Research letter

Q-switched 532-nm laser energy causes significant vascular damage in the capillary plexus: how does this affect laser tattoo removal?

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Dear Editor, Tattoos can be effectively removed using Q-switched and picosecond lasers at four wavelengths: 1064, 755, 694 and 532 nm.[1–4] However, there are two particular problems with the 532-nm line. Firstly, it is well absorbed by the melanin in the epidermis, because of its relatively high absorption coefficient,[5] (μ_{a_mel} = 56 cm^{-1} for typical white skin). Secondly, 532 nm is also strongly absorbed in the oxyhaemoglobin located in the capillary plexus[5] (μ_{a_HbO} = 260 cm^{-1}).

In this small study, I compared the effects of Q-switched pulses using all four of the above wavelengths on nontattooed skin. In particular, the effects of absorption in the blood layer was studied. The results indicate that treatments with 532 nm may be slightly more complicated than first thought.

A Lynton Q+ Ruby/Nd:YAG laser (Lynton Lasers, Holmes Chapel, U.K.) generated the 532-, 694- and 1064-nm wavelengths and a Candela Trivantage Q-switched alexandrite laser (Syneron Candela Corp., Wayland, MA, U.S.A.) was used to generate the 755-nm wavelength. I subjected myself to these tests (Fitzpatrick type 2). Both dorsal forearms were irradiated – the right forearm was treated with all four wavelengths at 10 J cm^{-2} in 3 mm diameter spots, except for the 532-nm wavelength, which was set at its maximum output of 5·5 J cm^{-2}. The left forearm was treated with 532 and 1064 nm at 5·5 J cm^{-2} in 3-mm spots, to compare them directly at the same radiant exposure (fluence).

The 'glass-slide technique' has previously been discussed in 2014.[6] This technique comprises the compression of a tattooed skin site by a standard microscope glass slide through which the laser energy is delivered. Half of the irradiated areas were compressed with a glass slide, whereas the other half were treated directly.

The difference between the sites irradiated with the 1064-, 755- and 694-nm wavelengths and the 532-nm wavelength was marked. The 532-nm sites all instantly displayed the telltale 'whitening' or 'frosting' often seen during laser tattoo removal treatments, much more so than with the other wavelengths. Note that there was no tattoo ink present in any of the above sites and no blood appeared on the skin surface. It is likely that the whitening appearance is mostly as a result of absorption of the 532-nm laser energy by the melanin in the epidermis.[1,7,8]

Twelve minutes after irradiation the initial whitening had faded significantly. However, 3 h after irradiation there was a clear difference between the compressed and the noncompressed spots. The compressed areas showed significantly less erythema and oedema than the uncompressed set. Figure 1 shows the extent of this erythema with a marked rise in the blood-filled spots 48 h after irradiation. Clearly, there is a significant difference between the two sets of spots.

At 48 h there appeared to be only a very marginal difference between the uncompressed and compressed sets of laser irradiated spots with the 1064-, 755- and 694-nm wavelengths. Only the 532-nm spots showed any obvious difference, with significantly more sub-surface vascular damage occurring in the uncompressed skin regions. This is because of the relatively low absorption coefficients for 1064, 755 and 694 nm compared with 532 nm in blood.[5] This indicates that much of the incident 532-nm laser energy is absorbed by the blood layer leaving significantly less energy available to deeper levels, where large amounts of tattoo ink may be located.[1,2,7,8]

The use of 532 nm is commonplace in laser tattoo removal. The cumulative absorption of this wavelength in both melanin and blood reduces the total amount of energy that can reach the reticular dermis, while also mechanically damaging melanin granules and capillary vessels.[2,7,8]

Compressing the skin with glass slides appears to be sufficient to occlude many of the vessels in the superficial capillary

Fig 1. Irradiation spots 2 days after 532-nm laser energy irradiation of nontattooed skin. The upper set of spots were irradiated without the use of the glass-slide compression technique, and the lower set were the compressed areas (5·5 J cm^{-2}, 3-mm diameter).

plexus. By doing so, the 532-nm laser energy absorption in blood is reduced significantly as can be seen in the 'compressed' irradiated spots (Fig. 1), leaving more energy available for deeper targets. Anecdotal evidence from the patients also appeared to indicate enhanced healing rates following treatment using the glass slide method.

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