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Spectroscopic studies of the silicone oil impact on the ophthalmic hydrogel based materials conducted in time dependent mode

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ABSTRACT

Silicone oil is the one of the artificial materials used in vitreoretinal surgery for retinal detachment treatment. Since the silicone oil is sometimes applied along with intraocular lens (IOL) implantation the direct influence of silicone oil on the artificial implant should be taken into account. Presented study was performed in order to determine the time-dependent impact of silicone oil on hydrogel based ophthalmic materials. Two kinds of IOLs based on hydroxyethyl 2-methacrylate (HEMA) hydrogel material were immersed in silicone oil based on linear poly(dimethylsiloxane) (PDMS). Incubation in oil medium was performed in 37 °C for 1, 3 and 6 months. After appropriate period of the incubation samples were examined by means of FTIR-ATR method as the technique of surface study as well as Positron Annihilation Lifetime Spectroscopy (PALS) as the method of internal structure investigation. Results obtained during the study revealed that silicone oil is not capable to penetrate the internal structure of investigated materials and its impact has come down to interaction with the samples surfaces only.

1. Introduction

Silicone oil, based on linear poly(dimethylsiloxane) (PDMS), is a commonly used material in vitreoretinal surgery for treatment of retinal detachments and injuries existing inside the eyeball [1]. Application of silicone oil tamponade, in some cases, requires simultaneously intraocular lenses (IOLs) implantation [2], hence some technical problems resulting from interactions between surface of polymeric implant and PDMS oil occur.

Since vitreous body and silicone oil have different refractive indices equaled 1.336 and 1.404, respectively, the question of implant optical power appears, which is changed during both injection and removal of the oil tamponade [3,4]. As it is known, continuous contact between silicone oil and intraocular implant, lasting even up to 1 year, leads to irreversible adherence of PDMS based oil to the surface of implant [5–8]. Studies performed in this field indicated higher oil coverage in the case of hydrophobic than hydrophilic implant materials. Besides of problems with appropriate refraction the influence of the silicone oil on the cataract formation in IOLs was reported [9–11]. Accordingly to above studies the effect of IOL material calcification occurs either at the surface or in the internal structure of the material.

Considering of implants calcification both at the surface and inside the materials related to the silicone oil injection into the eyeball, essential is to evaluate an impact of the silicone oil on the internal structure of polymeric implants. Research conducted so far have used methods such as light microscopy, gross photography and scanning electron microscopy (SEM), thus methods of surface examination. In order to verify of the silicone oil impact on the internal structure of implant material the method of interior networks investigation is required. An example of such a method is Positron Annihilation Lifetime Spectroscopy (PALS), the powerful tool for examination of materials interior. Studies of positron lifetimes based on the annihilation of positron-electron pair phenomena inside of investigated materials enables to obtain information relating to the material structure, especially defects and free volume holes sizes and concentrations [12–15]. Hitherto, the PALS method was successfully used for studies of hydrogel materials [16–18] as well as solid and liquid PDMS [19,20]. Furthermore, studies on the impact of PDMS oil on the hydrogel material was attempted suggesting penetration of silicone oil into the hydrogel network [21].

The aim of this study was to examine a time-dependent influence of the silicone oil on parameters describing internal structure of ophthalmic polymeric materials. Conducted studies have provided the information on the interaction between positrons and silicone oil as well as polymeric hydrogel based materials. In addition, the use of infrared spectroscopy as a complementary method allowed the assessment of

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the possibility of silicone oil penetration into the internal structures of tested materials.

2. Materials and Methods

Two kinds of hydrogel based materials used in ophthalmology as IOLs were chosen for the study. The first one was Quatrix (Croma Pharma GmbH, Leobendorf, Austria), hydrophilic lens composed of poly hydroxyethyl 2-methacrylate (PHEMA) with 26% of water content. The second one was En Vista (Bausch&Lomb, USA), hydrophobically modified lens, containing hydroxyethyl 2-methacrylate – polyethylene glycol phenyl ether acrylate (poly(EG)PEA) – styrene copolymer, crosslinked with ethylene glycol dimethacrylate (EGDMA) with around 10% of water content. Both materials were characterized by 6 mm of optics diameter. Samples were delivered in originally packaged containers on fully swollen state prepared in 0.9% saline solution without further examination of solution impact on studied materials. Commonly used in vitreoretinal surgery Mersilicon silicone oil (Meran Tip, Turkey) with refractive index equal 1.404, 0.971 $g \cdot cm^{-3}$ of density and 1000 cSt of viscosity was applied for the study. Lens materials used for study were chosen due to their potential application together with silicone oil injected during vitreoretinal surgery. Indeed, as it was mentioned in manufacturers specification cards delivered with IOLs, safety of chosen materials application in patients eyes suffered from retinal detachments was not evidenced. Moreover, one of the postoperative complications after implantation of IOLs can be retinal detachment leading to silicone oil applications. Thus, choice of materials for examination of PDMS oil influence is justified.

Six lenses of both materials were divided into three pairs and applied for immersion in 10 cm^3 of silicone oil for each pair. Subsequently, samples were incubated for 1, 3 and 6 months in 37 °C by means of Labnet Mini Incubator with ± 0.6 °C of temperature stability. Another pairs of both materials, not affected by silicone oil, were used for study as reference samples. After a given period of time samples were drawn from an oil bath and measured by means of FTIR ATR (Fourier Transform Infrared – Attenuated Total Reflectance) as well as PALS methods. In the next step, sample surfaces were washed mechanically by tissue paper soaked in acetone and analyzed again by methods mentioned above. Obtained results were used in comparison to measurements performed in dehydration process of reference samples performed in 24 h period.

