Updates on Lasers in Dermatology

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KEYWORDS

• Lasers • Dermatology • Updates • Vascular • Hair removal • Tattoo • Acne • Selective photothermolysis

KEY POINTS

- Lasers can cause ablative or non-ablative tissue damage. When a laser is used to destroy only a single tissue target (or chromophore), it uses selective photothermolysis.
- Since the advent of selective photothermolysis, lasers have played a large role in expanding the capabilities of the procedural dermatologist.
- Selective photothermolysis allows for the precise and targeted treatment of many skin conditions.
- Fractional photothermolysis further expands the ability of procedural dermatologists to improve a variety of medical and cosmetic conditions.
- This review highlights how lasers have evolved since their introduction in the treatment of a variety of dermatologic applications.

INTRODUCTION AND HISTORY

The history of laser medicine starts with Albert Einstein's theory of stimulated emission, introduced in 1916. He postulated that when excited molecules/atoms interact with each other, they are able to stimulate emission of new photons that are of a similar frequency, phase, and direction as the original atoms/molecules. This concept was used by early physicists, including Theodore Maiman, to develop the earliest lasers. In 1963, Dr. Leon Goldman, a pioneer in laser medicine, first used a laser on human skin to treat melanoma. Dr. Goldman also used the continuous wave CO_2 and argon lasers to treat port wine stains.[1] Although the lesions he treated lightened, they had high rates of scarring and complications due to the non-selective nature in which the laser energy was absorbed in the skin. The theory of selective photothermolysis, as elucidated by Drs. John Parrish and Rox Anderson, propelled the use of lasers and forever changed the field of dermatology, and other medical specialties.[2] The concept of selective photothermolysis refers to localized, "selective," destruction of the desired target by combining a selective wavelength that is absorbed by the target chromophore and a pulse duration that is equal or shorter than the thermal relaxation time of the target chromophore. The combination of these 2 notions allows for more precise control of thermal energy and allows for more focused destruction. With the advent of selective

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photothermolysis, the treatment of unwanted pigment, tattoos, and hair became possible. We went from non-selective lasers to early versions of both ablative and non-ablative lasers. Additional applications became possible with the advent of fractional photothermolysis.[3] The laser beam can be applied fully to the tissue, or it can be delivered in a pixilated pattern, called fractional photothermolysis (FP). FP can use both ablative and non-ablative wavelengths of light. This fractional injury is seen in the form of microscopic treatment zones (MTZ) that often form a grid pattern of injury on the skin. This allows for the sparing of normal tissue between each MTZ, and a shorter treatment recovery time. Interestingly, up to 50% of the tissue can be destroyed during FP without causing scarring or necrosis. By creating multiple laser holes in the skin, FP has been also used as a new method for drug delivery. This expansion continues with advances in technology and technique. Herein, we provide a review of updates in lasers as they are used in dermatology to treat a variety of medical and aesthetic conditions.

Vascular Lasers

One of the first applications of selective photothermolysis in dermatology was to help treat port wine stains.[4–6] Initially, the argon laser was introduced in the 1970s and was one of the first lasers used to treat port wine birthmarks (PWBs). These lasers functioned at a wavelength of 488 to 514 nm and although this wavelength is absorbed by hemoglobin in red blood cells, the thermal damage was not confined to the blood vessels but spread to adjacent tissue structures. Argon laser treatments caused significant scarring and were not an ideal treatment option for PWBs.[7] The pulsed deliver of the same wavelengths addressed these shortfalls and had fewer side effects, by allowing heat to diffuse strictly on the vessels. Earlier versions of the pulsed dye laser were 577 nm and worked well to selectively target blood vessels in port wine stains without significant thermal damage to the surrounding structures of the skin. However, as our understanding of laser-tissue interactions improved, so did technology. More recently, newer versions of the pulsed dye laser have larger spot sizes and a variety of pulse durations. This allows the dermatologic surgeon to treat lesions in purpuric and non-purpuric approaches. Having the option of larger spots sizes and more precise variation in pulse durations is advantageous because it allows for the treatment of certain vascular conditions, such as rosacea, with less purpura and downtime. The most recent previous version of the pulsed dye laser allowed for the delivery of a maximum of 8 J with a maximum spot size of 12 mm. The newer pulsed dye laser has a larger spot size of 15 mm, allowing a maximum delivery of 12 J, an almost 50% increase as compared to the previous generation. This is important, as larger beam sizes allow for greater photon densities to be delivered at a greater depth, thus allowing more energy delivery to larger, deeper vessels in the skin. Additionally, the deeper penetration of energy allows bypass of epidermal melanin, reducing the risk of postinflammatory hyperpigmentation (PIH). The larger spot size also allows for broader surface area coverage and perhaps quicker treatment time. In 2021, Sodha and colleagues found that the larger spot size and safe delivery of increased energy allowed for shorter and fewer treatments to clear a port wine stain in 7 patients aged 10 to 38 years.[8] Even though the pulsed dye laser is considered the gold standard in PWB treatment, other various wavelengths of light have also been demonstrated to be useful in treating PWBs, especially those that are resistant to 577 to 595 nm wavelengths (**Fig. 1**). One reason lasers in the 577 to 595 nm wavelength may not be able to clear or even lighten a PWB is due to the depth of the penetration. PWBs are made of vessels of various depths. To reach deeper dermal vessels, longer wavelength lasers have been used such as the 755-nm alexandrite, 810-nm diode, and 1064-nm neodymium (Nd):yttrium-aluminum-garnet (YAG) lasers.[9] Additionally, in 2001, Barton and colleagues described how the combined effects of both green visible light and infrared wavelength light worked better to coagulate cutaneous blood vessels.[10] They described a synergistic phenomenon in which green light changes the constituents of blood to form methemoglobin, which then is better absorbed by infrared wavelengths. This led to the development of several laser systems that combined both wavelengths including a 595/1064 combination device, a 532/1064 device, and more recently, a 532/1064 device with variable sequential pulsing and cryogen spray cooling. Eichenfield and colleagues demonstrated the clinical effects of combining the 532 nm with 1064 nm wavelengths in treating vascular malformations in a cohort of 23 patients. They showed that combining these 2 wavelengths, 532-nm potassium titanyl phosphate to target superficial components and long-pulse 1064-nm Nd:YAG for deeper components, can safely and effectively treat both capillary venous and venous malformations.[11] However, the authors do not recommend treating capillary malformations and arterial vascular entities with 1064 nm, as the wavelength can often penetrate deeper and inadvertently select for deeper arterial

