DOI: 10.7241/ourd.20123.43

NASZA DERMATOLOGIA Online
OUR DERMATOLOGY Online

STUDY OF FRACTIONAL ABLATIVE LASER IN SURGICAL AND POST TRAUMATIC SCAR

BADANIE NAD WYKORZYSTANIEM ABLACYJNEGO LASERA FRAKCYJNEGO W CHIRURGICZNYCH I POURAZOWYCH BLIZNACH

Nagat Sobhy, Adel El-Shafaei, Nanis Kamal

Department of Dermatology & Venereology, Faculty of Medicine, Alexandria University, Egypt

Corresponding author: Dr. Nagat Sobhy Mohamad nana_dermatology@yahoo.com

Our Dermatol Online. 2012; 3(3): 188-195
Date of submission: 02.03.2012 / acceptance: 01.04.2012
Conflicts of interest: None

Abstract

Introduction: Ablative, fractional lasers generate microscopic columns of coagulated tissue through the epidermis and dermis to evoke a wound healing response. In this study, we examined the efficacy and safety of fractional ablative 2940nm erbium: YAG laser in the treatment of surgical and post-traumatic scars. Fractional laser photothermolysis is the latest in the broad range of Er: YAG laser technique. This technique promises a novel means of providing treatments that would be as effective as traditional Er: YAG, while further reducing their down time and risk.

Aim of the Work: The aim of this work is to assess the efficacy and safety of variable square pulse (VSP) fractional Er: YAG laser for the treatment of surgical and post-traumatic scars; both clinically and histopathologically.

Methods: Clinical studies were conducted on a range of surgical and post-traumatic scars with a 2940nm erbium: YAG fractional ablative laser varying energy, pulse widths, treatment passes, and number of treatments: twenty subjects, with Fitzpatrick skin types III-IV, received two to five treatments at one month interval and a follow up period for 3 months. Clinical and histopathological evaluation of the results was performed.

Results: Almost all patients improved both clinically and histopathologically. Clinical improvement in scars according to investigator assessment: 40% of patients had excellent improvement of 76-100% (grade 3), 50% of patients had good improvement of 50-75% (grade 2), 10% had fair improvement of 26-49% (grade 1) at three month follow up. Histologic findings demonstrated remodeling of scar tissue with renewal and reorganization of collagen fibers in the dermis was noted two weeks post-treatment.

Conclusion: These data illustrate the safety and efficacy of the 2940nm erbium:YAG fractional ablative laser in the treatment of surgical and post-traumatic scars with short down time period, and almost no incidence of complication.

Streszczenie

Wstęp: Ablacyjne lasery frakcyjne generują mikroskopijne kolumny poprzez koagulację tkanek naskórka i skóry właściwej wywołując reakcję gojenia ran. W tym badaniu zbadaliśmy skuteczność i bezpieczeństwo frakcyjnego ablacyjnego lasera erbowego 2940nm: YAG w leczeniu blizn chirurgicznych i pourazowych. Frakcyjna laserowa fototermoliza jest ostatnio techniką o szerokim zakresie Er: YAG. Technika ta obiecuje nowy sposób świadczenia zabiegów, które byłyby tak samo skuteczne jak tradycyjne Er: YAG, przy jednoczesnym zmniejszeniu ich czasu i ryzyka.

Cel pracy: Celem niniejszej pracy jest ocena skuteczności i bezpieczeństwa stosowania zmiennego kwadratowego impulsu (VSP) frakcyjnego lasera Er: YAG do leczenia blizn chirurgicznych i pourazowych, zarówno pod względem klinicznym jak i histopatologicznym.

Metody: Badania kliniczne prowadzone były w zakresie chirurgicznych i pourazowych blizn za pomocą frakcyjnego ablacyjnego lasera erbowego 2940nm: YAG różnej energii, szerokości impulsu, przebiegu leczenia i liczby zabiegów: dwudziestu pacjentów, z typami skóry Fitzpatrick III-IV otrzymało od dwóch do pięciu zabiegów w oresie jednego miesiąca i następnie przez okres do 3 miesięcy. Przeprowadzono kliniczną i histopatologiczną ocenę wyników.

