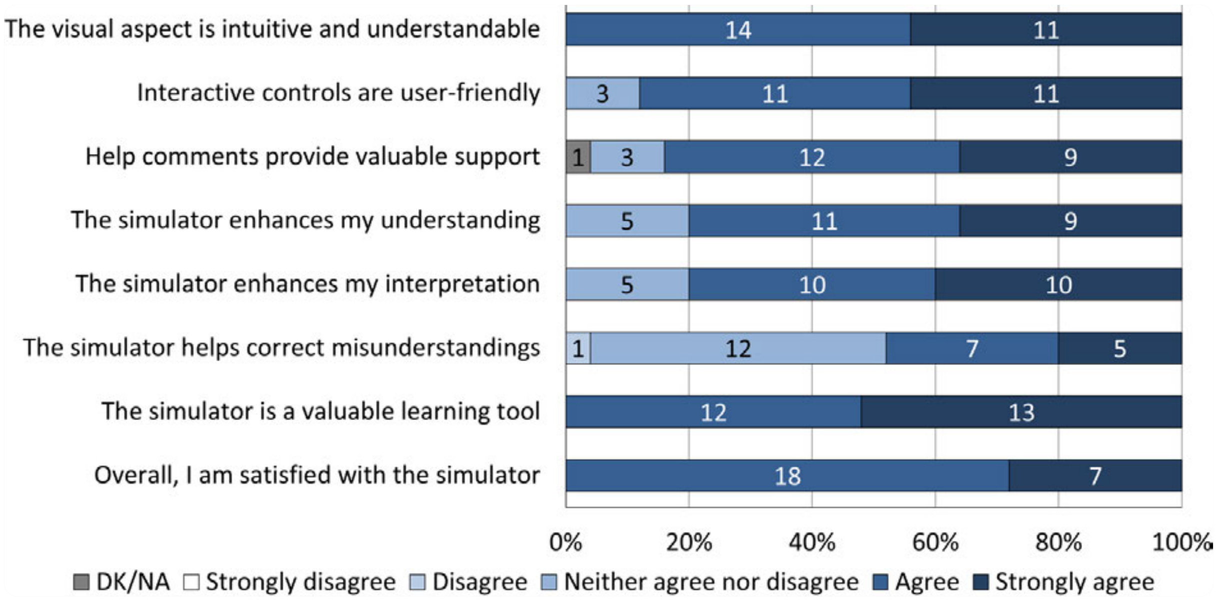

Figure 3. Results of the Likert type questions. The number within the bars indicates the number of students who gave that answer.

4 CONCLUSIONS

The developed interactive simulator of corneal topography is a valuable tool for educational purposes within university degrees like Optometry and Ophthalmology. Its value is highlighted by the positive feedback received from Optometry students, who have reported enriching experiences across all levels. These favourable results provide robust support for its implementation as a learning tool in university education.

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