

Beyond SPF: The Effects of Infrared and Visible Light on Skin Pigmentation and Aging

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Abstract: *Sunscreen and SPF are typically the first things that we come across when we consider sun protection. UV radiation has historically received the greatest attention because to its well-known effects on sunburn, pigmentation, skin aging, and skin cancer. But the sun rays do not comprise only of ultraviolet rays. Infrared rays and visible light are also a part of sun rays, each with their own effects on the skin. According to modern-day findings, visible light can increase skin pigmentation, particularly in individuals with dark skin types and those with a predilection for melasma and post-inflammatory hyperpigmentation. On the other hand, infrared radiation oxidative stress and collagen changes result in skin aging. This is why the topic of photoprotection needs to go beyond just SPF. Patients who are dealing with pigmentation issues such as melasma and post inflammatory hyperpigmentation will greatly benefit from protecting themselves from visible light. Tinted sunscreens with iron oxide help with this protection. Iron oxide-based tinted sunscreens offer further protection from visible light. This paper covers the importance of visible light and infrared radiation in relation to skin pigmentation and aging. It also justifies why today's photoprotection should be broader than the conventional UV protection. Photoprotection therefore has to be understood as a holistic strategy and not just a matter of selecting a product with an SPF that is high. An appreciation of the effect of various elements of the solar radiation will enable aesthetic clinicians to give their clients the best skincare recommendations based on science. This paper considers the relevance of visible light and infrared radiation in skin pigmentation and ageing in order to understand why modern day photoprotection needs to go beyond traditional UV protection. Healthy skin photoprotection is more than just SPF; it is all about skin protection against all types of solar radiation.*

Keywords: Infrared Radiation; Melasma; Photoprotection; Post-Inflammatory Hyperpigmentation; Skin Pigmentation; Visible Light

1. Introduction

The sun is one of the major environmental factors that affect our skin. Excessive exposure to the rays of the sun can result in tanning, pigmentation, irregular skin color, wrinkles, and reduction in skin elasticity. The main concern with regard to sun protection for a very long time has been UV radiation. That is why SPF is an essential factor in daily skincare routine. However, sunlight is much more complex.

It contains:

- Ultraviolet radiation
- Visible light
- Infrared radiation

Each of these wavelengths has different interactions with the skin. The visible wavelength has been receiving greater interest due to the influence of the pigment in the skin. This is especially true for dark skin types where the pigment is usually more durable. Infrared radiation has also been receiving much attention because of the influence of oxidative stress and collagen. For that reason, when giving advice to our patients regarding sun protection, we must not only ask ourselves "what is your SPF?" but also look at what kind of protection is needed according to their specific skin.

Understanding the Skin – Light interaction

The effects of the interaction of solar radiation and the skin depend on several parameters, among which are wavelengths, intensity, period of exposure, penetration depth, and individual characteristics of the skin. The effects caused by different wavelengths will be different, as they will be absorbed by different chromophores.

Melanin is one of the natural chromophores that plays an important role in the reaction of the skin to radiation. It absorbs various wavelengths and provides certain natural protection from radiation. However, the same melanogenic reaction that gives this protective effect may also cause undesired pigmentation due to repeated or excessive exposure to the sun.

The skin also contains various other cells that may be affected by the interaction with the light. Radiation may cause oxidative stress with generation of reactive oxygen species that affect inflammatory processes, cellular signaling, and components of the extracellular matrix. As a result, not only pigmentation but also some photoaging effects can be caused by the interaction of the sunlight with the skin.

Therefore, it should be noted that the effect of the biological effect of sunlight cannot be considered to be single. Different wavelengths of the light affect different cellular mechanisms, and their interaction may cause some visible effects that are observed after chronic sun exposure.

This knowledge is important in aesthetic dermatology as people may have pigmentation disorders or have undergone treatments that made them more sensitive to the sunlight. Thus, the photoprotection should be tailored to each patient individually.

Components of Sunlight

Sunlight reaching our skin contains different types of radiation.

Type of radiation	Approximate wavelength	Main effect on skin
UVB	280 – 315nm	Sunburn and DNA damage
UVA	315 – 400nm	Photoaging and pigmentation
Visible light	400 – 700nm	Pigmentation and oxidative stress
Infrared	> 700nm	Heat, oxidative stress and photo-ageing

The amount of radiation reaching different layers of the skin depends on its wavelength.

This is one reason why different types of radiation can produce different effects.

How Different Wavelengths Penetrate the Skin

The degree to which the solar radiation is able to reach the various layers of skin depends on the wavelength of the particular type of radiation. The reason for this is that the targets of the biological activity within the skin are different at various depths of penetration.