Wyniki: U prawie wszystkich pacjentów zauważono poprawę zarówno kliniczną jak i histopatologiczną. Poprawa kliniczna blizn według oceny badaczy: 40% pacjentów miało doskonałą poprawę w zakresie 76-100% (stopień 3), 50% pacjentów miało dobrą poprawę w zakresie 50-75% (stopień 2), 10% miało zupełną poprawę w zakresie 26 -49% (stopień 1) na trzy miesiące po terapii. Histololigiczne wyniki wykazały, przebudowę blizny z odnową i reorganizacją włókien kolagenowych w skórze właściwej co zostało zanotowane do dwóch tygodni po leczeniu.

Wnioski: Dane te ilustrują bezpieczeństwo i skuteczność 2940nm erbowego: YAG ablacyjnego lasera frakcyjnego w leczeniu chirurgicznych i pourazowych blizn w krótkim czasie i bez prawie żadnego przypadku wystąpienia komplikacji.

Key words: fractional ablative laser; surgical; post traumatic; scar
Słowa klucze: ablacyjny laser frakcyjny; chirurgia; pourazowy; blizna

Introduction

Scars affect approximately 4.5-16% of the general population and arise from either excessive or insufficient new collagen generation during the wound healing process [1]. Hypertrophic scars appear as hypo-pigmented or erythematous raised nodules or plaques containing excessive amounts of collagen, fibrin and proteoglycans [2,3]. In contrast, atrophic scars are dermal depressions with overlying thinned epidermis which results from a loss of dermal collagen following some types of inflammation or traumatic injury such as acne, varicella, post-traumatic wounds or post-operative scars [4].

On the surface, scars may appear to be only a cosmetic concern; however, they can significantly impact the patient on many different physical and psychological levels. Physically, scars can impede the patient's range of motion, and can cause pain, dysesthesia and pruritus [5-7]. Patients with severely disfiguring scars may also experience such psychological symptoms such as low self-esteem and feelings of psychosocial isolation [8,9].

Various treatments have been developed to improve the appearance of scars and to address these adverse effects, including silicone gel sheets, pressure garments, corticosteroid therapy, dermabrasion, surgical excision, chemical peels and more recently, laser treatments [7-11].

While some laser therapies have yielded positive results, others, such as the Nd: YAG and traditional ablative lasers, have actually worsened scar appearance [2,11,12]. Furthermore, traditional ablative treatments result in considerable patient downtime and adverse events such as oozing, infection, and hyper-pigmentation [13-15].

More shallow, full-surface horizontal resurfacing treatments with the short-pulsed ER: YAG laser have advantages of reduced patient downtime and minimal side effects; however, modest clinical results restrict treatment recommendations to only mild atrophic scars [1,16]. While Pulsed dye lasers (PDL) are considered to be the gold standard for scar revision based on their ability to improve scar pliability and texture and decrease erythema [17-23]. Fractional photothermolysis is a new technique for the treatment of scars [24] in which an array of microscopic thermal wounds (microscopic treatment zones) is induced into the skin to stimulate a therapeutic response deep in the dermis. Nonablative fractional photothermolysis at a wavelength of 1,550 nm has been found to be effective for the treatment of melasma, [25] mild to moderate rhytides, [26] acne scars, [27] surgical scars, [28] and even poikiloderma of Civatte [29]. However, this „coagulative" approach is time-consuming and painful, and the results are not always predictable.

Recently, „ablative" fractional photothermolysis using the Erbium: YAG laser (2940 nm) has been introduced as a novel means of providing treatment that would be as effective as traditional ablative approaches while avoiding their high downtime and risks [30,32]. The laser produces thousands of microscopic, clinically inapparent wounds on the skin surface that are rapidly reepithelialized by the surrounding, undamaged tissue, sparing the epidermis.

Materials and Methods

This study was conducted on 20 patients, 12 male and 8 female aged between 12-45 years old. All patients have surgical and post-traumatic scars. Exclusion criteria;History of keloid formation. Squamous cell carcinoma or melanoma. Immunodeficiency disorder. Hypersensitivity to light. Bleeding disorder or use of anticoagulant for which a 10-day washout is not allowed before study treatment. Active local or systemic infection; light-sensitive medication. The use of immunosuppressive medication. Use of botulinum toxin A, dermal fillers in areas to be treated within the previous four or six months. Facelift, use of isotretinoin, or ablative laser to target areas within the past 12 months.Treatment with chemical peels or dermabrasion within the past three months; treatment of the target areas with laser or other device within the past three months. In this study we attempt to confirm the effect of PST (Pixel screen technology) fractional ablative Erbium:YAG (Er:YAG) 2940 nm fractional laser on different types of scars.

