



# An approach for simulating the fitting of rigid gas-permeable contact lenses using 3D printing technology<sup>☆</sup>



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## ARTICLE INFO

### Keywords:

Rigid gas permeable Lens  
3D printing  
Contact lens fitting

## ABSTRACT

**Objective:** To introduce a new approach to simulate the fitting process of rigid gas-permeable (RGP) contact lenses using 3D printing technology.

**Methods:** A hemispherical or parabolic 3D model was created using 3D Builder or Tinkercad software. The horizontal and vertical diameters and the hemispherical or ellipsoid height were adjusted to simulate different morphologies of the corneal anterior surface. After exporting the file in stereo lithography (STL) format, a solid model was printed using a 3D printer and was used to simulate RGP contact lens fitting.

**Results:** Limited by the precision of the entry-level 3D printer which was used in this study, the print-outs of the corneal models were crude, but the models were tested for their ability to simulate common corneal morphologies with no corneal astigmatism and different axial corneal astigmatism. Compared with some built-in simulation programs for corneal topography, the solid models generated by 3D printing could well simulate the positioning of the lens under the influence of gravity and the eyelid, as well as lens eccentricity or the bubbles under lenses caused by an improper wearing method.

**Conclusion:** 3D printing technology can be well applied in the simulation of RGP contact lens fitting, which may become a new teaching method in optometry.

## 1. Introduction

The rigid gas-permeable (RGP) contact lens is an important means of correcting refractive errors [1–9], and optometry students must learn and master the technique for this lens in clinical practice. Although it is not difficult to understand the theoretical knowledge related to RGP lens fitting for simple myopia and regular astigmatism, proficiency in the RGP lens fitting technique still requires a long practice time for most students, even those with a good understanding of the relevant theoretical knowledge. The unskilled operation of internship students in the early stage of practice may cause eye discomfort during the actual fitting process, which may even lead to some disputes. A method that can well simulate the fitting process of RGP lenses obviously has practical teaching and clinical value.

To solve the above problems, this study tried to introduce a virtual simulation technology and 3D printing technology to the teaching process of contact lens fitting. A preliminary study of its feasibility and practicability were conducted.

## 2. Methods

A hemispherical or parabolic 3D model was created using the free 3D Builder (built into Windows 10, Microsoft) or Tinkercad (running online, Autodesk) software. The horizontal and vertical diameters, as well as the hemispherical or ellipsoid height, were adjusted to simulate different morphologies of the corneal anterior surface (Figs. 1 and 2) to create the desired 3D corneal model.

The components for hand-held or slit-lamp installation were added if needed and were assembled with the previously designed corneal model (Fig. 3), and the designed 3D model was saved in the format supported by the 3D printer being used.

The designed model was printed by a 3D printer (mini 2, TierTime Inc, China) and used for the simulation of RGP fitting (Fig. 4).

## 3. Results

Although the printed corneal models are relatively rough because of the low precision of the 3D printer being used, the models were tested for their ability to simulate common corneal morphologies with no

<sup>☆</sup> Research projects of medical and health in Nanjing, Project number YKK5091.

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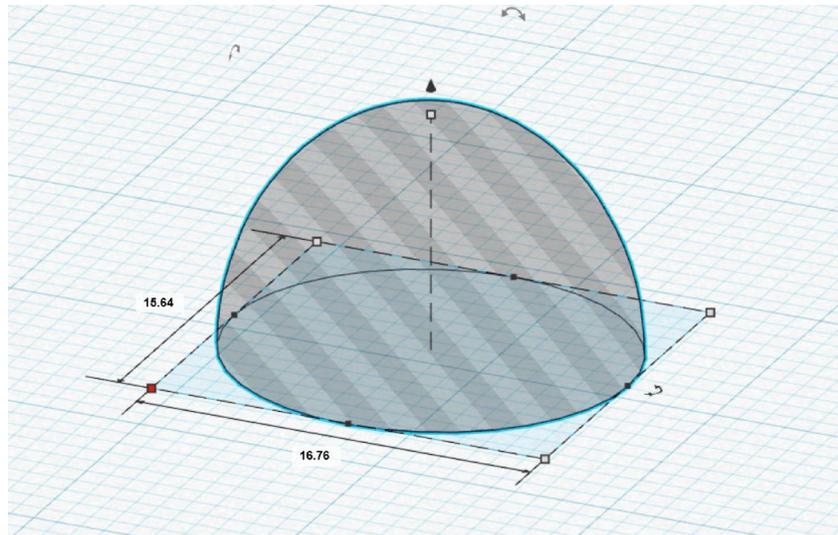


Fig. 1. Using Tinkercad software, the corneal astigmatism is simulated by adjusting the diameters of the two perpendicular axes.

