Clinical Letter

Laser tattoo removal: do we already have picosecond lasers?

Dear Editors,

Nanosecond pulses have been successfully used for decades to remove tattoos [1]. Since 2012, picosecond laser devices have been commercially available for tattoo removal. Theoretically, ultrashort pulse durations should be more efficacious in selectively removing tattoo particles, since the size of tattoo pigment particles generally ranges from 10–100 nm; this implies a thermal relaxation time in the picosecond range [2].

In Victor Ross’s recent commentary “The picosecond revolution and laser tattoo treatments: are shorter pulses really better?” he highlights how little we truly know about picosecond technology for tattoo removal [3]. He also makes clear how conscientious we must be about hasty promises and unrealistic expectations.

Progress in medicine thrives on discussion, and we are confident that a well-balanced exchange of ideas can take place in an academic manner. As a consequence, we wish to catalyze the scientific discussion by raising questions regarding the treatment of tattoos using picosecond lasers.

Before we attempt to answer the question, “Are shorter pulses really better?” we must recall that recently published preclinical results from tissue-mimicking phantoms are not easily translated to human skin [4]. From a biophysical point of view, human tissue comprises complex structures (e.g. blood vessels and sebaceous glands) that induce various laser-tissue interactions (e.g. optical scattering) and thus hinder a direct pulse-dependent comparison of biological processes.

Furthermore, we must realize that the picosecond lasers that are currently available (pulse duration: 350–900 ps) have very little in common with the prototype laser that Victor Ross and colleagues studied 20 years ago (pulse duration: 35 ps) [2]. This is the point of departure, since technically speaking, current devices do not operate in the picosecond range, but in the sub-nanosecond range. Biophysically, the differences in pulse durations are probably too minor to justify hopes for any significant therapeutic differences. The outcome of our randomized controlled trial clearly demonstrated this when we treated all-black tattoos [5], and the clear-cut findings really surprised us. In the meantime, both patients [6] and dermatologists [7] have realized this themselves in clinical practice.

From our perspective, the innovative approach defined by Victor Ross at the time has since been significantly modified. Indeed, the logical development process that would lead towards genuine picosecond lasers will be strongly impeded by “pseudo-picosecond lasers”. A pioneering technology that was inherently good was thwarted before it was even given a chance.

Against this background, what could be the reason for the greater effectiveness (or at least efficiency) of this new generation of commercially available lasers? Why was it that, as discussed in recent articles [8, 9], these devices were more effective with yellow and green tattoos in particular?

All of these questions are related to the respective absorption spectra of the tattoo pigments [10]. The primary issue is that only absorbed photons can have a biophysical effect according to the principles of selective photothermolysis [11]. For instance, none of the laser wavelengths currently in use is sufficiently absorbed by yellow pigments (Figure 1). However, with high light intensities, non-linear effects such as “two-photon absorption” and “optical breakdown” may be relevant here, although all of these complex phenomena have yet to be investigated [12, 13].

On the other hand, if higher intensities and shorter pulses did indeed destroy the pigment particles in the skin with greater efficacy, the removal of green pigments with sub-nanosecond lasers would function more effectively. The conventional nanosecond alexandrite lasers that are presently available for treating green tattoo pigments work with relatively long pulse durations (50–100 ns). The differences in pulse duration and the added therapeutic value which may result are particularly evident in these cases. However, only comparative clinical trials can shed light on this issue. Studies of this kind should be designed with as homogeneous a patient population as possible; trials that include black and multi-colored tattoos as if they were one and the same will not yield valid findings. For safety reasons, it is equally important for laser operators (both in the setting of clinical investigations and in their everyday clinical work) to orient their laser treatment towards visual endpoints (e.g. pin-point bleeding). It is probable that the complications with sub-nanosecond pulses that have been reported to date (in particular scarring and hypopigmentation) were related to fluences that were too aggressive [8, 14, 15].

Last but not least, we should bear in mind that tattoos always consist of many larger and smaller particles, and the smallest of these particles (< 0.5 μm) cannot be identified with light microscopy due to the resolution limit. Whether or not macroscopically evident lightening correlates with the destruction of the very small particles or large particles (or even both) is not known, and a compelling argument cannot be made for or against a particular pulse duration.
This is why we compared the clearance rates in our previous study [5] to see if there was a clinical and statistical difference between the two pulse durations in untreated vs. pre-treated tattoos. We have now assessed these data using the Cochran-Armitage trend test, which yielded no significant differences \( p = 0.8288 \) [sub-nanosecond] vs. \( p = 0.5392 \) [nanosecond]) between the pulse duration or the subgroups (untreated vs. pre-treated; unpublished data).

Despite great efforts, industry has not yet provided ultra-short pulses with an adequate spot size – something we all hope for. We strongly believe that this technology can eventually lead to success once it is optimized, but only if it is not hindered by unrealistic and premature promises made by any number of different parties.

Conflict of interest
None.

References
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