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Short Communication

The Applications of Fractional Lasers in Taiwan

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Abstract

The applications of fractional lasers are enormous. In Taiwan, the most commonly used fractional lasers can be divided into 3 different categories: ablative, non-ablative, and combined hybrid laser. The ablative fractional laser was invented as a new instrument to be used for facial resurfacing initially. On the contrary, the non-ablative fractional laser was introduced primarily to rejuvenate skin with minimal downtime. It produces dermal thermal damage without significantly affecting the overlying epidermal layers of the skin. Both the ablative and non-ablative lasers are applied increasingly to various dermatological conditions. Herein, the author will review the researches and multiple applications of fractional lasers in Taiwan.

Keywords

Fractional Laser; Taiwan; Percutaneous Enhancer; Hair Regeneration; Cosmetic Tattoo; Acne Scar

Introduction

In Taiwan, the most common fractional lasers used can be divided into 3 categories:

1. Ablative fractional laser
2. Non-ablative fractional laser
3. Combined hybrid laser

The ablative fractional lasers include 10,600 nm CO_2 laser, 2,940 nm Er-YAG laser, and 2,790 nm Er-YSGG laser. The non-ablative fractional lasers are 1,550 nm Er-Glass fiber laser, 1,540 nm Er-Glass fiber laser, 1,927 nm Thulium fiber laser, and 1,440 nm Diode laser. The combined 1,470 nm ablative and 2,940 nm non-ablative lasers were used as a hybrid laser (Table 1).

The ablative fractional laser is initially used as a new instrument for facial resurfacing. They are clinically used to treat scarring, photodamaged skin, and deep rhytides primarily. It can reduce postoperative downtime and stimulate collagen formation through multiple ablated vertical tissue damages. On the other hand, non-ablative lasers create multiple denatured Microthermal Zones (MTZs) without epidermal necrosis. These MTZs can result in similar wound healing responses as ablative lasers. The combination of ablative and non-ablative lasers may enhance the treatment effects for facial rejuvenation with less downtime and complications.

The spectrum of the applications of fractional lasers is not limited to skin rejuvenation only. Herein, the author reviewed the literature and described the various researches on the applications of fractional lasers in Taiwan.

Type of Laser	**Wavelength of Laser**	**Examples**
Ablative fractional laser	10,600 nm CO_2 laser	Lutronic eCO_2 DEKA SmartXide Sharplan 150XJ
	2,940 nm Er-YAG laser	Sciton ProFractional MCL30 Dermablate
	2,790 nm Er-YSGG laser	Cutera Pearl fractional
Non-ablative fractional laser	1,550 nm Er-Glass fiber laser	Reliant Fraxel SR 750, SR 1500 Dinona Sellas 3D, evo
	1,540 nm Er-Glass fiber laser	Starlux Lux 1540
	1,927 nm Thulium fiber laser	Perméa
	1,440 nm Diode laser	Perméa
Combined hybrid laser	1,470 nm and 2,940 nm hybrid laser	Sciton Halo

Table 1: Various fractional lasers used in Taiwan.

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Materials and Methods

On July 29, 2020, the author systematically searched PubMed for published studies examining the use of fractional lasers in Taiwan. The PubMed database was searched using the terms “fractional laser”, “Taiwan”, “dermatology”, and “skin”. The searches were filtered to only include studies involving skin and those written in English, and bibliographies were also searched for additional studies. Review articles and researches with inflammed skin were not included in this study.

Results

A total of 19 research articles were found in this review process. Of the 19 articles found, 11 articles met the inclusion criteria. The studies that met inclusion criteria are reviewed. Six studies examined the effects of percutaneous absorption by fractional lasers. Among them, five of the studies applied ablative fractional lasers, while only one research evaluated this subject by non-ablative fractional laser. One study evaluated the effect on hair regeneration by non-ablative fractional laser. Two studies examined the effects of cosmetic tattoo removal, one by ablative fractional laser, and the other by non-ablative fractional laser, respectively. Similarly, two studies examined the effects of depressed acne scar, one by ablative fractional laser, and the other by non-ablative fractional laser, respectively (Fig. 1).

