Objective Review of Monopolar Radio Frequency Device: Continuous Water Cooling and Single Radio Frequency Pulse Ⅱ

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Director Sang Hyuk Park of Shinchon ES Clinic, Vice President of the Korean Academy of Obesity & Aesthetic Treatment, is enthusiastic about a variety of non-invasive cosmetic treatments. His current focus is on a monopolar radio frequency (RF) with continuous water-cooling method and single RF pulse. With this method the temperature can easily be increased while greatly reducing side effects. This is achieved through the accumulating thermal diffusion effect as there is no heat loss caused by pulse division. We are presenting Director Sang Hyuk Park's RF treatment story over three articles.

Following the last article, I would like to discuss the meaning of continuous cooling using chilled water and the method of delivering energy with a single RF pulse at 1,000 ms.

The prolonged contact cooling of 1,000 ms has its limitations as well. First, as the cooling is performed by contact over a long time, it should be considered that parts of the dermal area shallower than 1 mm, or the vicinity of the papillary dermis, may be unnecessarily cooled depending on the thermal diffusion. Areas deeper than 1 mm are not cooled even with contact lasting up to 1,000 ms.

Second, in clinical practice, the temperature is raised to 38-42℃ for the epidermis and to 60℃ or more for the dermis in a state of contact with the skin between 1,000 and 1,500 ms in which one shot is irradiated. At this time, the contact surface temperature inversely rises due to reverse thermal diffusion from the skin in which the temperature has risen. In such a case, the contact surface temperature can be rapidly lowered by using a newly irradiated refrigerant in conjunction with the exist ing method of cooling the epidermis with a sprayed refrigerant. It allows for the procedure to be performed with a consistent cooling effect with each shot. On the other hand, the cooling method of circulating the chilled water should be performed considering that the contact surface temperature decreases gradually with the circulation of the chilled water immediately following irradiation. If the shot intervals are maintained for a long time regardless of the procedure duration, the next shot may be performed by predicting the cooling temperature after the contact surface temperature is sufficiently lowered. However, when the shots are performed while moving the tip with short intervals, as in actual clinical practice, it can be inferred that contact cooling is performed with a significantly higher contact surface temperature than the set chilled water temperature. As such, it should be noted that the actual set chilled water temperature and contact surface temperature may vary depending on the physician's shot interval.

Continuous Water Cooling with a Single RF Pulse

Figure 1 illustrates temperature changes according to the contact duration per depth in a contact cooling experiment using a sapphire tip at -10℃. Curve 3 shows that the temperature of the epidermal basal layer dropped rapidly by at least 15℃ after a brief contact lasting 50 ms or less and that the temperature remained low by 30℃ after longer contacts of 1,000 ms. Significant temperature changes did not occur for contacts of 1,000 ms for the dermis at the depths of 1 mm (curve 4) or 2 mm (curve 5). The temperature of the dermis at different depths and contact durations during the contact cooling experiment using a sapphire tip at -10℃ is displayed in Figure 2. ① shows that there is no cooling effect on the skin at a depth of 0.1 mm or less with contact cooling of 10 ms. The area shallower than the papillary dermis at a depth of 0.3 mm was cooled with contact cooling of 50 ms (②) and 100 ms (③).

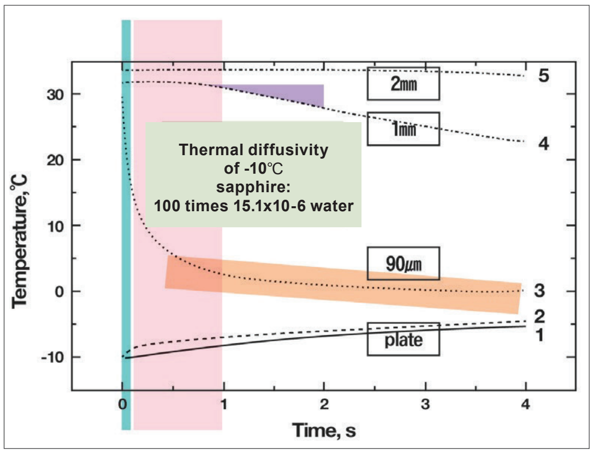

Fig. 1. Contact cooling experiment using a sapphire tip

Coolant	Density $(kg\ m^{-3})$	Specific heat $(J kg^{-1}\ ℃^{-1})$	Thermal conductivity $(Wm^{-1}\ ℃^{-1})$	Thermal diffusivity $(m^2\ s^{-1})$
Chilled water	1000	4180	0,6	$1,43\times10^{-7}$
Gel	1000	3200	0,5	$1,56\times10^{-7}$
Ice	917	1930	2,2	$1,24\times10^{-6}$
PMMA	1200	1500	0,2	$1,11\times10^{-7}$
Melted quartz	2650	890	1,36	$5,77\times10^{-7}$
Sapphire	4000	760	46	$15,1\times10^{-6}$ 약 100배
Copper	8960	385	400	$1,16\times10^{-4}$
Diamond	3400	331,2	2300	$2,04\times10^{-3}$

Thermal parameters of the plate materials.

