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REVIEW ARTICLE

Laser Tattoo Removal: An Update

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Abstract Tattoo art has been around for thousands of years in every culture and is currently flourishing in all age groups, social classes, and occupations. Despite the rising popularity of tattoos, demand for their removal has also increased. While various treatments, including surgical excision, dermabrasion, and chemical destruction have historically been applied, over the past 2 decades, lasers have revolutionized the way tattoos are treated and have become the gold standard of treatment. To achieve optimal cosmetic outcome of treatment, lasers emitting high energies and short pulses are required to adequately destroy tattoo ink. We review the history of laser tattoo removal, outlining the challenges inherent in developing lasers that can most effectively remove tattoo particles while safely protecting skin from unwanted injury.

Key Points

- Laser treatment remains the gold standard for tattoo removal.
- Recent advances in laser technology have improved clinical outcomes and decreased side effects.
- New treatment strategies utilizing various protocols, concomitant topical agents, and combination lasers may serve to further enhance tattoo removal.

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1 Introduction

Tattoos have existed since ancient times, and their popularity is increasing. According to a survey conducted in 2015 by The Harris Poll, 29 % of US adults have at least one tattoo, an increase of 8 % from 4 years earlier [1]. They are especially popular in younger people, with nearly half of millennials reporting having at least one tattoo [2]. Furthermore, 69 % of those with any tattoos have two or more. Results from the same group indicate that nearly one-fourth of people with tattoos regret getting them. Attempts to remove tattoos date back to ancient Egypt, and numerous techniques have been used throughout the past century, many of which have caused damage to surrounding skin structures, often resulting in scars and incomplete removal of the tattoo itself [3]. Recent advances in laser surgery have led to the development of technologies for tattoo removal that are more efficacious and have fewer side effects.

2 Classification of Tattoos

Professional tattoos are applied by a tattoo artist using a handheld tattoo gun that delivers uniformly deep dense dermal injections of ink. The ink colors are composed of organometallic dyes that are often mixed together to create a wide spectrum of colors. Over time, the ink colors fade as a result of pigment migration into the deeper dermis and to regional lymph nodes via lymphatics. Consequently, older tattoos often appear blurry with indistinct borders, and black inks discolor into blue-gray hues.

Amateur tattoos are applied using handheld needles that deliver India ink or carbon injected at variable depths into the skin. They generally have fewer ink particles and are more superficially placed than professional tattoos. Because of their superficial placement, relative paucity of ink, and lack of multiple colors, amateur tattoos are often easier to remove.

Cosmetic tattoos are often applied freehand by cosmetologists to provide permanent makeup in areas where one would apply eyeliner, lip liner, or eyebrow pencil. The various shades of brown, black, flesh-tones, and red inks frequently contain titanium dioxide and iron oxide pigments that are difficult to remove because of oxidative reactions that darken the ink when irradiated with laser light [4].

Medicinal tattoos are small gray or blue-black markings placed by medical personnel to designate radiotherapy fields or port placement sites. Similar to amateur tattoos, they are typically composed of a sparse amount of India ink or carbon pigment.

Traumatic tattoos result from deposits of foreign particles such as metal, glass, dirt, and carbon-containing particles into the skin following mechanical penetration. These often follow blast injuries or trauma involving road surfaces and can be difficult to remove if they are deeply embedded and/or contain incendiary material.

