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Dry Molecular Cooling (DMC™) in Laser Aesthetics and Dermatology

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ABSTRACT

Skin cooling is often used during laser treatments in aesthetics and dermatology to avoid or minimize patient discomfort and skin damage. All currently used cooling methods have certain disadvantages, such as having to be in contact with the skin, not being fast or continuous enough, or posing a risk of cryo-injury. The commonly used non-contact methods include cryogen spray cooling (CSC) and forced cold air cooling (CAC).

In this paper, a novel non-contact skin cooling method is presented that is based on dry molecular cooling (DMC™). DMC™ improves upon the currently used methods, with some of the following advantages:

- The maximal cooling rate of DMC is significantly faster in comparison with CAC.
- DMC is characterized by a self-regulating feature of the evaporating water molecules, which limits the lowest skin temperature to about 16°C. The DMC cooling, therefore, avoids the risks of over-cooling posed by the CAC and especially by the CSC method.
- As opposed to CSC spray droplets, the DMC's water droplets deposited over the skin persist on the skin for longer time periods. The prolonged passive post-cooling by DMC acts in a similar manner as other cryo-protective measures in medicine, including therapeutic hypothermia in cardiac arrest or cerebral ischemia. For example, the sooner and longer a burn is cooled with cold running water, the smaller the impact of the injury will be. Clinically, this soothing effect has been observed to result in milder or no edema within first 10-20 minutes following the treatment, and in milder or no erythema within several hours following the treatment.

Key words: dry molecular cooling, DMC™, cryogen spray cooling, cold air cooling, alexandrite laser, Nd:YAG laser, thermal imaging.

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I. INTRODUCTION

General

With laser treatments in dermatology and aesthetics, a non-specific heating of the surface tissue (such as the epidermis) is a common side effect [1]. Often, the threshold fluence which is needed for destroying the target chromophore or structure is very close to the threshold fluence for epidermal injury. For example, in hair removal the optimal laser wavelengths are the ones which get absorbed in the hair's melanin. Since melanin is abundantly present in the epidermis, heating of the epidermis is an inevitable consequence of the laser light's penetration to the hair bulb to achieve its destruction [2]. Consequently, if the temperature of the epidermis is not controlled this can in addition to pain induce acute epidermal damage or blistering and can also lead to scarring and hyperpigmentation [3].

To avoid or minimize the above complications, the epidermal surface layer needs to be cooled. Examples of applications where high-fluence laser pulses are used and cooling is necessary for avoiding epidermal damage include laser hair removal and coagulation of veins and vascular lesions [4,5]. In other applications, such as transdermal lipolysis, relatively low single-pulse fluences are delivered during a prolonged exposure to repetitively delivered laser pulses. In these applications, epidermal cooling is applied to prevent a temperature rise of the epidermis while the deeper lying subdermal fat is heated to temperatures above 42°C, which causes apoptosis of adipose cells and subsequent reduction of the fat layer [6].

There are various methods of skin cooling that are being used during laser treatments, ranging from ice packs to sophisticated equipment. The most frequently used advanced methods include contact cooling with a chilled solid surface [7], cryogen spray cooling (CSC) [8, 9], and forced cold air cooling (CAC) [2, 6].

Contact cooling with chilled glass achieves localized and rapid cooling but has several disadvantages, including absorption and reflection of the laser light in the chilled glass, skin compression, mandatory use of heat conductive gels, and relatively slow positioning of the small laser spot over the larger treated skin area.

Cooling with cryogen spray is another commonly used method. In this cooling method, a cryogen spray is sprayed for a very short period only prior to laser pulse delivery, minimizing the exposure of skin to cryogen spray cooled to very low temperatures (down to -58°C) [9]). This method is efficient in epidermal protection when high fluences are used, however, side effects from excessive skin cooling, such as hyperpigmentation and skin irritations have been reported [3]. The method is also very sensitive to the exact timing of the CSC's spurt prior to the laser pulse. Additionally, the pressurized cryogen gas is demanding to transport, and burdensome for the environment, as it has a high global warming potential. It is also expensive since gas cylinders require regular replacements.

Forced cold air cooling (CAC) is also often used in laser treatments wherein cold air is directed to the treatment area before and during the laser treatment [4]. A disadvantage of air cooling is the relative inefficiency of the medium air for cooling tissues, thus requiring long exposure times to cold air. To speed up the cooling rate the air is typically cooled to very low temperatures which can lead to patient discomfort and over-cooling.

Consequently, all currently used cooling methods have certain disadvantages such as having to be delivered in a contact with the skin, not being fast enough or presenting the risk of tissue over-cooling.

In this paper, we report on a novel skin-cooling technology, CoolMist™ [10, 11], which improves upon the currently used skin cooling methods. The CoolMist™ technology is based on dry molecular cooling (DMC™) of the skin surface, overcoming some of the disadvantages of the standard cooling methods by delivering a digitally controlled, very fine water mist to the laser-treated skin surface.

Water-based spray has been commonly used in dental laser applications, mainly for moistening of the hard tissues, debris removal and as an aid for a more efficient ablation. However, water-based spray has been rarely used for cooling soft-tissue surfaces, and especially not for cooling skin surfaces. The reason for this is that the commonly available liquid sprays, e.g., such as the ones used with dental lasers, operate continuously, and would generate a liquid film on the skin surface which acts as a thermal barrier for the heat transfer. Namely, when a thick liquid layer is present a quick evaporation of droplets cannot take place anymore, thus preventing efficient cooling. To avoid the formation of a liquid layer, the liquid must be in a constant flow and must be constantly removed from the treatment area. Such a removal of the liquid can be relatively easily achieved by means of a suction device in an enclosed treatment area that is already wet, such as the mouth, but becomes very impractical when trying to cool large body surfaces. In addition, in many dermatological applications such as hair removal, skin tightening and fat reduction, an effective and homogeneous cooling of large skin areas of up to about 5000 cm^2 is required; this has represented a considerable technical challenge for liquid spray cooling.

