THE ADSORPTION OF MAJOR TEAR FILM LIPIDS *in vitro* TO VARIOUS SILICONE HYDROGELS OVER TIME

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Abstract

PURPOSE: As lipid fouling is a prevalent issue with silicone hydrogel materials, a novel *in vitro* study was conducted to measure the adsorption of major tear film lipids over time. This study may give clearer insight into the rate of accumulation of both polar and non-polar lipids during the wear of silicone hydrogel soft contact lenses.

METHODS: Commercial balafilcon A (PureVision®), galyfilcon A (Acuvue® Advance™), lotrafilcon A and B (Night & Day® and O_2Optix™) and senofilcon A (Acuvue® Oasys™) were all soaked for 14 hours in the dark at 34.5°C in either cholesterol (CH,1.75 µg/mL; Avanti) or phosphotidylethanolamine (PE, 0.5 µg/mL; Molecular Probe), both of which were tagged with fluorescent labels. All solutions were made up in phosphate buffered saline (PBS) at pH 7.2. The lenses were then washed 3 times in PBS. Fluorescence was measured using the Wallac 1420 fluorometer and the corresponding lipid concentration calculated from an appropriate standard curve. The lenses were then placed into a fresh 1mL aliquot of the lipid being tested and the protocol was repeated for 20 days.

RESULTS: *In vitro* adsorption of cholesterol was greater for all lens types for CH compared to PE. After 20 days of soaking in PE, lotrafilcon A and B showed the lowest *in vitro* adsorption, at 0.4 and 1.5 µg/lens, respectively. Galyfilcon A and senofilcon A showed significantly higher *in vitro* PE adsorption at 5.1 and 4.9 µg/lens respectively. Balafilcon adsorbed 3.2 µg/lens of PE.

Senofilcon A and balafilcon A had the highest *in vitro* affinity for cholesterol compared to all other lens types after 20 days, with adsorptions of 23.2 and 24.1 µg/lens respectively. Lotrafilcon B showed the lowest *in vitro* adsorption of cholesterol at 3 µg/lens. *In vitro* adsorption of both polar and non-polar lipids appeared to reach saturation with galyfilcon A at approximately day 12-14. *In vitro* adsorption for lotrafilcon A and B plateaus at approximately day 17. For balafilcon, *in vitro* saturation of adsorption of PE occurred by day 14, whereas saturation was not complete with cholesterol by day 20.

CONCLUSION: *In vitro* lipid adsorption varied greatly depending upon the lens material for both polar and non-polar lipids. Overall, there was less *in vitro* adsorption of lipid to the lotrafilcon A and B polymers than for any of the other silicone hydrogel polymers tested.

Introduction

Spoilage of contact lenses by either proteins or lipids is an important factor in the biocompatibility of contact lens materials (Rebeix *et al.*, 2000). Such fouling may produce unfavorable effects on the function of the contact lens as well as the wearer's experience. Some of these effects may include tear film disruption, decreased vision, discomfort, intolerance and bacterial adhesion (Mizutani *et al*, 1988; Leahy *et al.*, 1990; Glasson et *et al.*, 2002). Silicone hydrogel lenses have been shown to adsorb lower amounts of protein compared to conventional hydrogel materials, however, lipid adsorption appears to be more significant (Jones *et al.*, 2003).

The tear film lipid layer is formed from lipids secreted by meibomian glands of the eyelid (McCulley and Shine, 1997). The lipid layer protects the aqueous tear fluid from evaporation and provides a more stable and smooth tear film for refractive properties. The lipid layer is composed of 2 phases: a thin polar phase that is adjacent to the aqueous-mucin phase of the tear fluid, and a thick non- polar phase that is associated with both the polar phase and the environment. While the non-polar phase protects the aqueous tear fluid from evaporation, providing a more stable and smooth tear film for refractive properties, the polar phase is in direct contact with the contact lens material.

This study focuses on the phenomenon of *in vitro* lipid adsorption to silicone hydrogel lenses over time. All commercially available silicone hydrogel lenses currently on the US market were compared for adsorption levels of either polar (phosphotidylethanolamine, PE) or non-polar (cholesterol, CH) lipids to investigate the *in vitro* affinity of various materials to lipid over time.

