New Optimized Light™ Source for Treatment of Vascular Lesions of the Skin

E. Victor Ross, MD[1]; Emil A. Tanghetti, MD[2]; David B. Vasily, MD[3]; Robert A. Weiss, MD[4]; James J. Childs, PhD[5]; Andrei Erofeev, PhD[5]; Mikhail Z. Smirnov, PhD[5]; and Gregory B. Altshuler, PhD, ScD[5]

[1]Scripps Clinic Carmel Valley, San Diego, CA 92130, [2]Center for Dermatology and Laser Surgery Sacramento, CA 95819,
[3]Aesthetica Cosmetic and Laser Surgery Center, Bethlehem, PA 18018,[4]Maryland Laser Skin and Vein Institute, Hunt Valley, MD 21030
[5]Palomar Medical Technologies, Inc. Burlington, MA 01803

Objective:

We report on an optimized light source for the treatment of vascular and pigmented lesions of the skin. A discussion of the technical characteristics and early clinical findings are included.

Conclusions:

This new light source provides a range of pulse durations and fluences with output power free from high intensity spikes. The dynamic dual-band spectrum facilitates treatment of vessels ranging in size and depth including small, superficial vessels and larger deeper-lying vessels while minimizing heating of the skin surface. Our clinical experiences with this device have demonstrated excellent clearance of facial telangiectasia and poikiloderma.

Introduction

We investigate the efficacy of an optimized pulsed light source (MaxG™, Palomar Medical Technologies, Inc., Burlington, MA) with customized features including smooth spike-free output power, a dual-band output spectrum, and dynamic spectral shifting. The results of clinical case studies are described to evaluate the safety and effectiveness of the MaxG™ for treating vessels of various sizes and depths in patients with facial telangiectasia and poikiloderma.

It has long been established that vascular lesions of the skin, including port wine stains (1-4), facial telangiectasia (5, 6) and rosacea (7, 8), respond well to treatment with lasers such as the pulsed dye laser (PDL) or frequency-doubled Nd:YAG (532 nm) through careful selection of wavelength, energy level, and pulse duration (9-11). A current limitation of PDL devices is their inability to deliver uniform, long pulses of energy. Instead, the energy is delivered over a series of very short pulses (12) that potentially compromise skin safety and increase the risk of ablative, rather than coagulative, damage. Another limitation of PDL devices is the use of a single, short wavelength with limited penetration through larger vessels or to vessels lying deeper in the dermis (13, 14).

Reports have also shown that treatment with traditional broad-spectrum Intense Pulsed Light (IPL) devices provides clearance of vascular lesions, though sometimes to a lesser degree than with lasers (15, 16), possibly due to limited fluence levels at shorter pulse widths. The MaxG™, with its technical features described below, is designed to treat vessels over a wide range of sizes and depths.

Pulse Width and Peak Power

Improvement of vascular lesions requires complete coagulation of vessels that vary widely in diameter and depth. Following principles described in the theory of selective photothermolysis (17), the minimum absorbed energy necessary to coagulate the targeted blood vessels should be delivered in a time comparable to the vessel's thermal relaxation time to cause the least thermal injury to surrounding tissue. In other words, there is an optimum power and pulse width for each vessel size. For indications that do not require treatment of the smaller, more superficial vessels and capillaries, short pulse widths and/or high peak powers lower the purpuric threshold fluence and should be avoided.

Unlike PDLs and IPLs, the MaxG™ output power is very uniform and free of high peak-power spikes. This means that the peak power is the same as the average power for every pulse so you know what you are delivering and what vessels will be targeted. Figure 1 highlights the differences between the pulse width structures showing a 36 J/cm^2, 10 ms pulse of the MaxG™ plotted against a 7.5 J/cm^2, 6 ms pulse from a PDL. While the power density

(fluence divided by pulse width) is 3.6 kW/cm^2 and constant throughout the MaxG™ pulse, a 6 ms pulse from the traditional "long–pulsed" PDL consists of four 100 µs micro-pulses separated by 2 ms intervals as shown by Kimel, et al (14). The average power density of this pulse train is 1.25 kW/cm^2, but the peak intensity of each spike is 18.75 kW/cm^2. For fluences 7.5 J/cm^2 and higher, the PDL has enough energy in each of the individual micro-pulses to cause purpura. In contrast, lower peak power of the MaxG™ increases the purpuric threshold fluence allowing treatment of vessels with less purpura.