The CoolMist™ cooling technology generates an atomized liquid spray for the treatment area, wherein the atomized pulsed liquid spray is based on a digitally controlled mixture of liquid and gas. The pulsed application of the spray on the tissue has the advantage that, in between two subsequent pulses, the evaporation of the droplets leads to a drying of the tissue so that the formation of a water layer on the skin surface is avoided. Further, the CoolMist™ nozzle is operated in such a way as to achieve a fine "micro-pulsed" liquid spray with optimal liquid content, droplet size and velocity, which together enable "dry" molecular cooling (DMC™) based on quick evaporation of the molecular droplets [11].

II. MATERIALS AND METHODS

a) Laser system

The laser devices used in the study were AvalancheLase® LXP (with Alexandrite and Nd:YAG laser sources) and Nx Dynamis SP (with Er:YAG and Nd:YAG laser sources), both manufactured by Fotona, d.o.o., Ljubljana (See Fig. 1). Both systems incorporate the CoolMist™ skin cooling technology for cooling the skin during Alexandrite or Nd:YAG laser treatments. The long-pulsed Alexandrite (755 nm) and Nd:YAG (1064 nm) solid crystal lasers have become preferred wavelengths for various dermatological and aesthetic treatments due to their effective absorption in the skin pigments, with sufficient penetration to the deeply located pigmented targets within the skin. In addition, as compared to other devices, it is only these two types of light sources that can deliver sufficiently high pulse powers at sufficiently short pulse durations (in a range of milliseconds) as required for effective selective thermolysis of the hair within the surrounding skin matrix [2, 4, 12-15].

Fig. 1: Fotona AvalancheLase® LXP laser system, incorporating the CoolMist™ technology and two solid-crystal hair-removal laser sources: Alexandrite (755 nm) and Nd:YAG (1064 nm).

In addition to DMC, the CoolMist™ handpieces are designed to also enable cold air cooling, either separately or in parallel with the DMC™ cooling.

In order to compare the cooling characteristics of DMC, cryogenic spray cooling (CSC) and cold air cooling (CAC), the following additional devices were used in the study: i) the Cryo 6 cold air chilling device (manufactured by Zimmer, G.m.b.H, Germany) that was for certain tests connected to the AvalancheLase's handpieces; and ii) the GentleMAX alexandrite laser system and handpiece incorporating a CSC assembly (manufactured by Candela corp, USA). The cold air flow of the Zimmer's device is adjustable through FC = 1- 9 different levels. The Candela's CSC device offers adjustments of the pre-spray, post-spray, and spray delay durations in milliseconds.

b) CoolMist™ technology

CoolMist™ is a skin cooling technology integrated within the latest Fotona laser systems, such as AvalancheLase® and SP Dynamis Nx.

The CoolMist assembly contains a microprocessor-controlled system for precise DMC spray adjustment for the R35X/Nx manual handpiece (Fig. 2) and the LX/Nx-Runner scanning handpiece (Fig. 3). The DMC spray control allows the user to adjust the spray to different water spray (W = 1-9) and air spray (A = 1-5) level combinations.

Both handpieces are equipped with a non-contact temperature sensor MatrixView™ having an array of thermopile detectors as sensors and infra-red optics for imaging the skin surface. The infra-red image of skin on the thermopile detector array is analyzed, processed, and sent to the host laser system's graphical user interface (GUI) to display the temperature of the treated skin. The handpieces also incorporate multicolor LED diodes for displaying a quick visual indication of the skin's temperature.

Fig. 2: R35X/Nx manual handpiece (spot sizes 2-30 mm) with DMC™ spray emanating from the CoolMist™ nozzle.

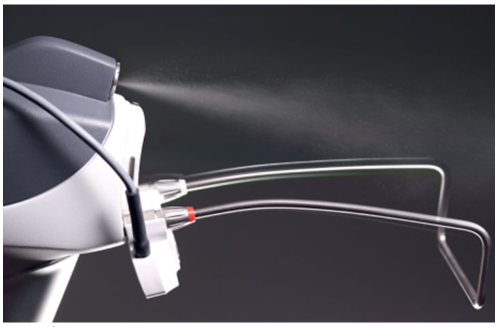


Fig. 3: LX/Nx-Runner scanning handpiece (spot sizes 9 and 11 mm; scan area up to 8 x 8 cm^2) with DMC™ spray emanating from the CoolMist™ nozzle.

A detachable cooling water reservoir enables the user to easily re-fill the reservoir with the cooling liquid (Fig. 4).

Fig. 4: CoolMist's re-fillable cooling liquid reservoir.

c) Thermal imaging

The temporal evolution of the skin temperature T_S, before, during and following skin cooling and laser irradiation was measured with a commercial thermal camera (ThermaCAM P45, manufactured by FLIR Systems, USA). The camera was fixed in position above the patient's skin surface and focused on the treated skin site (Fig. 5).

