

# Messung der Hauttemperatur nach Intense Pulse Light (IPL)-Anwendung sowie Low-Level-Light-Therapie (LLLT)

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## Skin temperature measurement after intensive pulse light (IPL) and low-level light therapy (LLLT) application

**Das Ziel dieser Studie** war die Hauttemperatur der entsprechenden Gesichtsareale nach Anwendung von Intense Pulse Light (IPL) und Low-Level Light Therapy (LLLT) zu messen.

**Methoden** | Die Temperatur der Ober- und Unterlider, Wange und Schläfe vor und nach einmaliger Anwendung von IPL und LLLT wurde mit einer Thermokamera vor ( $T_{\text{vorher}}$ ) und direkt nach Anwendung bei 10 Testpersonen mit Dysfunktion der Meibomdrüsen gemessen. Nach der jeweiligen Anwendung wurde sofort ( $T_{0\text{min}}$ ), nach 2 Minuten ( $T_{2\text{min}}$ ), nach 15 Minuten ( $T_{15\text{min}}$ ) und 25 Minuten ( $T_{25\text{min}}$ ) die Temperatur gemessen.

**Ergebnisse** | Direkt nach der Anwendung ( $T_{0\text{min}}$ ) von IPL war die Temperatur an den Ober- und Unterlidern gegenüber  $T_{\text{vorher}}$  nicht signifikant erhöht. Die Temperatur der Wange ( $T_{0\text{min}}$  39,6° C) und Schläfe ( $T_{0\text{min}}$  37,6° C) war signifikant höher ( $T_{\text{vorher}}$  35,5° C; 36,0° C). Nach Anwendung ( $T_{0\text{min}}$ ) von LLLT war die Temperatur an den Ober- (40,4° C) und Unterlidern (39,6° C) sowie der Wange signifikant höher als vor LLLT. An den Oberlidern wurde bei  $T_{2\text{min}}$  und  $T_{5\text{min}}$  eine signifikant ( $p < 0,001$ ) höhere Temperatur als an den Unterlidern gemessen.

**Zusammenfassung** | Wogegen nach LLLT-Behandlung eine ausreichende Erwärmung der Lider zu messen war, konnte nach IPL nur die Erwärmung der Wangen und Schläfen festgestellt werden.

**The aim of this study** was to measure the heat after application of Intense Pulse Light (IPL) and Low-Level Light Therapy (LLLT) of the according facial areas.

**Methods** | The heat of the upper and lower eyelids, cheek and temple before and after a single application of IPL and LLLT was measured with a thermal camera before ( $T_{\text{before}}$ ) and directly after application in 10 meibomian gland dysfunction subjects. After each application, the temperature was measured immediately ( $T_{0\text{min}}$ ), after 2 minutes ( $T_{2\text{min}}$ ), after 15 minutes ( $T_{15\text{min}}$ ) and 25 minutes ( $T_{25\text{min}}$ ).

**Results** | Immediately after the application ( $T_{0\text{min}}$ ) of IPL, the heat at the upper and lower eyelids was not significantly increased compared to  $T_{\text{before}}$ . The heat of the cheek ( $T_{0\text{min}}$  39,6° C) and temple ( $T_{0\text{min}}$  37,6° C) was significantly higher than before ( $T_{\text{before}}$  35,5° C, 36,0° C). After LLLT ( $T_{0\text{min}}$ ) the temperature at the upper (40,4° C) and lower eyelids (39,6° C) as well as the cheek was significantly higher than before LLLT. At the upper eyelids a significantly ( $p < 0,001$ ) higher temperature was measured at  $T_{2\text{min}}$  and  $T_{5\text{min}}$  than at the lower eyelids.

**Summary** | Whereas after LLLT treatment a sufficient warming of the eyelids was measured, no warming of the eyelids but of cheeks and temple could be observed after IPL.

Meibomian gland dysfunction (MGD) appears to be the most common cause of dry eye. In the international MGD workshop, this was defined as a "chronic, diffuse disorder of the meibomian glands, mostly characterized by obstruction of the glandular ducts and / or qualitative / quantitative changes in gland secretion".<sup>1</sup> A large number of different tear substitutes are available for treatment, if possible with a lipid component, as well as topical antibiotics, oral tetracycline derivatives,

corticosteroids or topical cyclosporin.<sup>2,3</sup>

Furthermore, eyelid edge care with local heat application and manual expression of the glands is the gold standard of therapy.<sup>2,4</sup> The therapy is not insignificant for those affected; in the United States, an average dry eye patient spends \$ 783 a year. The treatment is therefore very expensive and accordingly there is an economic interest in treatment alternatives with longer-term effectiveness.<sup>5</sup>

One of these new concepts is Intense Pulsed Light (IPL) and / or a special light mask for Low-Level Light Therapy (LLLT). Studies have shown that both “light applications” can significantly improve the tear film and the symptoms in an existing MGD.<sup>5-12</sup>

The system of the manufacturer Espansione examined in this study (Eye-Light® and My Mask®, Bologna, Italy (Fig. 1); (Distributed in Germany by bon Optic Vertriebsges.mbH, Lübeck) is a combined concept of IPL and LLLT.

