Objective Review of Monopolar RF Device: Continuous Water Cooling and Single RF Pulse Ⅰ

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Director Sang Hyuk Park at Sinchon ES clinic, who is also the vice chairperson of KOAT, is interested in various non-invasive aesthetic procedures. He is currently focusing on monopolar RF with continuous water cooling method and single RF pulse. The key point is that the temperature can be raised with heat expansion effect while greatly reducing side effects, as there is no heat loss from pulse division. We introduce the story of RF procedures by Dr. Park in 3 series.

Aging skin and treatment

Skin aging can be classified into endogenous aging, which naturally occurs with age, and extrinsic aging, which is caused by external factors including photoaging by ultraviolet (UV) rays, i.e. solar elastic fibrosis. When persistently exposed to UV rays, collagen synthesis decreases, and skin loses elasticity as the dermis is replaced by elastic fiber. This aging process leads to wrinkles, laxity, pore dilation, flushing, and dyschromia. Traditionally, these outcomes can be treated with rhytidectomy, blepharoplasty, and brow lifts, or by promoting collagen synthesis and removing damaged tissues using non-surgical methods such as chemical peeling, microdermabrasion, and laser peeling.

However, surgical improvements require recovery time. The ablative rejuvenation that damages the epidermis requires a lengthy recovery period and has the risk of complications such as infections, scarring, skin redness, and pigmentation. Thus, non-ablative rejuvenation is currently preferred.

The collagen absorption curve only exists at ≥3 μm, peaking at 6~7 μm (<Fig. 1>). The application of direct heat at this wavelength would be ideal, but free electron lasers using this wavelength have not yet been commercialized. Thus, rejuvenation involves a laser that has an absorption coefficient for water or blood vessels, or induces collagen remodeling by delivering heat to collagen indirectly using a device that delivers heat to water.

This methods include lasers such as the 1450-nm diode laser that uses mid-infrared, the 1320-nm/1064-nm Nd:YAG laser that targets water, a laser that targets blood vessels such as the PDL to indirectly deliver heat to collagen, or indirect delivery of heat to collagen with a device that delivers heat to water using a high radiofrequency (RF). Here, I would like to discuss the monopolar RF devices that target water.

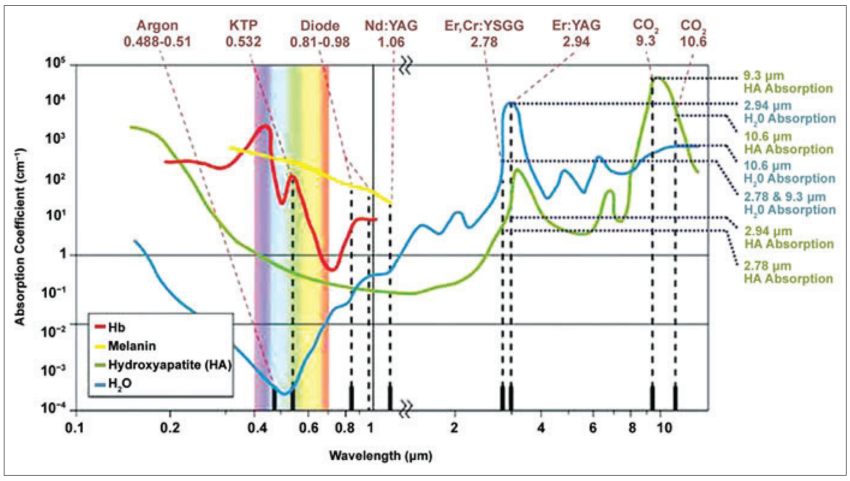

Fig. 1. Correlation of material absorption coefficient and laser wavelength; both axes are exponential1. Courtesy of Daniel Fried/University of California, San Francisco.
(http://www.photonics.com/Artides/High-Precision_Laser_Therapy_Transforms_Dentistry/a63797)