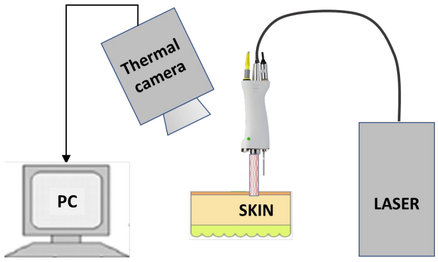


Fig. 5: Experimental set-up.

d) Measurements of skin temperature during laser hair removal procedure

The following set of thermal camera measurements was made during an alexandrite laser hair removal treatment on a patient's legs. Three methods of skin cooling were used: dry molecular cooling (DMC), cold air cooling (CAC) and cryogen spray cooling (CSC). DMC and CAC were delivered using the manual R35 handpiece. The DMC setting was Water 7/Air 5. The cold air cooling was generated by the Zimmer Cryo 6 device, set to level FC5. The cryogenic spray cooling was generated by the Candela GentleMax's handpiece, with the CSC setting of 30/20 (20 ms long spurt delivered with 30 ms delay).

Hair removal was performed in a stamping manner. The same laser parameters were used with both alexandrite laser devices (AvalancheLase with DMC and CAC cooling, and GentleMax with CSC cooling): laser spotsize d = 15 mm, pulse duration t_p = 3 ms and laser pulse fluence F = 14 J/cm².

III. RESULTS

a) Cooling rate measurements in absence of laser radiation

<u>i) DMC and CAC cooling with R35 manual handpiece</u>

Figure 6 shows the temporal evolution of the reduction of the skin temperature $\Delta T_S = T_S - T_0$ in the absence of laser radiation during and following a period of skin cooling with DMC using the manual R35 handpiece.

Similarly, Fig. 7 shows the temperatures achieved with the R35's CAC cooling during the first 5 seconds of skin cooling. A comparison with DMC cooling shows that the initial rate of skin cooling by CAC is about 3-times slower than DMC.

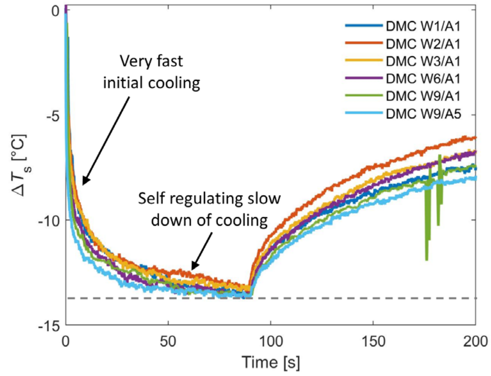


Fig. 6: Temporal development of the average skin temperature decrease ΔT_s during and following the skin cooling period of t = 0-90s, for different DMC's water/air settings of the manual R35 handpiece.

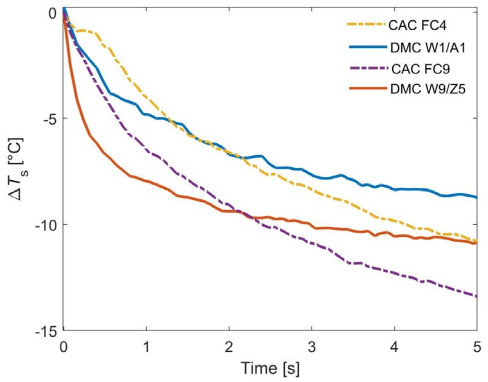


Fig. 7: Temporal development of the average skin temperature decrease ΔT_s following the start of skin cooling for two CAC settings (FC4 and FC9) with the R35 manual handpiece. For comparison, the temperature evolution during DMC cooling (W1/A1 and W9/A5) is also shown.

There are two important differences between DMC and CAC (See Fig. 8).

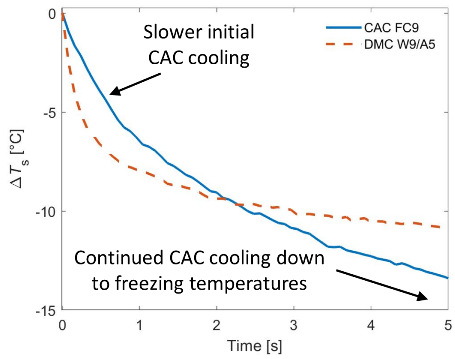


Fig. 8: Comparison of the cooling rates during CAC and DMC cooling.

First, the initial rate of skin cooling by DMC is significantly faster (~3-times) than with CAC. Second, the DMC's cooling rate is self-regulating, with the cooling rate saturating at $\Delta T_s \sim$ 14°C (see Fig. 7), meaning that the skin temperature will not be reduced below the safe and comfortable temperature of about

16°C. On the other hand, during long exposures the CAC cooling continues down to $\Delta T_s \sim 30$°C (see Fig. 9), i.e., down to freezing temperatures.

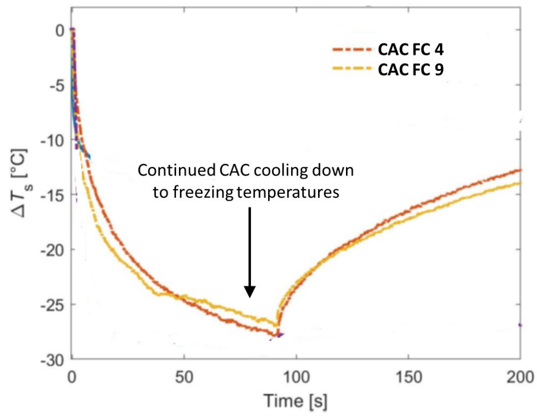


Fig. 9: Temporal development of the average skin temperature decrease ΔT_s during and following the skin cooling period of t = 0-90s, for CAC's settings FC4 and FC9, with the manual R35 handpiece. During long exposures the CAC cooling continues down to freezing temperatures.

ii) CSC cooling with GentleMax manual handpiece

Figure 10 shows the measured temporal development of ΔT_S in the absence of laser radiation during and following the GentleMax's cryogen spray's spurt.