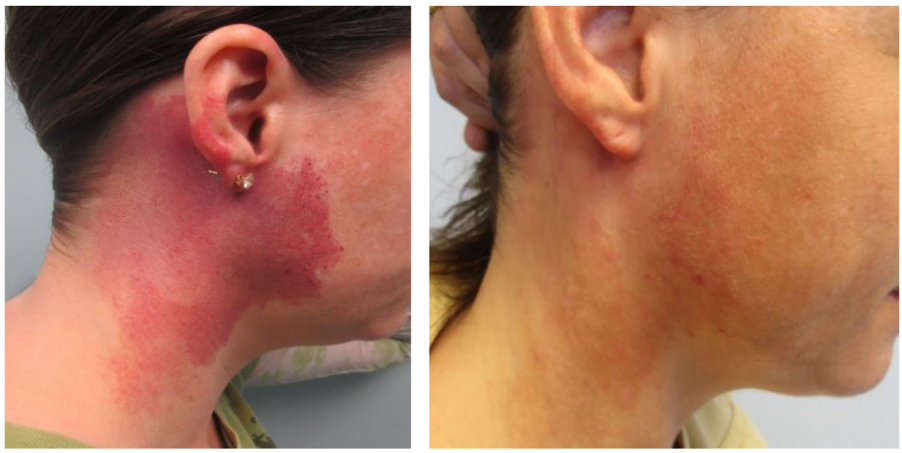

Fig. 1. Before and after 4 treatments of a port wine stain in an adult patient with a 595-nm pulsed dye laser. (*Courtesy of* Dr. Omar Ibrahimi.)

branches, leading to complications. Additionally, caution is also advised when treating venous entities with the 1064 nm wavelength as well, as the 1064 nm wavelength is more selective for oxyhemoglobin than it is for deoxyhemoglobin; therefore, sticking to the 755 nm wavelength is advised when treating older, more hypertrophic PWBs. Lastly, PWBs may be made of vessels of various diameters, requiring various pulse widths. A recent 532 nm/1064 nm combination device includes variable sequential pulsing with both sub-milli and sub-micro pulse modes, allowing for absorption by a broader size range of vessels.

In addition to revolutionizing how we treat vascular birthmarks, vascular lasers have also become standard of therapy for several other applications including angiomas, venous lakes, erythematous scars, and rosacea (**Fig. 2**).

CLINICS CARE POINTS

- Port wine stains typically take numerous treatments to lighten and complete removal is often challenging. Treatment should be initiated as early as possible as infants tend to respond better than adults.
- Treating within the bony orbit required the use of eye shields to protect the retina. While hemoglobin is the target chromophore, melanin is present in the retina and it also absorbs energy from most vascular lasers.
- Conditions such as rosacea can be treated with non-purpric settings and typically entail minimal downtime but require a series of treatments to bring about improvement.

Hair Removal

The most popular cutaneous application of laser energy is hair removal.[12] Laser hair removal (LHR) was first reported using a normal mode ruby laser and histologically showed selective destruction of the follicular shaft and epithelium.[13] The mechanism of action for LHR is unique in that the chromophore in LHR is the melanin found in the hair shaft, however, the intended target are the follicular stem cells found in the "bulge" and "bulb" of the hair shaft. Because of the small distance between where the melanocytes and stem cells are located, the extended theory of selective photothermolysis is used to fully describe the mechanism of action of laser hair removal. This theory suggests that there is some degree of diffusion of heat from the chromophore (melanin) and the desired target (stem cells).[14]

It is important to note that all devices for LHR target melanin as a chromophore and melanin is also present in the dermal–epidermal junction. Thus, some laser energy is absorbed into the epidermis and poses risk for adverse events such as burns, scarring, and postinflammatory dyspigmentation. A variety of methods for skin cooling have been developed to cool and protect the epidermal melanin and is a critical element in safely performing LHR procedures, especially when performed on darker Fitzpatrick phototypes. Cooling of the skin helps efface epidermal damage while also allowing treatment at higher fluences.[15] Most laser hair removal systems have built in cooling systems that act as heat sinks and help remove heat from the surface, either in the form of contact cooling with a cold sapphire or dynamic cooling with cryogen spray.

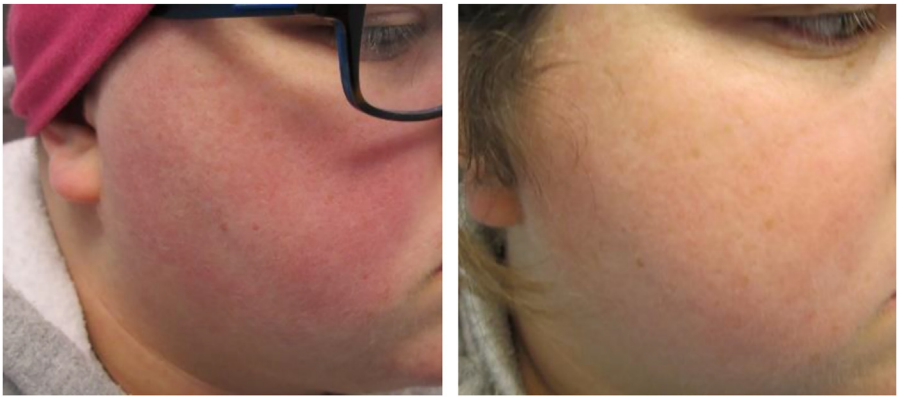

Fig. 2. Before and after 4 treatments for rosacea with a 595-nm pulsed dye laser. (*Courtesy of* Dr. Omar Ibrahimi.)