3 Laser Tattoo Removal

Laser tattoo removal is based on the concept of selective photothermolysis. This theory, first described in the early 1980s by Anderson and Parrish [2], paved the way for laser-based destruction of specific substances in the skin (such as melanin, pigment, water, and oxyhemoglobin) while leaving surrounding tissue intact. Different chromophores (or targets) in the skin preferentially absorb different wavelengths of laser light. The theory of selective photothermolysis states that when a chromophore is heated for shorter than its thermal relaxation time (the time required for the target to lose 50 % of its heat after laser irradiation), selective destruction of that chromophore can occur without damaging surrounding tissue. Since a target's thermal relaxation time is a function of size, larger chromophores have longer thermal relaxation times. Ink particles in a mature tattoo are stored within fibroblasts and macrophages in the skin. These exogenous pigment particles are very small and have very short thermal relaxation times, so very rapid heating is necessary to cause their destruction [5, 6]. Quality-switched (QS) lasers are designed to produce a pulse duration in the nanosecond range (10^{-9} s) with peak energies upwards of 10 J/cm^2 and have been the mainstay of tattoo removal for the past 2 decades [7]. The QS ruby laser (694 nm) was the first such laser to be commercially available [8], followed shortly thereafter by the QS Nd:YAG (1064 nm, frequency-doubled 532 nm) and QS alexandrite (755 nm) laser systems.

Most recently, picosecond (10^{-12} s) lasers have emerged as a more effective and expedient method of treating tattoos since most tattoo pigments have particulate sizes ranging from 30 to 300 nm with relatively shorter thermal relaxation times (<10 ns) [9]. As such, picosecond pulse durations can create greater thermal stress in targeted tattoos [10]. In addition to exerting photoacoustic effects within the targeted tattoos that lead to mechanical dissolution of the ink particles, endothermic steam carbon reactions occur that alter the optical properties of the tattoo inks, producing shell-like structures and reducing their visibility [11, 12]. Computer simulation has verified these distinct mechanisms of picosecond laser tattoo removal [13]. In addition to increasing clinical efficacy, picosecond technology permits lower fluences to be delivered during treatment, which theoretically decreases the risk of adverse effects [14].

3.1 Pre-Operative Considerations

Several factors must be examined prior to selection of the appropriate laser for tattoo removal. It is important to identify whether the tattoo was placed professionally or by an amateur, as the composition of the ink as well as the density and depth of ink placement influence the likely number of treatments required. Professional tattoos typically necessitate the greatest number of laser sessions for effective removal due to their high density and deep dermal placement of organometallic dyes. Older tattoos may require fewer treatments due to partial breakdown of ink particles by the body over time, whereas tattoos containing multiple ink colors often require more than one laser wavelength for removal. Tattoos that contain iron oxide or titanium dioxide (e.g., tan, brown, flesh-colored, or white inks often used in permanent makeup) can permanently darken after laser irradiation, so a test spot should be considered prior to full treatment. Similar precautions should be exercised in tattoos that have received 'color correction' as iron oxide and titanium dioxide inks are also commonly used for this purpose. Patients who experienced allergic reactions upon tattoo placement (local or systemic) can potentially have a relapse with laser treatment, so premedication with an antihistamine and anaphylactic precautions should be exercised in these patients. Tattooed patients with darker skin types should be counseled that hypopigmentation may occur when epidermal pigment absorbs and is destroyed by the pigment-specific laser light.

Patients should be thoroughly counseled on the tattoo removal process to set realistic expectations and to obtain a satisfactory clinical outcome. Risks of treatment should be reviewed and discussed, including incomplete ink removal, overlying skin hyper/hypopigmentation, textural changes, and scarring, as well as the expected post-treatment side effects of transient vesiculation, crusting, and edema. Darker-skinned patients should be forewarned that they are more likely to experience such side effects and complications. Strict sun protection before and after treatment is critical to reduce the risk of complications [15].

The Kirby–Desai scale has been proposed as an aid to help clinicians estimate the likely number of treatment sessions needed for tattoo removal and can be used during patient counseling. Numbers are assigned to six factors: patient Fitzpatrick skin type, tattoo location, tattoo color, amount of tattoo ink, inherent scarring or tissue change, and ink layering. Scores are then tabulated that estimate the number of treatment sessions needed for tattoo removal. Kirby et al. [16] found a correlation coefficient of 0.757 after performing a retrospective review of 100 patients treated with laser tattoo removal and comparing the actual number of required treatments with their Kirby–Desai scores. While helpful, the scale is limited because it does not take into account the type of laser used (e.g., wavelength, picosecond vs. nanosecond pulse duration).