The application of LLLT on its own is recommended for mild to moderate MGD, preceded by IPL application for severe MGD. Another special feature is that when this device is used with IPL, contrary to other devices, no gel has to be applied to the skin of the person to be treated beforehand. Instead, a special filter is used for the Eye-Light® (Figure 2).

On the one hand, it may be more pleasant for the treated person not to have gel applied, on the other hand, the need for a gel may pose a certain risk if the protective gel is accidentally applied too thinly.

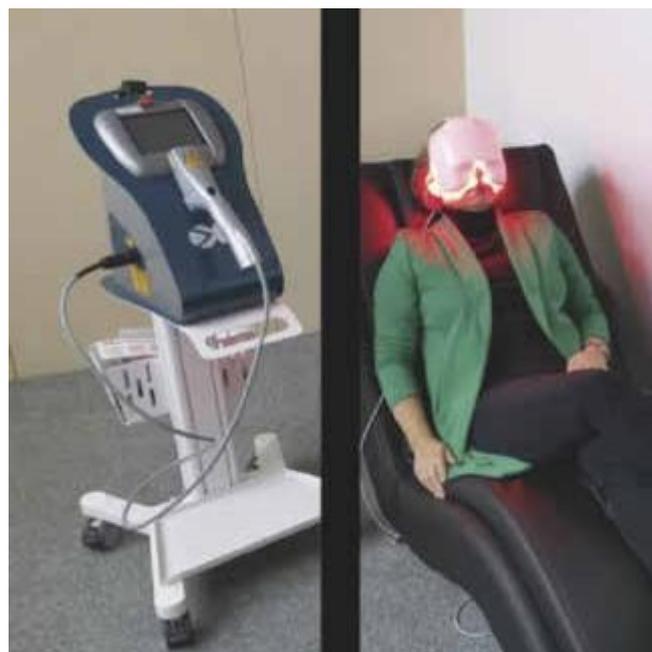
Both IPL and LLLT generate endogenous heat at the point of use. The depth of penetration of light with a wavelength of 600 - 650 nm into the skin is 1 - 2 mm, at 650 - 950 nm it is 2 - 3 mm, at 950 - 1200nm it is 1mm.<sup>13</sup> When using IPL, a hot but extremely short “light flash” or bundled series of “light flashes” reaches the skin surface. Common devices from different manufacturers differ in terms of wavelength, energy and pulse shape / pulse duration.<sup>14</sup>

With LLLT, a light mask with red LEDs is placed over the patient's face for an average period of 15 minutes. These LEDs are also said to cause endogenous heat for the upper and lower eyelids.

If you summarize “light applications” under the light spectrum of 600 - 1070 nm<sup>15</sup> wavelength, a number of mechanisms of action are hypothetically postulated in various literature summaries related to the dry eye.

It could be selective photothermolysis within the fine vascular structures along the eyelids, a mild, local heat development that makes the meibomian secretion less viscous and could, therefore, lead to improved expressibility, reduction of inflammatory and neuropathic pain, stimulation of the parasympathetic nervous system affecting the meibomian glands, photobiomodulation mechanism that stimulates at the cellular and molecular level, coagulation of telangiectasias.

Other key points include reducing epithelial turnover and reducing the risk of gland obstruction, activating fibroblasts and improving collagen synthesis, minimizing demodex mite infestation, modulating the secretion of pro- and anti-inflammatory molecules, and reducing the concentration of MMPs by downregulating at the mRNA level and influencing reactive oxidative species (ROS).<sup>5, 16, 17 18</sup>



▲ Image 1 | The IPL instrument (Eye-Light®) used in this study as well as the LLLT-My Mask® (right).



◀ Image 2 | The handpiece of the Eye-Light®.

A: "Protection filter" -  
B: Sensor for the automatic detection of skin pigmentation

Accordingly, there are numerous possible mechanisms of action, which unfortunately have not yet been researched directly, but have been transferred from other approaches and areas to the treatment of MGD.