In addition to cooling, spot size is an important parameter in laser hair removal. Larger spot sizes allow more photons to be delivered to the target due to less scatter. Smaller spot sizes allow more scattering of photons. With less scatter and larger surface area covered, also minimizes the number of pulses required to cover a treatment area, thereby reducing treatment time. In one double-blinded, randomized controlled study, when all other treatment parameters are kept identical, an 18 mm spot size, as compared to a 12 mm spot size, led to 10% more reduction in hair counts.[16]

Today, there are multiple wavelengths available for LHR including 755 nm, 800 to 810 nm, and 1060 to 1064 nm (**Figs. 3** and **4**). Although long-pulsed ruby lasers are not commercially available in the United States, in one study, a majority of nearly 200 patients had >75% hair loss at the 6-month follow-up after 4 treatments.[17] Alexandrite and diode lasers, which are commercially available in the United States, showed similar results at about 76% to 84% at the 18-month mark for the Alex laser and 84% hair reduction at the 12-month mark for the Diode laser.[18,19] Although long-term hair reduction data are less convincing for the long-pulsed Nd:YAG laser at 1064 nm than other devices, this is thought to be the best wavelength for Fitzpatrick skin phototype V and VI.[20] A 1060-nm diode laser has also been recently reported to be safe and effective for LHR of all skin types, including darkly pigmented individuals.[21] The 1060 and 1064 nm wavelengths have much lower peak absorbance by melanin, making it less likely for epidermal melanin to be heated, and thus decreasing the risk of complications (see **Fig. 3**). Although intense pulsed light (IPL) is sometimes used for hair removal, IPL uses a flashlamp with broad band cutoff filter at different wavelengths that may not be as selective and deliver as much fluence as LHR. Therefore, one has to be careful, especially in treating darker skin types. Two studies that provide head-to-head comparison between the long-

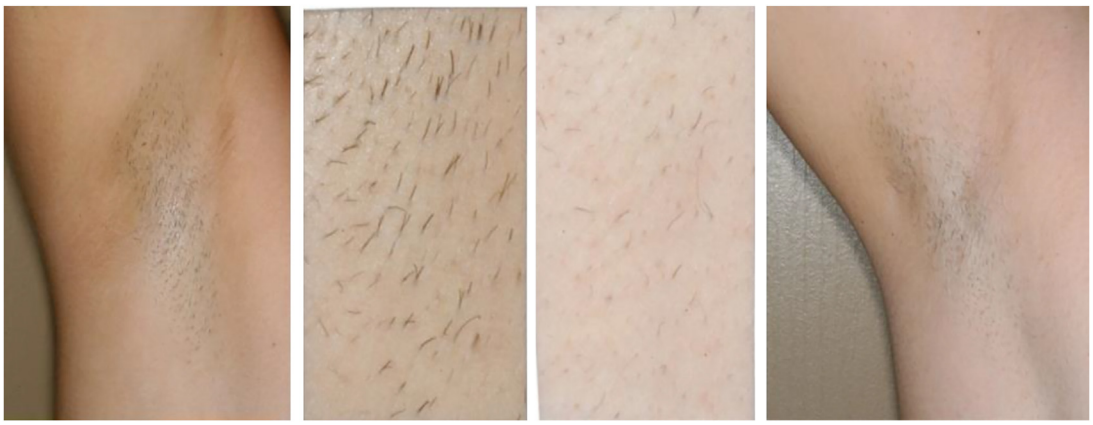

Fig. 3. Before and 15 months after 3 laser hair removal treatments in the axillae of a patient with a 1060-nm device. (*Courtesy of* Dr. Omar Ibrahimi.)

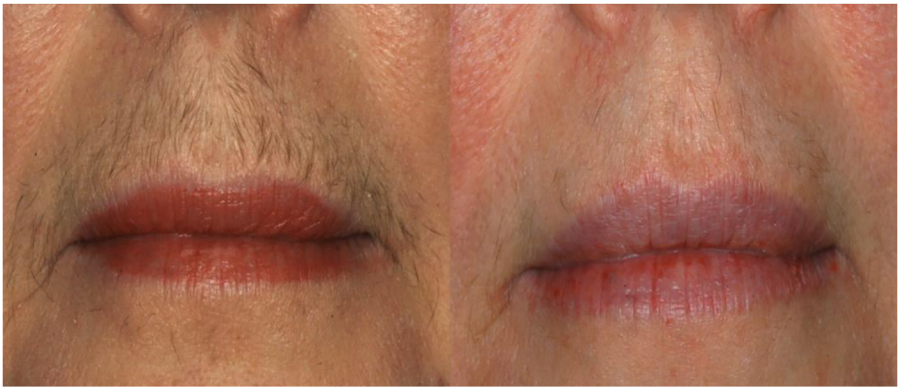

Fig. 4. Before and after 3 treatments of laser hair removal of the upper lip with a 755-nm device. (*Courtesy of* Dr. Omar Ibrahimi.)

pulsed Alexandrite and Nd-YAG found results from an IPL to be inferior.[22,23]

Prior to any treatments, it is important that clear expectations are set for the patient, and it should be communicated that LHR does not provide 100% *permanent* hair removal. Instead, there will be a significant permanent reduction in the growth of hair but there will be a few hairs which persist, though they are on average, 19% thinner and 10% lighter in color.[24] To help combat this problem, newer hair removal laser devices have the ability to deliver several long duration pulses in rapid succession such that the hair does not have the time to disperse the heat between pulses. The short delay between pulses is shorter than the thermal relaxation time of the melanin in the hair follicle being treated, and thus the hair does not cool off between the pulses, allowing for more damage to the hair follicle (patent). Although lasers in the 694 to 1064 nm range became the most effective way to achieve long-term hair removal, recently there have been devices that combine all 3 wavelengths for laser hair removal. In 2020 and 2021, 2 retrospective cohort studies showed that a simultaneous triple wavelength laser device is safe and effective.[25,26] The simultaneous triple-wavelength devices were shown to be safe in skin types III toV as well.[27,28] There are several devices that not only blend various wavelengths but also help deliver pulses at a programmed percent overlap. Lastly, along with advances in the technology itself, there have also been advances in procedure safety. In 2016, a group out of Massachusetts General Hospital used gas chromatography–mass spectrometry to analyze plume after laser hair removal and found several carcinogenic compounds within the plume and thus concluded that the plume should be considered a biohazard, warranting the use of smoke evacuators, ventilation, and respiratory protection.[29] In 2018, Ross and colleagues showed that cold sapphire skin cooling suppressed plume from laser hair removal as compared to cryogen spray cooling, possibly eliminating the need for smoke evacuators, ventilation, and respiratory protection if using this method of cooling that required contact with a gel.[30] Nowadays, several newer lasers have built in smoke-evacuators to enhance user and patient safety.

CLINICS CARE POINTS

- Patients should be counseled that on average 15% of hairs will be removed with each laser treatment and treatments should be spaced about 6 to 8 weeks apart to allow hairs to properly cycle through the various growth phases.
- Avoid treating within the bony orbit, including the glabella, due to the high risk of retinal damage (the retina contains melanin dense tissues).
- Be careful to keep the handpiece perpendicular over convex and concave surfaces to ensure that the laser energy and any skin cooling methods are being delivered uniformly and will help avoid complications.