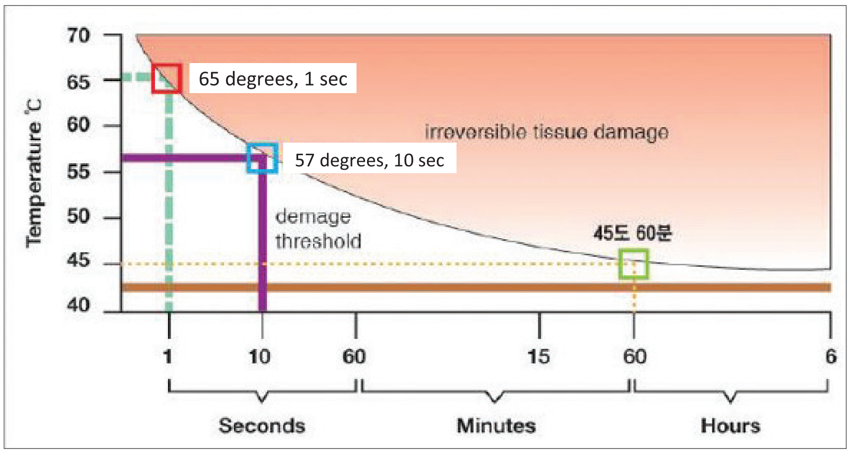

Fig. 2. Relationship between time and temperature in tissue damage.

Arrhenius Equation

When a laser meets the chromophore or the high frequency meets resistance, heat is generated, and depending on its degree, processes of coagulation, vaporization, carbonization, and melting occur. Among them, the Arrhenius equation is applied at a temperature of ≤100 °C, at which vaporization does not occur.

Temperature and time are involved in tissue degeneration. For example, the same level of tissue degeneration occurs at 65 °C in 1 s, 57 °C in 10 s, and 45 °C in 60 min. Thus, no absolute temperature for tissue degeneration exists, but various parameters consider temperature and time (<Figure 2>).

The effect is shown once the threshold for effect has been reached, and side effects occur past the survival threshold. If high energy can be used in the range permitted by the patient's pain and the cooling ability of the selected device, the same effect can be obtained using a lower number of shots.

Structural changes occur when collagen is stimulated at 42~45 °C, and heat-induced shrinkage occurs while three dimensional (3D) covalent bonds break, up to 1/3 of the original size. Partially denatured

42~45℃	Beginning of hyperthemia, conformational changes, and shrinkage of collagen
50℃	Reduction of enzymatic activity
60℃	Denaturation of proteins, coagulation of collagens, membrane permeabilisation
100℃	Tissue drying and formation of vacuoles
〉100℃	Beginning of vaporization and tissue carbonisation
300~1000℃	Thermoablation of tissue, photoablation and disruption

Table 1. Changes in skin tissues by temperature.

collagen sends triggers for synthesizing new collagen or acts as scaffolding. However, past 60 °C, the 3D structure becomes a two-dimensional (2D) structure due to denaturation and coagulation, so the cell is completely destroyed before being regenerated (<Table 1>). At this temperature, the epidermis is damaged, and epidermal sparing through cooling is required. The most appropriate temperature for the dermis for collagen regeneration through coagulation can be estimated as 55~68 °C based on various literature sources reporting that 63% of collagen is denatured with 1-s exposure at 65 °C, that subcutaneous temperature of 65~68 °C and epidermal temperature of 38~42 °C are required, and that collagen synthesis reaches its peak when heat is applied for 3 s at 67 °C on the dermis. These reports require further research. However, to allow high temperatures, adequate epidermal cooling must take place to avoid burning of the epidermis. Further, pain induced by high energy must be controlled.

Epidermal cooling

When targeting the collagen in the dermis using a monopolar RF device, the energy does not go directly to the dermis but goes through the epidermis. To prevent side effects such as burns that may occur when the temperature rises too high and to prevent the pain and edema that accompanies the procedure, cooling the epidermis during high RF procedure increases resistance in the epidermis, and the heat energy reaching the dermis increases. Thus, epidermal cooling is an important part of the monopolar RF procedure. Existing THERMAGE/OLIGO/10THERMA uses a contact cooling method through intermittent cooling agent spraying. Spraying a -26 °C cooling agent such as HFC-134a on the skin has an excellent effect and is not affected by variables such as reverse thermal diffusion caused by long-time contact with the dermis, which increases in temperature during the procedure, for a period of time around 1,500 ms.