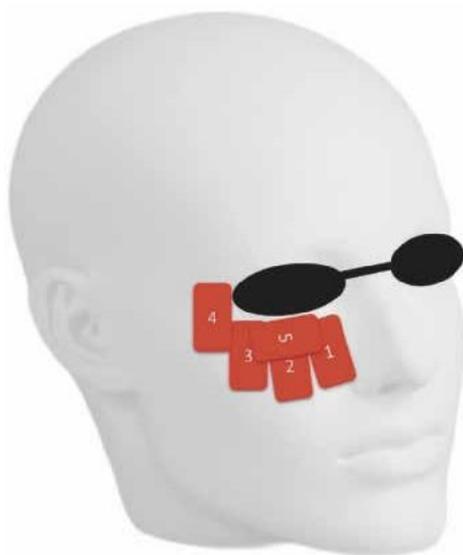
A spectrum of the mechanisms of action is based on direct heat along the eyelids. It is therefore interesting to know which temperatures are to be measured here. The aim of this pilot study was to investigate the heat effect of the IPL and the LLLT on the skin areas corresponding to the application, by means of infrared thermography.

## Method

The temperature of the upper and lower eyelids, cheek and temple before and after single use of IPL and LLLT (Eye-Light® and My Mask®, Espansione, Bologna, Italy, Figure 1) was measured with a thermal camera (FLIR A 300, Flir Systems, Danderyd, Sweden) before (T before) and directly after application in 10 test subjects (average age 57 years, 6 women, 4 men).

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◀Image 3 | The five positions of the Eye-Light® handpiece specified by the manufacturer when used.

After each application the temperature was measured immediately (T 0min), after 2 minutes (T 2min), after 15 minutes (T 15min) and 25 minutes (T 25min).

There was at least two weeks between the IPL and LLLT applications. According to the manufacturer's recommendation, the intensity was adjusted according to meibomian gland failure and skin pigmentation (600 nm; 59 - 65 J / cm<sup>2</sup>) and the IPL was used at the five defined points below and to the side of the closed eye (Fig. 3).

Applying the LLLT technology, the LED mask was put on for 15 minutes to each respective test person in accordance with the manufacturer's recommendation. The test subjects who felt the heat was too intense were allowed to hold gently the mask with their hands accordingly. All test persons came without make-up. Birthmarks or similar were covered with a bright concealer before IPL. Exclusion criteria were test subjects younger than 18 years, no dysfunction of the meibomian glands, epilepsy, no medical approval, known skin sensitivity to light, IPL or LLLT treatments less than two weeks prior to the application, strong sun exposure of the facial skin over the past two weeks, acute inflammation, debris in affected facial areas and / or eyes and eyelids, pregnancy, operations on the face or on the eyes / eyelids of ocular dystrophies less than 1 year old.

### Statistical analysis

The data were checked for normal distribution using the Shapiro-Wilk test. Differences from the same areas in the repeated measurements were analyzed with ANOVA (post-hoc without Bonferroni correction), differences between different areas of lower eyelid versus upper eyelid were calculated with the non-connected t-test. The number of cases was determined with power analysis (n = 8; 1-β = 0.80; mean difference 1.0 °C ± 1.0 SD)

### IPL results

The ambient room temperature was 22.4 °C ± 0.5. Immediately after the application (T 0min) of IPL, the temperature on the upper and lower eyelids was not significantly increased compared to (T before) (Table 1). The temperature of the cheek and temple was significantly increased. This effect on the cheek and temple continued for up to two minutes (T 2min). The initial temperature was reached again at measuring point T5min.

### LLLT results

After application (T 0min) of LLLT, the temperature on the upper and lower eyelids and cheek was significantly higher than before LLLT. This significant effect continued for up to 2 minutes (T 2min). From the measuring point T 5min to T 15min the temperature was higher than T before. At the next measuring point T 25min, the initial temperature was reached again. At T 2min and T 5min, a significantly (p < 0.001) higher temperature was measured on the upper eyelids than on the lower eyelids (Fig. 4).

### Discussion

The tested IPL device did not increase the temperature of the eyelids but the temperature of the cheek by around 4°C and of the temples by around 1.6°C. Craig J. et al.<sup>19</sup> on the other hand, after an IPL treatment with a device in which gel had to be used, reported a skin warming of the cheek of less than 1°C. This may be due to the fact that Craig J. et al. had only measured the skin temperature after removing the gel. Since, according to our investigation, the skin temperature had returned to normal at measuring point T 5 minutes, it can be assumed that with the device used by Craig J. et al., the temperature on the cheek was higher immediately after application, but it could be measured too late. Craig J. et al. a warming of the eyelids (personal communication 12/2019).

