The Clinical Application of LED Light for Healing and Skin Rejuvenation

By Sarah McGrath

While there is much information available about IPL and lasers on what they can achieve, less appears to be known about LED light and the physics that govern its capabilities in healing and skin rejuvenation. As LED is currently experiencing renewed interest, new research that has come to light reveals the power of this amazing technology. Sarah McGrath is a master trainer in LED and microcurrent. Here she presents some interesting research findings that unveil the potential of this amazing technology and how it can be used more successfully.

After years in the corporate manufacturing world, I decided on a "sea-change" so that my husband and I could start a family. I have always been interested in natural health remedies, and was introduced to the world of IPL and LED by my good friend and mentor Bonnie Sleep.

During my training and clinical experience I have seen and treated many people for skin issues completely unrelated to skin rejuvenation, such as cuts, burns, psoriasis, eczema and dermatitis, and some pretty nasty open wounds caused by manufacturing accidents, and it's the healing mechanism of light therapy that has really ignited my interest to learn more.

In the beauty clinic I currently work in, we operate an Omnilux Light Therapy, which was developed by Dr Colin Whitehurst of the Christie Hospital in Manchester, who while researching alternatives to laser in the treatment of skin cancer created a PDT (photodynamic therapy) - a lamp that was able to kill cancer cells without damaging any of the surrounding tissue. A wonderful side-effect, he noticed, was that the lamp was not only improving cancer lesions, but also rejuvenating the surrounding skin.

Dr Whitehurst went on to spent five years developing the Paterson lamp (designed at the Paterson Institute in Manchester), which has morphed into the modern Omnilux.

Last year I was at a seminar in Melbourne of Dr Robert Glen Caulderhead, who has a long and distinguished career in laser medicine. In the past 25 years he has delivered more than 150 invited and special guest lectures at national and international congresses, and more than 200 free papers. The co-author of two books on laser therapy, he has also collaborated on several others and has had more than 110 papers published in peer-reviewed journals. He is also the author and co-author of more than 130 scientific papers on biomedicine and phototherapy, and has been the author and collaborator of 10 books on laser therapy, laser surgery and simulation surgery. *See below his extensive credentials.

The following studies quoted below use various Omnilux LED Light Therapy Lamps, because they are considered to be the quintessential technology in LED.

WHAT IS PHOTOTHERAPY?

Phototherapy comes from the Greek terms "phos, photos" meaning "light" and "therapoeia" meaning "I treat or heal". In its broadest meaning, phototherapy is any kind of treatment where a form of light

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is used. In the modern era, it has come to mean the use of non-invasive levels of light (photon energy) to achieve a non-surgical but clinical effect, in an atraumatic and athermal manner (cf 'photosurgery').

LED (Light Emitting Diode) Light Therapy is the application of a very specific frequency of light to the skin. The various colours are determined by their wavelength. This produces a biological response called photo-biostimulation, whereby reactions take place in the cells and skin tissue in response to the wavelength of light. Both visible and near-infrared wavelengths stimulate changes in the body's cells.

PHOTOTHERAPY LIGHT SOURCES

Flash-lamp technology (IPL) is non-coherent, polychromatic and delivers thermal damage to the skin cells.

Non-ablative skin rejuvenation laser systems are coherent in their wavelengths, but also deliver thermal damage.

LEDs are quasi-monochromatic (generally +/- 3-6 nm) and deliver photo-bioactivation, which is athermal and atraumatic. They work with the body's own natural frequencies to induce ***change***, as opposed to delivering ***damage*** to induce change. There is no downtime, or side effects, no damage to sub-dermal tissue, and it's relaxing and calming to the candidate. LED is compatible with existing skin rejuvenation techniques such as Botox, IPLs, laser resurfacing and cosmetic surgery.

HOW DOES LED LIGHT THERAPY WORK?

Light is the movement of photons, the fundamental particle of light. They have a unique property in that they are both a particle and a wave. This is what gives them the unique properties of refraction and diffusion both very important concepts in Phototherapy.

