Circular Directed Suction Technique for Ablative Laser Treatments

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BACKGROUND The use of ablative laser treatments is steadily increasing. A side-effect is plume, which can potentially transmit infectious material. Insufficient plume removal may lead to transmission of infectious diseases.

OBJECTIVE To introduce a newly developed circular suction technique for ablative interventions.

MATERIALS AND METHODS The new plume removal system consists of a circular master tube and four smaller suction tubes. This design guarantees plume removal around the whole treatment area. This system can be connected in principle to any common aspiration device. The suction system worked effectively with perfect satisfaction in daily routine. Its effect on skin surface temperature was evaluated using thermography and surface temperature measurements.

RESULTS The circular system removed the laser-associated plume much better than ordinary single-point plume-removal systems. Split-face investigations confirm additional benefits in terms of better skin surface cooling.

CONCLUSION The combination of providing a cool air flow during laser treatment and circular suction is a new approach for directed cooling air streams and streamed plume evacuation without obstructing the physician because of its architecture.

Patent pending for the circular suction system presented and has already passed German declaration as an utility patent.

The number of ablative and especially ablative fractional laser (AFXL) treatments, which have become state of the art for various applications in aesthetic dermatology, is steadily increasing,[1,2] but accumulating skin particles in the air with fragment diameters up to 0.31 μm,[3] which AFXL treatments produce, may also transmit infectious materials to patients and physicians.[4–7] Viral particles are detectable for approximately 1 m around the operating field,[8] and case reports have described the infectious potential in the case of condyloma treatments using ablative lasers. The infectivity of plume enriched with human papilloma virus DNA has been confirmed; clinic staff members were infected and consequently contracted laryngeal papillomatosis simply because the majority of the vacuum devices had not been replaced for years and were largely inefficient during procedures.[9,10] Moreover, hazardous chemical materials are released into the air, for example (polycyclic) aromatic hydrocarbons (cresol, phenol, benzene, toluene, xylene), aldehydes (formaldehyde, acetaldehyde, acrolein), hydrocyanic acid, carbon monoxide, and nitrile compounds. Some of these chemical materials have probable carcinogenic effects on human beings according to the International Agency for Research on Cancer. The most important precautionary method is the use of sufficient smoke evacuation during laser treatments.[11]

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In practice, it is challenging to ensure the correct, protective skin temperature and plume evacuation during laser treatments. Systems that provide on-time cooling by applying a cold air flow along with the laser beam are available.[2] Single-point plume evacuators are most often used in combination. The operator moves the laser over the skin to be treated, but the single plume point evacuator is often placed next to the patient in a static place. To ensure dynamic movement of the smoke evacuator, assistance is frequently needed to follow the air flow for more effective results. Some laser companies provide hand pieces combining air cooling and suction in semi-enclosed housings.

Infectious plume and its sufficient removal; correct skin cooling; and a small, overloaded treatment area with many devices limiting the visual field of the operator are challenges during ablative and especially AFXL treatments.

Materials and Methods

Design of the Circular Plume Removal System

The plume removal system consists of four quadrants, with one tube in each (Figure 1), guaranteeing plume removal by directed airflow for the whole treatment area. The main (master) tube is circular and releases a variable number (in our case, four) of smaller semiflexible tubes. These smaller tubes point to the treatment area (e.g., face) and may be fixed in any position. Optionally, the inspiration volume of each tube is adjustable using plug valves. The circular main tube can be connected to any aspiration device using specific connectors.

Efficacy Testing for Plume Removal

To visualize and to test the effectiveness of this system experimentally, a nebulizer (Eurolite, Fog machine N-10, Germany) was used (Figure 1) to simulate larger amounts of plume at low velocity with a blow-out volume of 50 m^3/min. Aspiration was achieved using the conventional suction device (LN 100; TBH GmbH, Straubenhardt, Germany) with an extraction arm (Alsident System A/S, Hammel, Denmark).

Figure 1. The circular suction device (prototype) displaying its efficacy to absorb plume in an experimental setting using a powerful nebulizer with excessive smoke production at low velocity.

Having passed the proof-of-principle test, it was transferred into a clinical setting using an artificial nontoxic party plume as used in discos and clubs. Finally, the system was tested during ablative and fractional ablative interventions.

Skin Surface Temperature Monitoring

Cooling was accomplished using the standard cooling device (Cryo 6; Zimmer, Ulm, Germany) fixed to the carbon dioxide (CO_2) laser scanner hand piece (Exelo2, Quantel-Derma, Erlangen, Germany).