The treatment parameters in the present study ranged from 600-1100 mJ fluence, with a spot size of 7 mm, a frequency of 5 Hz and pixel 3 (medium ablation pixel number 30 and pixel size 800 micrometer). Using the soft fractional PS 01 laser hand piece R 04. The number of passes depend on the treated area and type of scars. The patients had two to five sessions.

The clinical assessment was objectively based on clinical photography before treatment and three months after laser treatment by means of clinical improvement, patient satisfaction and histopathological findings.

Clinical improvement assessed by Investigator assessments performed at one- month follow-up visits using the quartile assessment scale („excellent 3 „: 76-100%; „good 2 „: 50-75%; „fair 1 „: 26-49%; „poor 0 „: 0-25%). Two blinded-dermatologists evaluating clinical photographs taken before and after laser treatment. Investigators will be asked to select which image represented the post-treatment image and to rate the percent improvement in the appearance of the surgical or post-traumatic scar. Who will grade the results on a five- point scale, as follows: (excellent, 75% to 100% improvement; good, 50% to 75% improvement; fair, 25% to 50% improvement; poor, 0-25% improvement; or worse, final results were worse than the pre treatment results).

Patients self assessment: Patients will assess their improvement using the following five-point scale: 0=no or minimal improvement, not satisfied (0%-10%); 1=slight improvement, slightly satisfied (11-25%); 2=moderate improvement, satisfied (26-50%); 3=significant improvement, very satisfied (51-75%); and 4=substantial improvement, extremely satisfied (> 75%). Patient assessments will be gathered using phone interviews or written questionnaires.

Some patient will be subjected to two millimeter punch biopsy of hidden scar will be taken prior treatment and two weeks post-treatment, tissue samples will be fixed in formalin and processed for hematoxylin and eosin (H&E) staining and elastic tissue with orcein stain.

All subjects involved in the current work will be informed about the nature and the details of the work and a written consent will be obtained also approval by ethical committee was obtained.

Results

This study included 20 patients having surgical and post-traumatic scars with a broad range of atrophic and hypertrophic scars.

Regarding the age of patients varied from 12-42 years with a mean of 21.15 ± 8.92 years.

The study included 12 males (60%) and 8 females (40%).

The skin type, 12 patients (60%) had Fitzpatrick skin type III and 8 patients (40%) had Fitzpatrick skin type IV.

As regard the cause, 8 patients (40%) were surgical scars (post trauma repair four patients, open repair of fracture two patients, post appendicectomy two patients) and 12 patients (60%) were traumatic scars (fall in sharp or blunt object six patients, scratch marks two patients, burn two patients).

As regard scar location, 7 patients (35%) had scars located on the arm, 4 patients (20%) had scars located on cheeks, 2 patients (10%) had scars located on forehead, 1 patients (5%) had scar located on chin and 1 patient (5%) had scar located in upper lip.

As regard the duration of the scars, it ranged between 5 months and 15 years, with a mean of 4.40 ± 3.20. 5 patients (25%) had scar duration less than 1 year and 15 patients (75%) had scar duration more than one year.

Regarding the clinical improvement of scars to laser therapy (Fig. 1-3a,b), the present study revealed that all patients had clinical improvement in scars according to investigator assessment; 40% of patients had excellent improvement of 76-100% (grade 3), 50% of patients had good improvement of 50-75% (grade 2), 10% had fair improvement of 26-49% (grade 1) at three month follow up.

The clinical improvement according to blinded dermatologist assessment revealed that there was no significant difference between it and investigator assessment.

The degree of patient satisfaction differed from one case to another. Seven patients were slightly satisfied (35%), one patient was satisfied (5%), five patients were very satisfied (25%), seven patients were extremely satisfied (35%). Even, the majority of patients including those who were slightly improved asked for more session.