While the LLLT had warmed the eyelids significantly, such an effect could not be found after IPL application. Nevertheless, alongside LLLT, IPL is a promising treatment for MGD according to the current study situation. In several independent studies, the tear film stability and the lipid layer as well as the symptoms of the dry eye improved significantly after IPL application.<sup>5-12, 18, 19</sup>

In this study, the "residual heat" was measured after treatment. The decisive factor is the energy that penetrates the skin. After flashing for a few milliseconds, this energy led to a noticeable increase in skin temperature.

A purely mathematical model has shown that in medium and large blood vessels (> 0.150 µm) a single IPL



◀Image 4 | Example recordings of a series of measurements before and after LLLT- (above) and IPL application (bottom row).

pulse of 30 msec duration the temperature in the middle of the vessel would be raised to 80 - 90 ° C and would be sufficient for coagulation. On the contrary, the temperature in small blood vessels (60 µm) can only reach 45 - 70 ° C depending on the fluence.<sup>20</sup> It remains to be seen whether this temperature will effectively reach the eyelids (photothermolysis on the edge of the eyelid and / or liquefaction of the meibom oil) or whether it is simply derived in general. A few seconds after IPL application, a warming effect was measured on the cheeks, but not on the lids.

It is known that, for example, the warmth of warm compresses

only reaches the meibomian glands after several minutes. The hypothetical postulated effect of IPL might have reached the meibomian glands, but it might have been so short that it could not be measured on the skin surface.

Similar to photothermolysis along the edges of the eyelids, in my view, this seems rather unlikely, since areas with strong blood flow are known for quickly dissipating heat. So why should this heat reach the meibomian glands to the extent and with sufficient effectiveness?

	T <sub>before</sub>	T <sub>0min</sub>	T <sub>2min</sub>	T <sub>5min</sub>	T <sub>15min</sub>	T <sub>25min</sub>	T <sub>before</sub> T <sub>0min</sub>	T <sub>before</sub> T <sub>2min</sub>	T <sub>before</sub> T <sub>5min</sub>	T <sub>before</sub> T <sub>15min</sub>	T <sub>before</sub> T <sub>25min</sub>
<b>IPL</b>											
Lower eyelid	36.2°C ±0.72	35.7°C ±0.64	35.8°C ±0.60	36.0°C ±0.71	35.9°C ±0.69	36.1°C ±0.68	<b><i>p=0.028</i></b>	p=0.100	p=0.270	p=0.177	p=0.326
Upper eyelid	36.5°C ±0.65	36.3°C ±0.69	36.7°C ±0.67	36.4°C ±0.73	36.5°C ±0.66	36.1°C ±0.72	p=0.257	p=0.253	p=0.371	p=0.500	p=0.103
Cheek	35.5°C ±0.70	39.6°C ±0.72	37.1°C ±0.59	35.7°C ±0.68	35.6°C ±0.70	35.5°C ±0.71	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	p=0.262	p=0.320	p=0.323
Temple	36.0°C ±0.67	37.6°C ±0.68	36.5°C ±0.63	35.9°C ±0.65	36.1°C ±0.64	35.8°C ±0.66	<b><i>p&lt;0.001</i></b>	<b><i>p=0.016</i></b>	p=0.316	p=0.316	p=0.171
<b>LLLT</b>											
Lower eyelid	35.9°C ±0.69	40.4°C ±0.58	39.6°C ±0.60	37.1°C ±0.72	36.5°C ±0.63	35.3°C ±0.72	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p=0.001</i></b>	<b><i>p=0.006</i></b>	<b><i>p=0.042</i></b>
Upper eyelid	36.2°C ±0.65	41.8°C ±0.65	40.7°C ±0.67	37.5°C ±0.69	37.5°C ±0.67	36.1°C ±0.70	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	p=0.371
Cheek	35.4°C ±0.79	39.8°C ±0.75	38.8°C ±0.63	36.7°C ±0.67	36.5°C ±0.71	36.1°C ±0.76	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p=0.012</i></b>
Temple	35.0°C ±0.73	37.7°C ±0.70	37.1°C ±0.69	36.1°C ±0.70	36.1°C ±0.65	35.6°C ±0.69	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p&lt;0.001</i></b>	<b><i>p=0.025</i></b>

**Table 1** shows the measured temperatures at the different areas at the different times, as well as the standard deviation and the p-values between the repeated measurements. Significant p-values are in italics, those that would still be significant after a Bonferroni correction are additionally italic.