Materials and Methods

Materials **Lenses**	**Lipids**
Balafilcon A (PureVision®)	Phosphotidylethanolamine – FITC (PE –FITC) ***[Polar species]***
Galyfilcon A (ACUVUE® ADVANCE™)	Cholesterol –NBD (CH-NBD) ***[Non-polar species]***
Senofilcon A (ACUVUE® OASYS™)	
Lotrafilcon A (NIGHT & DAY®)	
Lotrafilcon B (O2OPTIX™)	
Etafilcon A (ACUVUE®2) Control	

Methods

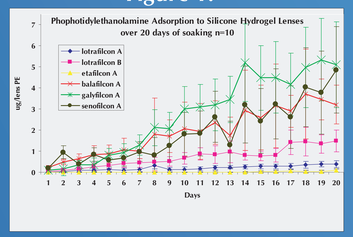
Standard curve

- A separate standard curve was developed for each lens type assayed.
- PE and cholesterol standards were made up in duplicate in phosphate buffered saline over a concentration range of 0-20 µg/mL.
- 1 mL of standard at each concentration was placed in the well of a 24-well plate (Costar 3473) in duplicate.
- An appropriate lens was also placed in each well of the standard curve plate to correct for any auto fluorescence by the lens material.
- The plate was then wrapped in foil and incubated along with the samples at 34.5°C with rocking.
- The standard curve plate was removed from the incubator each day and read on the Wallac Victor II 1420 multilabel fluorescence counter, along with the samples.

Samples

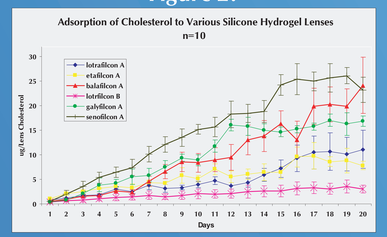
- Five lenses for each lens type tested were placed in a 24-well plate (Costar 3473) and soaked for 14 hours in 1 mL of a physiological concentration of either 0.5 µg/mL PE (PE-FITC, Molecular Probes) or 1.75 µg/mL of cholesterol (CH-NBD, AVANTI).
- All solutions were made up in 1x phosphate buffered saline (PBS) at pH 7.2.
- Control lenses were soaked in 1 mL of PBS for 14 hours.
- Lenses were incubated at 34.5°C in the dark with rocking.
- The lenses were then washed three times in 1 mL of PBS and placed in a fresh 24-well plate with 1 mL of PBS.
- The lenses were then read on a Wallac Victor II 1420 multilabel counter at a wavelength of 465 nm.
- A fresh solution of either PE or cholesterol was then placed on the lenses and incubated as described above.
- This was repeated for 20 days and all results were calculated as µg/lens from the standard curve read that day.

Figure 1:



The adsorption of phosphotidylethanolamine by various silicone hydrogel lenses over 20 days of exposure to concentrations of this lipid comparable to that found in the tear film.

Figure 2:



The adsorption of cholesterol by various silicone hydrogel lenses over 20 days of exposure to concentrations of this lipid comparable to that found in the tear film. Note the difference in scale between Figures 1 and 2.

Results

- Overall, cholesterol showed a greater rate of *in vitro* adsorption for all lens types (including Etafilcon A) as compared to that found for PE.
- Balafilcon A, galyfilcon A and senofilcon A had significantly higher *in vitro* adsorption of both cholesterol and PE after Day 1 of in vitro soaking compared to lotrafilcon A and B and etafilcon A at physiological concentrations ($p \leq 0.05$).
- On Day 14 of *in vitro* lipid exposure, galyfilcon A, senofilcon A and balafilcon A exhibited approximately 2.5 times more cholesterol adsorbed than lotrafilcon A and approximately 6 times more than lotrafilcon B.
- On Day 20 of *in vitro* lipid exposure, the same polymers exhibited 1.5 times more adsorption of cholesterol than lotrafilcon A and up to 6 times more than lotrafilcon B.
- Compared to lotrafilcon B, *in vitro* adsorption of PE was 6 times greater on galyfilcon A and 3.5 times greater on senofilcon A and balafilcon A on Day 14. By Day 20 the ratio difference between these polymers and lotrafilcon B was at least 2 times.
- *In vitro* adsorption of PE on both Day 14 and Day 20 for senofilcon A, galyfilcon A and balafilcon A was in excess of 35 times more adsorption compared to lotrafilcon A.
- Lotrafilcon polymers exhibited *in vitro* lipid adsorption concentrations closer to the range found with "conventional" hydrogels such as etafilcon A.

Discussion/Conclusions

- The higher *in vitro* adsorption of cholesterol indicates that hydrophobic interactions play a greater role in adsorption of lipids than that of charge.
- If hydrophobicity is implicated to be more of the driving force in lipid adsorption for silicone hydrogels, it may be inferred that the lotrafilcon lenses are more hydrophilic than galyfilcon A, senofilcon A and balafilcon A.
- This study reflects the affinity of various materials to two distinct lipid species.

References

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