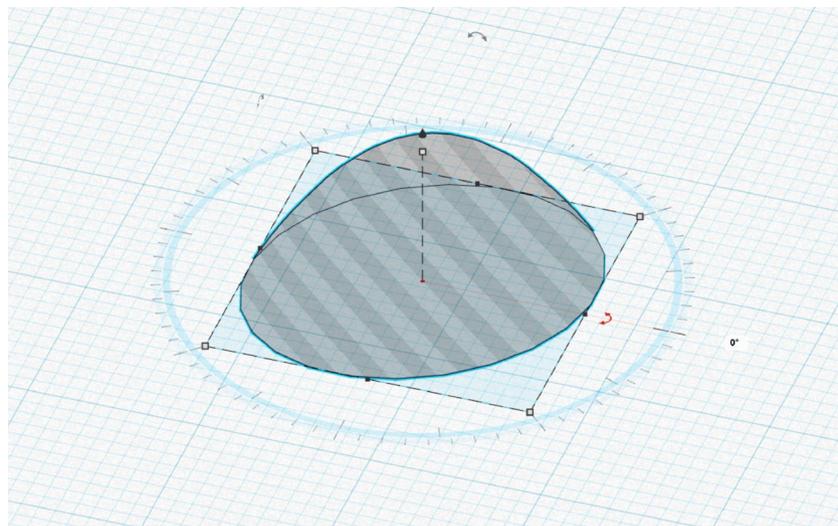


Fig. 2. The axis of astigmatism can also be set by Tinkercad software.

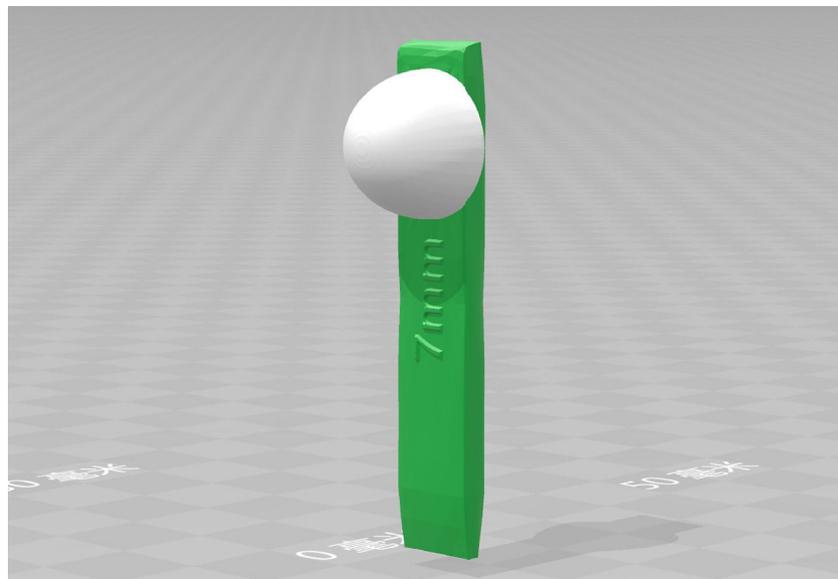
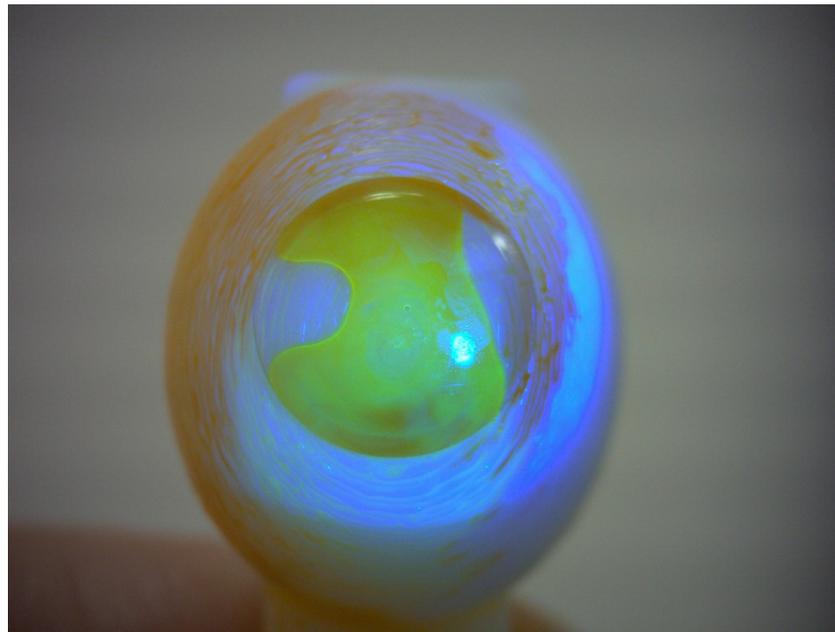