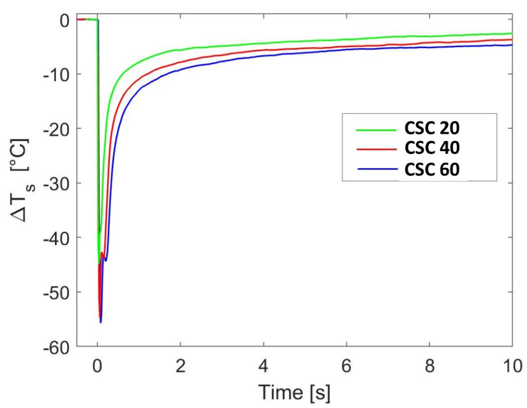


Fig. 10: Temporal development of the average skin temperature decrease ΔT_S following the start of skin cooling at t = 0 by CSC using the Candela GentleMax device. The temporal duration of the cryogen spray's spurt was set to 30, 40 or 60 ms. Notice that following the cryogen spray's spurt, the skin temperature returns rapidly back to the initial temperature.

iii) DMC and CAC cooling with LX/Nx-Runner scanning handpiece

Figures 11 and 12 shows the temporal evolution of the reduction of the skin temperature $\Delta T_S = T_S - T_0$ in the absence of laser radiation during and following a period of skin cooling with DMC or CAC using the LX/Nx Runner scanning handpiece.

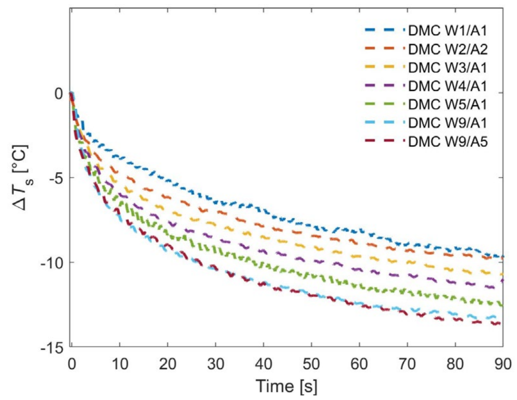


Fig. 11: Temporal development of the average skin temperature decrease ΔT_s following the start of skin cooling for different DMC settings with the LX/Nx-Runner scanning handpiece.

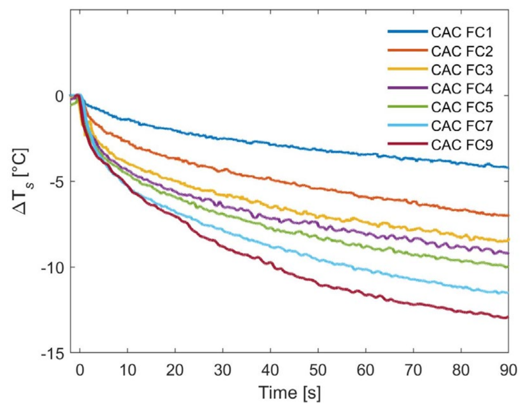


Fig. 12: Temporal development of the average skin temperature decrease ΔT_s following the start of skin cooling for different CAC settings with the LX/Nx-Runner scanning handpiece.

A comparison of the temperature developments during DMC and **CAC** cooling using the LX/Nx-Runner scanning handpiece is shown in Fig. 13. As is the case with the R35 manual handpiece, the cooling rate of DMC is higher than that of CAC.

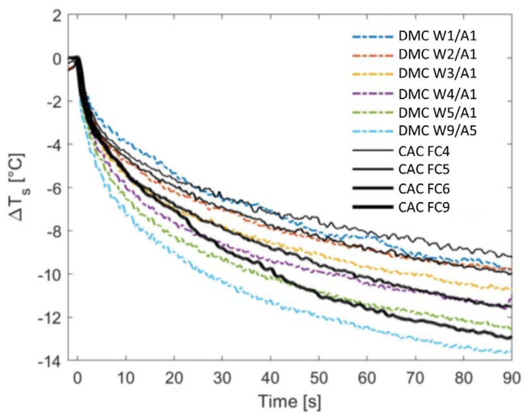


Fig. 13: Comparison of the development of the average skin temperature decrease ΔT_s during skin cooling with DMC and CAC for different settings

The homogeneity of the reduced temperature over the scanned area as achieved with DMC can be seen in the thermal image shown in Fig. 14 below.

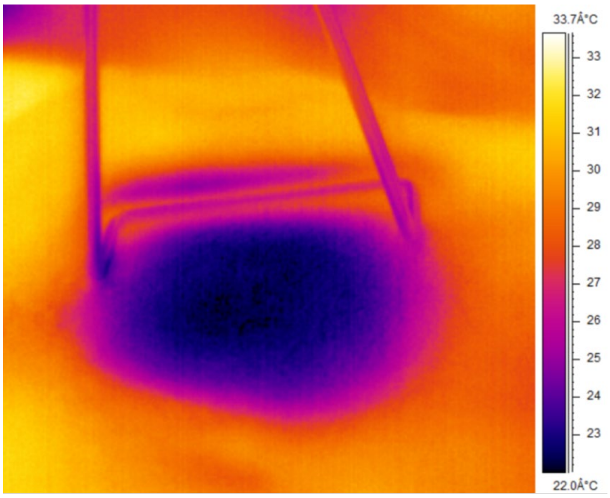


Fig. 14: Thermal image of the DMC-cooled skin area of the LX/Nx-Runner scanning handpiece.

iv) Combined DMC and CAC cooling

The design of the DMC's manual and scanning handpieces offers an interesting possibility where both methods of skin cooling, DMC and CAC are applied simultaneously. As can be seen in Fig. 15, a combined use of both methods results in extremely fast cooling rates.

