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Hydrogen-peroxide and silicone-hydrogel contact lenses: Worsening of external eye condition and tear film instability☆

A. Moro[a], M. Fagnola[c], S. Picarazzi[a], A. Di Dio[a], V. Pastori[b,c], M. Lecchi[b,c], S. Tavazzi[a,c,*]

[a] Materials Science Department, University of Milano Bicocca, Via Cozzi 55, I-20125 Milan, Italy
[b] University of Milano Bicocca, Department of Biotechnology and Bioscience, Piazza della Scienza 2, I-20126 Milan, Italy
[c] COMiB, University of Milano Bicocca, Via Cozzi 55, I-20125 Milan, Italy

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ABSTRACT

Purpose: The aim is discussing the origins of worsening of external eye condition (EEC) and of tear film (TF) instability after wear of silicone-hydrogel contact lenses (CLs) with hydrogen-peroxide (H_2O_2) care system.
Methods: EEC and TF stability were evaluated before and after 15 days of wear combined with different care systems: (1) H_2O_2, (2) detergent solution and H_2O_2, (3) multipurpose solution (MPS), (4) H_2O_2 and artificial tears. In-vitro cell mortality tests were performed after 24 h cell incubation with CLs treated with H_2O_2. Photon correlation spectroscopy (PCS) was carried out on tears of non-wearers and CL wearers who used MPS or H_2O_2 solution.
Results: Worsening of EEC was observed only for the group using H_2O_2 (group 1). In-vitro, cell mortality was found higher for worn CL than for unworn CLs. Worsening of TF stability was observed regardless of care system and also PCS results on tears of CL wearers were found different compared to non-wearers regardless of care system. The only observed remedy for tear instability of CL wearers was found to be the administration of artificial tears.
Conclusions: Worsening of EEC of CL wearers using H_2O_2 is attributed to H_2O_2 scarce cleaning efficacy, which can be solved by adding a CL detergent solution. The origin of TF instability is found to be different. A remedy was found to be the administration of artificial tears, whose effect could be attributed either to the role of specific components or to rinsing and replacement of TF during wear.

1. Introduction

Contact lenses (CLs), which are often used for the correction of ametropia, are in contact with the external surface of the eye and are many times thicker than tear film, thus influencing the ocular environment as discussed by many authors. For example, many years ago Young and Efron discussed the characteristics of the pre-lens tear film during hydrogel CL wear [1]. CL interactions with tear film were also more recently discussed in details by Mann and Tighe [2] and by Nichols and Sinnott [3], who found that CL–related dry eye may be explained by increased tear film thinning rate (evaporation or dewetting) resulting in increased tear film osmolality. Other studies can be found in the literature. The advent of silicone-hydrogel (SH) CLs raised even more the attention on ocular surface reactions due to the physical characteristics of these materials [4]. Several studies were carried out on the interaction between SH CLs and care systems [5–16]. Lievens et al. [17] investigated if, independently on the material, CL solutions could solely contribute to adverse ocular surface effects, but they concluded that the CL/solution interaction, rather than the CL itself, can be ruled out as a causal factor of corneal/conjunctival epithelium injury. Among care systems, specific considerations hold for hydrogen-peroxide (H_2O_2) solutions. Many authors investigated the disinfecting effect of H_2O_2 and its oxidant anti-microbial activity [18–23]. While many studies concerning disinfection favor H_2O_2 systems over multipurpose solutions (MPSs), the situation may be different as far as the impact on the material properties is concerned. For example, a recent study showed that some solution/material combinations result in significant changes in the Young's modulus [24]. Lira et al. [25] reported changes of CL surface roughness and refractive index induced by care systems. Chandler found that CL fit alterations may occur due to the use of H_2O_2, which may lead to corneal/conjunctival epithelium injury [26]. Differences between MPS and H_2O_2 care systems were also recently reported from the optical point of view as deduced from the analysis of the transmitted light wavefront pattern [27].

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* Corresponding author at: University of Milano Bicocca, COMiB and Materials Science Department, Via Cozzi 55, I-20125 Milan, Italy.
E-mail address: silvia.tavazzi@unimib.it (S. Tavazzi).

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Table 1
Care systems for the 4 groups of subjects (of sample size N) under investigation.

	N	detergent solution (Flexigel Plus Baush & Lomb) after daily wear	H_2O_2 Sauflon One-Step solution over night	MPS (Fusionsol, Safilens) over night	Artificial tears OPTOidro + A, Opto^X during daily wear
Group 1	21		X		
Group 2	22	X	X		
Group 3	21			X	
Group 4	16		X		X

This paper is focused on external eye condition and tear film stability, which represent key aspects to evaluate biocompatibility of CLs. The aim of this paper is to report clinical results showing worsening of external eye condition and worsening of tear film stability, occurring as a consequence of wear of SH CLs associated with a H_2O_2 care system over night.

