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The effects of smoking on the tear film and on soft contact lenses

F. MIGLIO([1]), A. BORGHESI([1])([2]), F. ZERI([1])([2])([3]), E. PONZINI([1])([2]) and S. TAVAZZI([1])([2])

([1]) *Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca Milano, Italy*
([2]) *Optics and Optometry Research Center, COMiB, Università degli Studi di Milano-Bicocca Milano, Italy*
([3]) *College of Health and Life Sciences, Aston University - Birmingham, UK*

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Summary. — Smoking is frequently associated with systemic and ocular diseases. Considering the fundamental role in eye health of the precorneal tear fluid, its analysis could offer unique contributions to gather information on ocular status. Smoking has a negative effect on tear film stability and quality by affecting different components, which can be assessed only by multiple tests. In addition, smoking is a risk factor for microbial keratitis and corneal infiltrates in contact lens (CL) wearers. In this work, the interaction between nicotine and CL materials is analysed. CLs belonging to the FDA groups I, II, IV, and V were incubated in a nicotine solution for 24 hours. The amount of absorbed nicotine per CL was monitored by ultraviolet spectrophotometry, normalizing it to the mass of the hydrated CL. Group IV and V CLs displayed the highest and lowest nicotine absorption, respectively. The results suggest that CL affinity for nicotine could be ascribed to the interaction between the positive charge of nicotine pyrrolidine nitrogen and the negative charges of the CLs.

1. – Introduction

Smoking (active, passive, and produced by e-cigarettes) is frequently associated with systemic [1] and eye diseases [2-4]. Considering the fundamental role in eye health of the precorneal tear fluid, its analysis could offer unique contributions to gather information on ocular status [5, 6]. In particular, this work focuses on the effects of different types of smoking on the precorneal Tear Film (TF), whose condition is fundamental in optometry and contact lenses (CLs) wearing as an important indicator of ocular health. Most of the studies available in the literature show that smoking has negative effects on the components of the TF by decreasing its quality and stability [7]. For example, the Tear Evaporation Rate (TER) provides information about tear dynamics, quantifying

the evaporation of the aqueous layer of the TF. For active smokers, higher TER values were reported, compared to the non-smoker control group [8,9]. Non-smokers exposed to cigarette smoke display a significantly higher TER value compared to the control group [10, 11]. TF stability can also be evaluated using Tear Break-Up Time (BUT). In most studies, BUT shows a significant decrease in smokers compared to non-smokers [8, 12-18]. As for e-cigarette smokers, the only result available in the literature agrees with those concerning traditional cigarettes and shows a decrease in the TBUT value [19]. Also, passive smoking reduces TF stability of non-smokers [10,11]. The Ferning Test revealed abnormal patterns (*i.e.*, with a higher score) in the smoker group compared to the control group [20]. In advance, higher values of osmolarity were detected in the tears of smokers [16] and for what concerns lipid layer, there is abnormal redistribution of TF after blinking in active and passive smokers [8, 10, 13]. The tear protein profile of smokers was also found to be altered [21-23]. The mechanism by which smoke damages TF is highly complex and still not fully understood due to its interaction with all the components of TF and, more generally, with all body districts. However, it seems that the most damaged layer is the lipid one, due to lipid peroxidation by radicals [24-26]. A damaged lipid layer fails all its functions, including delaying the evaporation of the aqueous layer of the TF, making it unstable and of poor quality. Smokers and, at the same time, CL wearers are more exposed to the risk of microbial keratitis [27] and corneal infiltrates [28, 29] than non-smokers. Nicotine is here taken into consideration. Among the potential extra-ocular contaminants present in smoke, nicotine is particularly important, because even non-smokers are exposed to it due to its presence as a common environmental contaminant [30]. It is a toxic compound that belongs to the alkaloid family. It is found in the leaves of tobacco plants and is a chiral molecule of which the S-enantiomer is the most common in nature [31]. It is difficult to say whether the risk factor for CL wearers is mainly associated with the presence of nicotine in the eye or its adherence to CLs [32]. The aim of this work was to deepen the interaction between nicotine and CLs, which is not widely treated in the literature.