3.2 Laser Selection

It is important to consider the tattoo colors as well as the skin type of the patient when selecting the appropriate laser system for tattoo removal. Certain wavelengths have proven more effective at removing different colors (Table 1).

Black tattoos can be effectively treated with QS 694-nm ruby, 755-nm alexandrite, or 1064-nm Nd:YAG lasers (Fig. 1a, b). Studies comparing these wavelengths in the treatment of blue-black tattoos have shown the QS 694-nm ruby laser to be superior in ink clearance but more frequently associated with long-lasting pigmentary changes [17, 18]. The QS 1064-nm Nd:YAG laser is associated with a lower risk of pigmentary changes and has thus been considered the laser of choice for tattoo removal in patients with darker skin types [19, 20].

When the light emitted from the 1064-nm Nd:YAG laser is frequency doubled, light with a 532-nm wavelength is produced. Orange, red, and yellow inks respond well to this wavelength [18, 19, 21]. Purple ink responds best to the QS 694-nm ruby laser, and green ink is best removed with the QS 755-nm alexandrite laser [21].

Newer studies examining picosecond lasers with these same wavelengths demonstrate enhanced clinical efficacy with fewer treatment sessions (Fig. 2a, b). Brauer et al. [22] reported a series of 12 patients with blue and/or green tattoos, 11 of which achieved >75 % ink clearance after only one treatment with a picosecond 755-nm alexandrite laser. Saedi et al. [23] performed a similar study in 12 patients with dark black or blue tattoos; an average of 4.25 treatments with a picosecond 755-nm alexandrite laser achieved >75 % clearance (the maximum study score). In contrast, studies using QS 755-nm alexandrite and 1064-nm Nd:YAG lasers to treat black and blue-black tattoos showed that an average of eight or nine treatment sessions were needed to obtain >95 % ink clearance [24–28].

A similar study was performed by Bernstein et al. [29] using a picosecond Nd:YAG laser to treat 31 multicolored tattoos. Black, blue, green, and purple inks were treated with the 1064-nm wavelength, whereas red and yellow inks were treated with the 532-nm wavelength. After an average of 6.5 treatments, black pigment showed an average of 92 % clearance, purple ink 78 %, green 65 %, and blue 43 %. The weaker clinical response of green and blue inks mimicked that with QS Nd:YAG lasers [28]. The 755-nm alexandrite wavelength is optimal for treatment of these colors [22–26]. Red and yellow tattoo inks required an average of four to four and a half treatments with the 532-nm wavelength to achieve 80 % clearance.

The successful treatment of yellow ink with picosecond lasers is of particular interest because yellow has historically been a difficult color to treat using QS laser technology. Alabdulrazzaq et al. [30] reported a case series of six patients with tattoos that contained yellow ink that achieved >75 % clearance after 1- to 4-picosecond frequency-doubled 532-nm Nd:YAG laser treatments. The authors postulated that the photomechanical effects of the picosecond technology was more responsible for the ink destruction than was the direct photothermal effect on the targeted yellow chromophore. Their theory was based on in vitro studies demonstrating that the peak absorption wavelengths of yellow ink (440 and 470–485 nm) do not align with the wavelengths of currently available Q-switched or picosecond laser systems [31, 32].

Table 1 Optimal laser wavelengths for different tattoo ink colors

Tattoo ink color	Optimal treatment wavelength (nm)
Black	694; 755; 1064
Green	694; 755
Blue	694; 755; 1064
Red	532
Orange	532
Yellow	532
Purple	694; 755
Tan/nude/white	10,600