Differences in skin temperature were compared using a static single aperture and the four-quadrant suction system in a single patient using a thermography camera system (VarioCAM hr research 600; InfraTec, Dresden, Germany) immediately after the procedures (Figures 4 and 5). This split-face investigation included a fractional treatment of both cheeks using a fractionated CO_2 laser. Both sides were cooled using the cooling device at

approximately 550 L/minutes with the outlet attached directly to the laser handpiece. On the right side, a conventional one-aperture suction system was used for aspiration with an extraction arm. The distance between the aperture of the static extraction arm and skin surface was approximately 15 cm and the aperture of the static extraction arm was pointed to the skin surface of the cheek. The newly developed circular suction device (Figure 1) was used on the left side of the face.

Supplementary to this test, 10 patients were evaluated in a split-face trial under identical conditions; cooling was accomplished using the cooling device (at 550 L/minutes), which was fixed to the CO_2 laser scanner hand piece and directed to a single skin area on the cheeks without a laser application.

Aspiration was achieved on the right side using the single-point suction device with the extraction arm and coupled to the circular system used for the left sided cheek. Differences in skin surface temperature were measured 2 minutes after a cooling period of 2 minutes using an infrared noncontact thermometer (MiniTemp MT, Raytek, Fluke Corporation, Everett, WA) in duplicates.

Statistics

Data are expressed as means ± standard deviations. The Wilcoxon test for dependent samples was used to calculate the difference. All tests were two-tailed, and significance was indicated by $p < .05$. Statistical analysis was performed using Statistica 6.0 software (StatSoft, Tulsa, OK).

Results

Here we present a circular suction device with continuous aspiration for the whole face. This suction device can be connected in principle to any available aspiration system using connectors.

In preliminary treatments, this circular suction device provided much better air quality within the treatment room than a traditional single-point evacuator. Patients and physicians noticed the reduced acrid smell subjectively. The lateral position of the circular suction device influences the plume dynamic, so the plume is extracted laterally down—away from the patient's nose.

The suction is divided in four quadrants because of the four tubes, positioned around and lateral to the treatment area, which allows unrestricted movement of the laser hand piece (Figure 1). The airstream is not divided or diverted between the aspiration and cooling system (Figure 2). The cooling airstream that emanates from the laser hand piece and finds its way to one of the four tubes transports the plume produced. The suction itself was sufficient to remove the entire plume in all four quadrants (Figure 3). The new system (Figure 4) also ensures much better skin surface cooling than the conventional system (Figure 5). Using the digital thermography system, skin surface temperatures during AFXL treatment were measured as a difference in temperature up to 7°C.

The results of a split-face trial of cooling and suction using a single-point or circular suction device without laser intervention resulted also in a much better cooling effect as measured using an infrared noncontact thermometer. The mean difference between groups in all measured temperatures was 13°C. Temperatures were 19.6 ± 3.2°C on the

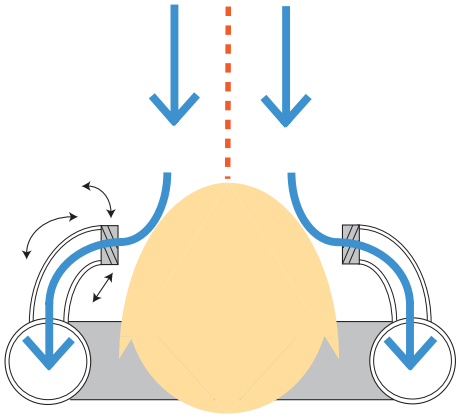

Figure 2. Schematic drawing of the anticipated direction of cold air stream along the skin down to the suction points.

Figure 3. Clinical treatment setting simulating plume evacuation with a nebulizer at low velocity.

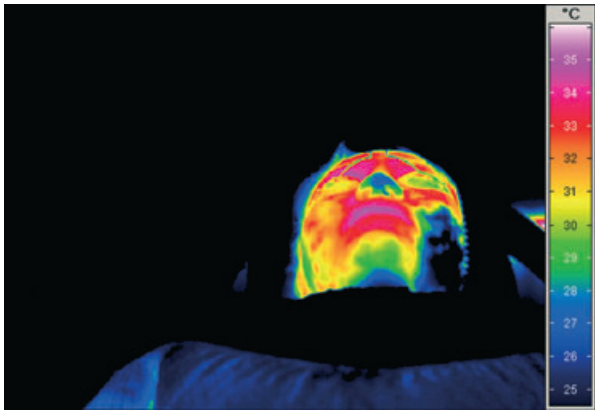

Figure 4. Real-time thermography using the new four-quadrant suction system on the left side of the face displaying an approximately 26°C lower skin surface temperature.

conventionally treated side of the face and 18.4 ± 3.6°C on the opposite side treated using the prototype ($p < .05$).

