Better wound healing and less postoperative pain with laser procedures compared with the same procedure performed with the cold scalpel or with electrothermy were reported by those who first used the surgical laser in the late 1960’s and early 1970’s, which was an added beneficial component associated only with laser surgery compared with conventional methodology. This was obviously a photo-mediated effect rather than purely thermal or electrothermal and was first termed the ‘γ-effect’ in the early 1990’s, was then classified by the author as simultaneous laser therapy in the mid 1990’s, but is now more accurately classified by the author in his latest classification of laser treatment as part of the auto-simultaneous aspect of laser treatment, whereby a number of different reactions can be obtained at the one time with a single laser. Laser/tissue reactions fall into three broad groups. Irreversible and destructive photoreactions in the tissue is classified as high-reactive-level laser treatment (HLLT), as in laser surgery for incision, excision, vaporization and tissue coagulation. If some irreversible damage occurs together with reversible photodamage, as in tissue welding, the author refers to this as mid reactive-level laser treatment (MLLT). If the level of reaction in the target tissue does not cross the survival threshold of the cells making up the tissue, then this is called low reactive-level laser therapy (LLLT). All three of these classifications can occur simultaneously in the one target, and fall under the umbrella of laser treatment (LT). Auto-simultaneous laser treatment (ASi-LT) is used to describe a treatment situation whereby 2 or more tissue reaction types are achieved simultaneously in tissue with the one laser, and accounts for the successful surgical application of the laser in many fields compared with conventional modalities, such as in laser full face resurfacing, nonablative skin regeneration and tissue welding, due to the beneficial actions on the wound healing process of the zone of photobiomodulated cells at the periphery of any such surgical beam.

Key words: Low-reactive level laser therapy, laser treatment, photobiomodulation, tissue welding, wound healing

Introduction and History

When the first ruby laser was successfully developed by Dr Theodore Maiman in 1960, a new tool became available to clinicians, although at first its applications were really unknown so that the application of the laser in medicine and surgery was often called a solution in search of a problem. The ruby laser opened up the way for other systems, and from 1960 to 1964 all of the major lasers used to this day in medicine and surgery were developed, including the argon, helium-neon (HeNe), neodymium yttrium aluminium garnet (Nd:YAG) and the carbon dioxide (CO2) laser. By the time the author first started using the ruby and argon lasers in Japan in the mid 1970s, reports were appearing in which procedures performed with this cold medicine and surgery were developed, including the argon, helium-neon (HeNe), neodymium yttrium aluminium garnet (Nd:YAG) and the carbon dioxide (CO2) laser. 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toos compared with dermabrasion. In figure 1a, a hemangioma simplex (port-wine stain) had been treated in another institute with electrocautery. Particularly in large lesions of this type, it was very difficult to achieve a homogeneous treatment effect, and the result was typical 'tapioca skin' comprising tiny areas of lustered and hypertrophic scarring corresponding to the needle treatment points, surrounded by untreated areas of the lesion. When the argon laser was used to treat this lesion, using the author's first version of the zebra technique for lesion revision, it not only removed the remaining color of the nevus, but also treated the areas of scarring, thus illustrating the beneficial $\alpha$-effect associated with laser treatment.

The case which really sparked the author's attention and encouraged him to investigate the so-called $\alpha$-effect further concerned a lady who had intractable postherpetic neuralgia (PHN) for which she had received many treatments but without effect. The pain was so severe that she was contemplating suicide, and, to save her relatives any embarrassment after her death, decided to have a hemangioma simplex on her chest removed (Figure 2a) and consulted the author. After a test treatment (seen as the small square area on the lower left of Figure 2b), the author started treatment with his modified zebra technique as seen on the upper portion of the lesion. When the patient returned to continue the treatment, she announced that her PHN had totally resolved.

The author considered this very carefully. When a laser is used in the surgical mode, it creates a typical pattern in stained tissue specimens (Fig 3), consisting of the ablated tissue at the target, a layer of carbon char if the temperature is high enough (1 in Figure 3), a zone of necrotic coagulated tissue (2 in Figure 3), a zone where the protein is at first degraded (3) and then denatured (4) as the photothermal gradient drops in the irradiated tissue, giving a zone of tissue in which the damaged cells gradually merge towards normal tissue, as seen by the basophilic to eosinophilic changes in the stained specimen. The author surmised that the photon energy did not stop there, however, but continued on into the normal tissue and somehow athermally modulated the behavior of the various cell types, including axons as in the case of the patient already mentioned, thereby bringing around pain relief. This is shown schematically in Figure 4, with the peripheral photon energy of the argon laser penetrating down to and involving the intercostal nerves.
With fuller understanding of laser-tissue interaction, it is now recognized that these phenomena are due to the simultaneous induction in the target tissue of a range of effects, but usually culminating in a zone of athermally photobiomodulated tissue at the outermost periphery of the thermal or other destructive reactions (Figure 5). The author first called this the α-effect, then simultaneous laser therapy, and now classifies this simultaneous generation of a range of tissue effects with the one laser as auto-simultaneous laser treatment (ASi-LT).