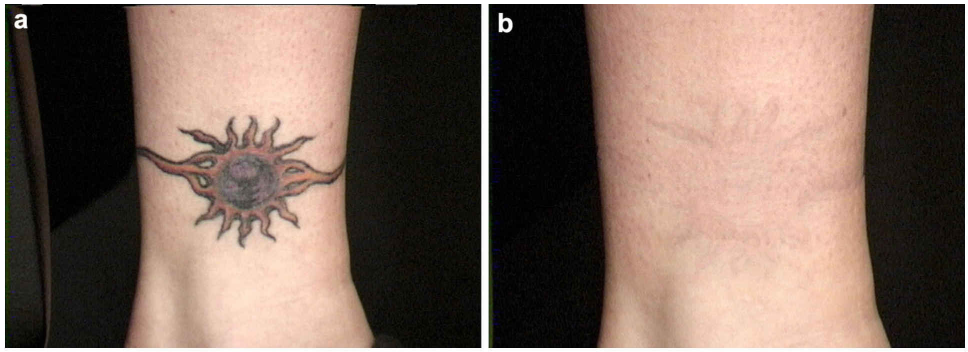

Fig. 1 Professional multicolored tattoo (**a**) before and (**b**) after nine QS 755-nm alexandrite laser and four 532-nm Nd:YAG laser treatments for *black* and *red inks*, respectively

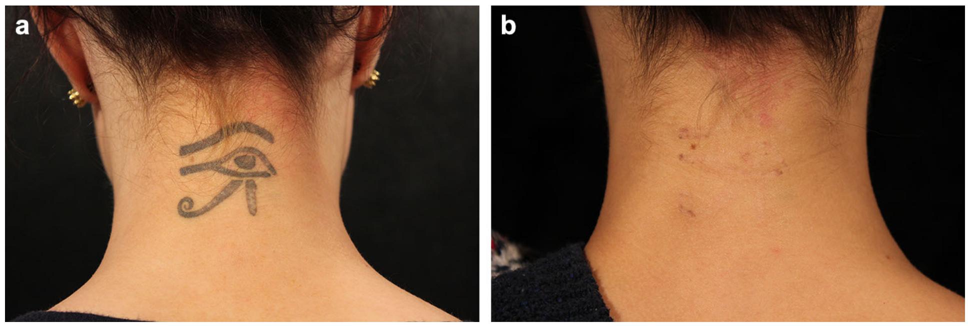

Fig. 2 Professional black tattoo (**a**) before and (**b**) after six picosecond 755-nm alexandrite laser treatments

3.3 Laser Protocol

Topical anesthetic ointment or local infiltration of lidocaine is typically administered prior to treatment. Appropriate ocular protection should be supplied, including wavelength-specific protective goggles for all individuals present in the treatment room as well as intraocular patient eye shields if the tattoo to be treated is located near the orbit.

Laser treatment should be performed using the lowest fluence that achieves the desired clinical endpoint of immediate skin whitening on laser impact (a result of gas formation from rapid tissue heating). Increasing fluences are often required during subsequent treatments as ink density decreases. Care should be taken to minimize pinpoint bleeding when higher fluences are used. One laser pass should be performed over the desired treatment area with minimal (<10 %) overlap of spots. Laser treatments are typically administered at monthly intervals or longer to permit adequate clearing of ink and appropriate skin healing between treatments [15].

Patients should be provided with postoperative instructions that include strict sun protection as well as application of emollient healing ointments and protective bandages for 7–10 days after treatment. Tenderness can be ameliorated with ice. Vesiculation and crust formation are anticipated side effects of treatments.

3.4 Laser Precautions

Pulsed (Q-switched or picosecond) laser treatment should be avoided in tattoos that are suspected of containing iron oxide of titanium dioxide inks (e.g., white, tan, brown, or rust pigments in cosmetic tattoos) because the risk of ink darkening is high [33, 34]. The paradoxical reaction is attributed to chemical reduction of rust-colored ferric oxide to black ferrous oxide or white titanium^{4+} to blue titanium^{3+} dioxide. These tattoos are best removed with an ablative laser system (e.g., CO_2 or erbium) in much the same manner as is used for vaporizing rhytides and atrophic scars [35].

Lower fluences and/or longer laser wavelengths (e.g., 1064 nm) should be used in tattoo patients with dark skin to reduce the risk of hypopigmentation [36].