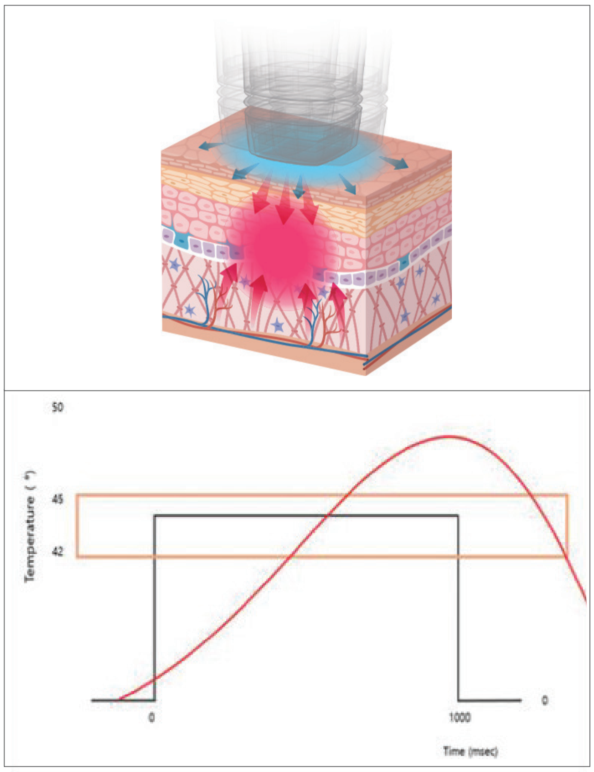

Fig. 4. 1000ms single RF pulse. Provided by Sang Hyuk Park.

In addition, an advantageous predictable cooling effect can be maintained through regular cryogen injection. However, as the cooling time increases, the risk of frostbite and pigmentation increases, so spraying time should be limited to <100 ms. In addition, since the TRT of the epidermis, which is about 100-μm thick, is about 10 ms, a limitation is introduced, as it must be cooled by spraying for >10 ms to achieve a cooling effect by thermal diffusion. Taking these limitations into consideration, the existing monopolar RF devices were designed to raise dermis temperature only to >60 °C while maintaining the epidermal temperature at 38~42 °C by irradiating energy in 5~6 pulses for 200 ms while performing contact cooling 4~7 times as pre/parallel/post. However, 10THERMA was designed with automatic control so that the cooling agent spraying time is 15~45 ms depending on the energy level. In this case, the temperature drops when the pulse is delayed at 200 ms (<Figure 3>). We also examined the effects of the novel energy delivery method of a 1000-ms single RF pulse and the meaning of continuous cooling using chilled water. A device with a new method of cooling water circulation was released, rather than the previous method of spraying a cooling agent. It enabled continuous contact cooling over 1000 ms by circulating cooling water at a relatively high temperature of 12~20 °C while considering the limitation of short-duration contact cooling due to side effects associated with a very low temperature of -26 °C for contact cooling with a cooling agent. Since the epidermis could be protected with contact cooling for 1000 ms, a 1000-ms single RF pulse could be irradiated without dividing the pulse into 5~6 200-ms instances.

(Continued on the next volume)

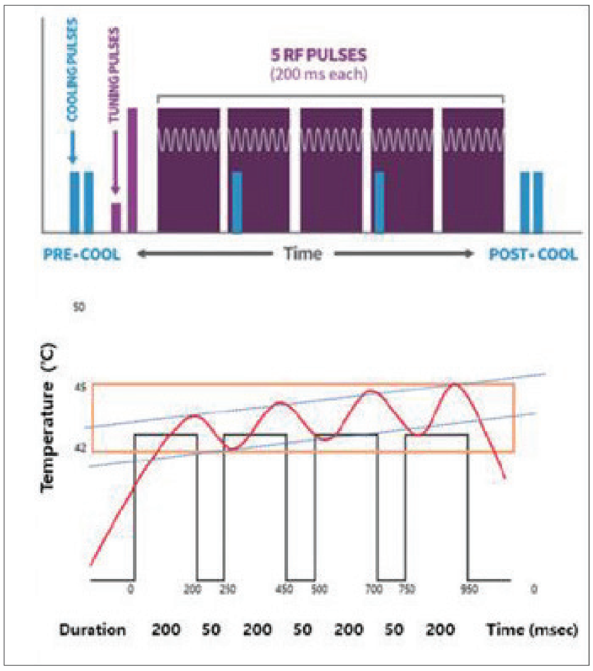

Fig. 3. RF irradiated by 200ms unit. Provided by Sang Hyuk Park.