Fig. 3. A computer image of the corneal model and handle designed by 3D builder.



**Fig. 4.** Photograph of a 3D-printed corneal model with an RGP lens. (A corneal model was generated with 3D Builder or Tinkercad software. Subsequently a 3D printer was used to create a physical model of the cornea mounted on a handle which would allow the model to be held in an upright position for viewing with a slit-lamp biomicroscope.)



**Fig. 5.** Photograph of a 3D-printed corneal model with an RGP lens demonstrating a fluorescein pattern of a spherical lens on an astigmatic cornea.

corneal astigmatism and different axial corneal astigmatism. Compared with some built-in simulation programs for corneal topography, the solid models generated by 3D printing could better simulate the positioning of the lens under the influence of gravity and the eyelid, as well as lens eccentricity or the bubbles under lenses caused by an improper wearing method as shown (Figs. 5 and 6).

#### 4. Discussion

Some manufacturers of corneal topography systems developed software for fitting simulation based on corneal topography data to simplify the fitting process of RGP lenses. The principle is to create a simulated fluorescence evaluation diagram (Fig. 7) based on the data for the corneal anterior surface obtained from a corneal topography examination and the lens design parameters of some RGP brands; a try-on lens is chosen on this basis to improve the fitting efficiency

[6,10,16]. There are some obvious disadvantages in this approach: the actual position of the RGP lens on the cornea is also affected by the lens's own weight and the eyelid, and the built-in corneal topography simulation software can not accurately simulate these impacts; in addition, the simulation software cannot simulate lens eccentricity and the bubbles under lenses caused by an improper wearing method.

Based on preliminary experimental results, the method proposed in this study has some advantages: Compared with the traditional teaching methods, this method of constructing a 3D corneal model using 3D printing technology for applications in optometry teaching can stimulate students' interest, allowing intuitive and multi-angle observation of the lens position and fluorescence staining and effectively promoting the understanding and mastering of the relevant knowledge. In addition, it is increasingly difficult for Chinese medical students to directly participate in invasive examinations and treatments during clinical practice due to the serious medical-patient relationship in China. This