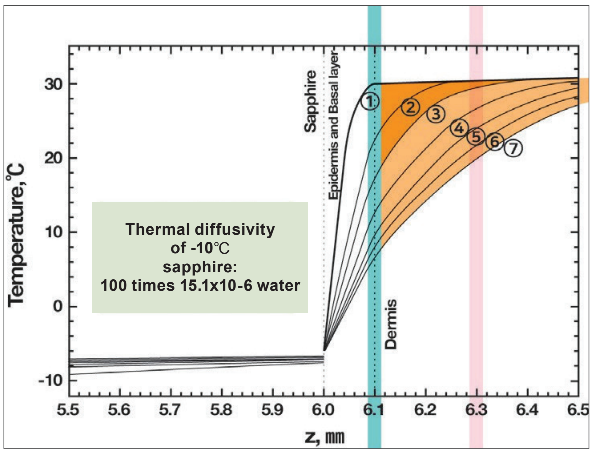

Fig. 2. Temperature per depth by contact duration in contact cooling experiment using a sapphire tip

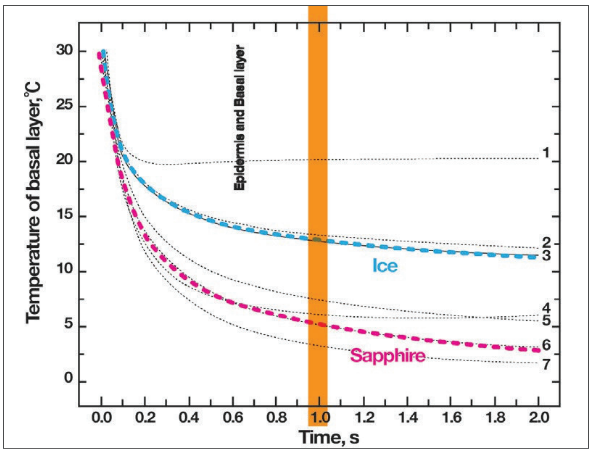

Fig. 3. Comparison of contact cooling between an ice tip and a sapphire tip

The temperature of the epidermal region was sufficiently lowered without cooling the deeper area. However, when contact cooling is performed over an extended time of 500 ms or longer (⑦), while there was no cooling of the dermis deeper than 1 mm, as shown in Figure 1, undesired cooling occurred in shallower areas of 1 mm or less, i.e., shallow dermis around the papillary dermis.

The above experiments were conducted assuming a contact temperature of -10°C, and there was a limitation that the sapphire used in the experiment has a thermal diffusivity of approximately 100 times higher than that of water. Subsequently, it was aimed to reduce unnecessary cooling near the papillary dermal layer of 1 mm or less and obtain more precise experimental results by using water with 1/100 thermal diffusivity and a cooling device with a cooling temperature set high between 12 and 20°C.

The comparison of contact cooling using a sapphire tip at -8°C and an ice tip with a thermal diffusivity 100 times lower than the sapphire tip is displayed in Figure 3. The basal layer temperature according to contact duration was examined, and then the difference in cooling efficiency was analyzed. With contact cooling of 1,000 ms, ice at -8°C induced a temperature change of -17°C from 30°C to 13°C, while sapphire, which has a 100-fold higher thermal diffusivity, at -8°C induced a temperature change of -25°C from 30°C to 5°C. Figure 4 compares contact cooling using a sapphire tip at 5°C and a chilled water tip with a 1/100 thermal diffusivity of a sapphire tip. Again, the basal layer temperature according to contact duration was examined, and the difference in cooling efficiency was analyzed. After contact cooling of 1,000 ms, Figure 6. Temperature changes in the basal layer and papillary dermis by contact cooling method chilled water of 5°C induced a temperature change of -11°C from 30°C to 19°C, and sapphire, with 100-fold thermal diffusivity compared to water, at 5°C induced a temperature change of -17°C from 30°C to 13°C. In this experiment, contact cooling using chilled water at 12°C and 20°C, adopted by VOLNEWMER, decreased epidermal temperature by only 8°C and 5°C, respectively (Figure 5).