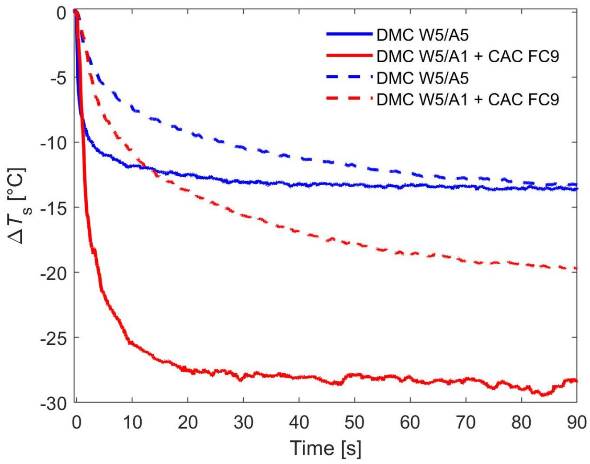


Fig. 15: Comparison of the development of the average skin temperature decrease ΔT_s during skin cooling either under DMC W9/A5 alone, or under the combination of DMC W9/A5 and CAC FC9 cooling. The dashed lines represent temperatures obtained with the LX/Nx-Runner scanning handpiece, and full lines represent temperatures obtained with the R35 manual handpiece.

Further research is needed to evaluate where and how this unique capability can be utilized clinically.

b) Measurements of skin temperature during laser hair removal procedure

Thermal images of the patient's legs during the hair removal treatment are shown in Fig. 16. The image of the calf being pre-and post-cooled by DMC is shown in Fig. 16a, and the image of the calf being pre-cooled by CSC is shown in Fig. 16b.

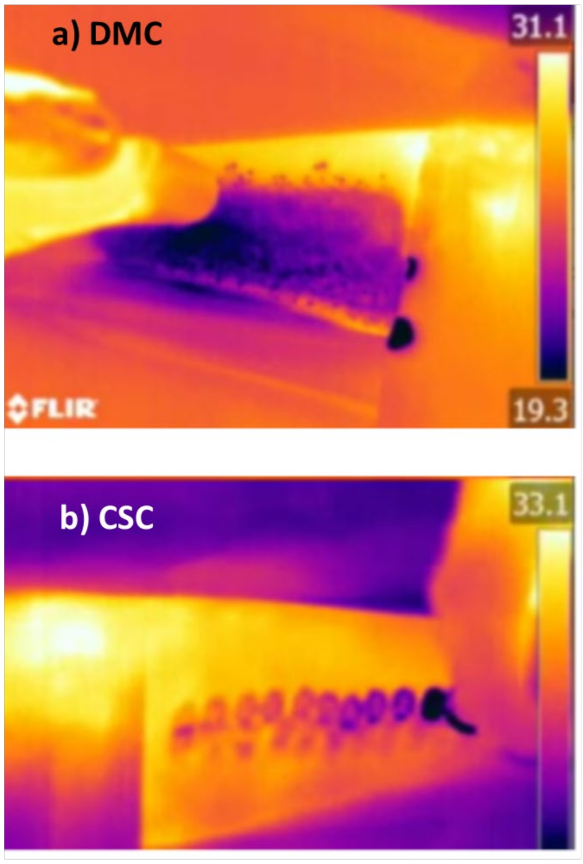
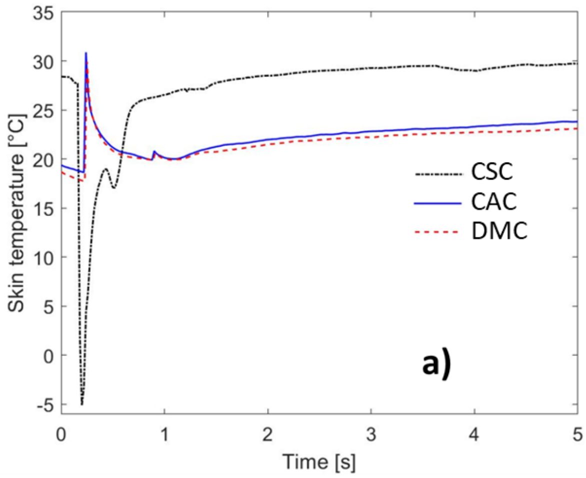


Fig. 16: Thermal images during a hair removal treatment on the patient's calves. One calf was pre-and post-cooled by DMC during the stamping treatment (Fig. 16a), and the other calf was being pre-cooled by CSC.

As can be seen from Fig. 16, the cooling with CSC remains predominantly limited to a currently treated laser spot, while with DMC the skin cooling persists over the whole treated area of the calf. This observation is attributed to the thin water film that remains on the skin for longer times following the laser pulse delivery.