Tattoos

An important parameter within the theory of selective photothermolysis is laser pulse duration. Unlike the lasers used for vessels and hair removal, which are on the order of milliseconds, lasers designed for tattoo removal have optimal pulse duration in the order of picoseconds (**Figs. 5** and **6**). This is because the chromophore that is targeted in tattoo removal is tattoo ink, which is 10-

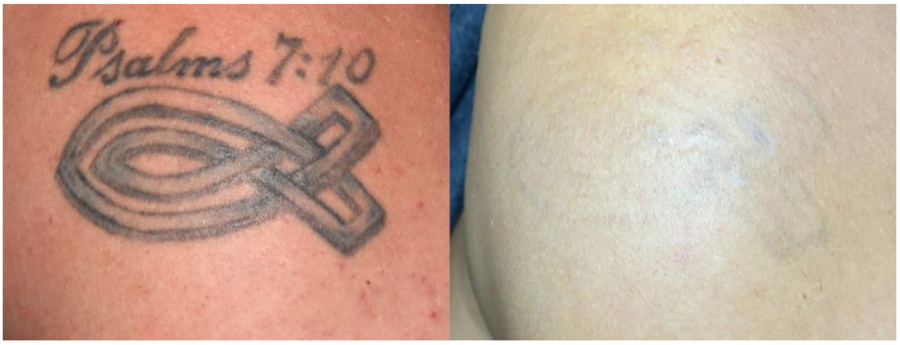

Fig. 5. Before and after 22 laser tattoo removal treatments with a 1064-nm picosecond device. (*Courtesy of* Dr. Omar Ibrahimi.)

4 to 10-3 mm wide. Based on this size, the pulse duration should be on the order of picoseconds. In 1998, Ross and colleagues tested this theory by comparing nanosecond domain pulses with picosecond domain pulses to remove black ink tattoos.[31] There was significantly more lightning with the picosecond laser pulses than the nanosecond laser pulses. In vitro studies show that picosecond lasers can remove smaller tattoo ink particles using lower fluences, and fewer number of treatments.[32] More recent human studies have corroborated this data and showed that, at matched fluences, picosecond lasers have been able to remove tattoos statistically more significantly than nanosecond lasers.[33,34] Today, picosecond lasers are considered the gold standard in tattoo removal. Conversely, long-pulse lasers and particularly IPLs, which also run in the millisecond domain, should not be used for tattoo removal, with a potential to cause severe scars.

In addition to pulse duration, successful tattoo removal depends on correct selection of wavelength. Colors in tattoo inks absorb the most visible light in the range of their complementary color. Based on this complementary matching of colors, green ink, for example, will be best removed by a laser that emits red light (694 nm). Some colors such as yellow and orange are more difficult to remove because there are few to no lasers on the market that operate in their complementary color ranges (400–520 nm).

However, tattoo removal remains a challenge even when using a picosecond laser in the correct wavelength range. There have been newer methods and technological developments that can be combined with picosecond.[35] A fractional ablative laser will allow extrusion of ink through the micro-columns that the laser creates.[35] Gas bubbles that are created during treatment with a picosecond laser can also escape faster through the micro-columns and thus allow for repeat passes. A recent study showed that the micro-focused arrays of a fractional nanosecond or picosecond laser allow for fewer treatments and more passes within 1 treatment session.[36] Alternatively, one can also do the fractional picosecond laser

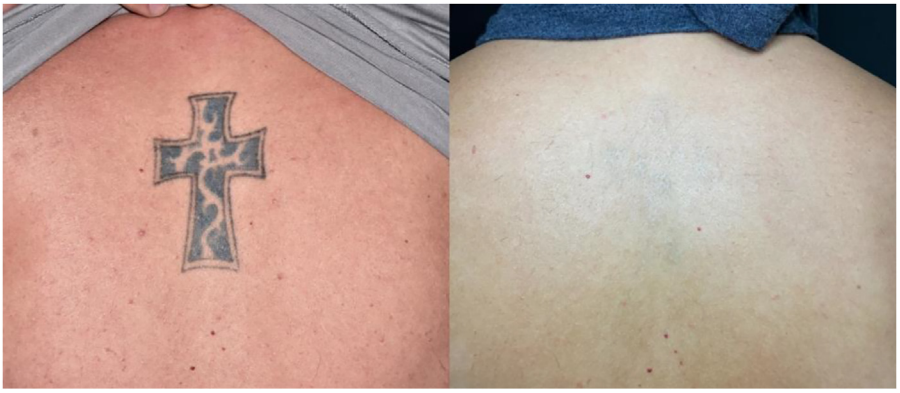

Fig. 6. Before and after 22 laser tattoo removal treatments with a 1064-nm picosecond device. (*Courtesy of* Dr. Omar Ibrahimi.)

after doing picosecond tattoo removal. Sirithanabadeekul and colleagues showed that this method allowed 84.6% of tattoos to be 50% cleared after multiple treatments versus 69.2% with picosecond laser alone.[36] Another shortcoming of tattoo removal has been that multiple treatments are required, even with picosecond lasers, to successfully lighten or clear a tattoo. In 2012, Kossida and colleagues reported that 4 passes of a Q-switched laser, separated by 20 minutes, was superior to a single pass treatment.[37] A waiting period of 20 minutes was necessary to allow the gas bubbles formed during picosecond laser treatment to fully dissipate before another pass of picosecond laser energy can be absorbed. This method of repeating treatments 20 minutes apart was dubbed the "R20 method." Given that the R20 method showed more clearance with a single pass, but took more time, the perfluorodecalin (PFD) patch was re-purposed for use in tattoo removal. PFD patches are silicon patches that contain fluorocarbon in them, a potent gas dissolver. Using this patch allowed for multiple laser passes in 1 treatment session without having to wait 20 minutes between sessions. PFD patches were shown to have other benefits as well, including limits in the increase of skin temperature during laser treatment.[38]

CLINICS CARE POINTS

- Laser tattoo removal requires matching an unwanted tattoo ink color to its complementary laser wavelength.
- Picosecond lasers are an improvement that has led to faster and better clearing of tattoos but most tattoos still fall short of complete clearance.
- Be cautious when treating a multicolored tattoo in the skin of color patient as melanin is targeted by many of the laser wavelengths used and can result in significant depigmentation and hypopigmentation.
- Newer, professional, and single ink color tattoos (ideally black) are easier to fade with laser treatments.
- The use of fractional ablative, repeat treatments, PFD patches, and rapid acoustic pulses may enhance and speed up laser tattoo removal.
- Never use a long pulse laser or an intense pulsed light (IPL) for tattoo removal, even if the device has the right wavelength for the color of the tattoo.