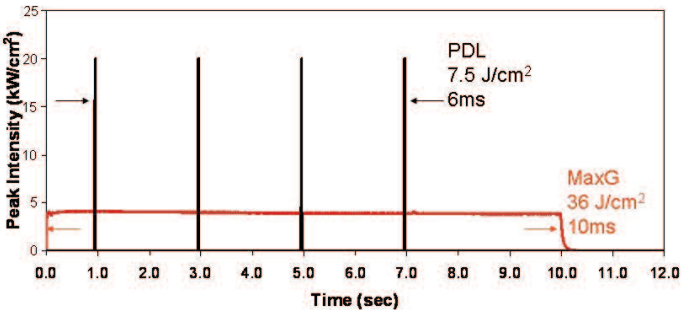

Figure 1: Pulse width structure of 6 ms PDL (black arrows and lines) and 10 ms MaxG™ pulses (red arrows and lines). PDL Fluence is 7.5 J/cm^2; MaxG™ is 36 J/cm^2.

The above discussion also applies to IPLs whose output powers are not uniform. The displayed parameters of fluence and pulse width can only provide the device's average output power and not its peak power. For example, if an IPL's pulse structure is similar to the PDL's pulse structure described above, then increasing the displayed pulse width will still effectively target the smaller vessels unless the fluence is held fixed or decreased appropriately.

Selective Energy Absorption

Clearance of vascular lesions is achieved by delivering energy from a laser or light source to the targeted hemoglobin (Hb) in blood vessels, where it is absorbed and converted into heat. The degree to which light is absorbed by blood vessels is largely determined by the target chromophores Hb and methemoglobin (MetHb), for which the absorption profiles are shown in Figure 2. The MaxG™ delivers light in two spectral bands: 500 to 670 nm and 870 to 1200 nm. These bands were specifically selected for preferential absorption by oxygenated hemoglobin (O_2Hb), deoxygenated hemoglobin (HHb), and MetHb versus melanin, the pigment found in the dermal/epidermal (D/E) junction of the skin which acts as a competing chromophore. In addition to decreasing the energy available to the underlying blood vessels, melanin absorption causes heating of the D/E junction that can thermally damage the epidermis. The blue shaded region of Figure 2 depicts a spectral band between 670 and 870 nm which is filtered out by the MaxG™ to help protect the skin surface during treatment. For greater safety, the temperature of the contact sapphire window on the hand-piece can be adjusted to provide cooling.

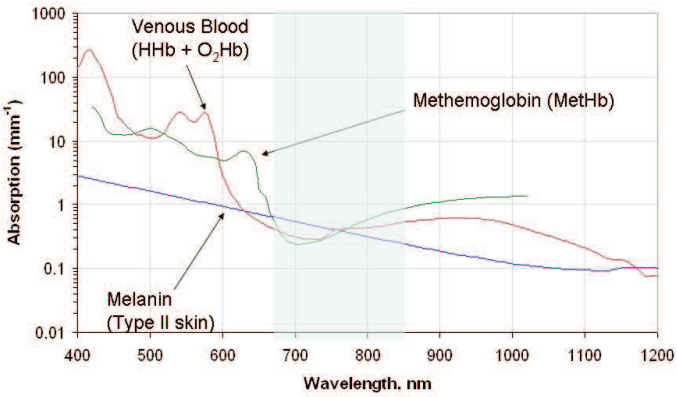

Figure 2: Absorption of venous blood (HHb and O_2Hb), Methemoglobin (MetHb) and melanin for spectral bands of the MaxG™.