UVB radiation only reaches the superficial layers of the skin and mainly acts on the epidermis. This radiation is associated with the phenomenon of sunburn and DNA damage. UVA radiation is able to penetrate deeper and reach the dermis layer of skin, thus contributing to oxidative stress and photo-ageing.

Visible light may act on the structures located in both the epidermis and the dermis. However, the effects of visible light on melanocytes are particularly interesting as visible light is able to induce pigmentation in susceptible individuals. It is worth noting that this property of visible light is especially characteristic of dark-skinned individuals and people with melasma and/or post-inflammatory hyperpigmentation.

Infrared radiation can penetrate deep into the skin. Biological activities of infrared radiation are known to include oxidative stress, cell communication and modification of the extracellular matrix. The possible role of infrared radiation in skin ageing is currently under investigation.

Thus, the different patterns of penetration of various wavelengths of solar radiation make it impossible to evaluate the protective action of sunscreens by means of only one measurement, such as SPF.

Visible Light and Pigmentation

Visible light is that component of solar light which is visible to our naked eyes. For many years, it was considered to be less significant compared to UV light as far as skin damage was concerned.

Now scientific investigations have found that visible light could also influence the behavior of melanocytes. The receptor opsin-3 (OPN3), present in melanocytes, is one such investigation.

The melanocyte may increase its melanin synthesis when exposed to visible light through some signaling process. Blue light is one form of visible light that can influence this process.

This may lead to hyperpigmentation.

It is important to note that this reaction does not occur in all individuals. Individuals with darker skin types have been known to experience a more potent pigmentation reaction after exposure to visible light.

This is particularly important for individuals with pigmentation issues.

Mechanism of Visible-Light-Induced Pigmentation

The connection between visible light and pigmentation is complicated and depends on various cellular pathways. Specialised cells, melanocytes, are responsible for melanin production and their functioning is affected by some environmental factors including different wavelengths of light.

One of the cellular pathways that have been widely studied and which can be influenced by visible light is the activation of the opsin-3 light-sensitive receptors expressed in melanocytes. Such stimulation may affect cellular pathways and increase melanogenesis. Thus, this could be a reason for visible pigmentation in spite of the lack of visible sunburn after the exposure.

Another possible effect of visible light on skin pigmentation is related to the ability of such light to create oxidative stress. Reactive oxygen species can affect activity of melanocytes and signalling pathways in which melanin synthesis participates. Thus, the combination of direct cellular stimulation and oxidative stress can cause persistent pigmentation in some people.

It is important to note that the effect of visible light on pigmentation may differ in various skin types. Darker skin types can show stronger and longer-lasting reaction to such exposure. It is significant from a clinical point of view as melasma and post-inflammatory hyperpigmentation are usually seen in people with Fitzpatrick skin types III-VI.

Thus, the duration and frequency of the exposure play role as well. Daily exposure, even without visible sunburn, may cause cumulated pigmentation.

In conclusion, visible light should be regarded as one of the environmental factors that affect pigmentation disorders. However, it does not mean that visible light is the only reason for the development of melasma or PIH, it may be one of the aggravating factors in predisposed patients.

What is the Role of Visible Light in Melasma?

Melasma is a condition of excessive pigmentation which affects a large number of women.

Some of the causes of melasma include:

- Exposure to ultraviolet rays
- Hormones
- Genetics
- Heat
- Inflammation
- Visible light

Therefore, UV protection plays an integral role in the treatment of melasma. But there are some patients who seem

to be nonresponsive to the UV protection alone. From studies it has been found that visible light can increase pigmentation in darker skin types.

This explains why some patients feel that

"I have been applying sunscreen regularly each day but still my pigmentation reappears."

The formula of the sunscreen product used by such patients is as much important as the SPF value.

Visible Light and Post Inflammatory Hyperpigmentation
Inflammatory Post-Hyperpigmentation (PIH) is one more condition where inflammation combined with light exposure becomes clinically significant. PIH occurs because inflammation or trauma leads to the stimulation of melanogenesis and deposition of melanin in the skin.

Inflammation can be caused by various skin conditions like acne, burns, dermatitis or aesthetic interventions.

Chemical peeling, laser, IPL treatment, microneedling and RF treatments may also cause PIH, especially in dark skin patients.

After inflammation starts melanogenesis, further exposure to light will contribute to the aggravation of the pigmentation process. In case of exposure to visible light, it also may play a role in exacerbating pigmentation, especially in cases where the patient has a predisposition to hyperpigmentation.