Pigmentation/Pigmented Lesions

Another way selective photothermolysis of melanin can be used in dermatology is for treating pigmented lesions. There are a wide variety of pigmented lesions in dermatology, and they vary in the amount of melanin deposition and/or increased density of active melanocytes. Common pigmented conditions that may be treated by lasers in dermatology include PIH, melasma, lentigines, café au lait macules, and nevus of Ota. There are occasional reports of lasers being used to treat more diffuse disorders of hyperpigmentation, including erythema dyschromium perstans, lichen planus pigmentosus, and drug-induced hyperpigmentation.[39–41]

Laser technologies have been extensively used to treat these benign epidermal and dermal pigmented lesions over the past 20 years since Anderson and colleagues first described the use of the Q-switched (QS) Nd: YAG laser to treat cutaneous pigmentation.[42] Although Q-switched lasers did provide some improvement in pigmented lesions, they produced high rates of PIH in certain skin types.[43,44] Picosecond pulses, however, are able to generate higher peak temperatures in a short amount of time, allowing for less unwanted heat diffusion. With picosecond pulses, lower fluences could be used for effective treatments, reducing the chances of PIH. Thus, more recently, picosecond lasers have played a huge role in our ability to treat individual pigmented lesions.[45] Many different wavelengths in the picosecond pulse duration range have been reported to safely treat pigmented lesions, ranging from 532 to 1064 nm.[46–49] Although picosecond lasers work well for individual lentigines, there have been several advances in near infrared wavelength resurfacing devices, which have allowed us to improve larger areas of pigmentation, including photodamage and even melasma. Since the introduction of the dual 1550/1927 nm fractional non-ablative laser, several variations in non-ablative technology have been released including the dual 1440/1927 low power diode laser, and the 1927 thulium laser. Each of these varies in power and downtime but can be paired with picosecond lasers for synergistic effects in treating pigmentation.

CLINICS CARE POINTS

- A proper evaluation of the pigmented lesion is needed prior to any laser treatments, ideally with dermoscopy.

- Lasers are not a first-line treatment for melasma. Melasma should be carefully evaluated and treated with first-line standard of care treatments to help stabilize pigment formation.

Scars

Lasers have also revolutionized how we treat scars in the past decade. In brief, injury to the skin triggers a multiphase healing process categorized into 3 main phases: inflammatory, proliferative, and remodeling. The proliferative phase occurs about 1 week post injury and is characterized by new vessel formation, fibroblast growth, and the creation of new extracellular matrix. During the remodeling phase, new collagen is being laid down, all while the scar is slowly decreasing its cellularity and vascularity to eventually build a mature scar.[50] In this long and tightly orchestrated chain of events, much can go wrong. Prolonged erythema, for example, can be an early sign of a pathologic scar. Vascular devices are often used to treat erythematous scars. Although we do not know the exact mechanism by which vascular devices are thought to help, there is some thought that the laser tissue interaction sets forth a cytokine cascade that triggers scar remodeling rather than simple vascular destruction.[51] Besides erythema, scar texture and thickness are also treatable via lasers. Fractional lasers, both ablative and non-ablative, are crucial in treating the spectrum of scars from atrophic to hypertrophic—the fractionated injury allows for remodeling of the scar without delivering too much thermal heat. Additionally, fractional lasers create microscopic treatment zones with cuffs of thermal coagulation. These channels are held open, due to the cuff of coagulation, and allow for subdermal delivery of topicals via a concept termed "laser-assisted drug-delivery""(LADD). Ablative fractional lasers are a landmark treatment for hypertrophic scars in the last 10 to 15 years. In one consensus paper, 75% of the respondents use both a vascular and ablative fractional laser with or without LADD for thickened and/or contracted scars.[52] These lasers have been noted to allow improvement of texture, color, pliability, thickness, and quality of life.[53–56] Non-ablative fractional lasers have also shown to improve texture, specifically in hypertrophic and atrophic burn scars.[57,58] (**Fig. 7**).

CLINICS CARE POINTS

- Vascular lasers and fractional lasers (ablative and non-ablative) can treat a variety of scars with success.
- Be careful about laser parameters when treating scars. Treating at lower densities and higher pulse energies (depth) is safer for scars.
- It is never too late to initiate laser treatment for scars, though earlier treatment is better. Lasers can be implemented as early as right after wound formation. Complete epithelialization is not necessary to initiate laser treatment of scars.
- Although ablative fractional lasers can be used in darker skin types, one must tread with caution. In some circumstances, such as non-hypertrophic scars, non-ablative fractional lasers may be preferred over ablative to decrease the risk of PIH.

Acne

One of the newest applications of selective photothermolysis is for acne. Acne is one of the most

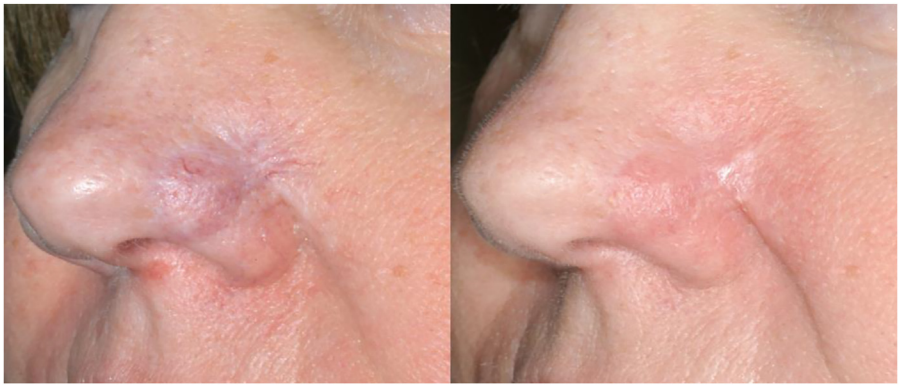

Fig. 7. Before and 6 weeks after a single fractional ablative CO_2 laser treatment for a scar. Note the improved texture, color, and thickness in certain areas. (*Courtesy of* Dr. Omar Ibrahimi.)