Deeper Penetration

Deeper penetration of light energy into the skin occurs with less absorption and less scatter. The near-infrared, 870 nm to 1200 nm spectral band of the MaxG™ satisfies both of these properties, allowing coagulation of blood vessels that are larger in diameter and/or located deeper in the skin. The advantage is illustrated by a computer model with results shown in Figure 3 comparing coagulation profiles for the MaxG™ versus a PDL in 300 µm vessels located 300, 600, and 900 µm below the surface of Fitzpatrick Skin Type II skin. Following a single 6 ms pulse of the 595 nm PDL with fluence of 7.5 J/cm^2, only the more superficial vessel at 300 µm is fully coagulated (indicted by reddish brown color); the vessels at depths of 600 µm and 900 µm display either partial or no coagulation, respectively. In contrast, a single 10 ms pulse from the MaxG™ with 36 J/cm^2 results in complete coagulation of all three vessels.

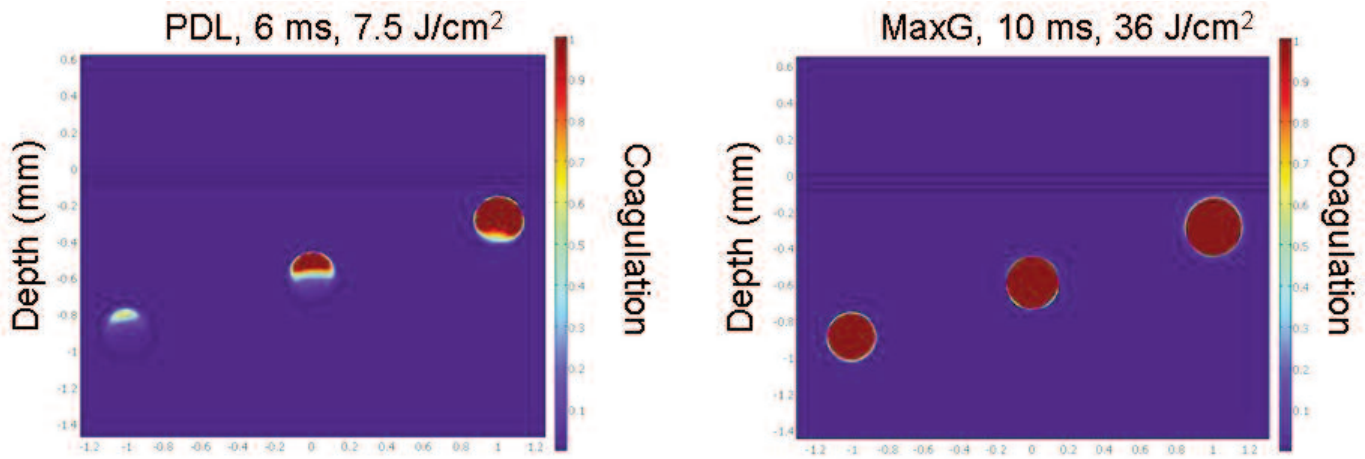

Figure 3: Modeling of blood vessel coagulation with single pulses of PDL and MaxG™ based on ex vivo data. Vessels depicted measure 300 µm in diameter at depths of 300, 600 and 900 µm in skin type II. Coagulation is indicated by red to brown shading.

Dynamic Spectral Shifting

Due to the diversity of vessel sizes within vascular lesions, treatment of the entire lesion in principle should include a range of wavelengths, pulse widths, and fluences. The design of the MaxG™ enables treatment of both deep, large vessels and small, superficial vessels with a dynamic spectral shift that occurs when power density is changed by changing fluence and/or pulse width. In Figure 4, the green curve is the MaxG™ output spectrum for 50 J/cm² and 10 ms (power density = 5 kW/cm²) and the red curve is the spectrum for 80 J/cm² and 100 ms (power density = 0.8 kW/cm²). With this decrease in power density, 30% of the energy in the highly absorbed spectral band (500 to 670 nm) is shifted to the deeper penetrating longer wavelength band (870 to 1200 nm). This decrease shifts energy to wavelengths that reach deeper vessels and more uniformly heat larger diameter vessels.

