



Effect of tissue and atmosphere's parameters on human eye temperature distribution

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ABSTRACT

A three dimensional finite element method analysis was employed to investigate the effect of tissue and atmosphere parameters namely, ambient temperature, ambient convection coefficient, local blood temperature, and blood convection coefficient upon temperature distribution of human eyes. As a matter of simplification, only eye ball and skull bone are considered as the system of eye modeling. Decreasing the local blood temperature and keeping it cool is one of the most important ways to control bleeding during surgeries. By lower temperature of body organs such as the eye, the need for oxygenated blood is reduced, allowing for an extension in time for surgery. With this in mind, this study is done to see which one of parameters, such as ambient temperature, ambient convection coefficient, local blood temperature, and blood convection coefficient, has an effective role in decreasing the temperature of the eye. To this end, 3 different paths were employed to find out about the temperature distribution through the eye. The analysis of the three paths demonstrates the interaction of ambient and blood temperature in modeling temperature changes in specific locations of the eye. These data will be important in applications such as eye surgery, relaxation, and sleep therapy.

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1. Introduction

One of the most sensitive and vital part of human body which is directly exposed to environment is the eye. By virtue of lacking protective layer, severe alteration of atmosphere parameters would have sadly influence human eyes. Ambient temperature and convection heat transfer coefficient are the most prominent parameters that could be considered as the environmental parameters which have strong influence on the human eye system.

In the past decade, quite a few of researches and investigations have been done in order to investigate temperature distribution through the eye. For example, Ooi used the boundary element method to analyze the steady state temperature distribution in a two dimensional model of human eye (Ooi et al., 2007). Also, using the Green's function-based FEM, presented the steady state temperature distributions of the eyeball in two dimensional spaces with non-linear boundary condition (Wang and Qin, 2010). Moreover, Efron used a wide-field color coded infrared imaging device in order to measure the temperature profile across the ocular surface of the eye (Efron et al., 1989). Eye structure were simulated by using FEM in transient fields (Ng and Ooi, 2006).

Interaction between aqueous humor and iris were studied (Heys et al., 2001). Shafahi used different models of human eye to investigate the effect of environmental and physiological parameters through human eye geometry (Shafahi and Vafai, 2011). All of the researches mentioned above, were based on a two-dimensional analysis.

Decreasing the local blood temperature and keeping it cool is one of the most important ways to control bleeding during surgeries. By making body organs cool, the need for oxygenated blood becomes less and this makes it possible to spend more time on the operation. In order to make the eye cool, it is possible to change the tissue and atmosphere parameters. In this regard, in this study, the parameters which play a major role in decreasing the eye temperature are investigated.

As mentioned before, one way to control bleeding during surgeries is decreasing the local blood temperature. There is a cavity behind the eye ball which is called orbital cavity. This cavity is a good region to pour the cooling substances. The cooling substances make the local blood temperature of eye cool. So, in this study, considering a new volume for cooling local blood temperature is one of this study's novelties which, as far as the researchers are concerned, have not been considered in other studies. In this manner, the blood temperature is kept close to physiological condition, but the local temperature of eye can be changed. Eyeball with a bone layer of skull was considered as the system which is shown in Fig. 1. Different tissues of this system

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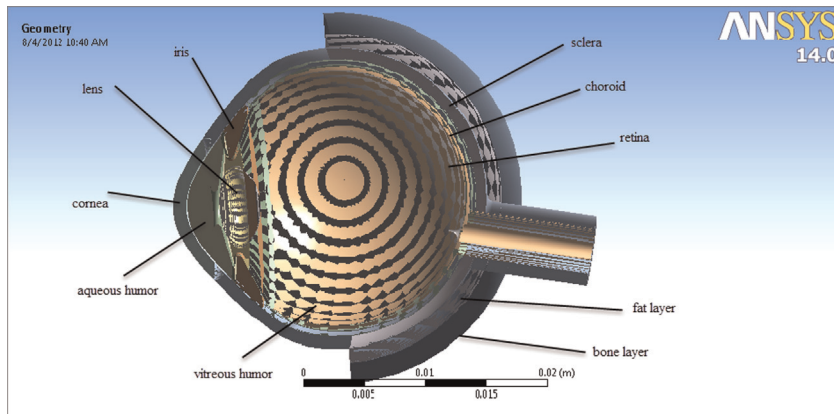


Fig. 1. Different parts of human eye anatomy in three dimensions.

were exposed to variables of atmosphere. Temperature distributions were investigated in the field of steady state and in a three dimensional model. Three different paths were considered to see how different parameters mentioned above influence on temperature distributions through the eye. By changing relative parameters, the temperature distribution in each path was predicted.

2. Human eye (Suri, 2008)

Human eyes are undeniably one of the most vital and sensitive parts of human body. The eye function is definitely complex, on account of its size and intricateness. Human eye has six major parts which are cornea, aqueous humor, lens, iris, vitreous humor, and sclera. It is possible to add two other parts, called retina and choroid, to the following eye system. In addition, the eyeball is surrounded by a thin fat layer which is called orbital fat that plays a backbone role in protection issues and in making eye movement and twirling easier. This layer is between the eyeball and the cone-shaped cavity which is called orbit.

As mentioned before, human eyes are made of different parts each of which has a special function; some of the most prominent ones are mentioned as follows.

2.1. Cornea

The outer part of the eye which is exposed to environment is called cornea. This transparent and dome-shaped part focuses the entering light rays into the sensitive retina. It consists of 78% water and does not have a uniform thickness. Because cornea is avascular, it needs to nourish itself from the atmosphere and tear film.

2.2. Aqueous humor

It is a watery part that fills the space between cornea and lens, and is responsible to nourish them. Owing to aqueous humor flow, an intraocular pressure, which is 15 mmHg for normal eye, is existed within human eye structure.

2.3. Iris

It is such a group of pigmented tissues which make the eye colorful. The amount of eye-entranced light is controlled by a group of constricting and dilator muscles. Iris divides the eye into two parts, anterior and posterior chambers.

2.4. Lens

This part is located behind the Iris and is responsible to focus light into the retina. It is suspended within the eye by zonules and consists of 65% water and 35% protein. However, the radii curvature has been reversely changed with age changes, thickness and amount of lens's water has, also, been directly increased with age changes.

2.5. Vitreous humor

The space between lens and retina is filled up by clean and gelatinous fluid which is called vitreous humor. It is mainly a watery part but has a bit protein which makes it a viscous fluid. 2/3 Of the eye's volume is made by vitreous humor.

2.6. Sclera

The outer protective part of the human eye which serves the inner regions is called sclera. A group of muscles which allow and control eye movements is connected to this part. Additionally, most of sclera's volume consists of water.

2.7. Retina

The multi layered sensory region which enjoys vast amount of photoreceptors is called retina. In this tissue, light is converted into electrical impulse which passes through optic nerves into the brain where they are transformed into images. Two sorts of photoreceptors which are called rods and cones have been identified within the retina.

2.8. Choroid

Among human eye regions, there is an important part which is called choroid. Most of this part, approximately 85%, consists of blood. This part is located between retina and sclera. All of these parts and other parts of human eye are shown in Fig. 1.

3. Materials and method

A 3D eye was designed in CATIA, which is shown in Fig. 1. Eight sections of an eye structure which were considered to model the system are cornea, aqueous humor, iris, lens, vitreous humor, sclera, choroid, and retina. In addition, one more component, a bone layer, was considered to have such a real eye in reality which is illustrated in Fig. 1. It is worth noting that total number of

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