Table 1: Ohshiro's subclassification for ASi-LT

<table>
<thead>
<tr>
<th>Laser Treatment</th>
<th>Description</th>
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<tbody>
<tr>
<td>Auto-simultaneous laser treatment</td>
<td>ASi-LT</td>
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<tr>
<td>Protein denaturation laser treatment</td>
<td>Pd-LT</td>
</tr>
<tr>
<td>Protein breaking laser treatment</td>
<td>Pb-LT</td>
</tr>
<tr>
<td>Protein coagulation laser treatment</td>
<td>Pc-LT</td>
</tr>
<tr>
<td>Vaporization laser treatment</td>
<td>Va-LT</td>
</tr>
<tr>
<td>Carbonization laser treatment</td>
<td>Ca-LT</td>
</tr>
<tr>
<td>Miscellaneous others</td>
<td>Mi-LT</td>
</tr>
</tbody>
</table>
Auto-simultaneous Laser Treatment (ASi-LT): Theory and Practice

In the case of the surgical laser impact seen in Figure 5, ASi-LT incorporates a range of laser treatments. Starting from the most destructive and with the highest thermal energy and working in descending order these are carbonization LT (C-LT), vaporization LT (V-LT) which includes incision, excision and ablation, protein coagulation LT (Pc-LT), protein breaking LT (Pb-LT), and protein denaturation LT (Pd-LT). These are listed in Table 1. In the case of C-LT, V-LT and Pc-LT, there is total destruction of the target cells, in Pb-LT, some cells will be damaged along with the degraded collagen protein, but some will be left alive and in Pd-LT, most of the cells will be left alive. Depending on the laser wavelength being used, and also on the incident power and energy densities of the laser beam, these will be accompanied by a layer of tissue in which the incident photons have transferred their energy to the cells themselves in an athermal manner without any cell death at all, so that the energy level of the cell is increased by the addition of the photon energy, activation LT (A-LT). In theory, one single photon can energize a cell, but in practice multiple photon absorption is required to photobiomodulate a cell’s activity. The result of this increase in intracellular energy might be promitotic, with an increase in the division rate of the cell; it might be profunctional, with the cell performing its usual function, only better; or in the case of damaged or compromised cells the autorepair processes are activated, and the cell recovers.

Components of the above range of laser treatments can be used selectively by increasing or decreasing the incident power density of the beam, since it is the power density which determines in the first instance what the laser-tissue interaction is. This can often be accomplished without changing the output power of the beam, and simply focusing or defocusing the beam on the tissue by correct positioning of the laser handpiece as illustrated in Figure 6. When none of the first 5 treatment reactions occurs, i.e., from C-LT down to Pd-LT), and A-LT occurs alone, this is not within the ASi-LT classification, but falls under A-LT in the pure LT (Pu-LT) classification, as explained in the author’s previous paper.(3)

Practical examples

Specific groups of the ASi-LT family can be used to achieve specific effects. Figure 7 shows a lip which was treated with the CO2 laser for the removal of a mixture of cavernous hemangioma and hemangioma simplex.(4) The CO2 laser was used in the focused mode first to excise tissue (excision component of Ca-LT, Figure 6A). The laser was then slightly defocused to debulk tissue in ablative vaporization (Va-LT, Figure 6B). Finally, the laser was defocused slightly more to control bleeding in the field with haemocoagulation (Pc-LT, Figure 6C), giving the dry field as seen in Figure 7. All of these processes fall under high-reactive level laser treatment (HLLT). However, all of the LT components below the active component also occurred in the tissue, which would help to induce and accelerate the wound healing process and give less postoperative pain, the latter due first of all to the cauterization of nerve endings and secondly, because of the low photobiomodulative photon densities at the periphery of the beam pattern in the tissue.