Photons are the most visible portion of the electromagnetic spectrum. Because light is another form of energy, it can be transferred or converted into other types.

For example, when light hits the skin it is both reflected from the stratum corneum and is transmitted through the epidermis and dermis. In the dermis the light is scattered and this is where a large volume of tissue can be targeted from a comparatively small light source. In skin therapy we want the light to be absorbed in the target tissue where the most important interaction of energy exchange can occur. If you don't get absorption of the light, then you don't get a bio-stimulating reaction.

The different colours of LED (determined by their wavelength) penetrate the skin to varying depths, causing the skin to respond by undergoing the Wound Healing Response.

With the different wavelengths, we want to target very specific cells at specific depths. This is where *intensity* is very important. Without enough intensity, the light won't reach its target. If the light is matched to its target with good penetration, then the photo-biostimulatory response will occur.

If there is increased optical density (absorbance) then there will be less penetration to target tissue – the higher the optical density the less the penetration of the wavelength of light.

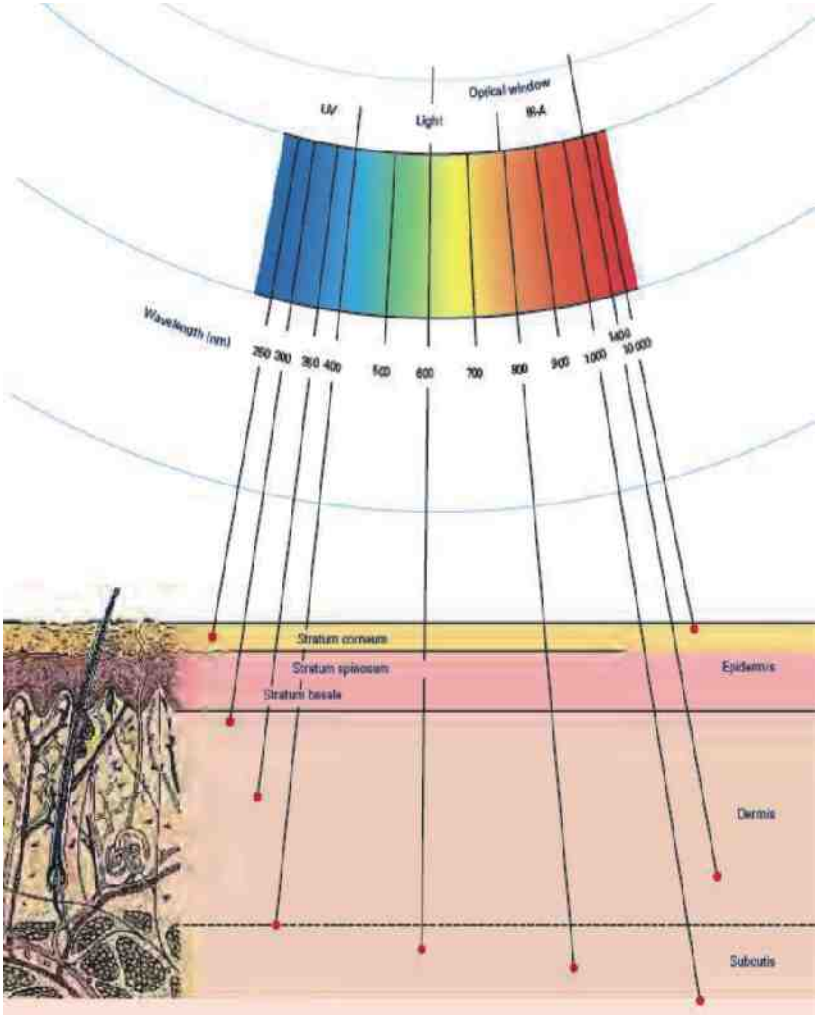
Blue, green and yellow light wavelengths penetrate poorly because of their absorbance, while deep penetration happens with red (633nm), and the deepest penetration occurs at near-infrared (830nm.)