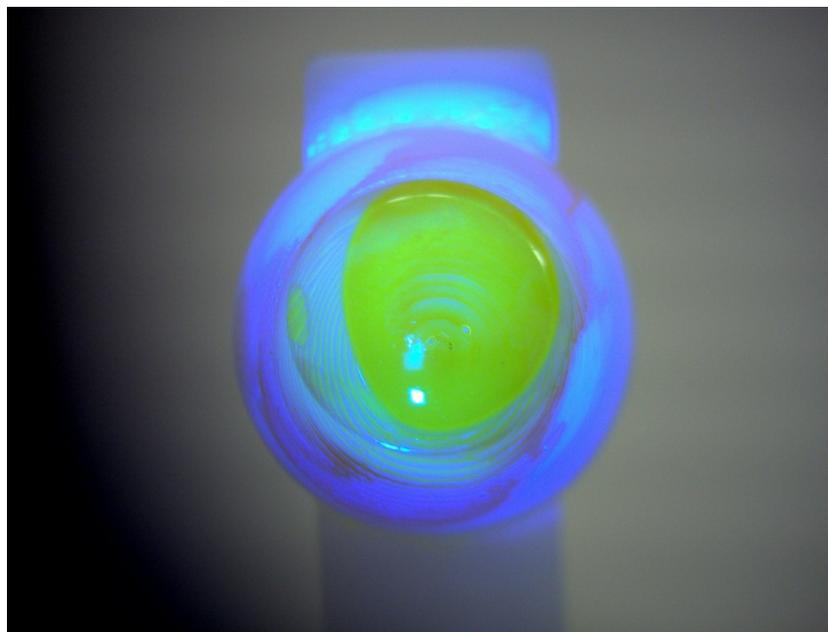


Fig. 6. Photograph of a 3D-printed corneal model with an RGP lens demonstrating a fluorescein pattern of eccentric lens positioning.

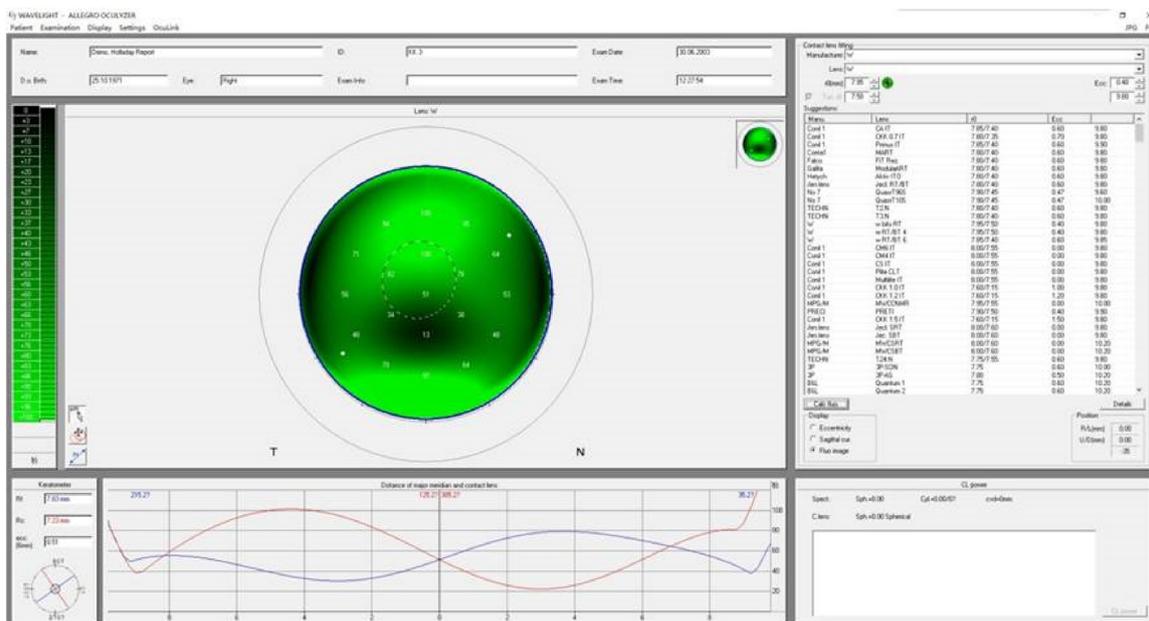


Fig. 7. Simulation software for contact lens fitting built in to some corneal topography systems.

situation will inevitably lead to a decline in the quality of medical education. The application of 3D printing technology in contact lens fitting simulation may help to alleviate the current predicament in medical education in China.

The actual effect of this method awaits further verification by institutions with better experimental conditions, including a 3D printer with higher precision, to evaluate its role in the clinical fitting of RGP lenses. In the future, this approach will be extremely easy if the manufacturers of corneal topography systems include a software option for exporting the corneal anterior surface data in a format supported by 3D printers, and this technique will allow individualization of the corneal model based on the actual conditions of each patient, which will help to improve the success rate of RGP lens fitting in complex cases, such as keratoconus and corneal transplantation cases [10–16].

### Acknowledgement

We thank Ms. Na Song for providing the free RGP lenses for this study. Funding from the Nanjing Medical and Health Foundation is gratefully acknowledged.

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