The Effectiveness of Physical Sunscreens in Preventing UVB-Induced Mechanical Damage to the Stratum Corneum

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Introduction:

The stratum corneum (SC) is the outermost layer of skin and the body's first line of defense against environmental exposures such as ultraviolet (UV) radiation [1]. The SC consists of cells, called corneocytes, held together by corneodesmosomes and intercellular lipids [1]. Previous research in the Dauskardt lab has shown that medium wave UV (UVB) decreases the cohesion of corneocytes, quantified by a decrease in delamination energy, by affecting the properties of intercellular lipids and corneodesmosomes. The focus of this project was to investigate whether physical sunscreens, whose active ingredients are zinc oxide (ZnO) and titanium dioxide (TiO_2), prevent UVB-induced damage to the mechanical properties of the SC.

Experimental Procedure:

Experiments were conducted using cadaver SC. Each experiment had a control group, which consisted of SC samples coated with sunscreen, and an experimental group, which consisted of SC samples coated with an equal amount of sunscreen but exposed to UVB radiation. Experiments were performed with broadband (BB) UVB, having a wavelength of 280-315 nm, as well as narrowband (NB) UVB, having a wavelength of 311 nm [2]. Double cantilever beam (DCB) testing was done to determine the delamination energy, G_c, of the samples. The DCB sample configuration is shown in Figure 1. For all experiments, G_c is the amount of energy required to remove the top layer of the SC.

Results:

The size of the ZnO and TiO_2 particles may have had an effect on the mechanical properties of the SC. Currently, many physical sunscreens are produced with nanoparticles (< 100 nm in diameter) of ZnO and TiO_2 [3,4]. These small particles do not scatter visible light and therefore, appear clear on the skin [3]. Little research has been done regarding the mechanical effects of these particles on the SC, and since sunscreen companies are not required to label the presence of nanoparticles in their products, particle size within the two sunscreens used was initially unknown [4]. Dynamic light scattering (DLS) and scanning electron microscopy (SEM) were performed to characterize particle size.

The results of DLS testing showed that the TiO_2 had an average diameter of 3 μm. SEM images showed that both sunscreens contained particles less than 200 nm, as well as larger agglomerations. However, there are limitations with DLS that should be taken into consideration, such as the risk of contamination from environmental particles, such as dust. Furthermore, SEM images would ideally be taken of the active ingredient alone, without the inactive ingredients present.

UV visible spectroscopy testing was done to determine any wavelengths of light passing through the sunscreens. In both cases, very little UVB penetrated the sunscreen. However, slightly more UVB penetrated the ZnO sunscreen.

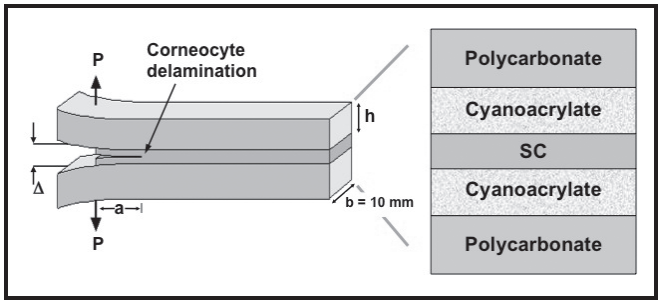

Figure 1: DCB apparatus. The SC (sunscreen removed) was adhered between two pieces of polycarbonate using Krazy® glue. The sample was placed in tension at a rate of 2 µm per second, allowing the sample to slowly fracture over time.

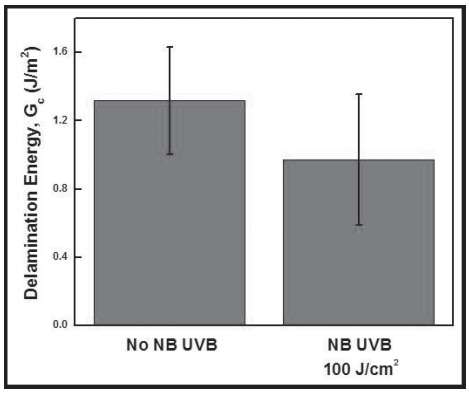

Figure 2: Delamination energy of SC with 21% ZnO sunscreen exposed to NB UVB.