The above effect can be observed also in Fig. 17, which shows the temperature dynamics of a single spot before, during and following a laser pulse. While the temperature of the CSC-cooled laser spot returns to the initial temperature within less than a second, the reduced temperature of the DMC-cooled spot persists for several minutes.



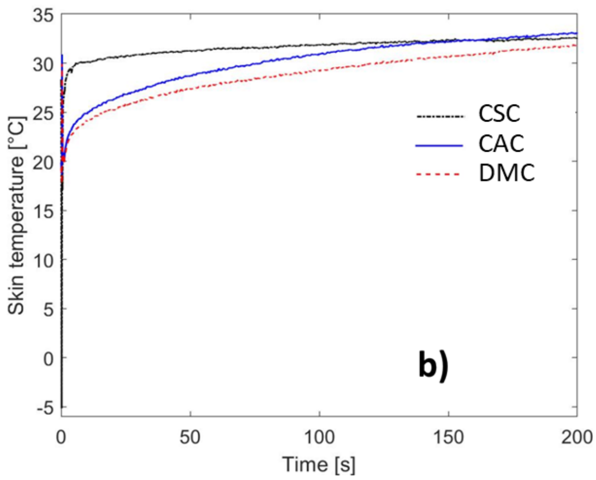


Fig. 17: Temporal evolution of the skin temperature within a laser spot area (*d* = 15 mm) for times starting at 0.25s before the initiation of an alexandrite laser pulse, and during and following the laser pulse, for three methods of skin cooling: DMC, CAC and CSC. The temperature development is presented over two timescales: t = 0 - 5s (a) and t = 0 - 200 s (b).

A more detailed depiction of the temporal evolution of the skin temperature within one of the first initially irradiated laser spots is shown in Fig. 18 for times starting 0.5 s before the initiation of an alexandrite laser pulse, and during and following the laser pulse, for three methods of skin cooling: DMC, CAC and CSC. The observed skin temperature's rise during the laser pulse of about 10°C is approximately the same for all three skin cooling methods.

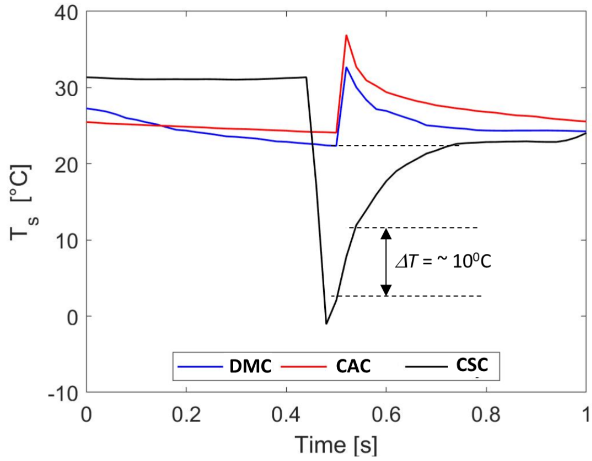


Fig. 18: Temporal evolution of the skin temperature within one of the first initially irradiated laser spots for times starting 0.5 s before the initiation of an alexandrite laser pulse, and during and following the laser pulse, for three methods of skin cooling: DMC, CAC and CSC.

There is also a difference in the thermal images during the time following the treatment. Figures 19 and 20 show thermal images of the two differently treated calves at 5 s and 10 minutes following the treatment.

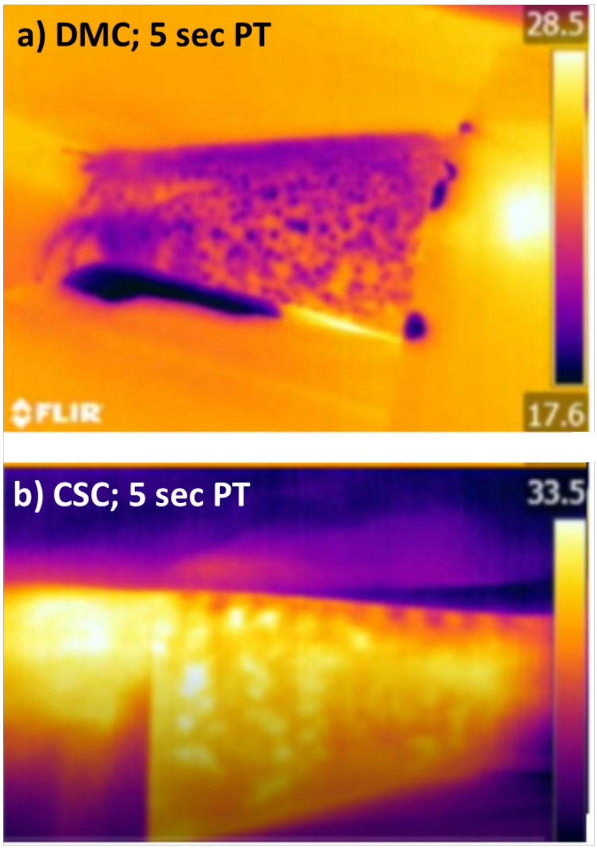


Fig. 19: Thermal images at 5 seconds following the hair removal treatment on the patient's calves. The upper image shows the calf that was pre-and post-cooled by DMC during the treatment, and the lower image shows the calf that was being pre-cooled by CSC during the treatment.

