Measurement of the Reduction of UVA-Induced Oxidative Stress After Application of Photostable Sunscreens

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Abstract

UVA exposure is known to induce oxidative stress in skin by generating free radicals that can interact with various molecular species and cause damage to the skin. UVA-induced oxidative stress can be studied *in-vivo* by measurement of chemiluminescence which is markedly increased after UVA exposure. Sunscreen products containing avobenzone provide the highest and broadest protection against UVA radiation. However, unless avobenzone is properly stabilized in sunscreen products, the sunscreen filters can chemically degrade upon solar irradiation. A patented, photostable technology containing diethylhexyl 2,6-naphthalate and oxybenzone combined with avobenzone has been developed to provide broad UVA/UVB protection. This technology has been incorporated into topical sunscreen formulations to provide enhanced protection from solar damage. An *in-vivo* study was performed on the volar forearm of human volunteers to assess the protection of two SPF 30 products against free radical formation. Irradiation of the skin with UVA light was performed on the photostable and the non-photostable formulations as well as an untreated control site. The formulations were applied evenly at a dosage of 2 mg/cm². Each site was irradiated with 20 J/cm² of UVA light. The site treated with the photostable sunscreen showed 76% less free radical counts after UVA irradiation compared to control, while the non-photostable sunscreen site showed only a 32% reduction. This study demonstrates that photostable sunscreen systems provide significantly better protection for the skin from UVA-induced free radical damage. Because of the different levels of protection provided between the photostable and the non-photostable sunscreens, it is important for dermatologists to be aware of the sunscreen photostability when recommending sunscreen products to their patients.

Introduction

Sun protection is essential in helping prevent skin damage and reducing the risk of skin cancer. Some damaging effects of overexposure to UV light include sunburned skin, photodamage, and skin cancer. One important element to an individual's sun protection routine is their choice of sunscreen. All sunscreen products are not the same. It is important that the filters in the product have broad coverage in both the UVA and UVB region, covering as much as possible from 290 nm through 400 nm, and simultaneously provide high absorbance at these wavelengths. Avobenzone is the sunscreen filter with the highest and the broadest absorbance in the UVA region,[1] but must be stabilized in the formulation to remain photostable once exposed to sunlight. Many sunscreen products currently containing avobenzone are not photostable. A patented, photostable technology containing diethylhexyl 2,6-naphthalate and oxybenzone, combined with avobenzone, has been developed to provide broad UVA/UVB protection.

In the present study these sunscreens were tested *in-vivo* to determine their effectiveness in reducing UVA-induced oxidative stress by measuring the skin chemiluminescence. Most biological processes generate some free radicals, emitting a weak chemiluminescence signal. UVA exposure generates a significant amount of free radicals in the skin, producing strong chemiluminescence signals that undergo a fast decay immediately following exposure (**Figure 4**), which can be measured with the equipment shown in **Figure 1**.[2]

Methodology

Two SPF 30 sunscreen products (both containing avobenzone) were tested on the volar forearm of four human volunteers, skin types I – III. Each formulation was applied evenly at a dosage of 2 mg/cm². All test sites were irradiated with UVA light, with an irradiance of 20 mW/cm² and a fluence of 20 J/cm². After UVA irradiation, chemiluminescence signals were measured with the equipment shown below. In addition to an untreated control site, the photostable and the non-photostable sunscreen were tested. An unirradiated control site was also measured.

In-Vivo Chemiluminescence Set-Up

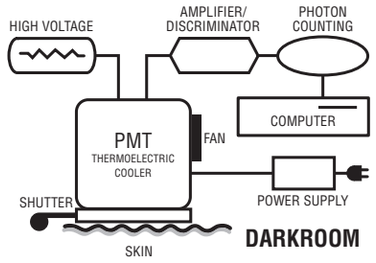

Fig. 1 – Instrumental set-up for chemiluminescence measurements.

After the site was irradiated, the subject placed the site under the photomultiplier (PMT) and opened the shutter. The system then recorded the time decay curve of the free radicals generated from UVA exposure for 300 seconds. The initial burst of signal, averaged between 10 and 30 seconds, corresponded to the relative amount of free radicals generated in the skin.

Results

This patented sunscreen technology has been tested *in-vitro* to determine the UVA protection provided by the product (PFA). The photostability of each sunscreen was also assessed *in-vitro* after UV exposure. Absorbance spectra for a sunscreen containing this patented technology and for a non-photostable sunscreen are illustrated in **Figure 2** and **Figure 3**, showing their response to UV irradiation. The non-photostable sunscreen spectra demonstrate the degradation of the sunscreen filters after UV irradiation, whereas the photostable sunscreen spectra show minimal change after irradiation.