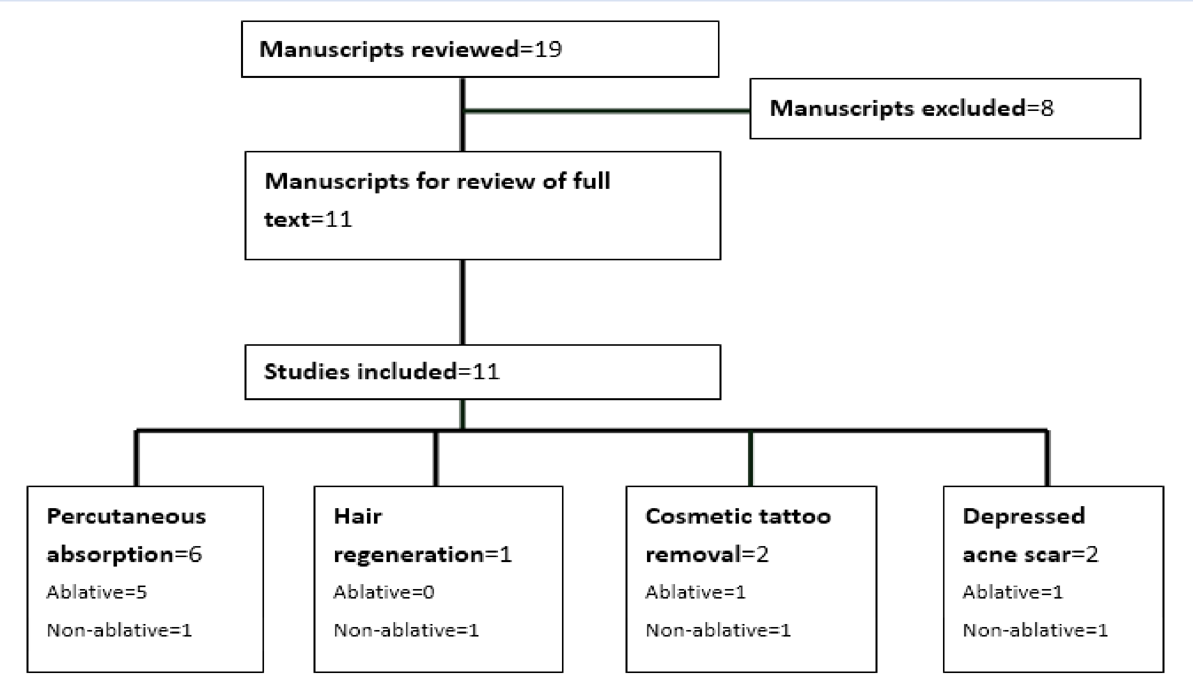

Figure 1: Search strategy and results.

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Discussion

Percutaneous Absorption

1. Ablative fractional laser

The upper limit for passive drug permeation is considered to be below the molecular weight of 500 Da. Applying ablative fractional lasers to enhance the absorption of topical chemicals into the skin has been successfully demonstrated as a minimal invasive procedure recently. The ablative fractional laser creates multiple tiny pores on the skin surface with microchannel array formation, facilitating the penetration and absorption of topically applied chemicals. Lee, et al., evaluated the results of permeation enhancement of large molecular weight molecules, small interfering (si)RNA, and plasmid (p)DNA vectors by irradiation with fractional 2,940 nm Er-YAG laser and 10,600 nm CO_2 laser on nude mice skin [1]. After 5 J/cm^2 of Er-YAG laser (MCL30 Dermablate, Asclepion Laser Technologies, Jena, Germany) irradiation, the percutaneous absorptions of dextran (10 kDa) and siRNA or other similar molecular size were 56 and 11-fold greater than that of untreated skin, respectively. The permeations of dextran and siRNA were 42 and 12-fold higher than that of intact skin respectively by the CO_2 laser (Lutronic eCO_2, San Jose, CA, USA) at the settings of 4 mJ and densities of 400 spots/cm^2. They demonstrated the importance of hair follicles as the deposition areas for fractional laser-assisted delivery. A higher follicular selectivity of siRNA was found with Er-YAG fractional lasers than the CO_2 modality. In another similar study, the laser enhanced a 2 to 5-fold increased absorption of small-molecule drugs after single irradiation of a fractional CO_2 laser (Lutronic eCO_2, San Jose, CA, USA) under the fluence of 2 or 4 mJ and densities of 100-400 spots/cm^2 [2]. The fractional laser could selectively enhance drugs targeting follicles such as imiquimod and dextran but not hydroquinone. These results indicated that selecting adequate drugs is important in laser-assisted percutaneous delivery. It is also noted that within 12 hours after irradiation, the skin barrier function (defined by trans-epidermal water loss, TEWL) can be recovered completely.