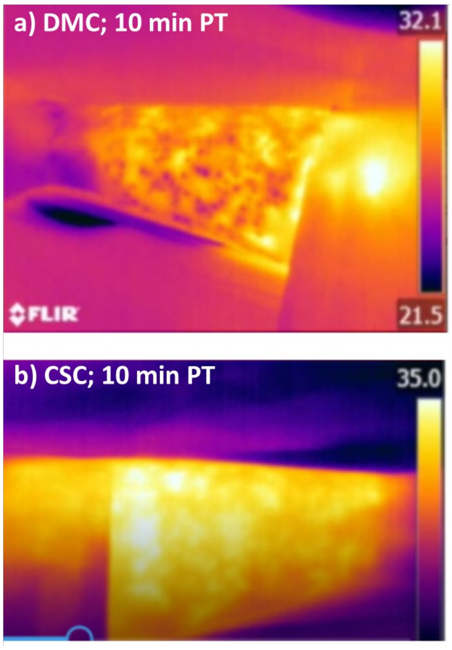


Fig. 20: Thermal images taken at 10 minutes following the hair removal treatment on the patient's calves. The upper image shows the calf that was pre-and post-cooled by DMC during the stamping treatment, and the lower image shows the calf that was pre-cooled by CSC during the treatment.

Figures 19 and 20 demonstrate that in the absence of post-cooling by DMC, the heat diffusion from the heated deeper skin layers to the un-cooled skin surface results in thermal hot spots. This effect can be even more clearly seen in Fig. 21, which shows the temporal evolution of the maximal temperature ($T_{S\text{-}max}$) within the whole treated area, for both treatment methods.

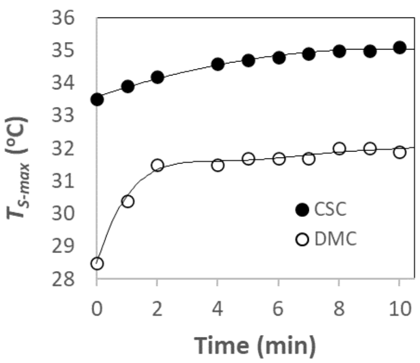


Fig. 21: Temporal evolution of the maximal temperature over the treated area during the time following a hair removal treatment using either the DMC or CSC skin cooling method.

IV. DISCUSSION

All three tested methods of skin cooling, CSC, CAC or DMC, perform in a similar manner, by removing heat from the skin to a cooling agent (either gas or liquid) in "contact" with the skin. However, the heat transfer dynamics of the three methods are significantly different, which can have a significant influence on the clinical outcome of a laser procedure.

The cryogen and cold air cooling are both characterized by below-freezing temperatures of the cooling agent. This can be uncomfortable to the patient and can result in cryo-injury [3,8].

For cryogen spray cooling (CSC), the cooling agent is a pressurized cryogen liquid at room temperature whose boiling temperature is significantly lower than the skin surface temperature (-26.1°C for commonly used tetrafluoroethane) [8]. Heat is removed by conduction from the skin into the cryogen liquid sprayed over the skin, and the cryogen is cooled down by rapid evaporation.

On the other hand, there is no evaporation process during cold air cooling. Additionally, air is a bad conductor of heat. For this reason, the air that is blown over the skin surface needs to be cooled to very low temperatures (down to ~ -30°C) by an external chiller prior to being blown over the skin area.

The most effective form of cooling is where the skin undergoes post-cooling in addition to the cooling prior and during an irradiation by the laser pulse. This is because, apart from protecting the epidermis by reducing the skin temperature before and during a laser pulse, a post-cooling of the laser-induced "burn" reduces pain, swelling and the risk of scarring. In this regard, CSC is at a disadvantage since the cooling rate by the evaporating cryogen is extremely fast, with the heat transfer coefficient h_T of about 10,000 W/m^{2}K [8, 9]. For this reason, to reduce the risk of cryo-injury the duration of the cryogen spurt is limited to below 100 milliseconds. The cryogen cooling is therefore not very suitable for prolonged post-cooling.

On the other hand, the cold air cooling (CAC) can be used for post-cooling since the skin-to-air heat conduction is slow, with h_T in the range of 50-100 W/m^{2}K [6]. However, the small heat transfer coefficient of CAC also means that the pre-cooling phase needs to be long in order for the skin to get sufficiently cooled down prior to the delivery of a laser pulse. Additionally, due to the low temperature of the delivered cold air, the skin can get over-cooled during prolonged post-cooling.

Based on the above, the newly developed dry molecular cooling (DMC) represents "the best of both worlds" solution. On one hand, the DMC is faster than CAC, enabling appropriately short pre-cooling times. And on the other hand, the DMC is not as intense as CSC, thus allowing longer duration post-cooling periods.

Additionally, since with DMC the post cooling is accomplished in a passive manner, i.e., by the molecular water droplets remaining on the skin following a laser pulse, there is no need for continued active cooling as is the case with CAC. Further, as opposed to CSC and CAC, the DMC method is self-regulating. Namely, since the evaporation of water droplets takes place at temperatures significantly below the water's boiling temperature of 100°C, the evaporation process is (for standard relative humidity levels within medical facilities) effective only at skin temperatures above about 16°C. Therefore, the skin temperature cannot be reduced to significantly below this temperature. With DMC, the risk of over-cooling or cryo-injury has been eliminated.

The clinical advantage of post-cooling with DMC as opposed to no post-cooling with CSC can be observed in Figs. 22 and 23, which show the skin reaction post hair removal treatment according to the protocols presented in section III b.