The practical application of this information in aesthetic medicine implies that photoprotection cannot be applied after the pigmentation appears but should be a part of treatment in case there is an increased risk of developing PIH.

Aesthetic patients should receive recommendations about avoiding sun exposure, wearing protective clothing and applying sunscreen. Patients with melasma or PIH history may be prescribed a tinted sunscreen with iron oxides that will provide additional protection against visible light in comparison with UV-only sunscreen.

In addition, it is necessary to control inflammation and support the skin barrier after any intervention. Some irritant components of skincare or early application of active ingredients may stimulate the inflammatory process.

The prevention of PIH should be performed through appropriate procedure technique, inflammation management and photoprotection.

Tinted Sunscreen: More Than Just Colour

This is where tinted sunscreens become clinically interesting.

Most regular sunscreens are largely developed to defend from UVA and UVB rays. These sunscreens may fail to provide adequate defense across the visible light spectrum.

Iron oxides are common components in most tinted sunscreens and these may absorb visible light rays.

It has been found that sunscreen with iron oxides provides enhanced protection from visible light-induced pigmentation than sunscreens which defend from only UV rays.

Hence, tinted sunscreens may especially help individuals who have:

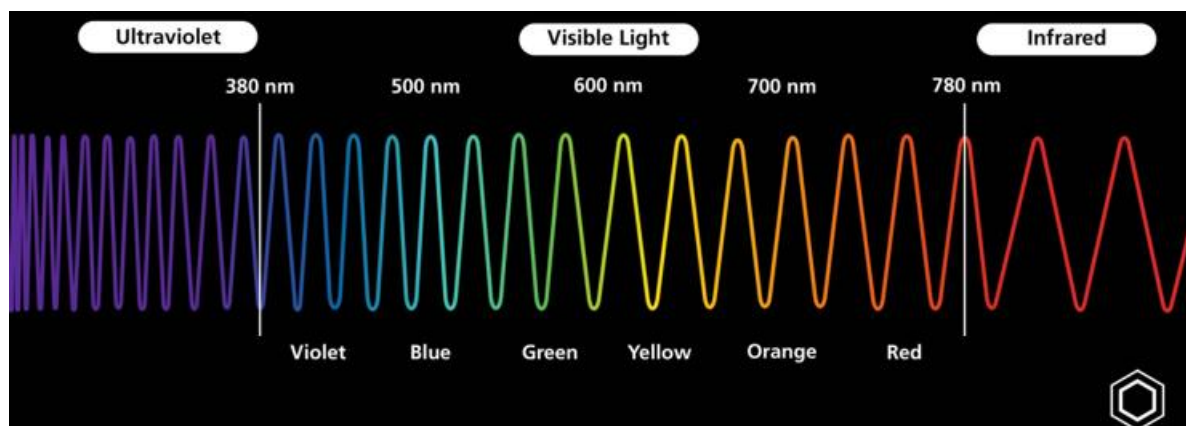
- Melasma
- PIH
- Acne associated pigmentation
- Post procedure pigmentation
- Darker skin phototypes
- Recurrent pigmentation

Sunscreen for such patients is not just something to prevent from burning, but it can be very significant for regulating pigmentation.

Choosing Photoprotection according to Skin type and Condition

Patient profile	Photoprotection approach
General daily skincare	Broad-spectrum SPF 50+
Melasma	Broad-spectrum SPF + visible-light protection
PIH-prone skin	SPF 50+ + tinted sunscreen
Darker skin types	UV + visible-light protection
Post-procedure skin	Strict photoprotection + physical protection
Recurrent pigmentation	Consistent daily protection + reapplication

Infrared Radiation: An Overview



Infrared rays are also constituents of sunlight.

Unlike the ultraviolet rays, infrared rays are known to be associated with heat more often. However, researches prove that the infrared rays can also lead to biological changes in the skin due to constant exposure to those rays.

The Infrared-A rays penetrate deeper into the skin than many other rays.

Constant exposure to the infrared rays can result in oxidative stress and collagen degradation.

A recent study demonstrated enhanced secretion of matrix metalloproteinase-1 (MMP-1) upon repeated exposure to infrared radiation. MMP-1 is an enzyme responsible for collagen degradation.

On the other hand, alterations in type I procollagen synthesis have also been noted.

All these results point out that prolonged exposure to infrared radiation may be responsible for the occurrence of processes characteristic for skin ageing.

It is worth mentioning, however, that while the scientific evidence concerning infrared photo-ageing is rather limited, there is more scientific evidence concerning UV photo-ageing.