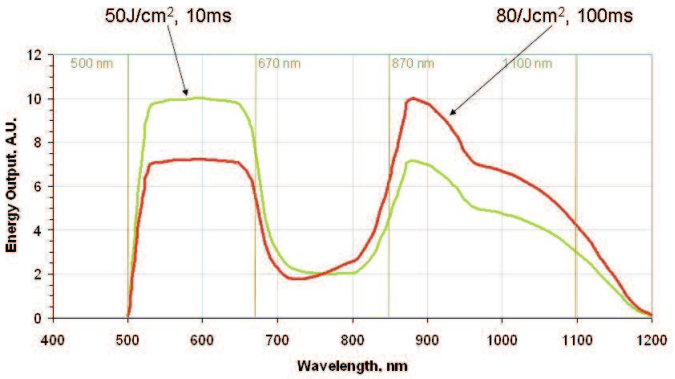

Figure 4: Dynamic Spectral Shift to longer near-infrared wavelengths contributes to more effective coagulation of larger, deeper blood vessels.

It is important to note that the dynamic spectral shift depends on the device's output power pulse structure and peak power. All IPLs shift energy to the longer wavelengths of their spectral range with increasing pulse width or decreasing fluence. However, for a given fluence and pulse width, the greatest fraction of energy emitted from a lamp in the longer wavelength band is provided when the output power is uniform throughout the pulse.

Clinical Case Studies

Methods

Device description:

The MaxG™ is an arc lamp-based handpiece with dual-band spectral output in the 500 to 670 nm range and in the 870 to 1200 nm range for targeting of Q-bands of Hb and melanin and near-infrared bands of Hb and MetHb, respectively. Available pulse widths range from 5 ms to 100 ms and fluence ranges from 5 to 85 J/cm². Treatment area is defined by a 10 by 15 mm sapphire optical window with uniform output fluence and selectable temperature if cooling is desired (Figure 5).

MaxG™ Technical Specifications	
Spot Size	10 mm x 15 mm
Spectral Range	570-600 nm & 870-1200 nm
Pulse Duration	5 to 100 ms
Fluence	5 to 85 J/cm^2
Sapphire Tip Temp.	Room Temperature to 5°C

Figure 5. Palomar MaxG™ Optimized Light Handpiece and Specifications.

Treatment parameters:

Patients received either one or two total treatments with the MaxG™ depending on the severity and extent of baseline facial telangiectasia present. Some patients received split-face treatments with MaxG™ performed on one side and 595 nm PDL (V-Star®, Cynosure, Westford, MA) on the other. Settings for all devices were optimized based on the size of the vessels in the treated area. With the MaxG™, smaller vessels were typically treated with settings of 34 to 40 J/cm^2 and 10 ms pulse widths and larger vessels were treated with 60 to 70 J/cm^2 and 100 ms pulse widths. V-Star® settings ranged from 8.3 to 8.5 J/cm^2 and 10 ms pulse widths using the 10 mm spot with pulse stacking and multiple passes. Selected larger vessels were treated with the V-Star® 7 mm spot at 14 J/cm^2 and 3 ms. The poikiloderma patient received two treatments with the MaxG™ at 30 J/cm^2 and 10 ms.

Results

Our collective experiences thus far demonstrate that MaxG™ treatments were well-tolerated by patients and effective for clearance of vessels of variably-sized diameters and at variable depths within the skin. Patients experienced only minimal discomfort during the treatment and no downtime. As mentioned previously, settings for a given area were determined based on the size of vessels present within the treatment area with lower fluence and smaller pulse widths used for smaller vessels and higher fluence and longer pulse widths used for larger and deeper vessels.

