The Photobiology of LED Phototherapy

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The application of non-ablative skin rejuvenation using lasers and intense pulsed light (IPL) sources to repair the results of chronological and photo-aging of the skin is one of the fastest growing procedures for dermatological and aesthetic clinics. However, instead of treating the symptoms of chronological and photo-aging, it seems logical to prevent or halt them at an early stage through the use of less invasive or less damaging phototherapeutic techniques.

The evolution of therapeutic light-emitting diodes (LEDs), plus the development of superluminescent LEDs with extremely narrow bandwidths, has offered the aesthetic dermatologist a new and exciting tool. LEDs can be placed in arrays developed and designed to deliver precise doses of phototherapeutic energy over comparatively short periods of time.

In mid-2003, LED-based light systems OmniLux® Blue™ and OmniLux® Revive™, (Photo Therapeutics Limited, Altrincham, U.K.) were granted FDA clearance for acne and vascular and pigmented lesions. The company has more recently enlarged their scope with the development of a 633 nm visible red LED array, a minimally invasive skin rejuvenation system for anti-aging.

Ablative skin rejuvenation and residual thermal damage

Ablative skin resurfacing has been the modality of choice for the improvement of major wrinkles. For milder wrinkles and minor photo-aging, non-ablative skin rejuvenation with laser and IPLs has offered extremely good results in selected patients. Both modalities involve the creation of a precise zone of thermal damage, evoking a wound healing response, which results in the synthesis and deposition of new collagen fibers in the extracellular matrix along with elasotogenesis and angiogenesis.

Minimally-invasive skin rejuvenation and its photobiological basics

The use of high levels of thermal damage associated with lasers and IPLs may not necessarily be required to regenerate skin.

Given that the dermal cellular components are functioning normally it is logical that through the correct LED array, the bodies own cellular mechanisms can halt or reverse the signs of aging.

Recent studies have applied sophisticated photobiological principles to the treatment of photo-aging. Matching wavelengths with specific cellular targets have produced significantly better patient satisfaction in treatments, which look at using optimal or combined wavelengths, to achieve the desired photoresponse.

Finding the right wavelength

Research into light therapy stems back to the 19th century, the Italian scientist Fubini demonstrated that red light had a specific effect on mitochondria, increasing their metabolic rate. The intracellular specificity of red light on organelles has been more recently corroborated, in work from a number of clinicians and researchers. When this peer reviewed evidence is taken into consideration, the visible red spectral area around 633 nm seems the most effective to stimulate dermal cells and activate the cascade of events required to achieve reorganization and tightening of the skins supportive matrix and modulate the activity of the key cell in the dermis, the fibroblast.


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Inflammation: a 'necessary evil'

Inflammation is key in non-ablative skin rejuvenation, including minimally invasive red LED phototherapy. The phases of wound healing and the cells involved must be understood in order to appreciate the important role of inflammation in these processes. In the inflammatory phase, leukocytes peak, monocytes transform into phagocytes and mast cells peak and degranulate. This response initiates the migration of more macrophage cells and fibroblasts to the target stimulated by chemotactic signals from pre-existing fibroblasts, leukocytes and macrophages.

At the start of the proliferation phase macrophages gradually decrease and the number of fibroblasts peak then start to drop off. At the end of the proliferation phase two transitional events occur: the differentiation

of active fibroblasts into myofibroblasts and the de-differentiation of active fibroblasts into dormant fibrocytes. The role of the myofibroblasts, is to position themselves on collagen fibers and exert a longitudinal force on them, tightening and aligning them.

Red light at 633 nm has been shown to make mast cells preferentially degranulate. Mast cells are present in the dermis, located near blood vessels. The stimulation given by their fast-acting proallergenic granules is seen by the surrounding tissue as inflammation, so the wound healing process is triggered without any thermal damage.

This process is assisted by the continuous wave 633 nm light from the OmniLux Revive head, which penetrates far into the target dermis to involve not only the superficial and fine reticular dermis, but into the mid and deep reticular dermis.

The first law of photobiology clearly states that without any absorption there can be no reaction. With the depth of penetration and absorption obtained with photons at 633 nm there is absorption in all skin cells at all levels, including blood vessel endothelial cells and erythrocytes.