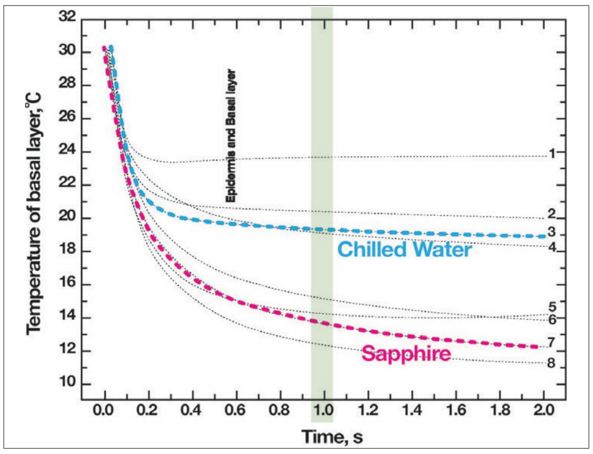

Fig. 4 Comparison of contact cooling between a chilled water tip and a sapphire tip

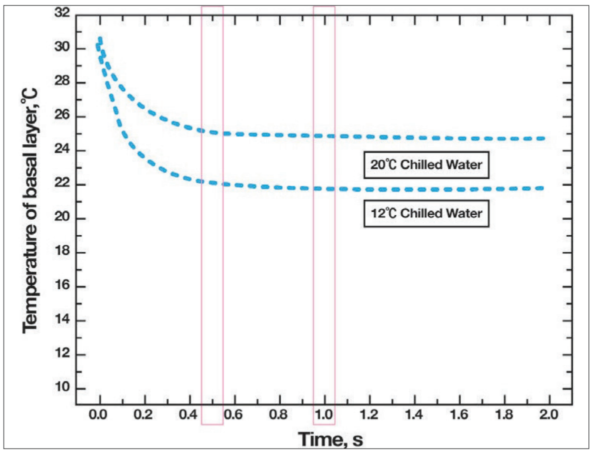

Fig. 5. Comparison of contact cooling using chilled water tips at 20℃ and 12℃

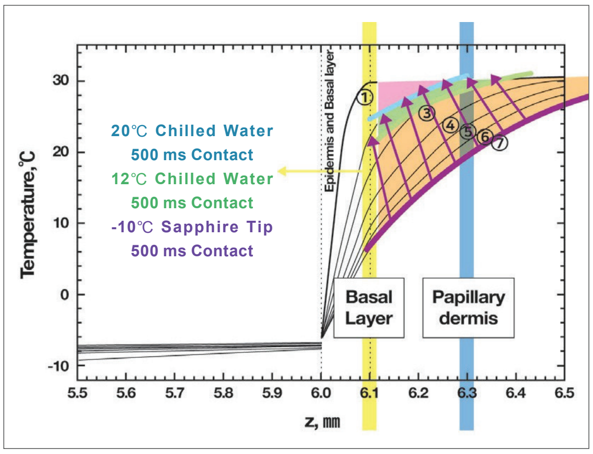

Fig. 6 . Temperature changes in the basal layer and papillary dermis by contact cooling method

In the 500 ms contact cooling experiment using sapphire with a thermal diffusivity 100-fold higher than water at a temperature of -10°C, unnecessary cooling of shallow dermal tissues around the papillary dermis was observed. VOLNEWMER used a relatively higher temperature between 12 and 20°C to compensate for this, selecting chilled water with a thermal diffusivity of 1/100 of sapphire as the medium. Unnecessary cooling was significantly reduced when the degree of unnecessary cooling around the papillary dermis after 500 ms contact cooling was inferred, assuming the chilled water temperatures of 12°C and 20°C. These results highlight the advantages of irradiating high energy with a single RF pulse. That is, it can be inferred that utilizing chilled water for contact cooling, which has a 1/100 thermal diffusivity of sapphire, at a higher temperature range of 12 to 20°C can sufficiently cool the epidermal area, which constitutes the basal layer, and minimize the unnecessary cooling in the papillary dermal area of 1 mm or less that occurred during contact cooling using a -10°C sapphire tip. The temperature changes after 500 ms contact cooling were sufficiently inferred, as the degrees of cooling of the dermal area did not significantly differ between 500 ms and 1,000 ms contact coolings, and neither showed a cooling effect in areas deeper than 1 mm.

(To be continued in the next issue)