Comparative Evaluation of 15 Laser and Perfluorodecalin Combinations for Tattoo Removal

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Background and Objectives: We present a case of laser tattoo removal treated with 15 different combinations using picosecond 1064 nm, picosecond 755 nm, nanosecond 755 nm, and a fractionated CO_2 laser, both with and without a perfluorodecalin (PFD) patch to ascertain the most effective approach.
Study Design/Materials and Methods: A single lower extremity black tattoo was divided into 15 treatment sections allowing for testing of various laser and PFD combinations. Sectioned treatment was conducted until a treatment superiority was noted.
Results: After two sessions using sectioned combination treatments with a 4-week interval clinically significant results were produced.
Conclusions: The combination of picosecond 1064 nm, picosecond 755 nm, and a fractionated CO_2 laser without the PFD patch showed superior clinical improvement over the other combinations. Lasers Surg. Med. © 2019 Wiley Periodicals, Inc.

Key words: tattoo removal; PFD; tattoo; 755; 1064; CO_2

INTRODUCTION

Nanosecond lasers have been used for laser tattoo removal for decades. Although this procedure is well-tolerated, complete tattoo removal can require over twenty treatment sessions [1,2]. Recently, the picosecond laser has become popular in tattoo removal as it requires lower fluences and fewer treatments [3]. However, complete tattoo clearance can still take 6–10 treatments [4,5].

Perfluorodecalin (PFD) is an inert fluorocarbon that reduces microcavitation bubbles created with laser tattoo removal [3,5]. Current literature suggests that the use of these patches decrease the number of treatments required for complete clinical tattoo removal [3,5,6]. In addition, multiple passes can be conducted at each visit due to the ability of the laser beam to penetrate through the reduced microcavitation bubbles. This approach is based upon our understanding that microcavitation bubbles impede laser penetration.

We present a case of laser tattoo removal treated with 15 different combinations using a picosecond Nd:Yag 1064 nm (PW), picosecond alexandrite 755 nm (PS), nanosecond alexandrite 755 nm, and carbon dioxide 10600 nm (A) lasers, both with and without a PFD patch to ascertain the most effective approach. The combination of picosecond 1064 nm, picosecond 755 nm, and carbon dioxide (CO_2) laser without the PFD patch showed superior clinical improvement over the other combinations.

After obtaining informed written consent, the patient's leg tattoo was divided into 15 treatment sections Figure 1 allowing for testing of various laser and PFD combinations as shown in Table 1. Figure 2 shows the tattoo appearance 4 weeks after the second treatment session and the noted percent improvement is listed in Table 2. The safety controls incorporated in our study included limiting each laser to a single pass regardless of the clinical endpoint. This limitation was added to prevent over treatment when combinations required multiple lasers but maintained for continuity when the protocol required a single laser. The time to transition between lasers was 2–5 minutes. In addition, when a combination included CO_2, the patch was removed before treatment.

DISCUSSION

The clinical endpoint of laser tattoo removal is the presence of immediate dermal whitening in the treated area formed by the microcavitation of a small volume of gas bubbles. This endpoint is thought to restrict optical penetration and limit further precisely controlled laser

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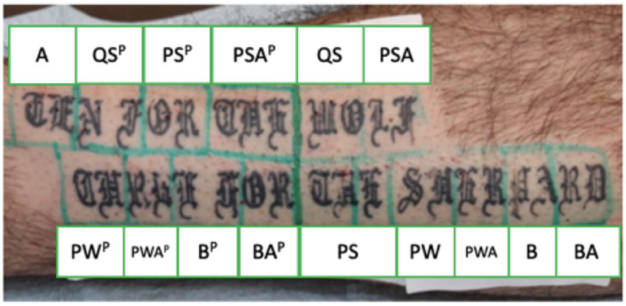

Fig. 1. Pretreatment photo with labels.

treatments into the dermis [4]. Numerous studies have evaluated various techniques which would allow multiple treatments on the same visit by decreasing the dermal whitening. Older approaches employed a 20-minute delay between treatments, however, this is often impracticable in the clinical setting [6–8]. More recent addition of the PFD patch has suggested that multiple laser passes can be completed without additional time delay [3,6]. The PFD patch subsequently has demonstrated safety in allowing multiple treatments on the same visit [8], further validated in darker skin types [9]. Kaminer et al. [8] demonstrated the use of Rapid Acoustic Pulse (RAP) device as another therapeutic option to allow multiple passes in a single visit. The treatment approach is to enable the safest and most efficient treatment regardless of the modality.