The inflammatory response from 633 nm is a controlled short-lived phase, which transcends through to the proliferation phase, together with the creation of neovascularization and the increase of local blood and lymphatic vessel flow. Lymphatic drainage is important in transporting leukocytes and lymphocytes into the target area and maintaining homeostasis of the treated skin. An increased blood supply raises the oxygen tension in the target area, creating cellular gradients and ensuring that the connection between the papillary dermis and the basement membrane of the dermal-epidermal junction (DEJ) and the basement membrane is supported.

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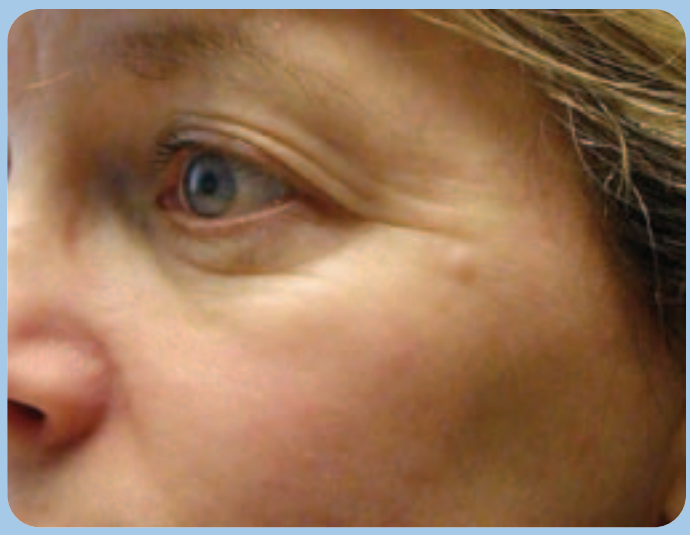
Fibroblasts are essential in achieving the desired effect in the dermis during the second and third phases following the inflammatory reaction caused by photomediated mast cell degranulation. The fibroblast is multifunctional, not only synthesizing collagen and elastin, but also regulating the homeostasis of the ground substance and maintaining collagen fibers.

LED phototherapy offers a new and exciting treatment modality, being non-invasive and safe with no patient downtime. However, the key to successful light therapy is the choice of the correct wavelength for photobiomodulation and the continuous delivery of the light in such a way as to maximize the light/photoacceptor interaction.



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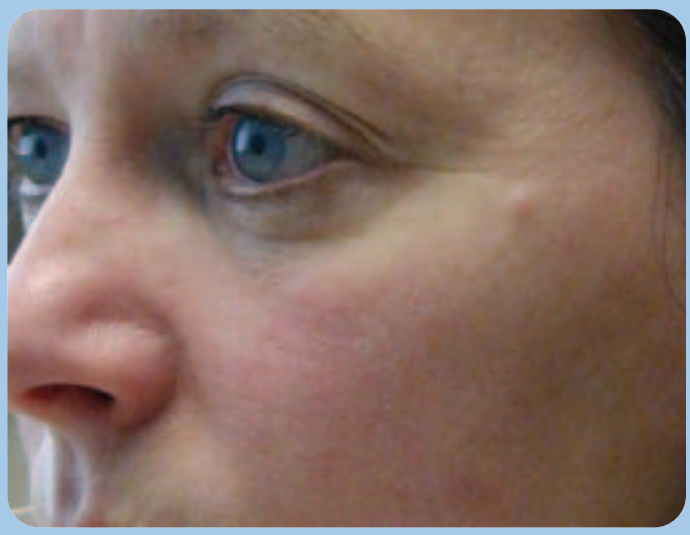

After Tx

And the future?

Work from Enwemeka, USA and the Trelles and Dyson groups have shown that near infrared (IR) light accelerates and strengthens the fibroblast-myofibroblast transformation, causing faster degranulation of mast cells when compared to 633 nm and has also been proved to increase the chemotactic efficiency of both leukocytes and macrophages.

Omnilux has recently developed an 830 nm head, and preliminary studies in combination with the 633 nm head for minimally-invasive LED skin anti-aging have been extremely effective with very high patient satisfaction. The clinical results will be published in detail in forthcoming articles. ■