Discussion

The use of laser treatments is rising. In particular, AFXL is state of the art for various applications in aesthetic dermatology.[1,2] A side effect of AFXL

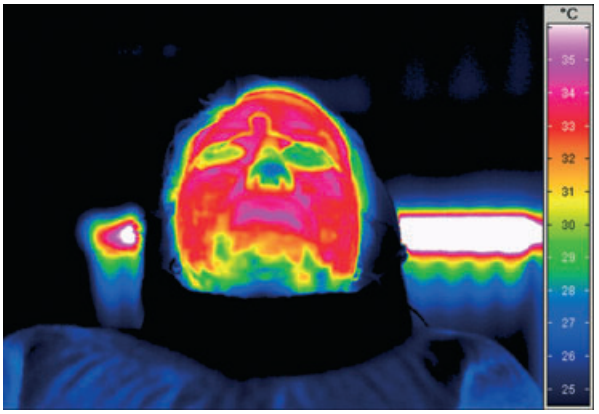

Figure 5. Real-time thermography using an ordinary single-point suction system on the right side of the face displaying an approximately 33°C higher skin surface temperature.

treatments is the generation of plume, which includes substantial amounts of skin particles with diameters up to 0.31 μm.[3] This plume is unpleasant and can transmit infectious materials, such as germs and viral particles.[4–7] These viral particles are detected approximately 1 m around the area of intervention[8] and underline the importance of good plume extraction. In general, smoke reduction of 98.6% is ensured when the inlet nozzle is no more than 1 cm away from the treatment area and can be nearly half that if the inlet nozzle is 2 cm away.[11] The risks are not limited to patients but are applicable to those using the lasers. The increasing frequency of ablative and especially fractional ablative interventions should draw the operator's attention to the potential risk of transmission of infectious diseases and to the burden of plume to the patient and the operator.[2] Due to its highly efficient cooling devices, a single point plume evacuation seems to be today's standard. The solution to that problem might be a newly developed system that connects the cooling device to the suction device figuratively using a directed airstream.

While the fractional ablative laser technique ensures fewer side effects and complications, on-time cooling further enhances the safety and efficacy of the procedure[12] by avoiding the so-called active

bystander effect of thermal damage.[13] Systems that allow on-time cooling by providing attachments for common cooled air flow devices are available.[2]

To the best of our knowledge, no system available on the market has fulfilled the resulting need for a combination of a cooling system and an on-time sufficient suction, which allows the generation of uniform circulation of the treated skin.

Generally, low or high velocities of the air stream affect suction capacity and might influence smoke evacuation dynamics.

The presented new suction device enhances plume removal and might serve as the "missing link" between commercially available cooling and suction devices that were approved successfully for practice. While using an experimental nebulizer in our experimental setting, the new system was able to manage the large quantity of artificial plume successfully. Additionally, the combination of efficient spatiotemporal cooling completely covering the treatment area and a corresponding suction device presents a new approach to directed cooling and plume evacuation during ablative and especially AFXL treatments not only of the face, which enhances safety and efficacy. The new system aspirates the plume simultaneously from four or more areas through inlets attached to a circular master pipe at the site of its origin without hindering the physician. The cooling airstream, released from the laser head, positioned on top of the skin, immediately directs the generated plume away from its source to the circular suction device positioned below the treatment area. This technique guarantees enhanced skin surface cooling by an airstream cooling effect, which was successfully measured using thermography and an infrared noncontact thermometer. Mono-aperture extraction arms are static and could not ensure complete plume removal; additional assistance is needed for moving the single aperture arm following the laser/airflow to enhance adequate suction.

In summary, this new device includes a number of benefits by applying a continuous aspiration stream for the whole treatment area. First, it is static and does not need to be held or repositioned with assistance. Furthermore, it is more effective than common suction systems because of the directed suction flow and can be used with most plume evacuation equipment using different connectors. In combination with air-cooling devices, the prototype described here resembles the "missing link" for plumeless, more-secure applications with high-quality skin cooling and suction. Although the reduction of transmission risk of infectious material is proposed, detailed studies are required.

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