Of course, the primary targets in phototherapy are skin cells. Our skin is the largest organ of the body that protects our body from the external environment. The skin has an ideal water content measurement and most importantly, contains all of the target cells for LED therapy. At any given time, the skin contains more than 20% of the body's blood.

DIFFERENCES IN THE WAYS CELLS ARE PHOTO-ACTIVATED

There are differences in how visible light and near-infrared light energy activate a cell. Visible light energy passes through the cell membrane and is absorbed by the intracellular organelles. The cell becomes activated from the inside-out to the membrane. The near-infrared energy is absorbed first in the membrane and then inwards, before returning back out to the membrane. The end result is the same though – a photo-activated cell. The difference is that one is photo-physical (visible red light) and one is photo-chemical (near-infrared.) This is important though, because using both visible red light and near-infrared light concurrently confuses the cell due to the mechanisms of photo-activation. Therefore only one wavelength of light should be used at a time.

The light energy recharges the mitochondria of skin cells (the "power generator or battery" of a cell), giving them energy to perform at their maximum capacity. The light also opens up the communication channels between cells, through increasing the production of calcium ions (inter-cell signalling), which is where the "Bystander Cell Theory" comes into play. Not every single cell needs to be specifically targeted. Because of cell communication and signalling,



surrounding cells receive the same messages and the Wound Healing Process (WHP) begins indirectly. Damaged or compromised cells begin to repair, cells perform their functions better and cellular proliferation is increased.

The body is a very intelligent system, and LED Light Therapy has a "Systemic Effect" in this regard. For example, you may be treating dermatitis, eczema or psoriasis on an arm, and if the condition exists elsewhere that will also improve, due to the body's ability to signal, communicate and exchange information.

USING MORE THAN ONE WAVELENGTH AT THE SAME TIME A NO-NO!

Remember that the intensity and the wavelength are very important, and that when there is a high optical density, penetration is poor. Because photons are little packets of energy, each wavelength has a different photon energy level. The light (photons) give the cell information, which is specific to its wavelength. If you give the cell conflicting information (as when combining different wavelengths or colours) you confuse the cell. If the cell is told to "go left" and "go right" simultaneously, the result is that the cell goes nowhere, or even worse, may shut down.

As mentioned previously, the way a cell is photo-activated by a visible frequency compared to a near-infrared frequency is completely different (photo-chemical versus photo-physical), so the cell again is confused when irradiated concurrently with different wavelengths, or even within the same 48-hour period.

Scanning an area with a specific frequency of LED light gives poor intensity, resulting in an under-active cellular process. The LED light source needs to be **focused and targeted** on the specific area for a specific level of time. Studies show that 20 minutes is the optimum time period (providing for intensity). There are no increased measurable benefits from a longer time period, however, below a 20-minute period cellular activity is not maximised.

Many questions are asked of yellow light at 590nm. While it is broadly accepted that red and near-infrared wavelengths (633nm & 830nm) provide the best outcomes for the Wound Healing Process and Skin Rejuvenation, there is conflicting information about yellow light. The latest research indicates that due to the poor penetration of yellow light at 590nm, (high optical density of 7.8, therefore poor penetration) through a human hand, in vivo, there is very little benefit to be gained from a healing or skin rejuvenation perspective. In contrast, the same studies show that the 633nm wavelength (red) penetrates much greater with an optical density of 4.5, with the 830nm penetrating the furthest with an optical density of 3.1.

SHOULD LIGHT THERAPY BE ADMINISTERED AS A CONTINUOUS WAVE (CW) OR AS A PULSED LIGHT (PL) FOR SKIN REJUVENATION?

Using an incident radiant flux (dose) of 2.25 joules/cm^2 with an incident power at 56mW (milliwatt one thousandth of a watt) and measuring various pulsed beams (at 10Hz, 60Hz, 120Hz and 180Hz) and a continuous wave (and using a control beam) measurements of fibroblast growth (counted by increase in fibroblast cells) over a time period of 0 to 6 days shows a lineal relationship over time. However, with the continuous wave increasing fibroblast cells by 60,000, in comparison to the pulsed light beams, which showed an increase of between 22,000 (10Hz) to 48,000 (180Hz) over the same time period.