As regard Pain which is inherently subjective, all patients tolerated the procedure with topical anesthesia (EMLA) for one hour before procedure, no pain to severe pain was reported by all patients, ranged between (0-3) with a mean 1.65 ± 0.88, all patients stated that the discomfort ceased upon removal of the light. 2 patients (10%) had no pain =0.

- 6 patients (30%) had mild pain =1, 9 patients (45%) had moderate pain =2, 3 patients (15%) had severe pain =3.
- As regard crust formation, 2 patients (10%) had crust for four days, 5 patients (25%) had crust for 5 days, 3 patients (15%) had crust for 6 days, 7 patients (50%) had crust for 7 days, with a range of (4-7) days and a mean of 6.05 ± 1.10 days.
- As regard erythema, 2 patients (10%) had erythema for 1 day, 10 patients (50%) had erythema for 2 days, 8 patients (40%) had erythema for 3 days with a range of (1-3) and a mean of 2.3 ± 0.66 days.
- As regard swelling, 16 patients (80%) had swelling for 1 day, 4 patients (20%) had swelling for 2 days. with a range of (1-2) days and a mean of 1.2 ± 0.41 days.
- No patients show permenant hypopigmentation or hyperpigmentation.

Histologic findings (Fig. 4-6a,b) demonstrated remodeling of scar tissue with renewal and reorganization of collagen fibers in the dermis was noted two weeks post-treatment.

The scar tissue had histologically improved by two weeks post treatment as evidenced by a thickened epidermis with normal rete ridge pattern and reduced number of hyperplastic collagen bundles. Two weeks post treatment, there is an increase in elastic fibers particularly in upper dermis and they appear thicker and more randomly distributed was noted.

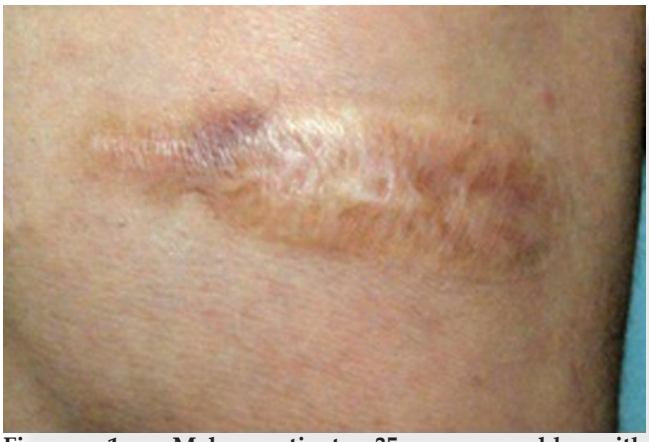

Figure 1a. Male patient 35 years old with hypertrophic scar with blotchy hyperpigmentation in the arm since 3 years (traumatic scar, before treatment)

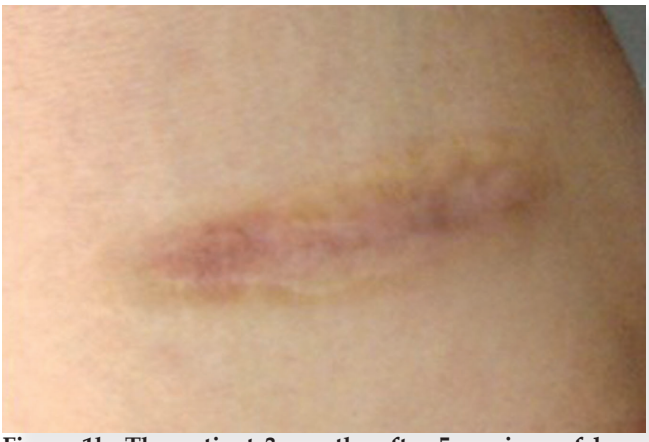

Figure 1b. The patient 3 months after 5 sessions of laser treatment showing flattening, reduced hyperpigmentation and better overall scar quality (excellent improvement 76-100%)

Figure 2a. Female patient 26 years old with hypertrophic and erythematous scar on the chest since 6 months (post-trauma repair, before treatment)

Figure 2b. The patient 3 months after 3 sessions of laser treatment showing reduced erythema and the scar appear flatter (good improvement 50-75%)