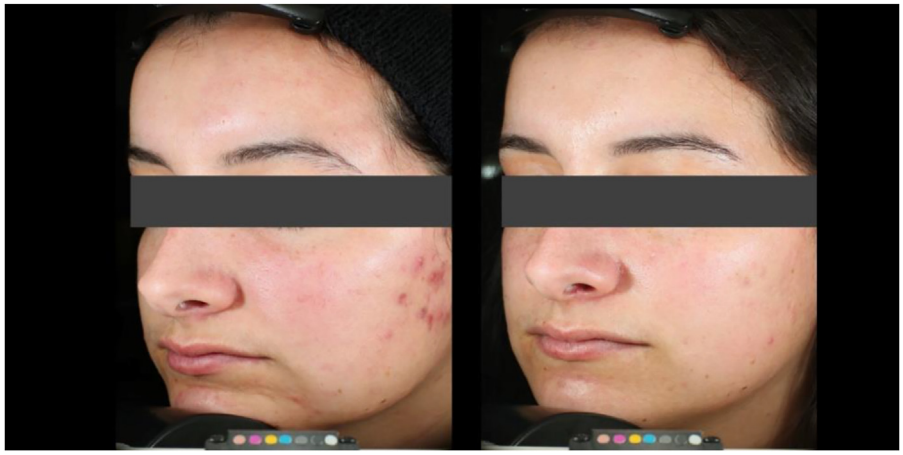

Fig. 8. Before and 24 months after a series of 4 monthly treatments with a 1726-nm device. (*Courtesy of* Dr. Emil Tanghetti & Accure Acne, Inc.)

common skin conditions worldwide, disproportionately affecting younger individuals. Although it is a very common condition, cure is difficult. Isotretinoin is an excellent oral option, but poses several side effects, compliance issues, and a minimum 6 months course on average. Additionally, many patients or parents are resistant to the use of isotretinoin. In the last decade, excellent developments have been made on targeting the sebaceous glands with selective photothermolysis as a hope to cure acne without the use of oral medications. In 2011, Sakamoto and colleagues described that both natural and artificial sebum had an absorption peak near 1,210, 1,726, 1,760, 2306, and 2,346 nm; however, laser-induced heating of sebum was approximately twice that of water at 1710 nm and 1720 nm.[59] Histologic skin samples exposed to ~1700 nm, with 100 to 125 milliseconds pulses, showed evidence of selective thermal damage to sebaceous glands.[59] At 1726 nm, the peak of absorption of acne sebum is about 30% higher than that of the surrounding tissue, making it possible to create a new acne-targeting laser by delivering high power (~40 W) with robust cooling (**Fig. 8**). Two new devices have been approved by the Food and Drug Administration (FDA) in 2022 to treat mild to severe acne and will likely forever change the way we approach the management of this common skin condition. In the FDA white papers, about 80% of inflammatory lesions were reduced in a multicenter study for both devices after 12 weeks of treatment, with sustained clearance for up to 2 years after 4 monthly treatment sessions. Even though both devices use the same wavelength, there are differences that might affect the overall efficacy and safety, but there are no comparative studies published to date.

CLINICS CARE POINTS

- Acne is the most common dermatologic complaint and complete cure remains elusive.
- Sebaceous glands are lipid rich and the development of a lipid-selective 1726 nm wavelength offers the ability to selectively damage sebaceous glands.

New Devices

Although there have been so many recent advances and updates in laser technology and its applications, there are continually new devices and applications in the pipeline. One promising development is a newer 3-dimensional (3D) laser that has been FDA cleared and will be commercially available in the United States soon. This 3D laser is highly focusable allowing laser energy to be targeted at precise depths in the dermis with reduced fluences at the epidermis. The reduced energy at the epidermis will make this a safer device for the skin of color patients. Additionally, there will be a high-resolution, high-speed imaging system that will be paired and integrated with the laser. This imaging system will not only allow mapping and guidance during treatment but also pretreatment and post-treatment skin changes to be archived, making way for a more personalized laser treatment for every patient.

Other devices modifications that may be on the horizon in the future include the integration of robots into dermatology. These laser "robots" may be programmed by humans, however, the action itself will be executed by robot software. Such a

laser "robot" may be useful in skin cancer surgery, where we can perform image-guided laser ablation. Another way to integrate robots into lasers may be fractional-laser robots. These laser robots may be able to penetrate the skin at any precise depth and target several imageable structures such as sweat glands, nerves, cells, tumors, etc. These ablative fractional robot lasers may even be used for very precise drug delivery. The future remains very bright when it comes to the emergence of new technology that will advance our ability to treat a variety of medical and cosmetic dermatologic conditions.

DISCLOSURE

The authors have no disclosures to share (the authors need to look at disclosure criteria, certainly Rox, Fernanda, Mat, Suzy, and OI may need to make disclosures). F.H. Sakamoto, science advisor for Accure Acne, Beiersdorf: receives portions of patent royalties from Massachusetts General Hospital.