ANY OLD "LED" WILL NOT DO

The type of LED used is very important, and this is where institutions such as NASA get involved. NASA has found that human cells need gravity to stimulate cell growth. Biologists have found that cells exposed to near-infrared light from LEDs (just outside the visible range) grow 150-200% faster than cells not stimulated by such light. This has led to the development of the NASA light emitting diode.

For the best outcomes, LED technology must have:

- An appropriate wavelength
- Be able to treat a large area uniformly
- Have a high photon intensity (mW/cm^2) at an appropriately high dose (J/cm^2).

For example, ideally red LED at 633nm should have around 105mW/cm^2 & 126 J/cm^2, with near-infrared at 830nm to have an intensity of 55mW/cm^2 and a standard dose of 66 J/cm^2 ,while the blue wavelength at 415nm should have an intensity of 40mW/cm^2 with a dose of 48 J/cm^2.

The NASA diode is considered the epitome of LEDs for aesthetics because of its high photon intensity and high dose output. However, there must be a sufficient number of diodes precisely aligned in a reflective base to ensure that a zone of very high photon intensity is created over the target tissue.

Remember that the skin has light-scattering characteristics as well as being able to absorb the light, so the more LEDs you have aligned, closely together, the greater the intensity (penetration) and area you are able to treat.

WHY ARE DIFFERENT WAVELENGTHS IMPORTANT?

When we use the term "red light" we are referring to the red wavelength of light in our visible light spectrum about 650 nm, although different LEDs may produce at slightly different wavelengths. There are many documented cases of cells undergoing change when exposed to red light. Red light is selectively absorbed by respiratory components of isolated cells (Fubini et al) at 633nm. Maesters found that it has excellent healing capabilities with slow-to-heal and non-healing ulcers (due to vascular insufficiency), and accelerates angiogenesis (development of blood vessels). Red light is absorbed preferentially in the redox chain of the mitochondria respiratory system (Karu), it stimulates fibroblasts in vitro to form mono-sheet faster with linear alignment (Trelles). Furthermore, it accelerates the recruitment and degranulation of mast cells (Trelles, Bolton, Dyson). Red light also increases the calcium ion production and inter-cell signalling in vitro and in vivo (Lubart). In a nutshell, red stimulates collage formation and is anti-inflammatory.

Near-infrared light accelerates the degranulation of mast cells even better than red light (Trelles, Bolton, Samoilova). It also stimulated better chemotaxis phagocytosis and internalisation in pooled human neutrophils (Shiroto, Dima). Additionally, it increases calcium ion production and inter-cell signalling in vitro and in vivo better than red (Lubart). Near-infrared stimulates collagen and promotes healing of tissue.

The 830nm wavelength in near-infrared light relieves muscle spasms and stiffness, relaxes muscle tissue and increases both the oxygen and nutrients to stiff muscle tissues, thereby increasing lymphatic drainage. This wavelength acts on the hypertensive nerves (sympathetic system flight versus fight) to control and calm. This then assists random nerve firing, which controls spasms, decreasing stress hormones (para-sympathetic response). The 830nm wavelength is excellent at assisting pain control (better than 633nm, because of the depth of penetration), and is recommended to apply 2-3 times a week before the pain is removed.

The blue wavelength of light (415nm) is used mainly to treat moderate inflammatory acne vulgaris, but has a much better outcome when used in combination with red LED. A study undertaken by David Goldberg MD & Bruce Russell MD from the Skin Laser and Surgery Specialists of New York/New Jersey, and department of Dermatology, Mount Sinai School of Medicine, New York, published in the *Journal of Cosmetic Laser Therapy* (2006, 8: 71-75) found that there was an optimum reduction of 82% at 12 weeks post treatment, a marked reduction in pore size, sebum production was reduced by over 50% and there was no damage to the sebaceous gland.