No laser treatment should be attempted in tattoos with active inflammation (e.g., eczema or psoriasis), infection (e.g., verrucae, herpes simplex), or concomitant disease (e.g., sarcoid). These conditions have been shown to worsen in intensity, slow postoperative healing, and cause scarring in laser-treated tattoos. Q-switched or picosecond laser treatment of traumatic tattoos caused by fireworks is contraindicated due to the risk of particulate microexplosions upon laser impact resulting in cavitation and the development of atrophic scars [37]. Incendiary debris are best vaporized with ablative lasers (e.g., CO_2 or erbium) that do not ignite the incendiary fragments.

Fig. 3 Traumatic tattoos and atrophic scars (**a**) before and (**b**) after one combination ablative CO_2 laser and QS 755-nm alexandrite laser treatments

4 New Treatment Strategies

4.1 Multiple Laser Passes

Recent studies have shown increased efficacy of laser tattoo removal when several laser passes are delivered during each treatment session, necessitating fewer treatment sessions for removal. For additional laser passes to be effective, the ash-white tissue response must resolve between passes. Two methods have been proposed to achieve this: the R20 and R0 methods. The R20 method, first introduced by Kossida et al. [38], investigated single-pass treatment compared with four consecutive passes separated by 20-min intervals (during which time resolution of ash-white tissue response occurs spontaneously). Results showed this approach is safe and more effective than traditional single-pass treatment. The R0 method, which involves the application of topical perfluorodecalin, a liquid fluorocarbon that immediately resolves the ash-white tissue response, was found to be faster and as clinically effective as the R20 treatment [39].

4.2 Concomitant Topical Therapies

In an attempt to enhance the effectiveness of laser tattoo treatment, topical immunomodulators (e.g., imiquimod) have been studied to determine whether tattoo pigment removal could be modified by interfering with tattoo pigment phagocytosis and preventing typical tattoo maturation. Daily application of 5 % imiquimod cream between laser treatments delivered at 4- to 6-week intervals failed to demonstrate an enhanced cosmetic outcome or a reduction in the number of laser treatment sessions required for tattoo clearance [40]. Additionally, adverse effects, including pain, erythema, pruritus, urticarial, scale, burning erosions, and poor wound healing, were significantly higher with the concomitant use of imiquimod.

4.3 Combination Laser Treatments

Fractional laser skin resurfacing (ablative and non-ablative) has been reported to be effective in tattoo removal either as monotherapy or in combination with pigment-specific lasers [41] (Fig. 3a, b). Weiss and Geronemus [42] reported enhanced tattoo ink clearance with shortened recovery and diminished side effects such as blistering and hypopigmentation when fractional resurfacing was used in combination with a QS 694-nm ruby laser. Consistent with their findings, Au et al. [43] reported reduced bulla formation after tattoo treatment using concomitant fractionated CO_2 ablation and picosecond alexandrite laser. Fractional laser resurfacing has also been used to remove traumatic, allergic, and multicolored tattoos [44]. Biopsies in animal models have shown tattoo ink granules located in microscopic coagulation zones that are extruded through the epidermis as necrotic debris several days following either ablative or non-ablative fractionated laser treatment [45, 46].

5 Summary

Laser treatment continues to be the gold standard for safe and effective removal of unwanted tattoos. Recent technologic advances have led to improved clinical outcomes with fewer treatment sessions. Continued research is necessary to further enhance the technology (or combination of therapies) to speed the treatment process and reduce its associated cost.