REFERENCES

1. Goldman L, Dreffer R, Rockwell RJ Jr, et al. Treatment of portwine marks by an argon laser. J Dermatol Surg 1976;2(5):385–8.
2. Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science 1983;220(4596):524–7.
3. Manstein D, Herron GS, Sink RK, et al. Fractional photothermolysis: a new concept for cutaneous remodeling using microscopic patterns of thermal injury. Lasers Surg Med 2004;34(5):426–38.
4. Kauvar AN, Geronemus RG. Treatment of port-wine stains. N Engl J Med 1998;339(9):635–6.
5. Goldman MP, Fitzpatrick RE, Ruiz-Esparza J. Treatment of portwine stains (capillary malformation) with the flashlamp-pumped pulsed dye laser. J Pediatr 1993;122:71–77 15.
6. Anderson RR, Parrish JA. Microvasculature can be selectively damaged using dye lasers: a basic theory and experimental evidence in human skin. Lasers Surg Med 1981;1:263–76.
7. Cosman B. Experience in the argon laser therapy of port wine stains. Plast Reconstr Surg 1980;65(2):119–29.
8. Sodha P, Richmond H, Friedman PM. Safe and Effective Use of a Novel Large Spot Size 595-nm Pulsed Dye Laser With High Energies for Rapid Improvement of Adult and Pediatric Port-Wine Birthmarks. Dermatol Surg 2021;47(8):1147–9. PMID: 33867471.
9. Izikson L, Anderson RR. Treatment endpoints for resistant port wine stains with a 755 nm laser. J Cosmet Laser Ther 2009 Mar;11(1):52–5.
10. Goldberg GN. Commentary on Efficacy and Safety of the 532-nm KTP and Long-Pulsed 1,064-nm Nd:YAG Laser for Treatment of Vascular Malformations. Dermatol Surg 2020;46(12):1540–1. PMID: 32604229.
11. Eichenfield, Dawn Z, Ortiz AE. Efficacy and Safety of the 532-nm KTP and Long-Pulsed 1064-nm Neodymium-doped Yttrium Aluminum Garnet Laser for Treatment of Vascular Malformations. Dermatol Surg 2020;46(12):1535–9.
12. Ibrahimi OA, Avram MM, Hanke CW, et al. Laser hair removal. Dermatol Ther 2011;24(1):94–107.
13. Grossman MC, Dierickx C, Farinelli W, et al. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996;35(6):889–94.
14. Altshuler GB, Anderson RR, Manstein D, et al. Extended theory of selective photothermolysis. Lasers Surg Med 2001;29(5):416–32.
15. Zenzie HH, Altshuler GB, Smirnov MZ, et al. Evaluation of cooling methods for laser dermatology. Lasers Surg Med 2000;26(2):130–44.
16. Nouri K, Chen H, Saghari S, et al. Comparing 18- vs. 12-mm spot size in hair removal using a gentlease 755-nm alexandrite laser. Dermatol Surg 2004;30(4 Pt 1):494–7.
17. Anderson RR, Burns AJ, Garden J, et al. Multicenter study of long-pulse ruby laser hair removal. Lasers Surg Med 1999;11(Suppl):11.
18. Davoudi SM, Behnia F, Gorouhi F, et al. Comparison of long-pulsed alexandrite and Nd : YAG lasers, individually and in combination, for leg hair reduction: an assessorblinded, randomized trial with 18 months of follow-up. Arch Dermatol 2008;144(10):1323–7.
19. Eremia S, Li C, Newman N. Laser hair removal with alexandrite versus diode laser using four treatment sessions: 1-year results. Dermatol Surg 2001;27(11):925–9. discussion 929–930.
20. Alster TS, Bryan H, Williams CM. Long-pulsed Nd:YAG laser-assisted hair removal in pigmented skin: a clinical and histological evaluation. Arch Dermatol 2001;137(7):885–9. PMID: 11453807.
21. Ross EV, Ibrahimi OA, Kilmer S. Long-term clinical evaluation of hair clearance in darkly pigmented individuals using a novel diode1060 nm wavelength with multiple treatment handpieces: A prospective analysis with modeling and histological findings. Lasers Surg Med 2018;50(9):893–901. Epub 2018 May 30. PMID: 29845623.
22. McGill DJ, Hutchison C, McKenzie E, et al. A randomised, split-face comparison of facial hair removal with the alexandrite laser and intense pulsed light system. Lasers Surg Med 2007;39(10):767–72.
23. Goh CL. Comparative study on a single treatment response to long pulse Nd : YAG lasers and intense pulse light therapy for hair removal on skin type IV to

VI – is longer wavelengths lasers preferred over shorter wavelengths lights for assisted hair removal. J Dermatolog Treat 2003;14(4):243–7.
24. Ibrahimi OA, Kilmer SL. Long-term clinical evaluation of a 800-nm long-pulsed diode laser with a large spot size and vacuum-assisted suction for hair removal. Dermatol Surg 2012;38(6):912–7. PMID: 22455549.
25. Lehavit A, Eran G, Moshe L, et al. A Combined Triple-Wavelength (755nm, 810nm, and 1064nm) Laser Device for Hair Removal: Efficacy and Safety Study. J Drugs Dermatol 2020;19(5):515–8. PMID: 32484620.
26. Noyman Y, Levi A, Reiter O, et al. Using blend wavelengths in order to improve the safety and efficacy of laser hair removal. J Cosmet Dermatol 2021;20(12): 3913–6. Epub 2021 Oct 25. PMID: 34694683.
27. Gold MH, Biron J, Wilson A, et al. Safety and efficacy for hair removal in dark skin types III and IV with a high-powered, combined wavelength (810, 940 and 1060 nm) diode laser: A single-site pilot study. J Cosmet Dermatol 2022;21(5):1979–85. Epub 2022 Apr 6. PMID: 35306725.
28. Raj Kirit EP, Sivuni A, Ponugupati S, et al. Efficacy and safety of triple wavelength laser hair reduction in skin types IV to V. J Cosmet Dermatol 2021; 20(4):1117–23. Epub 2021 Feb 22. PMID: 33567152.
29. Chuang GS, Farinelli W, Christiani DC, et al. Gaseous and Particulate Content of Laser Hair Removal Plume. JAMA Dermatol 2016;152(12): 1320–6.
30. Ross EV, Chuang GS, Ortiz AE, et al. Airborne particulate concentration during laser hair removal: A comparison between cold sapphire with aqueous gel and cryogen skin cooling. Lasers Surg Med 2018;50(4):280–3. Epub 2017 Dec 7. PMID: 29214662.
31. Ross V, Naseef G, Lin G, et al. Comparison of responses of tattoos to picosecond and nanosecond Q-switched neodymium: YAG lasers. Arch Dermatol 1998;134(2):167–71.
32. Jang WH, Yoon Y, Kim W, et al. Erratum: Visualization of laser tattoo removal treatment effects in a mouse model by two-photon microscopy: publisher's note. Biomed Opt Express 2018;9(9):4162. Erratum for: Biomed Opt Express. 2017 Jul 20;8(8):3735-3748. PMID: 30615732; PMCID: PMC6157788.
33. Lorgeou A, Perrillat Y, Gral N, et al. 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):265–70. Epub 2017 Aug 21. PMID: 28758261.
34. Kono T, Chan HHL, Groff WF, et al. Prospective Comparison Study of 532/1064 nm Picosecond Laser vs 532/1064 nm Nanosecond Laser in the Treatment of Professional Tattoos in Asians. Laser Ther 2020;29(1):47–52. PMID: 32903983; PMCID: PMC7447827.
35. Ibrahimi OA, Syed Z, Sakamoto FH, et al. Treatment of tattoo allergy with ablative fractional resurfacing: a novel paradigm for tattoo removal. J Am Acad Dermatol 2011;64(6):1111–4. PMID: 21571169.
36. Sirithanabadeekul P, Vongchansathapat P, Sutthipisal N, et al. Outcomes of 1064-nm picosecond laser alone and in combination with fractional 1064-nm picosecond laser in tattoo removal. J Cosmet Dermatol 2022;21(7):2832–9. PMID: 35488471.
37. Kossida T, Rigopoulos D, Katsambas A, et al. Optimal tattoo removal in a single laser session based on the method of repeated exposures. J Am Acad Dermatol 2012;66(2):271–7. Epub 2011 Oct 27. PMID: 22036610.
38. Danysz W, Becker B, Begnier M, et al. The effect of the perfluorodecalin patch on particle emission and skin temperature during laser-induced tattoo removal. J Cosmet Laser Ther 2020;22(3):150–8. PMID: 32516063.
39. Wolfshohl JA, Geddes ER, Stout AB, et al. Improvement of erythema dyschromicum perstans using a combination of the 1,550-nm erbium-doped fractionated laser and topical tacrolimus ointment. Lasers Surg Med 2017;49(1):60–2. Epub 2016 Aug 23. PMID: 27552666.
40. Shah DSD, Aurangabadkar DS, Nikam DB. An open-label non-randomized prospective pilot study of the efficacy of Q-switched Nd-YAG laser in management of facial lichen planus pigmentosus. J Cosmet Laser Ther 2019;21(2):108–15. PMID: 29768073.
41. Barrett T, de Zwaan S. Picosecond alexandrite laser is superior to Q-switched Nd:YAG laser in treatment of minocycline-induced hyperpigmentation: A case study and review of the literature. J Cosmet Laser Ther 2018;20(7–8):387–90. Epub 2018 Feb 5. PMID: 29400580.
42. Anderson RR, Margolis RJ, Watenabe S. Selective photothermolysis of cutaneous pigmentation by Q-switched Nd:YAG laser pulses at1064, 532 and 355 nm. J Invest Dermatol 1989;93:28–32.
43. Wang CC, Sue YM, Yang CH, et al. A comparison of Q-switched alexandrite laser and intense pulsed light for the treatment of freckles and lentigines in Asian persons: A randomized, physician-blinded, split-face comparative trial. J Am Acad Dermatol 2006;54:804–10.
44. Chan HHH, Fung WKK, Ying SY, et al. An in vivo trial comparing the use of different types of 532nm Nd: YAG lasers in the treatment of facial lentigines in oriental patients. Derm Surg 2000;26:743–9.
45. Wu DC, Goldman MP, Wat H, et al. A systematic review of picosecond laser in dermatology: Evidence