Another fractional 10,600nm CO_2 laser (150XJ, Sharplan Laser Inc., Yokneam, Israel) for transdermal absorption of ascorbic acid 2-glucoside (AA2G) was researched by Hsiao, et al., with the setting of 5-9 W, MTZ 150μm, and 2% coverage for a total of four passes [3]. The percutaneous absorption of L-ascorbic acid 2-phosphate sesquimagnesium salt (MAP-1) was 8 to 13-fold increased, while that of magnesium L-ascorbic acid-2-phosphate (MAP-2) was 20 to 22-fold higher after 5W irradiation by the fractional CO_2 laser. Similarly, the absorption of MAP-1 was 14 to 19-fold increased, while that of MAP-2 was 30 to 42-fold higher after 9W irradiation. This study showed CO_2 fractional laser is capable of enhancing the penetration of vitamin C derivatives into the skin. The skin permeation of tranexamic acid was also studied by the same research group using the same CO_2 fractional laser in another similar study design [4]. One to four passes of irradiation with the setting of 5 to 11 W, MTZ 150μm, and 2% coverage was performed on the skin. The ablative fractional laser could result in at least 85%

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of the absorption of tranexamic acid at the same fluence when comparing with conventional laser treatment. The number of passes needed to achieve a certain level of absorption will decrease when the fluence increased,

Other characteristics of skin absorption with antibiotics, sunscreens, and macromolecules were studied by Chen, et al., via a fractional CO_2 laser (Lutronic eCO_2, Fremont, CA, USA) [5]. The skin received single irradiation by using the settings of 4 to 10 mJ fluencies and 100-400 spots/cm^2. When drugs (such as tetracycline hydrochloride or macromolecules) were applied immediately after laser treatment, the optimized drug dose was 1/70-1/60 of the regular dose for skin treated with the fractional laser. However, the skin absorption of oxybenzone or other chemical sunscreens was not affected by fractional laser treatment.

2. Non-ablative fractional laser

Non-ablative fractional lasers cause dermal tissue damage without obviously destructing the superficial epidermal layers. The epidermal barrier function was preserved because the stratum corneum remains intact. Cutaneous penetration of small-molecule drugs, macromolecules, and nano-particles can be facilitated. A non-ablative 1,550 nm Er-Glass fractional laser (Dinona, Sellas evo, Daejeon, Korea) was used by Lee, et al., as an instrument to enhance percutaneous drug absorption [6]. They used the fluence of 30 mJ with MTZ 100 µm, and spot densities 256 to 529 spots/cm^2 on the pigs and nude mice skin. The delivery and penetration into the skin with dextrans (40 kDa) were achieved by quantum dots of a diameter of 20 nm. Depending on the densities of the laser spots, the barrier function of the epidermis could be recovered 8 to 60 hours after laser beam irradiation. They found the level of increased penetration was decreased according to the increase of lipophilicity of the drugs. For example, 2 folds increased absorption for tretinoin and 1200 folds for 5-aminolevulinic acid were found.

In conclusion, most of the studies showed that fractional CO_2 laser can increase the percutaneous absorption of topically applied chemicals from 2 to 42 folds (Table 2). The fractional Er-YAG laser can result in better skin permeation than that of the fractional CO_2 laser. Hair follicles were demonstrated to be important deposition areas for ablative fractional laser-assisted delivery. The permeation by non-ablative fractional lasers could vary enormously by permeant lipophilicity.

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Type of Laser		Parameters	Absorption
10,600 nm CO_2 laser	Lutronic eCO_2	4 mJ, 400 spots/cm^2	12-42 fold increase
	Lutronic eCO_2	2 or 4 mJ, 100-400 spots/cm^2	2-5 fold increase
	Lutronic eCO_2	4-10 mJ, 100–400 spots/cm^2	1/70–1/60 of the regular dose
	Sharplan 150XJ	5-9 W, MTZ: 150µm, 2% coverage	8-42 fold increase
	Sharplan 150XJ	5-11 W, MTZ: 150µm, 2% coverage	at least 85% of the cumulative permeation
2,940 nm Er-YAG laser	MCL30 Dermablate	5 J/cm^2	11-56 fold increase
1,550 nm Er-Glass laser	Dinona Sellas evo	30 mJ, MTZ: 100 µm, 256-529 spots/cm^2.	2-1200 fold increase

Table 2: The parameters used for enhanced percutaneous absorption by fractional lasers.

Hair Regeneration

The non-ablative fractional laser has been proposed as a treatment for patterned hair loss recently. It is hypothesized that the laser energy may trigger the inflammatory response and release of regenerative cytokines to stimulate hair growth. Various energies (5-35 mJ) and densities (500-3,500 MTZ/cm^2) of a 1,550nm Er-Glass fractional laser (Fraxel RE: STORE SR 1,500, Solta Medical, USA) were used to irradiate mice skin by Wu, et al., [7]. The energy settings that could activate the hair follicle stem cells are dependent on the laser beam fluence and density. As beam energy increased gradually from 10 mJ to 35 mJ, a corresponding trend of decreased density (10-12 mJ/1500 MTZ, 15 mJ/1000 MTZ, and 25 mJ/500 MTZ) was noted. Their research showed that the induction of anagen irradiated by lasers was an all-or-none response within 7-9 days. A threshold change within the irradiated skin could be induced by a laser before hair regenerate. Above the threshold, all the hair follicles within irradiated skin enter anagen. The anagen phase may be induced directly or indirectly by appropriate laser beam irradiation and adequate inflammation to the skin around an open wound. The various combinations of beam energy and density will result in anagen induction or ulcer formation. Ulcer formation followed by scarring may be caused by intense and persistent inflammation.