If one excludes heat-related mechanisms of action in IPL treatment of MGD after no eyelid warming effect was measured in this study, a whole series of other postulated hypotheses remain, as listed in the introduction. The discussion of the likelihood of this is already presented outside the study objective and in corresponding literature summaries.<sup>5,18</sup>

Nevertheless, it should be mentioned that the postulated mechanisms of action were not only transferred from other areas, but are also sometimes reproduced somewhat indistinctly. An example of this is acne rosacea. It has been shown that superficial blood vessels and telangiectasias of the facial skin can be treated very well by IPL. When talking about a reduction in telangiectasias in certain sources, this does not mean the telangiectasias of the edges of the eyelids, but rather those of the facial skin in acne rosacea patients. Destruction of abnormal erythematous blood vessels reduces a key reservoir of inflammatory mediators, eliminating a major source of inflammation on the face and possibly near the eyelids and meibomian glands. Accordingly, photothermolysis directly on the lids, at least in acne rosacea patients, would not be absolutely necessary. If a coagulation of the telangiectasia of the eyelid edges would be an IPL effect, how is it ensured that all other fine blood vessels of the eyelid and the conjunctiva of the ocular surface would not be damaged? Our further work on IPL and LLLT, for example, did not show any changes in the eyelid appearance after IPL.

The LLLT showed a significantly higher heat effect, which was within the range recommended for the treatment of MGD with warm compresses or the like.<sup>21, 22</sup> This was higher on the upper eyelids than on the lower eyelids. A warming effect was also found in the areas that are covered by IPL. The temperature to be reached in the meibomian glands during heat treatment of the MGD should be higher than 38 ° C.<sup>21</sup> When using warm compresses, the surface temperature of the skin is said to be at least 40 ° C.<sup>22</sup> In this way, the excessively viscous meibom oil in MGD patients is liquefied and is easier to express. This seems to have been achieved by using the My Mask® on the upper and lower eyelids. After 15 minutes of application, the warming effect continued at the temperature relevant for MGD treatment for up to two minutes after treatment, and a general effect of warming the face could be measured for up to 15 minutes. The effect of warming the face was significantly shorter with the IPL treatment. Due to the properties of LLLT, it can also be assumed that this temperature has penetrated deeper into the eyelids than when using external heat (warm compresses or similar). The LEDs on the My Mask® have a wavelength of 633 nm, which works in normal skin at a depth of one to two millimeters.<sup>13</sup>

After a few minutes, the temperature was felt by some test subjects to be very high, so they corrected the mask position somewhat with their hands. This option should be communicated to those to be treated before use.

LLLT is becoming increasingly important in the various medical fields, not only due to the endogenous heat, but also due to other effects of the light spectrum used. This ranges from Alzheimer's treatment to wound healing.<sup>15</sup>

The postulated hypotheses differ little from those for the IPL application. LLLT was successfully used for the treatment of chalazion and also for MGD.<sup>6,12</sup> In future work, it will have to be investigated whether it is exclusively the heat or whether the My Mask covers both, i.e. both the heat-relevant effects and the non-heat-relevant aspects. This combination effect (heat and light spectrum) compared to IPL is definitely possible.

Nevertheless, all hypotheses based on the transfer of mechanisms of action from other areas to the treatment of MGD must be discussed with caution, and it should be kept in mind that there were differences between the devices used (wavelength, energy, pulse shape / pulse duration) in the respective studies. This study can only provide information about the skin temperature before and after treatment of used IPL and LLLT devices.

## Summary

Both IPL and LLLT showed a significant skin warming effect, which lasted longer after treatment with LLLT than with IPL. Whereas after LLLT treatment sufficient warming of the eyelids was measured for MGD treatment, only warming of cheeks and temples could be measured after IPL, but not of the eyelids.



### Dr. Heiko Pult

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Dr. Heiko Pult is also the founder of "Dr. Heiko Pult - Optometry and Vision Research", a research institution specialized in questions of the anterior segment of the eye, especially the tear film, the contact lens supply and the visual system.

Dr. Heiko Pult supports around 40 clinics and research facilities in D-A-CH for international studies as a so-called 'Best Corrected Visual Acuity' certifier.

He is co-author of the current Dry Eye Workshop II of the Tear Film & Ocular Surface Society (TFOS), TFOS Ambassador for Germany and author of numerous scientific publications, and speaker at scientific congresses worldwide.

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