Figure 3a. Male patient 20 years old with erythematous and atrophic scar with elevated medial third in the cheek since 1 year (post-trauma repair, before treatment)

Figure 3b. The patient 3 months after 3 sessions of laser treatment showing decreased erythema and over all flattening of the scar (excellent improvement 76-100%)

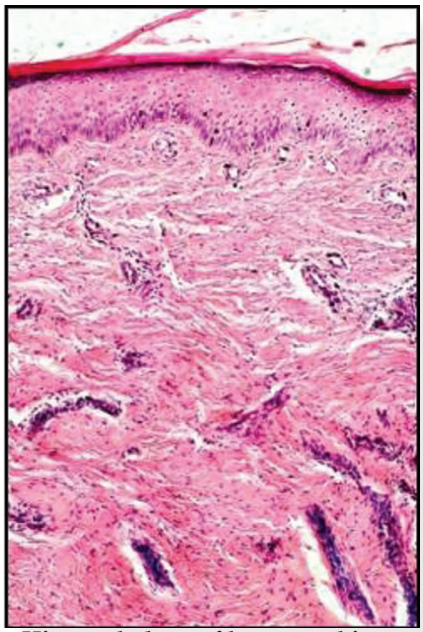

Figure 4a. Histopathology of hypertrophic scar before treatment. There are and significant replacement of papillary dermis with abnormal hyperplastic collagen fibers and excessive inflammatory cells in the scar tissue

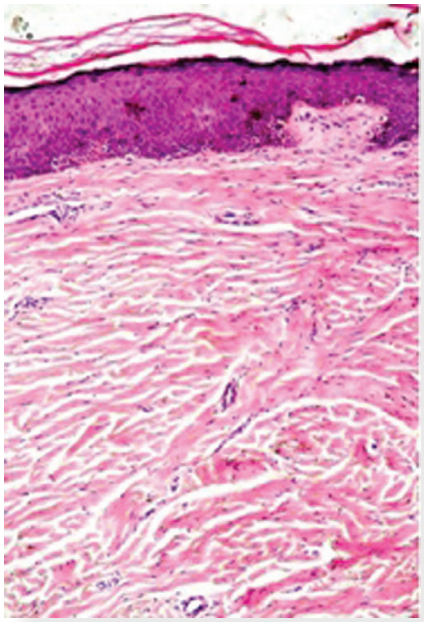

Figure 4b Two weeks post treatment, remodeling of a scar tissue with renewal and reorganization of collagen fibers in the dermis and reduced inflammatory cells was noted. (H&E X 100)

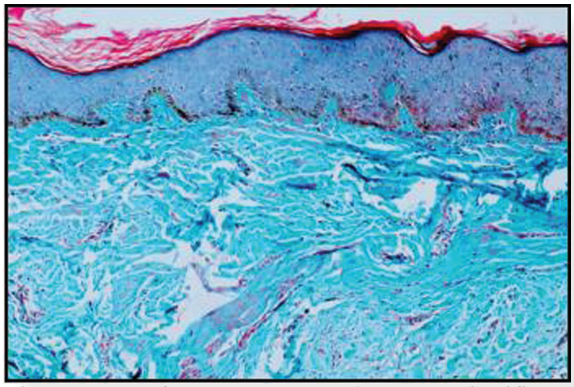

Figure 5a. Before treatment. There are significant replacement of papillary dermis with abnormal hyperplastic collagen fibers in the scar tissue

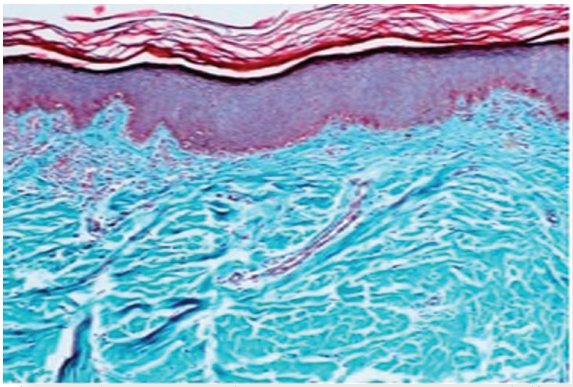

Figure 5b. Two weeks post treatment, remodeling of a scar tissue with renewal and reorganization of collagen fibers in the dermis was noted (Maisson trichrome X 100)