The patient shown in Figure 6 had prominent vessels in both nasal vestibules and along the external lateral portions of the nose. A single treatment with the MaxG™ was performed at a fluence of 34 J/cm^2 and a 10 ms pulse width for the smaller vessels and a fluence of 70 J/cm^2 and 100 ms pulse width for the larger vessels. Immediately after treatment, the vessels were significantly diminished in appearance (Fig. 6, right panel). Skin reactions were limited to localized mild and transient erythema.

Prior to treatment, the patient in Figure 7 had widespread telangiectasia across the nose and chin (left panel images). To compare efficacy of the MaxG™ against PDL, this patient received a single split-face treatment with MaxG™ on the right side and PDL treatment with the V-Star on the left side. Larger vessels on the right side were treated with the MaxG™ adjusted for 70 J/cm^2 and 100 ms and smaller vessels were treated with 34 J/cm^2 and 10 ms settings. PDL treatments on the left side were performed with the 10 mm spot at 8.3 to 8.5 J/cm^2 and 10 ms with

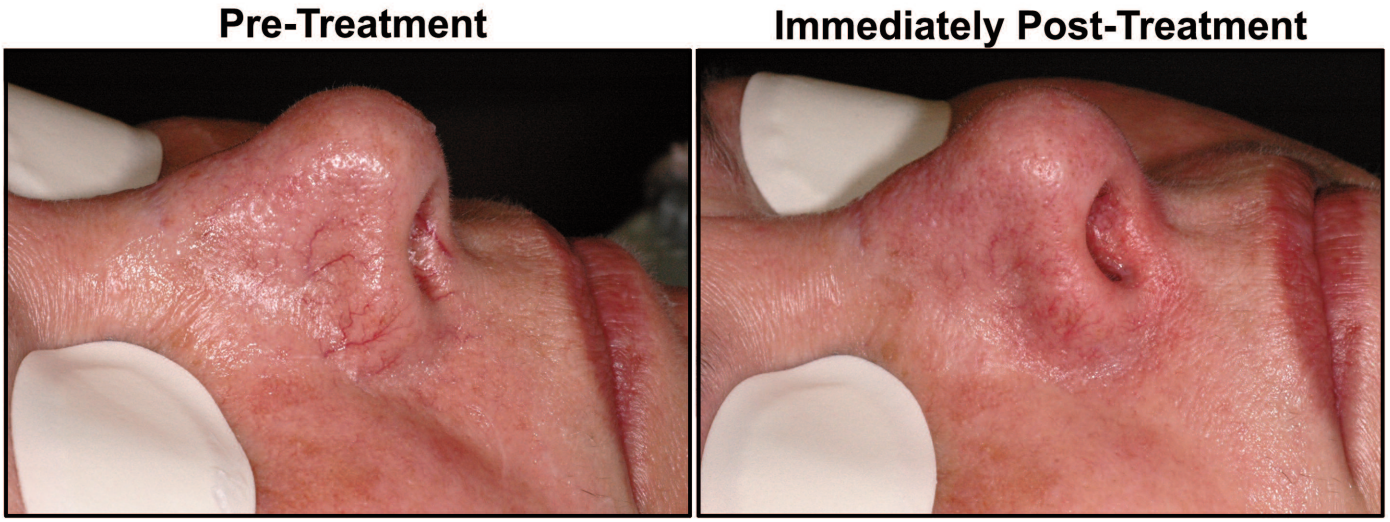

Figure 6. Significant improvements of nasal telangiectasia immediately following a single MaxG™ treatment. (E. Victor Ross, MD)

stacked-pulses and multiple passes. Larger vessels on the left side of the face were selectively treated with the PDL at 14 J/cm^2 at 3 ms. One month after treatment, the MaxG™-treated side displayed better clearance of vessels (75% improvement) as compared to the PDL-treated side (50% improvement) (Fig. 7, right panel images).