There were 22 subject with inflammatory or nodular acne (Burton grades II, 5; III, 4: IV, 8: and V, 5) treated with alternate blue/red light therapy (twice a week, but with a minimum 48 hours apart for four weeks). Another study undertaken by Seung Yoon Lee MD, Chung Eui You MD and Mi Youn Park, MD PhD at the Department of Dermatology, National Medical Centre, Seoul, Korea and published in the *Lasers in Surgery and Medicine Journal* 2007 39: 180-188, using the same treatment protocols (twice a week, sequentially with the Omnilux™ blue and Omnilux™ Red, over four weeks) found a final mean clearance percentage of 77.93% (reduction in inflammatory lesions, papules, pustules, nodules and cysts, eight weeks after the final treatment) with significant skin lightening highly desired in Asian societies.

HOW DOES LED LIGHT THERAPY WORK TO HEAL THE SKIN AND ALLOW FOR REJUVENATION?

When using LED Light Therapy for skin rejuvenation, we initiate the Wound Healing Process (WHP) which involves three stages Inflammation, Proliferation and Remodelling.

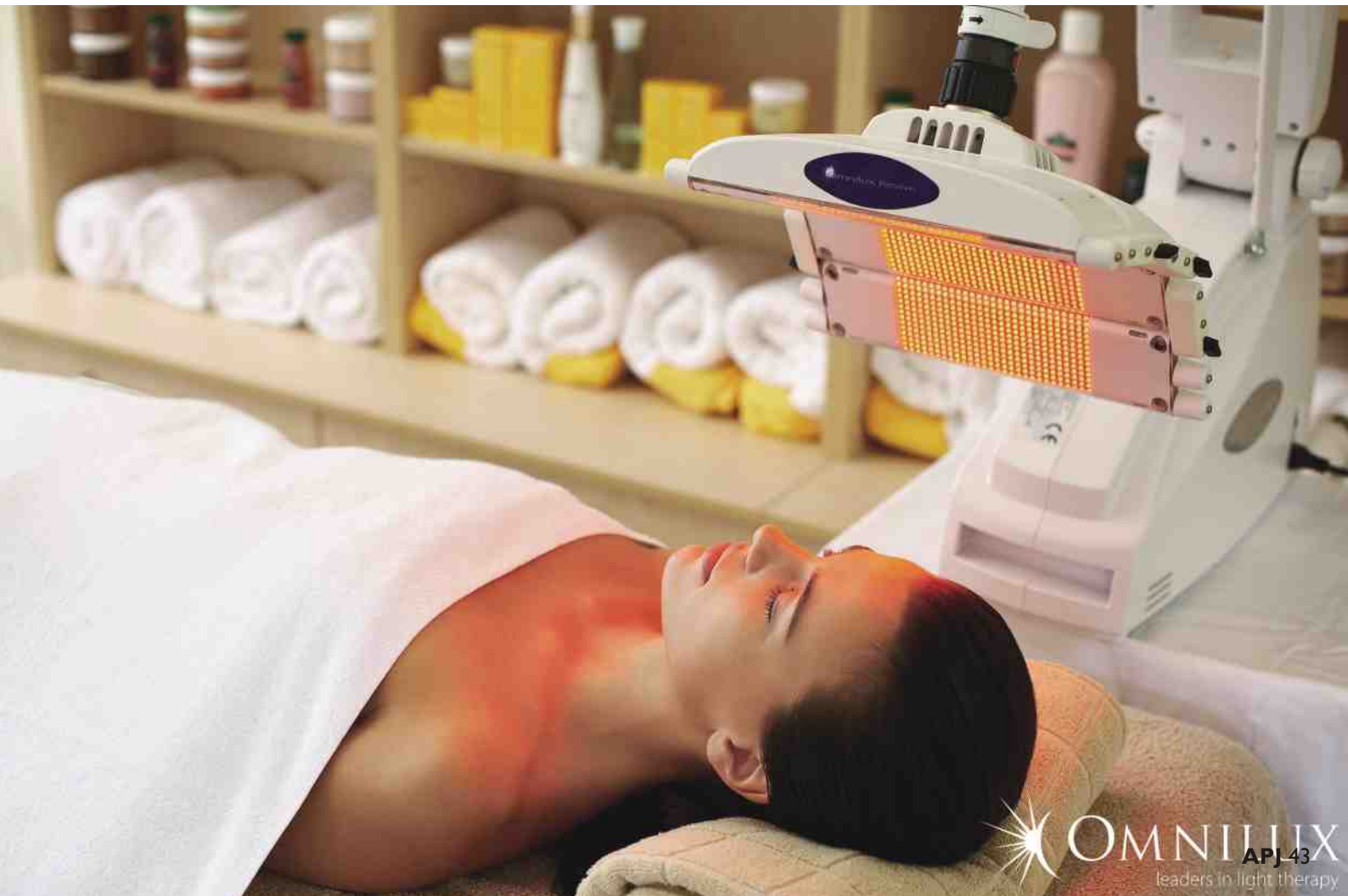
Inflammation is important as if we don't have inflammation we cannot get Proliferation. (Steroids inhibit the immune response and inflammation.) At the Inflammation stage (0-3/4 days) Mast cells, leukocytes and macrophages become active. The Mast cell releases cytokines and chemokines to attract other inflammatory cells. The leukocytes are the first line of defence against invading micro-organisms, and recruit T-cells. They are also responsible for the production of Transforming Growth Factor Alpha and Beta (Fibroblast Growth Factor), which is required for fibroblast proliferation. The macrophages remove the dead and dying cells, along with other detritus and synthesise growth factors.