Compliance with Ethical Standards

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References

1. Larry S. Tattoo takeover: Three in ten Americans have tattoos, and most don't stop at just one. Health & Life. The Harris Poll. http://www.theharrispoll.com/health-and-life/Tattoo_Takeover.html. Accessed 31 Mar 2016.
2. Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science. 1983;220:524–7.
3. Armstrong ML, Roberts AE, Koch JR, Saunders JC, et al. Motivation for contemporary tattoo removal: a shift in identity. Arch Dermatol. 2008;144:879–84.
4. Ortiz AE, Alster TS. Rising concern over cosmetic tattoos. Dermatol Surg. 2012;38:424–9.
5. Kent KM, Graber EM. Laser tattoo removal: a review. Dermatol Surg. 2012;38:1–13.
6. Doukas A, Flotte T. Physical characteristics and biological effects of laser-induced stress waves. Ultrasound Med Biol. 1996;22:1–9.
7. Bernstein E. Laser tattoo removal. Semin Plast Surg. 2007;21:175–92.
8. Reid WH, Miller ID, Murphy MJ, Paul JP, Evans JH. Q-switched ruby laser treatment of black tattoos. Br J Plast Surg. 1983;36:455–9.
9. Keaney TC, Alster TS. Tattoos and beyond: the clinical evolution of picosecond laser technology. Curr Derm Rep; 2016. doi:10.1007/S13671-016-0149-2 **(epub 13 July 2016)**.
10. Luebberding S, Alexiades-Armenakas M. New tattoo approaches in dermatology. Dermatol Clin. 2014;32:91–6.
11. Chen H, Diebold G. Chemical generation of acoustic waves: a giant photoacoustic effect. Science. 1995;270:963–6.
12. Freedman JR, Kaufman J, Metelitsa AI, et al. Picosecond lasers: the next generation of short-pulsed lasers. Semin Cutan Med Surg. 2014;33(4):164–8.
13. Ho DDM, London R, Zimmerman GB, Young DA. Laser-tattoo removal—a study of the mechanism and the optimal treatment strategy via computer simulations. Lasers Surg Med. 2002;30:389–97.
14. Izikson L, Farinelli W, Sakamoto F, Tannous Z, Anderson RR. Safety and effectiveness of black tattoo clearance in a pig model after a single treatment with a novel 758 nm 500 picosecond laser: a pilot study. Lasers Surg Med. 2010;42:640–6.
15. Alster TS. Laser treatment of tattoos. In: Alster TS, editor. Manual of Cutaneous Laser Techniques. Philadelphia: Lippincott Williams & Wilkins; 2000. p. 77–87.
16. Kirby W, Desai A, Desai T, Kartono F, Geeta P. The Kirby-Desai scale: a proposed scale to assess tattoo removal treatments. J Clin Aesth Dermatol. 2009;2(3):32–7.
17. Leuenberger ML, Mulas MW, Hata TR, Goldman MP, et al. Comparison of the Q-switched alexandrite, Nd:YAG, and ruby lasers in treating blue-black tattoos. Dermatol Surg. 1999;25:10–4.
18. Levine VJ, Geronemus RG. Tattoo removal with the Q-switched ruby laser and the Q-switched Nd: YAG laser: a comparative study. Cutis. 1995;55:291–6.
19. Kilmer SL, Anderson R. Clinical use of the Q-switched ruby and the Q-switched Nd: YAG (1064 nm and 532 nm) lasers for treatment of tattoos. J Dermatol Surg Oncol. 1993;19:330–8.
20. Jones A, Roddy P, Orengo I, Rosen T. The Q-switched Nd: YAG laser effectively treats tattoos in darkly pigmented skin. Dermatol Surg. 1996;22:999–1001.
21. Zelickson BD, Mehregan D, Zarrin A, Coles C, et al. Clinical, histologic, and ultrastructural evaluation of tattoos treated with three laser systems. Lasers Surg Med. 1994;15:364–72.
22. Brauer JA, Reddy KK, Anolik R, et al. Successful and rapid treatment of blue and green tattoo pigment with a novel picosecond laser. Arch Dermatol. 2012;148:820–3.
23. Saedi N, Metelitsa A, Petrell K, Arndt KA, Dover JS. Treatment of tattoos with a picosecond alexandrite laser: a prospective trial. Arch Dermatol. 2012;148:1360–3.