Current Evidence on Infrared Radiation and Skin Ageing

While infrared radiation and, in particular, infrared-A (IRA), has become increasingly interesting for photoageing research, the mechanism by which it affects the skin seems to differ from those used by ultraviolet radiation. In contrast to ultraviolet radiation, IRA does not have a strong relationship with DNA damage or photoageing.

The longer wavelength of infrared-A allows the radiation to penetrate deeper into the skin tissues and act on the underlying dermis. This effect of IRA has led to the study of its possible influences on cellular metabolism, oxidative stress, and the extracellular matrix.

The first of the suggested mechanisms is based on the ability of infrared radiation to increase oxidative stress levels and, consequently, change some cellular signalling pathways and collagen metabolism. It has been observed in experimental studies that repeated exposure to infrared radiation leads to increased MMP-1 production. This enzyme is responsible for breaking down collagen.

Infrared exposure was also studied for its influence on procollagen production. Collagen breakdown together with reduced production may affect dermis structure in the course of time. As a result, clinically one may observe reduced skin elasticity and fine lines.

However, the data on IRA's effect on photoageing is not as extensive as the data on ultraviolet radiation's effect. Much of the evidence has been collected experimentally, and there is a need for more long-term clinical studies to assess IRA's exact impact on skin ageing in humans.

Thus, infrared radiation can be seen as a factor in accumulating environmental damages but not an alternative for ultraviolet radiation.

Heat, Infrared Radiation and Pigmentation

Heat is one of the environmental elements that has been studied in relation to pigmentation disorders. Many individuals suffering from melasma report an increase in their pigmentation in high-temperature conditions. However, one cannot conclude that heat is the direct cause of melasma. It is rather a factor that makes things worse in people already affected by melasma.

As for infrared radiation, it is one of the biggest sources of solar heat that can be responsible for some physiological processes in skin connected with oxidative stress and cellular signalling. Simply put, heat processing and infrared exposure repeatedly can create conditions for inflammatory and melanogenic processes.

The relationship between heat and pigmentation is extremely relevant for such countries as India where people endure huge heat and spend much time outdoors. Factors like working in the open air, travelling outdoors, cooking with the help of heat, etc., make the total amount of heat exposure even bigger.

This does not imply that patients suffering from melasma should limit their exposure to heat, as knowledge about how heat affects melasma will help the doctors in their recommendations.

Oxidative Stress: A Common Link

Environmental damage to skin usually occurs via oxidative stress. When radiation hits the skin, it results in formation of reactive oxygen species which are also called free radicals. The effect of oxidative stress may be felt in:

- Skin cells
- Melanocytes
- Collagen
- Elastin
- Cellular communication

This may help both pigmentation and skin aging.

On the other hand, visible light is not restricted to the role of inducing oxidative stress. Studies on the receptors of the melanocytes have found that visible light may also have direct impact on pigmentation mechanisms.

This helps us understand the role of different wavelengths in skin.

Why is this Important for Indian Skin?

The following issue is of particular significance in the Indian population.

Fitzpatrick skin types intermediate or dark are prevalent in Indians. Such types of skin are characterized by development of post-inflammatory hyperpigmentation in case of inflammation or environmental factors impact. Some of the skin conditions include:

- Melasma
- PIH due to acne

- PIH due to any procedure
- Un-even skin tone

Therefore, photoprotection should be an important part of treatment- not something added only after pigmentation develops.

This is of great significance especially after procedures like:

- Chemical peeling
- Microneedling
- Lasers
- IPL
- RF procedures

Inflammation induced from such techniques may enhance the chances of pigmentation formation, especially in darker skin types.

SPF Is Important, but is it Sufficient?

SPF is an essential parameter when determining the effectiveness of sunscreens for protecting the skin against UVB rays. SPF, however, fails to provide all the necessary information on protection against visible or infrared light. This is the reason why an individual suffering from melasma might require more than just SPF.

A comprehensive strategy for photoprotection could be:

- Broad spectrum UV protection
- Visible light protection
- Physical protection
- Proper skin care

Forms of physical protection are:

- Hats
- Umbrellas
- Minimizing exposure to sun

Patients with skin pigmentation may be recommended to use sunscreen with iron oxides for their skin type.

Disadvantages of Regular Sunscreens

SPF is one of the key determinants of sunscreen efficacy when it comes to providing protection against UVB-induced erythema. However, SPF on its own is not sufficient to give a complete picture of how effective the product is in terms of protection against other wavelengths from the spectrum of sunlight.