Following the Inflammation stage the Proliferation stage is activated. This happens between 3-21 days. Here fibroblasts and endotheliocytes go to work; the fibroblasts synthesise new collagen and elastin fibres, creating a new structural matrix and maintaining the structural homeostasis. The endotheliocytes form new blood vessels, bringing nutrients and oxygen to feed the newly forming matrix.

The third and longest stage is the Remodelling stage. This occurs between 18 days to six months. As in the previous stage, the cells drop back to their normal level. Some fibroblasts change into myofibroblasts, this, however, only occurs through photo-activation.

Myofibroblasts have "barbs" and "hook" into the collagen bundles to pull them together into alignment, creating a compact, better linearly aligned matrix. Some fibroblasts de-differentiate into fibrocytes that replenish the stem cell store for the future.

Studies show that at 633nm and 830nm (compared with wavelengths at 590-595nm, 670nm, 790nm, 904nm and defocused beams of 1064nm & 10600nm) the greatest activation of Mast cells, macrophages and neutrophils occurs in the Inflammation Stage, however, a very high level of action occurs at the 830nm wavelength across all three cell types compared to the 633nm wavelength, where Mast cells rated high, macrophages rated moderate along with neutrophils. (Action Potential of cells was measured using five different levels of action; very high, high, moderate, none and



retardation.) This is due to the fact that the 830nm of light is mostly absorbed in the membrane and changes the permeability of the cell, where the sodium and potassium pumps are engaged.

In the Mast cell, there is an increase in the production of granules (histamine, serotonin, heparin and tryptase) so that pro-inflammatory and other granules move from the Mast cell into the surrounding normal tissue through the increase in cell permeability. This happens very quickly, within minutes. Following this, macrophage chemotactic factors, neutrophil chemotactic factors and fibroblast recruitment occurs within hours, instead of within 2-3 days.

At 830nm, LED induces "quasi-wounding", where the WHP Inflammation response is started, without the inflammation, so that the Proliferation stage can begin far more quickly.