Clinical dermatologists may enhance anagen induction without ulcer formation by choosing an appropriate therapeutic window of energy and density.

Cosmetic Tattoo Removal

The cosmetic tattoos were traditionally managed with q-switched ruby or Nd-YAG lasers. The picosecond laser is now the preferred laser for cosmetic tattoo removal. However, to remove non-black colored cosmetic tattoos is still very difficult. Using CO_2 ablative fractional resurfacing by five sessions at 1-month intervals with the settings of 17.5 mJ, 120 μm spot size, and 10% density (AcuPulse, Lumenis, Yokneam, Israel), Wang, et al., tried to treat white and flesh-colored cosmetic tattoos on rats [8]. Their results showed immediate ablation of tattoo pigments and the formation of Microscopic Exudative Necrotic Debris (MENDs) as tattoo pigments in the MTZ migrated to the epidermis on day 2 and exfoliated after 5 days. The effect of a 1,550 nm Er-Glass non-ablative fractional laser (Sellas, Dinona, Korea) on rat skin was also studied with 2 passes for five sessions at 1-month intervals under the energy settings of 17 mJ, and MTZ 169/cm^2 [9]. Their results demonstrated the non-ablative fractional laser could also disrupt the dermal-epidermal junction and remove skin-colored or white cosmetic tattoos successfully by trans-epidermal elimination of tattoo pigments. Although CO_2 ablative fractional laser is traditionally thought to be more effective than non-ablative fractional laser for cosmetic non-black colored tattoo removal, their reports revealed that non-ablative fractional laser was as effective as CO_2 ablative fractional laser.

Depressed Acne Scar

The most common application of fractional laser used in Taiwan is for the treatment of depressed acne scars. The safety and effectiveness of 2,940 nm ablative fractional Er-YAG laser for the treatment of atrophic facial acne scars in Taiwanese patients was evaluated by Hu, et al., [10]. They performed two passes of Er-YAG laser on the cheeks and nose first, followed by one more pass on the forehead with the setting of 100 to 150 μm, 5 to 20 mm^2 scanning mold, 430 μm spot size, and 11% coverage density (Profractional-XC, Sciton, Palo Alto, CA). In order to create more thermal effects, extra passes under a level 2 to 3 coagulation mode were performed on the cheeks, as well as level 1 on the forehead and mandible. Nearly three-quarters of the patients were noted to achieve good or excellent improvement. The safety and effectiveness of a 1,550 nm non-ablative Er-Glass fiber laser for the treatment of atrophic facial acne scars were also investigated [11]. Sixty percent of the patients had good or excellent results through one treatment session under the setting of 15-20 mJ/MTZ and a density of 1,000-2,000 MTZ/cm^2 (spot width: 146-160 μm, depth: 682-754 μm) (Fraxel SR 750, Reliant, USA). Similar results were found with the setting of 30-40 mJ/MTZ and a density of 392-520 MTZ/cm^2 (spot width: 180-190 μm, depth: 980-1,120 μm) (Fraxel SR 1,500, Reliant, USA).

In conclusion, the treatment of depressed acne scars can be achieved by ablative or non-ablative fractional lasers with similar comparable effective results. The ablative fractional Er-YAG laser seemed to have better results than the CO_2 laser did. With the higher fluence used, the lower density should be used to avoid thermal damage. It remains to be studied whether the effect of combined ablative and non-ablative laser treatment for depressed acne scars will be more beneficial to the patients.

Limitations

Interpretation of our search results is limited by the few numbers of studies found, small sample sizes, and various methodologies of the study designs.

Conclusion

The ablative fractional laser creates multiple tiny pores on the skin surface with MTZs formation. Non-ablative fractional lasers cause dermal tissue damage without obviously destructing the superficial epidermal layers, reserving the epidermal barrier function by intact stratum corneum. Both of their clinical applications are enormous, from percutaneous absorption, hair regeneration, cosmetic tattoo removal, to depressed acne scar treatments. We believe that through these researches described above, we can successfully apply the ablative or non-ablative fractional laser clinically to enhance the treatment results of different aspects of dermatological conditions on our patients.

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