Review: Raman Spectroscopy – A Novel Tool for Noninvasive Analysis of Ocular Surface Fluid

Chi-Chang Lin[1,†] Ming-Tse Kuo[2,3,†] Hsien-Chang Chang[3,4,5,*]

[1]Department of Chemical and Materials Engineering, Tunghai University, Taichung City 407, Taiwan, ROC
[2]Department of Ophthalmology, Chang Gung Memorial Hospital, Kaohsiung Medical Center, Kaohsiung 833, Taiwan, ROC
[3]Institute of Biomedical Engineering, National Cheng Kung University, Tainan 701, Taiwan, ROC
[4]Institute of Nanotechnology and Microsystems Engineering, National Cheng Kung University, Tainan 701, Taiwan, ROC
[5]Center for Micro/Nano Technology Research, National Cheng Kung University, Tainan 701, Taiwan, ROC

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Abstract

Many systemic diseases like diabetes, hypertension, or microorganism infections and accident injuries may damage the eyes. Using specific light to enter eyes from the controlled environment, ophthalmologists use light-transmitted information obtained with special instruments like slit-lamp biomicroscopes for clinical diagnosis. In this review, the major structures of the eyes and their important functions will be introduced first. A brief picture of eye diseases is presented, including infectious, immune-related, congenital, degenerative, and traumatic entities. We finally focus on Raman spectroscopy, which is a novel qualitative and quantitative optical technique to probe biological systems with advantages including noninvasiveness, less sample volume needed, and utility even in aqueous environments. The purpose of this paper is to review the applications of this developing non-invasive technology in ophthalmological studies, especially in the diagnostic technology of microbial keratitis, which is a vision-threatening disease necessitating rapid and correct diagnosis. Additionally, some clinical approaches for diagnosing microbial keratitis will also be addressed to fill the gap between clinical methods and this novel technique. Raman-based analysis platform, a promising technique for microbial keratitis diagnosis, can bring a new era, especially for patients with microbial keratitis.

Keywords: Raman spectroscopy, Ophthalmology, Tears, Microbial keratitis

1. Introduction

The eyes are the most important sensory organs and the window to the soul. Several instinct mechanisms in humans have been evolved to protect the eyes. The first line of protection for the eyes is the active and controlled movements of opening and closing eyelids. Tears act as the second line of protection, containing large amounts of constitutes such as proteins, lipids, electrolytes, active biomolecules, and water, between eyelids and ocular surfaces. Under these two lines of protection, the highly developed eyes with complex structures can complete their personalized functions. The cornea and lens permit light to penetrate through their transparent structures. Because of the non-transparent sclera connecting with the cornea, photoreceptor cells in the retina convert the light into electric signals without physical and chemical influences from outer environment. The electric signals resulting in the nerve action potentials are subsequently transported to the optic nerve, and then to the visual cortex of the brain. In the orbit, the soft tissue cushions the eyeball, the extra-ocular muscles control eye movements, and the rich lymphatic and vascular networks construct the connection (as the third line of protection) between central and local immune systems. The eye may be easily injured once any of three protection lines are disabled, damaged, or diseased. Important literature about Raman spectroscopy in ophthalmology, especially in tear researches will be illustrated in detail. Finally, part of our research work on the development of non-invasive Raman-based diagnostic platform for corneal ulcer studies will also be discussed.

2. The eye and diseases

2.1 Anatomy of eyes

Based on functional illustrations, the eyeball can be simplified as three major structures, from the outer to inner layers, to achieve focusing and the transmission of light. The

† These authors contributed equally to this work
* Corresponding author: Hsien-Chang Chang
Tel: +886-6-2757575 ext. 63426; Fax: +886-6-2343270
E-mail: hcchang@mail.ncku.edu.tw