Earlier studies by Ho et al report optimal pulse duration for tattoos within the picosecond range [10] in addition to multiple other authors validating the picosecond lasers superiority over the nanosecond [11,12] for laser tattoo removal. Similar to Kato et al. [12], our study did not include a direct comparison with a 1064 ns laser.

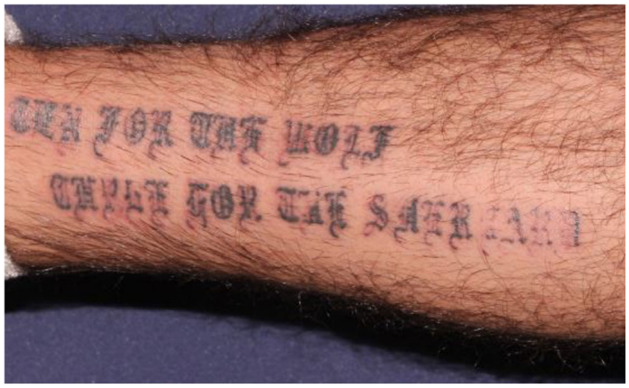

Fig. 2. Combination of 1064 nm, 755 nm, and CO_2 demonstrating greatest improvement

The fluence and spot size selected for our patient was based on settings typically required to achieve the targeted endpoint of frosting without bleeding. Using a grading scale of 10% intervals, blinded dermatologist were asked to grade the clinical improvement using the provided images in Figure 1 and Figure 2. The scores were averaged and recorded in Table 2. After two completed treatments at 4-week intervals, the results were clearly unparalleled; 90% clinical improvement through the use of the picosecond 1064 nm, picosecond 755 nm, and CO_2 laser without the PFD patch. This significant improvement can be explained by the 1064 and 755 nm lasers' superiority at targeting darker pigmented chromophores, such as the black ink in our patient. The 1064 nm has a penetration target depth of approximately 4,000 microns while the 755 nm typically reaches only 3,000 microns but can still target the deeper part of the dermis. After two passes targeting a specific chromophore, we employed an ablative CO_2 laser where depth is limited by absorption of water. We noted that the combination of 1064 and 755 nm allowed for optimum se-

TABLE 1. Treatment Spots Size, Energy Fluences and Combinations

Laser	Spot Size	Duration	Fluence
Nanosecond Alexandrite 755 nm (QS)	3 mm	50 ns	6.6–8.0 mJ
Picosecond 755 nm (PS)	3 mm	750 ps	2.83 mJ
Picosecond 1064 nm (PW)	3 mm	450 ps	4.30–5.50 mJ
Fractionated CO_2 10,600 nm (A)	10 mm	3–5 ms	5% density, 10 mJ

	Patch (P)	No patch
Laser(s)	Label	Label
Nanosecond Alexandrite 755 nm	QS-P	QS
Picosecond 755 nm	PS-P	PS
Picosecond 755 nm + CO_2 10600 nm	PS-A-P	PS-A
Picosecond 1064 nm	PW-P	PW
Picosecond 1064 nm + CO_2 10600 nm	PW-A-P	PW-A
Picosecond 755 nm + Picosecond 1064 nm	B-P	B
Picosecond 755 nm + Picosecond 1064 nm + CO_2 10600 nm	B-A-P	B-A
CO_2 10600 nm		A

TABLE 2. Treatment Combinations With Noted Improvement

Laser(s)	Percent Improvement	Order of Improvement
B	90	1
B-A	90	1
PW-A	75	3
A	55	4
QS-P	50	5
PS-P	50	5
PW-P	50	5
PW	45	8
PS-A-P	40	9
PW-A-P	40	9
B-P	40	9
QS	40	9
PS-A	40	9
PS	35	14
B-A-P	30	15

lective photothermolysis of the dermal pigment. Completing the treatment with CO_2 promoted transepidermal elimination of incompletely treated tattoo.

CO_2 lasers for tattoo removal have demonstrated multiple benefits. In addition to stimulating a more robust immune response by enhancing phagocytic elimination of tattoo particles, it has also shown to improve the healing time and increasing cosmetic results [13–16]. These benefits are secondary to the reduction of blistering potential that may develop following multiple passes or higher energy settings [17]. Furthermore, multiple authors have suggested an additional benefit of CO_2 by enabling transepidermal elimination of tattoo ink [13–16]. Wang et al. provided histologic evidence of transepidermal elimination of tattoo in rats with nonablative [18] in addition to ablative laser use [14]. He reports that epidermal damage to the DEJ leaves a channel promoting transepidermal elimination of necrotic debris and tattoo pigment that begins within the first 24 hours [14]. The use of ablative and nonablative lasers for tattoo removal may best be appreciated in the cosmetic tattoo patient where treatment with a single wavelength may induce the paradoxical tattoo darkening but should also be considered in more complex professional tattoos.