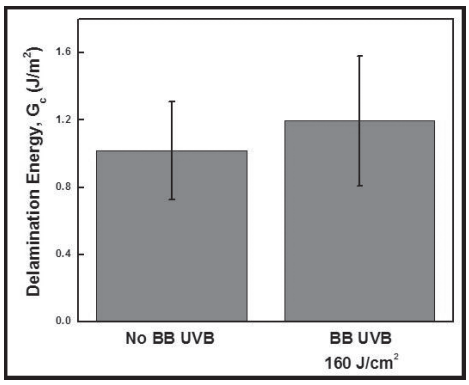

Figure 3, above: Delamination energy of SC with 9.1% TiO_2 sunscreen exposed to BB UVB.

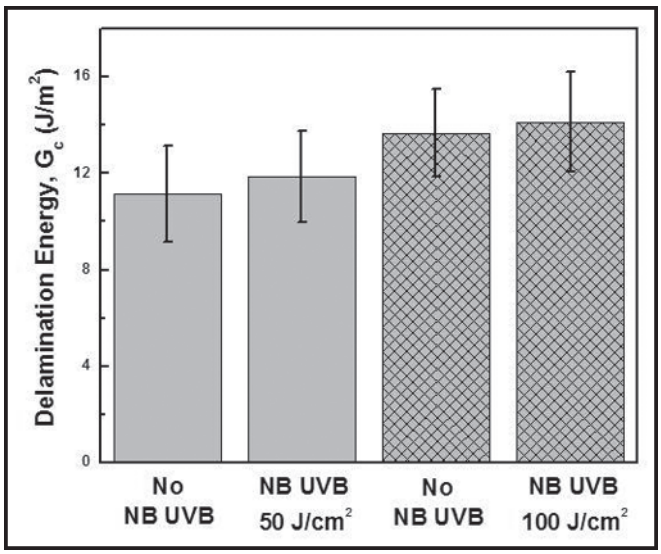

Figure 4, right: Delamination energy of SC with 9.1% TiO_2 sunscreen exposed to NB UVB.

When samples with a sunscreen of SPF 30 and an active ingredient of 21% ZnO were exposed to UVB, G_c slightly decreased, although it was within statistical error (Figure 2). Based on previous data revealing a significant decrease in G_c with increased UVB exposure, the slight difference in G_c between the radiated and non-radiated samples suggests that the sunscreen was effective in maintaining the mechanical structure of the SC.

Like the zinc oxide sunscreen, the TiO_2 sunscreen (SPF 30, 9.1% TiO_2) was relatively effective in maintaining the mechanical structure of the SC. The sunscreen appeared to be effective regardless of the dosage and type of radiation (BB versus NB).

Conclusions:

DLS and SEM testing showed that the TiO_2 and ZnO sunscreens contained micron-and nano-sized particles. The micron-sized particles may have resulted from agglomerations of nanoparticles.

The two sunscreens were effective in preventing mechanical damage to the SC when exposed to UVB. However, the G_c of the control group was not identical to the G_c of the radiated samples. Radiated samples coated with ZnO had a slightly lower G_c when compared to the control, suggesting that slightly more UVB was penetrating the sunscreen than was ideal. In contrast, radiated samples coated with TiO_2 had a slightly higher G_c when compared to the control, suggesting that there is a unique interaction between UVB and TiO_2 that may slightly increase the cohesion of corneocytes.

Future Work:

We would like to perform further experiments to verify the slight increase in G_c observed with the radiated samples coated with TiO_2. Additionally, particle size within more sunscreens should be characterized, and the UV exposure experiments should be repeated using sunscreens found to have nanoparticles to determine any mechanical effects on the SC caused by nanoparticles in combination with UV. Finally, we would like to look at the effects of UVA on the G_c of the SC. It is important to understand what affects the mechanical structure of the SC because with a loss of structure comes a loss of barrier function.

Acknowledgements:

I would like to thank Prof. Reinhold Dauskardt, Krysta Biniek, the Dauskardt lab, Dr. Michael Deal, Maureen Baran, James Conway, Stanford Nanofabrication Facility, Stanford's Center for Integrated Systems, National Science Foundation and National Nanotechnology Infrastructure Network Research Experience for Undergraduates Program.

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