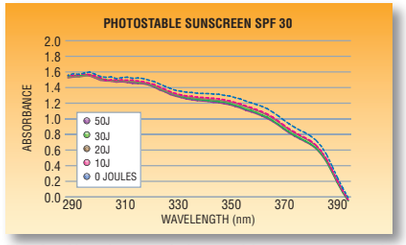

Fig. 2 – Absorbance of photostable sunscreen products after incremental UVA/UVB exposure.

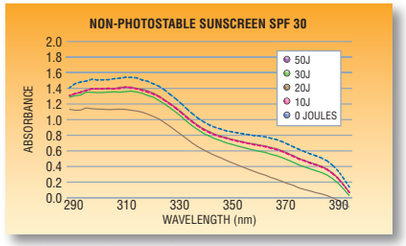

Fig. 3 – Absorbance of non-photostable sunscreen products after incremental UVA/UVB exposure.

The presence of free radicals after UVA irradiation was monitored, and **Figure 4** shows a representative subject's decay curves. All subjects exhibited a slight decrease in oxidative stress using the non-photostable sunscreen and a significantly greater decrease using the photostable sunscreen. The decay curve for the non-photostable sunscreen is more similar to the untreated site, while the photostable sunscreen is similar to the unirradiated baseline.

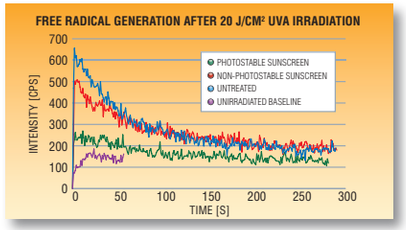

Fig. 4 – One subject's time decay curves.

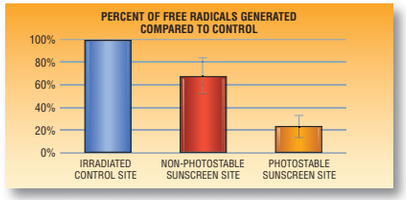

Fig. 5 – The site treated with the photostable sunscreen showed 76% less free radical counts after UVA irradiation compared to control, while the non-photostable site showed only a 32% decrease.

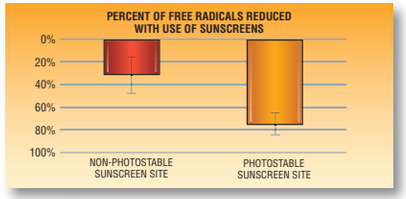

Fig. 6 – There were 3x more free radicals generated when using the non-photostable sunscreen compared to using the photostable sunscreen.

Data For All Subjects

	% of Free Radicals Generated Compared to Control					Average Free Radical Reduction
	Subject 1	Subject 2	Subject 3	Subject 4	Average	
Irradiated Control Site	100%	100%	100%	100%	100%	
Non-Photostable Sunscreen Site (NPS)	77%	52%	84%	60%	68%	-32%
Photostable Sunscreen Site (PS)	32%	17%	28%	18%	24%	-76%
Ratio of Free Radicals Generated from NPS to PS	2.40:1	2.96:1	2.96:1	3.29:1	2.90:1*	

* Photostable Sunscreen Site generated significantly less free radicals than Non-Photostable Sunscreen Site ($p<0.001$).

Conclusions

- Sunscreen products may have identical SPF and both contain avobenzone, but the resulting levels of UVA protection provided are not necessarily the same.
- When recommending sunscreen products to their patients, dermatologists and clinicians can now recognize photostability as an important characteristic of the product.
- This study demonstrates that use of sunscreens helps reduce the amount of free radicals generated in the skin from UVA irradiation. Photostable sunscreen systems provide significantly better protection for the skin from UVA-induced free radical damage than non-photostable sunscreen systems ($p<0.001$).
- The photostable sunscreen system was able to reduce free radical counts by 76% compared to control, while the non-photostable sunscreen system was only able to reduce 32% of the free radicals generated from UVA irradiation.

References

1. DeSimone II, E.M.: Prevention of Sun-Induced Skin Disorders. *Handbook of Nonprescription Drugs*. Ed. Berardi, R.R., *et al*. 13th ed. Washington, D.C.: American Pharmaceutical Association, 2002.
2. Ou-Yang, H., Stamatas G, Saliou C., Kollias, N.: A Chemiluminescence Study of UVA-Induced Oxidative Stress in Human Skin In Vivo. *J. Invest. Dermatol.* 2004; **122**:1020-1029.

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