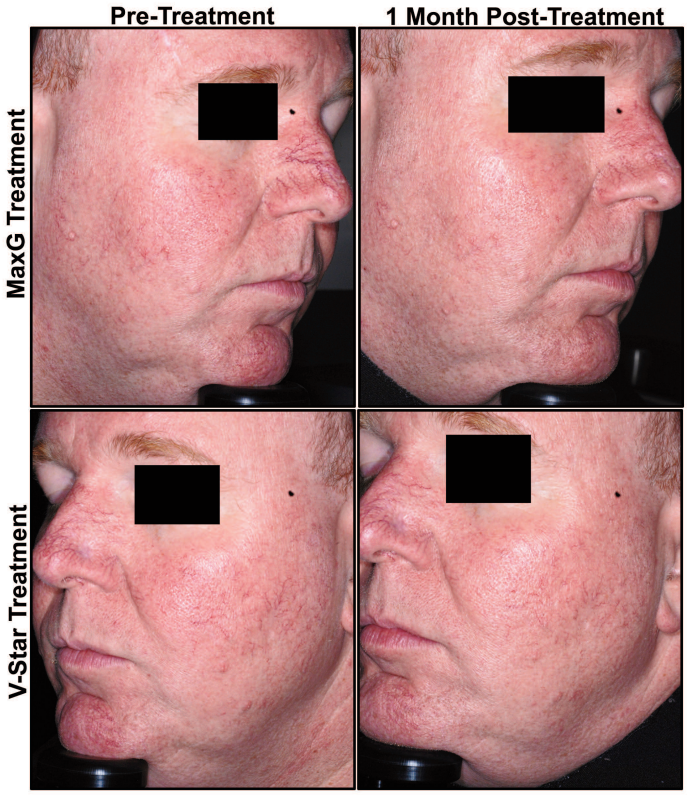

Figure 7. Efficacy of single MaxG™ treatment versus PDL treatment with the V-Star is visible one month after treatment. (Emil A. Tanghetti, MD)

A patient presenting with widespread telangiectasia across both cheeks, nose and chin underwent two MaxG™ treatments one month apart. The first treatment was performed with settings of 40 J/cm^2 and 15 ms for smaller vessels on the forehead and chin, 60 J/cm^2 and 100 ms for the larger vessels and nose, and 20 J/cm^2 at 5 ms on the cheeks. Two months after the second treatment, dramatic improvements of 80-90% were observed bilaterally with vessels significantly reduced in appearance (Fig. 8, right panel images).

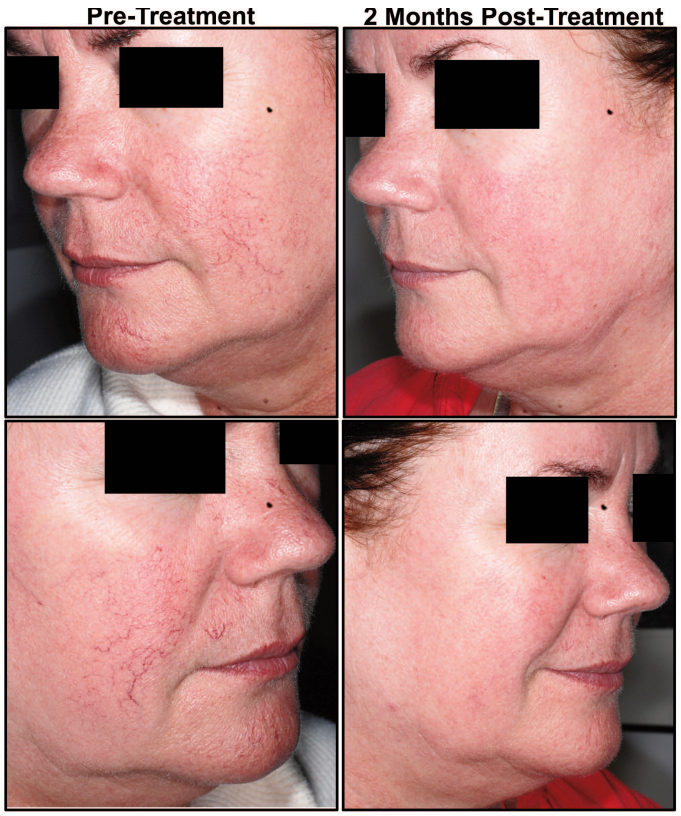

Figure 8. Widespread facial telangiectasia barely discernible two months after two MaxG™ treatments. (Emil A. Tanghetti, MD)