2. – Materials and methods

CLs belonging to four different FDA groups were investigated in the study (table I). To assess nicotine uptake by a CL, each lens was immersed in a glass vial containing a 2 mL saline solution (Saline Solution IOM, Bausch & Lomb, Rochester, New York, US) and nicotine (concentration 2 mM) (Sigma Aldrich, St. Louis, Missouri, US; CAS:54-11-5) and incubated for 24 hours at room temperature. To determine the mass of incorporated nicotine, 1 microliter of the incubation solution was analyzed with a spectrophotometer (NanoDrop One, Thermo Fisher Scientific, Waltham, Massachusetts, US) to measure the absorbance value at 260 nm, *i.e.*, at the wavelength corresponding to the maximum of thenicotine absorption band. The amount of absorbed nicotine by each CL was calculated by subtracting the nicotine mass in the vial at the time of measurement from the nicotine mass initially available in the incubation solution. Previously, a calibration line was obtained to correlate absorbance values to nicotine concentration (data not shown). With this protocol, absorbance measurements were performed at different time points (17 in total) for 24 hours during the incubation period. Each measurement was reproduced in triplicate.

TABLE I. – *Investigated CL materials, FDA group and EWC (equilibrium water content). EWC is provided by the manufacturer.*

Material	FDA Group	EWC (%)
Polymacon	I	38.6
Nesofilcon A	II	78.0
Omafilcon A	II	60.0
Etafilcon A	IV	58.0
Filcon IV	IV	60.0
Methafilcon A	IV	55.0
Ocufilcon D	IV	55.0
Comfilcon A	V	48.0
Lotrafilcon A	V	24.0
Lotrafilcon B	V	33.0

3. – Results and discussion

The absorption of nicotine for each material was measured as a function of time. The process occurred for all CL materials during the first few minutes of incubation, until they reached a plateau after around 10 minutes. An example is shown in fig. 1. Similar trends were observed for the other materials.

Since the investigated CLs differ in water content and total polymer mass, the data were normalized by considering the total mass of the CL [33]. For all investigated materials, the normalized mass of nicotine absorbed during the incubation time was found to be well described by mathematical function $M_{norm} = M_{plateau} - k \times t^{-1}$, where $M_{plateau}$ and k are two positive constants, t is the time, and M_{norm} is the mass of nicotine.

The constant $M_{plateau}$ (table II) represents the normalized mass of nicotine absorbed at the plateau. It can be used to compare the behavior of different materials in terms of affinity with nicotine.

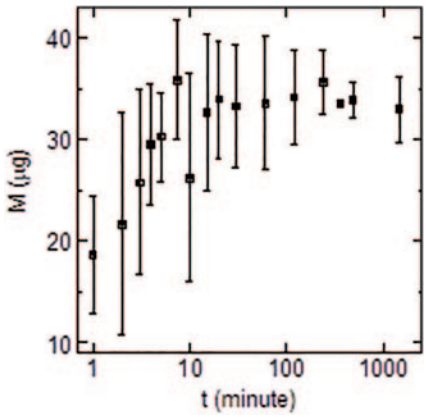

Fig. 1. – Mass (M) of nicotine absorbed by one Ocufilcon D CL as a function of time (t). Squares and error bars represent the average and standard deviation calculated on repeated independent experiments.

TABLE II. – *Constant $M_{plateau}$ (given micrograms mg^{-1} , i.e., μg of nicotine mass per mg of CL mass) deduced by fitting the normalized mass of absorbed nicotine by the equation $M_{norm} = M_{plateau} - k \times t^{-1}$.*

FDA Group	Material	$M_{plateau}$
I	Polymacon	0.561
II	Omafilcon A	0.468
	Nesofilcon A	0.346
IV	Etafilcon A	0.729
	Methafilcon A	0.917
	Filcon IV	0.745
	Ocufilcon D	0.813
V	Comfilcon A	0.336
	Lotrafilcon A	0.303
	Lotrafilcon B	0.179

Group IV materials show the greatest affinity. Materials belonging to Groups I and II reach lower values than Group IV. The values found for silicone hydrogels were found to be the lowest. Nicotine absorption could be driven by simple diffusion of the solute into CL. To test this hypothesis, the expected value of nicotine was calculated by the equilibrium water content and the concentration of nicotine in the incubation solution (data not shown). The expected values were significantly below the experimental values, especially for 4/5 times greater than that assumed for simple hydration. The results suggest that the absorption of nicotine in vitro is relatively fast and the affinity of nicotine in vitro depends on the chemical and physical properties of the material of which the lens is made. Nicotine shows ionizing pyrrolidine nitrogen that could interact with negative CL charges, especially in ionic ones. Further studies need to be performed, for example on worn CLs [34].

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