At the Proliferation stage, the 633nm wavelength reports the highest increase (very high) in fibroblast and endotheliocyte action potential, compared to all other wavelengths (as above), including the 830nm wavelength. In comparison, at 830nm, fibroblast action potential is only moderate and endotheliocyte action potential is high.

However it is at the Remodelling stage that we see significant change again. For the 830nm wavelength, the highest level (very high) of action potential is seen with the myofibroblasts, compared to only none to moderate increase seen with the 633nm wavelength. With the use of the 830nm wavelength of light, overall the WHP Remodelling stage sped up to occur from 10 days onwards, instead of 18 days to six months.

At the 633nm wavelength, fibroblasts, endotheliocytes, Mast cells and blood vessel walls are targeted. This is perfect for healing, and red light is wonderful for using both pre and post-surgery and for increasing the healing time (and reduction in scar tissue) of wounds.

At the 830nm wavelength keratinocytes, Mast cells, neutrophils, macrophages, fibroblasts, blood vessel walls, lymphatic cells and sensory nerves are targeted. Because of the more targeted approach and "quasi-healing" the Remodelling stage can occur between 12-15 days, instead of the 18 days to six months. The WHP time is cut dramatically and there is a dramatic increase in collagen.

SKIN REJUVENATION PROTOCOLS

A randomised, placebo-controlled double-blind and split-face clinical study on LED phototherapy for skin rejuvenation was conducted. It used clinical, profilometric, histologic, ultrastructural and biochemical evaluations and comparison of three different treatment settings - 633nm only, 830nm only, combination 830nm, 630nm and placebo red light. The study was conducted by Seung Yoon Lee, Ki-Ho Park PhD, Jung Woo Choi MD, Jung-Kyun Kwon PhD et al and published in the *Journal of Photomedicine and Photobiology* (2007) 88: 51-67. The clinical study used Omnilux Plus LED at 830nm and Omnilux Revive LED at 633nm and found that a combination of using first, the 830nm wavelength, then the 633nm wavelength, twice a week, with 2-3 days apart, for 20 minutes per session and delivered over four weeks delivered the greatest reduction in the severity of wrinkles. The reduction rate of the melanin level was highest in the red light alone (633nm group) and the satisfaction level was highest in the group where the 830nm LED was used.

A similar study to determine the efficacy of combination LED therapy (633nm & 830nm) in facial rejuvenation by Dr Bruce Russell and published in the *Journal of Cosmetic and Laser Therapy* 2005, 7: 196-200 also produced equivalent results, particularly in the reduction of lines and wrinkles.

Considering that skin rejuvenation aims at wrinkle reduction and reversal of other signs of aged skin such as unhealthy and irregular skin tone, the combination of the 830nm and 633nm LED light is the optimal protocol for this purpose and contributed to different therapeutic effects of each wavelength of light.

IN CONCLUSION

No single wavelength can attack all targets equally, so a combination of LED light therapies is required. However, because LED light therapy is non-invasive and non-ablative, and has such wonderful healing benefits (633nm in particular), intelligent professionals can exploit the synergy between LED Light therapy and other approaches, including conventional surgical procedures, IPL systems/fractional technologies, epidermal powder pells/chemical peels, non-ablative skin rejuvenation, vitamin iontophoresis, mesotherapy and other adjunctive epidermal treatments. APJ

Sarah McGrath graduated on scholarship from Bond University in 2002 with a double degree in Commerce and International Business. With a background in accounting, marketing and management she entered the mainstream business world before deciding on a career change in 2008. After studying both in Queensland and London under the auspices of her friend and mentor Bonnie Sleep, Sarah set up her own clinic "Lumiere De Peau - Skinlight", specialising in anti-ageing skin treatments using Light Therapy (non-contact IPL and LED) and Microcurrent. Her experiences with the healing and skin rejuvenation benefits of red LED drove her to research other frequencies of LED technology. Omnilux technology was on the cutting edge of healing and anti-ageing protocols and used by some of the world's most renowned and skilled surgeons. Sarah is a Master Trainer for CACI Australia, incorporating LED and micro current technologies.