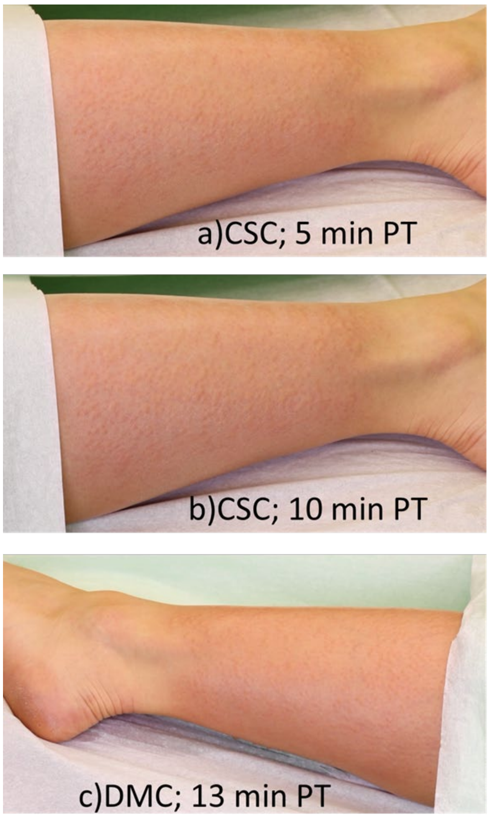


Fig. 22: Skin reactions following a stamping alexandrite laser hair removal treatment on a patient's right and left calf. The right calf was pre-cooled by the cryogen spray cooling (CSC) (Figs a and b); and the left calf was pre-and post-cooled by DMC (Fig. c). An edema can be observed at 5- and 10-minutes post treatment (PT) on the CSC's cooled leg while no edema was observed during the same time on the DMC-cooled leg. For the DMC-cooled leg, the edema started to develop only after the water droplets had been wiped away at 13 minutes post-treatment (Fig. c).

The earlier development of edema on the CSC-cooled leg is attributed to the difference of the skin temperature dynamics of the CSC and DMC cooling (see Figs. 16 and 17). The prolonged passive post-cooling by DMC acts in a similar manner as other cryo-protective measures in medicine, including therapeutic hypothermia in cardiac arrest or cerebral ischemia [16]. For example, the sooner and longer a burn is cooled with cold running water, the smaller the impact of the injury will be.

Similarly, the observed erythema on the CSC-cooled leg at 5 hours following the treatment (see Fig. 23) is attributed to the observed development of hot spots immediately following the CSC-assisted treatment (see Figs. 19 and 20), whose increased temperature continues to grow and persist for significantly longer than ten minutes (see Fig. 21).

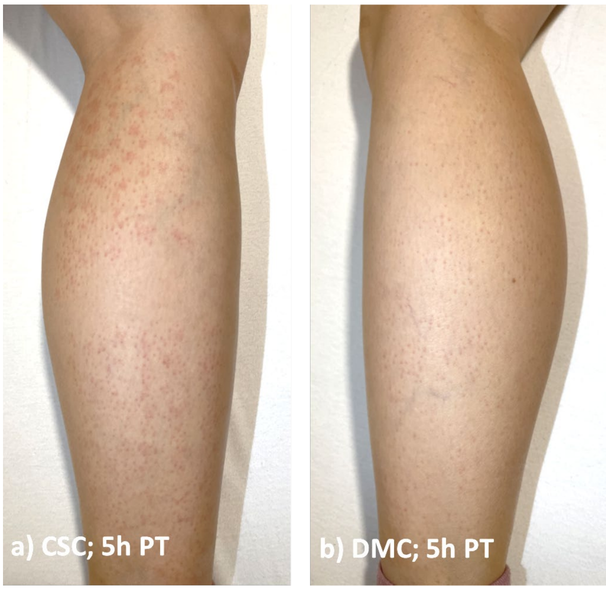


Fig. 23: Skin reactions following a treatment as in Fig. 16, at 5 hours post treatment. A strong erythema can be observed on the CSC-cooled leg.

V. CONCLUSIONS

In conclusion, a novel non-contact skin cooling method (DMC™) has been studied and compared with two standard non-contact cooling methods, cryogen spray cooling (CSC) and cold air cooling (CAC). A comparison of thermal camera measurements and clinical outcomes has shown the following:

a) The maximal cooling rate of DMC is significantly faster in comparison with CAC, especially for the manual handpiece. This is important since it is typically with the manual handpiece that the operator moves the position of the handpiece relatively quickly from spot to spot, not allowing much time for the cooling to take effect.

b) In spite of the enhanced cooling rate of the DMC there is no risk of over-cooling when using DMC. The DMC is characterized by a self-regulating feature of the evaporation rate of water molecules, which limits the lowest skin temperature to above about 16°C. The DMC cooling therefore avoids patient discomfort and the risks of cryo-injury posed by the CAC, and especially by the CSC method (see Figs. 8 and 9).

c) An important advantage of DMC in comparison with CSC is that the water droplets deposited over the skin persist on the skin for longer time periods. This can be seen in Fig. 15, which shows the thermal image of a treated skin area during a stamping hair removal treatment. With DMC, the whole treated area remains at a reduced temperature while with CSC the skin temperature not only returns to the initial skin temperature very quickly, but following the treatment continues to increase in the form of hot spots (see Figs. 19 and 20). The prolonged passive post-cooling by DMC acts in a similar manner as when a burn is cooled under cold running water. Clinically, this soothing effect has been observed to result in a milder or no edema within the initial minutes following the treatment, and in milder or no erythema within several hours following the treatment.

The novel DMC™ method has been, for example, positively evaluated during a recent hair removal study [17], with excellent hair removal results obtained by using either the stamping or avalanche [10, 15] technique.

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