and recommendations [published online ahead of print April 13, 2020]. Lasers Surg Med 2020. https://doi.org/10.1002/lsm.23244.
46. Guss L, Goldman MP, Wu DC. Picosecond 532 nm neodymium-doped yttrium aluminium garnet laser for the treatment of solar lentigines in darker skin types: Safety and efficacy. Dermatol Surg 2017; 43(3):456–9.
47. Chan JC, Shek SY, Kono T, et al. A retrospective analysis on the management of pigmented lesions using a picosecond 755-nm alexandrite laser in Asians. Lasers Surg Med 2016;48(1):23–9.
48. Alegre-Sanchez A, Jiménez-Gómez N, Moreno-Arrones ÓM, et al. Treatment of flat and elevated pigmented disorders with a 755-nm alexandrite picosecond laser: Clinical and histological evaluation. Lasers Med Sci 2018;33(8):1827–31.
49. Vachiramon V, Iamsumang W, Triyangkulsri K. Q-switched double frequency Nd:YAG 532-nm nanosecond laser vs. double frequency Nd:YAG 532-nm picosecond laser for the treatment of solar lentigines in Asians. Lasers Med Sci 2018;33(9): 1941–7.
50. Tredget E, Ding J. The cellular and molecular basis of scarring: the paradigm of hypertrophic scarring after thermal injury. In: Krakowski A, Shumaker P, editors. *The scar book*. Philadelphia: Wolters Kluwer; 2017. p. 104–8.
51. Kuo YR, Jeng SF, Wang FS, et al. Flashlamp pulsed dye laser (PDL) suppression of keloid proliferation through down- regulation of TGF-beta1 expression and extracellular matrix expression. Lasers Surg Med 2004;34(2):104–8.
52. Seago M, Shumaker PR, Spring LK, et al. Laser Treatment of Traumatic Scars and Contractures: 2020 International Consensus Recommendations. Lasers Surg Med 2020 Feb;52(2):96–116. Epub 2019 Dec 9. PMID: 31820478.
53. Blome-Eberwein S, Gogal C, Weiss MJ, et al. Prospective evaluation of fractional CO2 laser treatment of mature burn scars. J Burn Care Res 2016;37(6): 379–87.
54. Issler-Fisher AC, Fisher OM, Smialkowski AO, et al. Ablative fractional CO2 laser for burn scar reconstruction: An extensive subjective and objective short-term outcome analysis of a prospective treatment cohort. Burns 2017;43(3):573–82.
55. Anderson RR, Donelan MB, Hivnor C, et al. Laser treatment of traumatic scars with an emphasis on ablative fractional laser resurfacing: consensus report. JAMA Dermatol 2014;150(2):187–93.
56. Miletta N, Siwy K, Hivnor C, et al. Fractional ablative laser therapy is an effective treatment for hypertrophic burn scars: A prospective study of objective and subjective outcomes. Ann Surg 2019;274(6): e574–80.
57. Haedersdal M, Moreau KE, Beyer DM, et al. Fractional nonablative 1540 nm laser resurfacing for thermal burn scars: A randomized controlled trial. Lasers Surg Med 2009;41(3):189–95.
58. Waibel J, Wulkan AJ, Lupo M, et al. Treatment of burn scars with the 1,550 nm nonablative fractional Erbium Laser. Lasers Surg Med 2012;44(6):441–6.
59. Sakamoto FH, Doukas AG, Farinelli WA, et al. Selective photothermolysis to target sebaceous glands: theoretical estimation of parameters and preliminary results using a free electron laser. Lasers Surg Med 2012 Feb;44(2):175–83. Epub 2011 Dec 13. PMID: 22170298.