In conclusion, this case highlights a more effective approach to tattoo removal with the combination of 1064 and 755 nm. The addition of CO_2 to this combination did not alter outcomes as no blistering occurred on any treated section. Lastly and contrary to the recent literature, the use of the PFD demonstrated reduced efficacy in this single patient.

REFERENCES

1. Fitzpatrick RE, Goldman MP. Tattoo removal using the alexandrite laser. Arch Dermatol 1994;130(12):1508–1514.
2. Leuenberger ML, Mulas MW, Hata TR, Goldman MP, Fitzpatrick RE, Grevelink JM. Comparison of the Q-switched alexandrite, Nd:YAG, and ruby lasers in treating blue-black tattoos. Dermatol Surg 1999;25(1):10–14.
3. Costner C, Biesman BS. Commentary on safety of perfluorodecalin-infused silicone patch in picosecond laser-assisted tattoo removal. Dermatol Surg 2019;45(2):296–298.
4. Wanner M, Sakamoto FH, Avram MM, et al. Immediate skin responses to laser and light treatments: Therapeutic endpoints: How to obtain efficacy. J Am Acad Dermatol 2016; 74(5):821–833.
5. Feng H, Geronemus RG, Brauer JA. Safety of a perfluorodecalin-infused silicone patch in picosecond laser-assisted tattoo removal: A retrospective review. Dermatol Surg 2019;45(4): 618–621.
6. Shah SD, Aurangabadkar SJ. Newer trends in laser tattoo removal. J Cutan Aesthet Surg 2015;8(1):25–29.
7. Kossida T, Rigopoulos D, Katsambas A, Anderson RR. Optimal tattoo removal in a single laser session based on the method of repeated exposures. J Am Acad Dermatol 2012;66 (2):271–277.
8. Kaminer MS, Capelli CC, Sadeghpour M, Ibrahim O, Honda LL, Robertson DW. Increased tattoo fading in a single laser tattoo removal session enabled by a rapid acoustic pulse device: A prospective clinical trial. Lasers Surg Med. 2019.
9. Vangipuram R, Hamill SS, Friedman PM. Perfluorodecalin-infused patch in picosecond and Q-switched laser-assisted tattoo removal: Safety in Fitzpatrick IV-VI skin types. Lasers Surg Med 2019;51(1):23–26.
10. Ho SG, Goh CL. Laser tattoo removal: A clinical update. J Cutan Aesthet Surg 2015;8(1):9–15.
11. Lorgeou A, Perrillat Y, Gral N, Lagrange S, Lacour JP, Passeron T. Comparison of two picosecond lasers to a nanosecond laser for treating tattoos: a prospective randomized study on 49 patients. J Eur Acad Dermatol Venereol 2018; 32(2):265–270.
12. Kato H, Doi K, Kanayama K, et al. Combination of dual wavelength picosecond and nanosecond pulse width neodymium-doped yttrium-aluminum-garnet lasers for tattoo removal. Lasers Surg Med 2019.
13. McIlwee BE, Alster TS. Treatment of cosmetic tattoos: A review and case analysis. Dermatol Surg 2018;44(12): 1565–1570.
14. Wang CC, Huang CL, Sue YM, Lee SC, Leu FJ. Treatment of cosmetic tattoos using carbon dioxide ablative fractional resurfacing in an animal model: A novel method confirmed histopathologically. Dermatol Surg 2013;39(4):571–577.
15. Ruiz-Esparza J, Goldman MP, Fitzpatrick RE. Tattoo removal with minimal scarring: The chemo-laser technique. J Dermatol Surg Oncol 1988;14(12):1372–1376.
16. Weiss ET, Geronemus RG. Combining fractional resurfacing and Q-switched ruby laser for tattoo removal. Dermatol Surg 2011;37(1):97–99.
17. Au S, Liolios AM, Goldman MP. Analysis of incidence of bulla formation after tattoo treatment using the combination of the picosecond Alexandrite laser and fractionated CO2 ablation. Dermatol Surg 2015;41(2):242–245.
18. Wang CC, Huang CL, Lee SC, Sue YM, Leu FJ. Treatment of cosmetic tattoos with nonablative fractional laser in an animal model: A novel method with histopathologic evidence. Lasers Surg Med 2013;45(2):116–122.