24. Alster TS. Q-switched alexandrite laser treatment (755 nm) of professional and amateur tattoos. J Am Acad Dermatol. 1995;33:69–73.
25. Alster TS. Successful elimination of traumatic tattoos by the Q-switched alexandrite (755-nm) laser. Ann Plast Surg. 1995;34:542–5.
26. Fitzpatrick RE, Goldman MP. Tattoo removal using the alexandrite laser. Arch Dermatol. 1994;130:1508–14.
27. Herd RM, Alora MB, Smoller B, Arndt KA, Dover JS. A clinical and histologic prospective controlled comparative study of the picosecond titanium: sapphire (795 nm) laser versus the Q-switched alexandrite (752 nm) laser for removing tattoo pigment. J Am Acad Dermatol. 1999;40:603–6.
28. Ross EV, Naseef G, Lin C, Kelly M, et al. Comparison of responses of tattoos to picosecond and nanosecond Q-switched neodymium:YAG lasers. Arch Dermatol. 1998;134:167–71.
29. Bernstein EF, Schomacker KT, Basilavecchio D, et al. A novel dual-wavelength, Nd: YAG, picosecond-domain laser safely and effectively removes multicolor tattoos. Lasers Surg Med. 2015;47:542–8.
30. Alabdulrazzaq H, Brauer JA, Bae YS, Geronemus RG. Clearance of yellow tattoo ink with a novel 532-nm picosecond laser. Lasers Surg Med. 2015;47:285–8.
31. Gómez C, Martin V, Sastre R, Costela A, et al. In vitro and in vivo laser treatments of tattoos: high efficiency and low fluences. Arch Dermatol. 2010;146:39–45.
32. Beute TC, Miller C, Timko A, Ross E. In vitro spectral analysis of tattoo pigments. Dermatol Surg. 2008;34:508–16.
33. Holzer AM, Burgin S, Levine VJ. Adverse effects of Q-switched laser treatment of tattoos. Dermatol Surg. 2008;34:118–22.
34. Anderson RR, Geronemus R, Kilmer SL, Farinelli W, Fitzpatrick RE. Cosmetic tattoo ink darkening: a complication of Q-switched and pulsed-laser treatment. Arch Dermatol. 1993;129:1010–4.
35. Hamzavi I, Lui H. Surgical pearl: removing skin-colored cosmetic tattoos with carbon dioxide resurfacing lasers. J Am Acad Dermatol. 2002;46:764–5.
36. Grevelink JM, Duke D, Van Leeuwen RL, Gonzalez E, et al. Laser treatment of tattoos in darkly pigmented patients: efficacy and side effects. J Am Acad Dermatol. 1996;34:653–6.
37. Taylor CR. Laser ignition of traumatically embedded firework debris. Lasers Surg Med. 1998;22:157–8.
38. 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;66:271–7.
39. Reddy KK, Brauer JA, Anolik R, Benstein L, et al. Topical perfluorodecalin resolves immediate whitening reactions and allows rapid effective multiple pass treatment of tattoos. Lasers Surg Med. 2013;45:76–80.
40. Ricotti CA, Colaco SM, Shamma HN, Trevino J, et al. Laser-assisted tattoo removal with topical 5 % imiquimod cream. Dermatol Surg. 2007;33:1082–91.
41. Seitz AT, et al. Fractional CO_2 laser is as effective as Q-switched ruby laser for the initial treatment of a traumatic tattoo. J Cosmet Laser Ther. 2014;16:303–5.
42. Weiss ET, Geronemus RG. Combining fractional resurfacing and Q-switched ruby laser for tattoo removal. Dermatol Surg. 2011;37:97–9.

43. 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;41:242–5.
44. Ibrahimi OA, Syed Z, Sakamoto FH, Avram MM, et al. Treatment of tattoo allergy with ablative fractional resurfacing: a novel paradigm for tattoo removal. J Am Acad Dermatol. 2011;64:1111–4.
45. 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;39:571–7.
46. Wang CC, et al. Treatment of cosmetic tattoos with nonablative fractional laser in an animal model: a novel method with histopathologic evidence. Lasers Surg Med. 2013;45:116–22.