The less destructive members of the ASi-LT family, protein breaking and protein denaturation (Pb-LT
and Pd-LT, Figure 6D and 6E), can be used in tissue welding. The tissue to be welded is coapted, and may be held in place with a tie suture. The tissue is carefully irradiated along the line to be welded, so that the white change of hemocoagulation is not seen as photocoagulated tissue is frankly necrotic, and too much thermal damage has been caused to get good welding. As the tissue temperature reaches and passes 40°C, the hydrogen bonds holding collagen fibers together in bundles start to denature, thus allowing the bundles of viable collagen fibers to separate in the ground substance. Care must be taken to control tissue temperature to the lower range of Pb-LT. If the temperature is too high, i.e., the upper reaches of Pd-LT, the damage is not restricted to the hydrogen bonds, but also occurs within the collagen fibers themselves. The result of this is that the weld will not 'take' once the tissue is cooled down to normal, and the denatured hydrogen bonds once again renature so that collagen fibers from both sides of the tissue to be welded are bonded to each other, thus ‘welding’ the target tissue together.

The mild heating will stimulate the wound healing process, and the photobiomodulated cells in the A-LT zone will ensure a swift, but well-controlled inflammatory process, followed by a strong proliferative phase, rounded of by good remodeling so that the weld becomes stronger using the body’s own reparative processes.

The rejuvenation of photoaged skin has become a very hot topic in aesthetic dermatological and plastic circles. In laser ablative resurfacing, which involves complete ablation of the epidermis off the dermis, and
the deliberate deposition of residual thermal damage in the upper- and mid dermis, the entire range of the ASi-LT family is used, but with the attempt to minimize carbonization as this will interfere with wound healing.\(^5\) This residual thermal damage stimulates the wound healing process,\(^6\) and that is helped by the photobiomodulated cells in the Pd-LT and A-LT zones.

In nonablative skin rejuvenation, a less aggressive approach is taken, and thermal damage is delivered to the dermis under a cooled and intact epidermis so that the subsequent wound healing can occur under the skin’s own biological barrier, the epidermis. The aim is still to create controlled damage, however, which will induce good wound healing, and that will again be helped by the photobiomodulated cells in the Pd- and A-LT zones.

The success of these photomediated methods of skin rejuvenation compared with conventional approaches such as mechanical dermabrasion and chemical peels has been reported, and is believed to be due to the direct light-cell interactions and energy exchanges at the nondestructive regions of ASi-LT.\(^7\)

In almost all laser types, the range of ASi-LT-mediated reactions holds true. In some laser types, however, such as the eximer laser, there is no thermal reaction at all due the athermal photodisruption of molecules at the ultraviolet wavelengths associated with the eximer. In this case, no cascade of diminishing thermal effect can be seen radiating down into the tissue on biopsy specimens of tissue treated with the eximer laser. It is pure ablation with cell-layer by cell-layer accuracy, and as such is a form of Va-LT. However, there are associated nonphotothermal effects which do propagate down into the tissue, such as photo-osmotic and photodynamic effects: these are classed under the final subheading of ASi-LT, miscellaneous (Mi)-LT.

The author would finally like to draw the reader’s attention to the fact that none of these reactions in the ASi-LT range has been classified by the system which produced it. The most important point the author wishes to stress in this article is that the tissue reaction should be used to classify laser systems, or phototherapy systems, rather than any aspect of the hardware, and that is the base from which he evolved his new classification. A laser or other light source is merely the device which is capable of generating a beam of energy. It is the reaction with the tissue which gives this beam of energy its clinical utility, whether for HLLT, MLLT or LLLT. That is why the author in a previous report set out his visual classification systems to describe light-tissue interaction, the laser apple approach.\(^8\) The laser apple was the author’s concept and in vivo and in vitro experiments have provided visual corroboration of the author’s suggested nomenclature, reported in detail elsewhere.\(^9\) Figure 8 shows the basic laser apple. In addition to the classification of the laser treatment (LT), ranging from the carbonization apple (Ca-LT) to the activation apple (Ac-LT) additional information can be provided such as all the laser parameters from which the power and energy densities can be calculated, the scattering pattern, and the laser type and penetration depth can also be given in the body of the apple, if required.

Each component of the ASi-LT range is associated with the corresponding laser apple, and these have been shown in Figure 9, namely (starting from the most destructive) the carbonization apple (Ca-Apple), vaporization apple (Va-Apple), protein coagulation apple (Pc-Apple), protein breaking apple (Pb-Apple) and the protein denaturation apple (Pd-Apple). The tissue welding apple falls in between these last two. Please
note again that all of these ASi-LT types are accompanied by a zone of athermally modulated Ac-LT.

Conclusions

In summary, when Ohshiro’s laser apples are coupled with the author’s new classification criteria for ASi-LT, the laser clinician can accurately report in one simple diagram the entire range of parameters necessary for other colleagues to repeat the work, and at the same time show in a very easily understandable way exactly what is happening in the target tissue. This is extremely important when attempting to achieve a specific clinical endpoint through an understanding of the light-tissue interaction paradigm.

References