FTIR ATR measurements were conducted in the MIR (mid-infrared) range of wavelengths from 550 to 4000 cm^{-1}. Experiment was carried out on a DigiLab Excalibur spectrometer equipped with a Miracle Pike Diamond ATR. Every spectrum acquired during the experiment was consisted of 128 scans with resolution equals 4 cm^{-1} [22].

PALS experiment was performed by means of ORTEC positron lifetime spectrometer with 280 ps of resolution measured as FWHM (Full Width at Half Maximum) with use of ^{60}Co isotope. Scintillation counters containing BaF_2 crystals were used to record of positron-electron annihilation acts in studied samples. The ^{22}Na isotope with 300 kBq of activity in the form of NaCl powder closed in 8 μm thick kapton foil was used in the study as positrons source. The radioactive source was put between two identical samples and then annihilation acts were measured in order to obtain positron lifetime spectra [23].

3. Results

In order to verify silicone oil influence on the surface of samples after oil bath the infrared measurements were performed. Fig. 1a and b show the effect of incubation for both Quatrix and En Vista lens materials, respectively. Presented spectra were compared with results received for the silicone oil and the reference samples fully swollen in saline solution. Decrease in integral intensity of continuous band at 3400 cm^{-1} related to OH stretching oscillations can be noticed for each sample affected by oil. Moreover, appearance of characteristic bands at 2961, 1257, 1090, 1001 and 785 cm^{-1} corresponding to stretching vibrations of CH_3 in Si—CH_3, bending vibrations of CH_3 in Si—CH_3, asymmetric stretching vibrations of Si—O—Si and stretching vibrations of Si—C in Si—CH_3, respectively [24–26], are visible. Results of cleaning of sample surfaces are presented separately in Fig. 2a and b, where comparison between washed and reference samples can be noticed. For samples washed after 6 months incubation the procedure of surface cleaning did not work, since PDMS bands were still appeared in spectra. Moreover, bands 1221 and 1360 cm^{-1} from acetone are visible in the spectra of En Vista cleaned samples after 1 and 3 months incubation.

For each sample, ten positron lifetime spectra containing 10^6 of counts were provided by means of PALS technique. The next step for analysis of positron lifetime spectra was to fit theoretical positron lifetime components to experimental data with the best fitting variance. Fitting was made with the use of LT ver. 9.2 software, by Kansy [27]. As a result of numerical fitting, three lifetime components corresponding to different cases of positron annihilation in the samples were

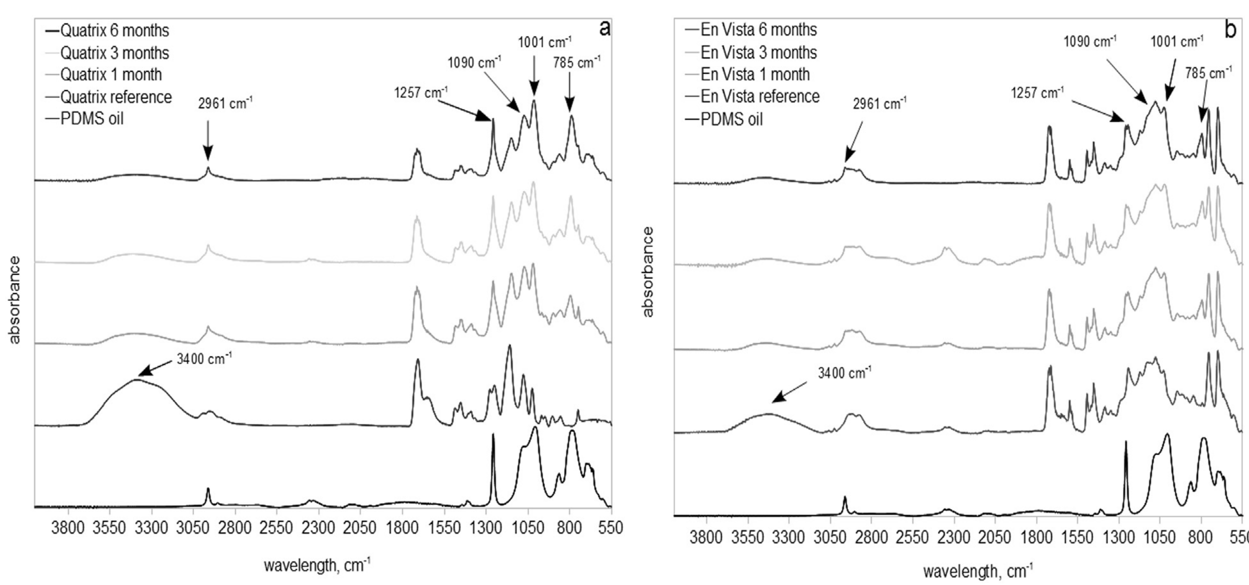

Fig. 1. Vibrational spectra of a) Quatrix and b) En Vista lens materials immersed in silicone oil bath. Results related to spectra of reference samples and silicone oil.