2. Materials and methods

2.1. Evaluation of external eye condition and tear film stability

Eighty healthy subjects were divided into four groups, who wore, during the day, Comfilcon A CLs for 15 days by adopting four different care systems over night. In the group of eighty subjects, there were both Comfilcon-adapted wearers (who had previously worn Comfilcon A CLs) and subjects who had previously worn CLs of other materials and changed specifically for this study (Comfilcon-new). In each of the four groups, no relevant differences were observed between Comfilcon-adapted and Comfilcon-new wearers. Therefore, this distinction will no longer be mentioned in the text. The care systems are described in Table 1. Subjects of group 4 also used artificial tears during CL daily wear, three times a day. External eye condition and tear film stability were evaluated by the protocol of tests reported in Table 2. The protocol was performed on the 1st day before CL application and on the 15th day after removing the CLs at the end of 15 days of CL daily wear. For tests concerning the external eye condition, which provide discrete data, Fisher's exact test ($p < 0.05$) was applied to each group to obtain information on changes of the obtained results on the 15th day compared to the 1st day. For tear film stability tests, statistical significance of differences ($p < 0.05$) between measured data in each group on the 1st and 15th day was obtained by Student's t statistics.

2.2. Cell mortality tests

TsA cells were cultured in a DMEM/F12 medium containing 10% fetal bovine serum and 2 mM glutamine (Sigma St Louis, Mo) and incubated at 37 °C in a humidified atmosphere with 5% CO_2. Cells were seeded onto 24-well tissue culture plates at density 45 10^3 cells per well. After 24 h, the medium was substituted with a serum-free medium, then the cells were incubated for 24 h with CLS, which were previously exposed to Sauflon One-Step solution. Two experiments were carried out. In one case, unworn Comfilcon A, Senofilcon A, and Lotrafilcon B CLs were exposed for 15 times (8 h each time) to the solution in-vitro. In the other case, Comfilcon A CLs were worn by different subjects for 15 days using Sauflon One-Step as care solution (as group 1 in Table 1). CLs were placed gently on top of the cellular monolayer, with the concave surface facing upward, and they were totally immersed in the culture medium. After incubation, cells mortality was tested by trypan blue (0.4% wt/vol) incubation and cell count. In each experiment, cells grown without any incubation were used as a control. Statistical significance of differences between the normalized cell mortality was obtained by unpaired Student's t statistic ($p < 0.05$).

Table 2
Protocol of clinical tests.

Evaluation	Test
External Eye Condition	Limbal hyperemia with score range 1–4 (worse condition: 1) Bulbar hyperemia with score range 1–4 (worse condition: 1) Tarsal hyperemia with score range 1–4 (worse condition: 1) Conjunctival staining with score range 1–4 (worse condition: 1) Corneal staining with score range 1–4 (worse condition: 1) Lissamine green conjunctival staining (LGCS) with score range 0–5 (worse condition: 0)
Tear Film Stabiliyt	Non Invasive Break Up Time (NIBUT) Break Up Time (BUT)

2.3. Photon correlation spectroscopy analyses of tears

The hydrodynamic diameter (d_H) of the main components of tear content was determined by analyses of Photon Correlation Spectroscopy (PCS) using a DLS Malvern Zetasizer ZS90 instrument. The method is based on the detection of intensity fluctuations as a function of time of scattered light by particles suspended in a solution. The speed of movement is then used to determine the particle size distribution from the intensity of scattered light. From this distribution, the intensity-weighted mean of the particle diameters can be calculated, called hydrodynamic diameter d_H, which is the diameter of hard spheres that would diffuse light at the same speed as the particles being measured. Tears of 65 subjects were analyzed: 10 wearers of SH CLs (Comfilcon A, Lotrafilcon B, Narafilcon A, Galyfilcon A, Balafilcon A, Senofilcon A), who used MPS as care solution over night (as subjects of group 3 in Table 1), 8 CL wearers (Comfilcon A) who used H_2O_2 solution over night (as subjects of group 1 in Table 1), and 47 non-wearers. Tears were collected by placing a glass capillary of 5 μL parallel to the lower meniscus tear. The measurements were performed on tear samples of 5 μL diluted with 45 mg (45 μL) of deionized water. Comparison of d_H for different tear samples was obtained keeping the same experimental conditions: the temperature was set to 25 °C, the selected stabilization time was 60 s, the viscosity and the refractive index of solvent were assumed to be those of water (n = 1.330, v = 0.8872 cP). Statistical significance of differences between different groups was obtained by Student's t statistic ($p < 0.05$).

3. Results

As far as external eye condition and tear film stability are concerned, the mean differences for each group between measured clinical values after 15 days of CL wear and initial values on the 1st day are reported in Table 3. Black cells indicate statistically-significant worsening of the clinical condition. White cells correspond to data which did not significantly change after 15 days of CL wear. Red cells indicate statistically-significant improvement of the clinical condition. Table 3 is divided into two parts concerning tests for the evaluation of external eye condition and tests for the evaluation of tear film stability.

The clear evidence of worsening of the external eye condition only for group 1 in Table 3 motivated the study of the effect of the corresponding CL care system (H_2O_2 solution) on in-vitro cell mortality. Table 4 shows the results obtained after 24 h of cell incubation with SH CLs. Two sets of experiments were performed. In one case, unworn SH CLs were exposed 15 times, for 8 h each time, to the H_2O_2 Sauflon One-Step solution and then incubated with the cells. In the second set of experiments, SH CLs were worn by different subjects for 15 days using the same Sauflon One-Step solution over night (as group 1 in Table 1).