A product with high SPF rating means it provides strong protection against UVB when tested under standard testing conditions but does not guarantee the same protection versus UVA or visible light. UVA protection will need to be addressed separately and visible light protection needs to be determined from the composition of the sunscreen product.

This becomes especially important in people with pigmentation disorders. A person may regularly use sunscreens with high SPF and still experience chronic or recurring pigmentation due to lack of proper protection from visible light.

Specifically, tinted sunscreens with iron oxide pigments have recently gained a lot of interest in the field of dermatology as

iron oxide pigments can absorb certain components of visible light allowing for additional advantages for the patients suffering from melasma and post-inflammatory hyperpigmentation.

What Should We Tell Our Patients?

Rather than saying to people, "Apply SPF 50", we can be more precise in giving this advice.

Such as:

"Apply a broad- spectrum sunscreen SPF 50+ every day. If you suffer from hyperpigmentation and melasma, then go for a tinted sunscreen with iron oxides."

Also, patients must be told about applying an adequate amount of sunscreen and applying it again when necessary.

Also, photoprotection must continue even on days when the patient feels that the sun is not too hot.

2. Future Trends in Photoprotection

There is an evolution happening with the idea of photoprotection.

While earlier the main discussion with sunscreen was about their SPF and UV-protection, scientists are now studying how different spectrums of the sunlight affect the skin.

Perhaps future sunscreens will be developed based on spectral protection, not just on SPF alone.

Also gaining interest is the use of:

- VIS filters
- Iron oxide
- Antioxidants
- Melanocyte signaling pathway
- Special protection for darker skin types

Additional studies will be required to determine the possible long-term impacts on patient care of visible light and infrared radiation.

Studies conducted using skin of color, such as Indians and others, would be especially useful.

Before starting treatment, practitioners must find patients with a history of melasma post-inflammatory hyperpigmentation or long-lasting pigmentation after procedures. Fitzpatrick skin type is also important because darker skin types can develop pigmentation more easily after inflammation.

Patients should use a broad-spectrum SPF 50+ sunscreen each day. Those with melasma PIH or recurrent pigmentation may benefit from a tinted sunscreen with iron oxides, which offers protection, against visible light.

Correct application is just as vital. Patients need to learn how sunscreen to use and when to reapply, especially after long outdoor time sweating or other activities that reduce protection.

After procedures photoprotection must be part of the post-procedure routine. When to start skin-care products depends on the skin's condition and healing progress because too much irritation can raise the risk of PIH.

In the end the practitioner's job is more than to recommend a sunscreen. The practitioner should educate the patient about steady photoprotection.

3. Current Future Research

Although more evidence shows that light and infrared radiation matter for skin biology many questions still need answers. Most current studies on visible-light-induced pigmentation have been done in controlled lab settings. Long-term clinical studies are needed to see how these results fit into sun exposure.

More research on people with skin types is especially useful. Skin of colour makes up a share of the world's people but many photoprotection studies have looked mainly at lighter skin types. Studies on South Asian groups could give good data on melasma, post-inflammatory hyperpigmentation and how each person reacts to visible light.

We also need research to set up ways to test protection against visible light. Unlike SPF, which people know as a way to measure UVB protection there is no widely accepted test for visible-light protection.

The role of radiation still needs more study. Experimental data say that infrared-A might affect stress, collagen metabolism and other routes that lead to photoageing. More clinical studies are needed to confirm how important this is for people, over time.

So future sunscreen may shift to spectral protection. Sunscreens could use UV filters plus pigments that absorb visible light and other protective ingredients. Antioxidants and other methods that fight stress may also become more important.

Overall future research should aim to build evidence-based, practical and personalised photoprotection plans that look at all types of radiation and the special needs of each skin type.

4. Conclusion

We are beginning to have new perspectives on sun damage.

The effects of UV rays still remain one of the leading causes of photoaging and pigmentation. However, recent studies have revealed that even visible light plays a role in the process of pigmentation, especially among people with dark skin types.

Even the effects of infrared rays could play a role in oxidative stress as well as collagen pathways, but more clinical studies should be conducted for further investigation.

In cases like melasma and post-inflammatory hyperpigmentation, it is not enough to just use an SPF.

A more comprehensive method involves including UV protection (UVA/UVB), visible light protection, physical protection, and good skin care.

As practitioners in aesthetics, it is a significant paradigm shift regarding photoprotection.

It is no longer just about the SPF value.

It should be more about:

"What wavelengths of light do we want to protect the skin against?"

This is the true essence of "beyond SPF".

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