Figure 9 shows another example of clearance of telangiectasia on the chin with the MaxG™. This patient was treated at MaxG™ settings of 38 J/cm^2 and 10 ms and exhibited almost total clearance six weeks after treatment.

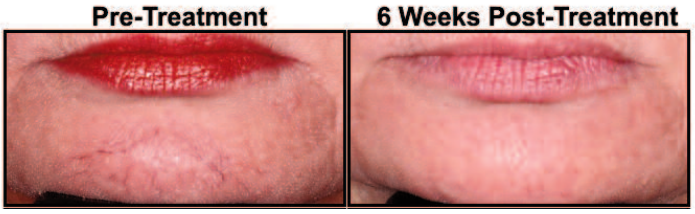

Figure 9. Telangiectasia on the chin considerably reduced following a single MaxG™ treatment. (David B. Vasily, MD)

The pre-treatment image shown in Figure 10 is an example of a patient with Poikiloderma of Civatte on his neck who was previously treated with PDL. The patient was dissatisfied with the PDL results as there was very little change after treatment. The post-treatment image shown in Figure 10 represents the results achieved two weeks after the first MaxG™ treatment, just before the second treatment. MaxG™ treatment settings were 34 to 40 J/cm^2 and 10 ms. After both treatments, appearance of the skin improved by 90% and the patient was extremely satisfied.

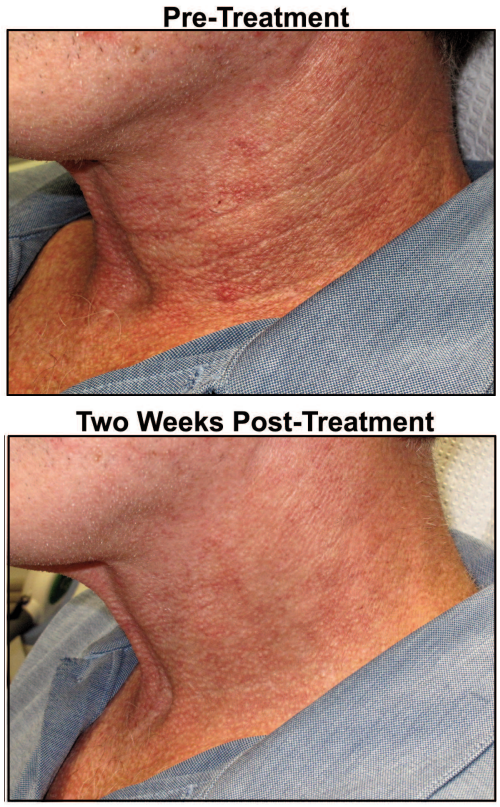

Figure 10. Two weeks after one MaxG™ treatment, poikiloderma on the neck was improved by 90%. (Robert A. Weiss, MD)

Conclusion

One of the challenges of treating vascular lesions is the inherent diversity in the size and depth of the blood vessels. In this report, various treatment settings, appropriate to the size and depths of the target vessels and skin type, were evaluated. Preliminary results demonstrate effective clearance of facial telangiectasia and significant improvement in poikiloderma using this new optimized light source. Consistent with basic principles, the superficial smaller cutaneous vessels responded well to shorter pulse widths (5 – 15 ms) with fluences from 20 to 40 J/cm^2 and larger, deeper vessels were safely treated with longer pulse widths (100 ms) and fluences from 60 to 70 J/cm^2. These findings warrant investigations comparing the MaxG™ to PDL in larger-scaled, randomized studies.

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