Title	光散乱モデルに基づく顕微鏡画像解析による眼内レンズの特性評価に関する研究
Author(s)	KAY THWE MIN HAN
Citation	
Issue Date	2020-09
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/16996
Rights	
Description	Supervisor:小谷　一孔，先端科学技術研究科，博士

氏　　　　　　　名	Kay Thwe Min Han
学　位　の　種　類	博士(情報科学)
学　位　記　番　号	博情第 436 号
学 位 授 与 年 月 日	令和 2 年 9 月 24 日
論　　文　　題　　目	Visibility evaluation for intraocular lens with glistening by microscopic image analysis based on light scattering model
論 文 審 査 委 員	主査　小谷一孔　　北陸先端科学技術大学院大学　　教授
	金子峰雄　　同上　　教授
	長谷川　忍　　同上　　准教授
	池田　心　　同上　　准教授
	Waree Kongprawechnon　　SIIT　　准教授

論文の内容の要旨

Visual function is decreased due to glistening and subsurface nanoglistening (whitening) after intraocular lens (IOL) implantation into human eyes. Glistening means fluid filled micro-sized vacuoles, on the other hand, whitening is nano-sized vacuoles in IOL which lead to light scattering and affect human's vision quality. Glistening observation and light scattering in IOL mainly depend on the characteristics of glistenings which are size, shape, refractive index, and number of glistenings. Furthermore, glistening occurrence in IOL depends on various conditions. Moreover, vision quality can also be different based on these facts. Glistening is increasingly over time and so it cannot be stopped by medicine and treatment. The best treatment for glistening is surgical removal and thus, the effect of glistening in IOL is required to study. We approach the light scattering problem from time and cost-effective way which evaluate the visibility of IOL.

Several researches studied glistenings from ophthalmology and assessed the consequence of glistening in vision quality by clinical tests such as contrast sensitivity, visual acuity and glare testing or wavefront measurements of the human eyes. This kind of research is required to participate by the patients and assessed light scattering in IOL by using clinical equipment such as C-Quant, spectrometer and Scheimpflug photography and thus, it is time consuming and costly to study. Moreover, these studies report the light scattering from single sphere particle but multiple particles scattering for IOL are not considered. For the real light scattering problem in IOL, light transmittance to the retina which can interfere by glistenings is not only for single particle, but also multi-glistenings. In multiple glistenings, the distance between particles are important in light scattering measurement of IOL. If the particles are brought closer together, so that their surfaces are from one another, then their scattering volumes begin to overlap. Therefore, the total scattering volume from the two glistenings is less than the sum of the two-individual scattering volumes. When light that enters the overlap volume, light can scatter less efficiently than light that enters a part of the non-overlapping scattering. Finally, there is no report to evaluate the visibility of IOL with glistenings to solve each of the above

problems.

This research proposes optical model to study the glistenings in IOL with visibility evaluation from multiple light scattering with T-matrix method. However, this optical model considers the important facts to overcome the real problems which are not yet developed by the previous studies. When glistening numbers are grown, light scatter problem may occur inside the lens and vision quality will be degraded. Firstly, visibility function is evaluated based on the glistening characteristics in the optical model. When microvacuoles are densely located in IOL, light scattering for single particle is not sufficient and multiple light scattering is important to be considered. Therefore, multiple light scattering of glistenings are calculated by using T-matrix theory. Moreover, light transmission through Intraocular lens (IOL) with glistenings and whitenings are also computed. In fact, the proposed model study the characteristics of laboratory-induced glistenings under temperature changes, calculate the light scattering from multiple light scattering theory and simulate the light transmission to the retina.

Although light scattering is measured from different approaches, there is no research of light scattering effects differs depending upon the human activities. In this research, the most important approach is visibility evaluation in considered from human activities such as driving at night, studying, and walking. Furthermore, this optical model evaluates visibility functions of IOL with glistenings through glare and quality of retinal image contrast. Glistenings give arise light scattering in IOL and as a result of intraocular light scatter called straylight in retina, disability glare. The quality of human vision depends on the image on the retina. Disability glare can cause the loss of retinal image contrast due to glistenings in IOL. Therefore, reduction of contrast due to glistenings are evaluated for visual functions and assessed the quality of the lens degradation. As a summary, this research combines all the important facts to model the visibility evaluation of intraocular lens with glistenings by microscopic image analysis based on light scattering model.

Key Words: Visibility Evaluation, Optical Model, Multiple Light Scattering, T-matrix, Glistening

論文審査の結果の要旨

本論文は、手術により水晶体から置換した眼内レンズ（IOL, Intra-Ocular Lenz）の経時劣化による光学特性の変化を解析・評価するモデルを与えた。IOL はシリコン樹脂により作られており、36 度程度の温度下では水分が内部に浸透して水分の泡（glistening）を形成する。glistening は入射光を減衰させるだけでなく glistening 間の多重反射によりグレアを生じて視界中のコントラストを著しく低下させる。本論文はこれら光学現象を電場内の電磁波の伝搬・反射理論を基にモデル化し、更に人の視覚特性を考慮して IOL 装着時の見えの良さ（visibility）を評価する関数を与えた。

これまでの glistering により劣化した IOL の評価方法は医療機器により眼球表面の IOL を拡大撮影し、IOL 中の単位面積あたりの glistering 数をカウントしていた。この評価方法は IOL を

装着した人がどのような環境でどのように見えているのかを反映しておらず、IOL 装着者の日常生活に支障が出るような状況が生じていた。

本論文は光の伝搬経路中に glistering のような小球体が散在・分布する物理モデルを与え、小球体表面での入射光の反射特性を電場内の電磁波の伝搬・反射理論を基にモデル化した。このモデルは IOL 内での glistering により生じる光学的現象を正確に表しており、特に小球体間の多重反射特性を定量的に表せる。本モデルは glistering による透過光の損失に加えて多重反射によるグレア（IOL 内を光が多重反射してまぶしく見える）を算出でき。これに人の眼球部網膜細胞における桿体と錐体の分光感度特性と中心窩の特性を加えて注視点近傍でのコントラスト低下を定量的に与えた。これら特性を統合して visibility 関数を定義し IOL の見えの良さを評価した。加えて、この評価方法は IOL 装着者の生活環境をパラメータとして設定可能である。例えば日中の屋外や照明のある屋内、夜間に街灯や発光部を持つサインが存在する道路を運転するドライバなどの具体的な生活環境条件下で IOL を評価できるため実用性が極めて高い。

以上、本論文は glistering により劣化した IOL の光学特性を高精度に評価する手法を与え、その有効性を示しており、学術的に貢献するところが大きい。また研究成果は Q1 レベルの国際学術論文（IF３.05）に採録され、高く評価されている。よって博士（情報科学）の学位論文として充分価値あるものと認めた。