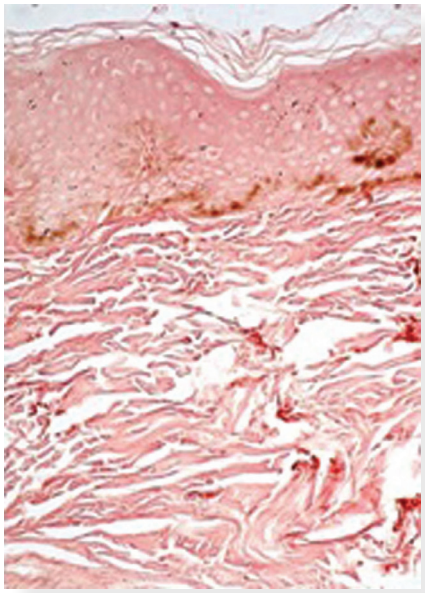

Figure 6a. Before treatment. There are thin, frayed elastic fibers arranged in a parallel orientation

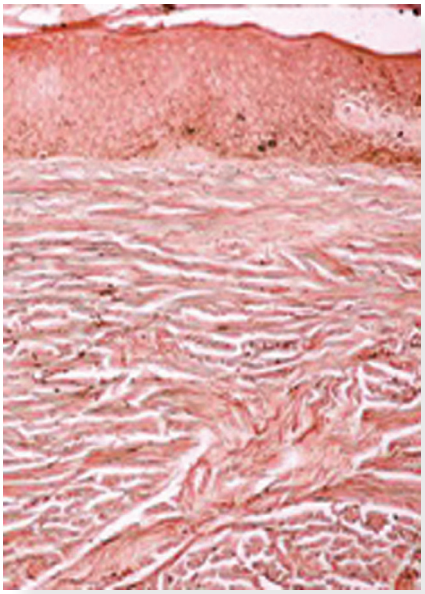

Figure 6b. Two weeks post treatment, there is an increase in elastic fibers particularly in upper dermis and they appear thicker and more randomly distributed was noted. (Orcein staining X 100)

Discussion

In this study, the PST (Pixel screen technology) fractional ablative Er:YAG laser with variable pulse width was used allowing the selection of the effect of the laser from ablation peeling to deeper thermal effect and coagulation. Pixel Screen Technology (PST) divides the basic Er:YAG treatment beam into parallel beam pixels. The advantage of PST compared to other fractional technologies is that it allows the laser beam quality and parameters within the pixels to remain unchanged compared to the basic beam properties. Other fractional technologies use focused beams with modified pulse fluences in the fractional spots and therefore with modified and relatively uncontrolled thermal treatment modalities. PST ensures that the laser fluence in each pixel is exactly as it would be with a standard Er:YAG laser handpiece. PST hand piece has been designed and developed for "stamped" fractional photothermolysis techniques, as opposed to the scanning fractional techniques. The latter technique requires a scanner and in some systems expensive consumables [1,2,4].

In the present study, the clinical assessment was objectively based on clinical photography before treatment and three months after laser treatment by means of clinical improvement, patient satisfaction and histopathological findings. Regarding the clinical improvement of scars to laser therapy, the present study revealed that all patients had clinical improvement in scars according to investigator assessment; 40% of patients had excellent improvement of 76-100% (grade 3), 50% of patients had good improvement of 50-75% (grade 2), 10% had fair improvement of 26-49% (grade1) at three month follow up. In this study, there was improvement in all hyperpigmented and erythematous scars and over all flattening in scars. Hypertrophic scars and atrophic scars responded to treatment with fractional laser photothermolysis. The question elaborated, how the same technology can benefit atrophic and hypertrophic scars is intriguing and deserves further investigation. Perhaps dermal heating normalizes collagen or vascular neogenesis or breaks and realigns abnormal collagen fibers [33-35].

Karen et al [36] investigated an Er:YAG 2940 laser with thermal mode in 12 patients with scars including post traumatic scars and fascial atrophic scars. Two treatment were applied two month apart, at 3–6 months follow-up was graded as excellent in 50%, good in 25%, fair in 25%, and no improvement in 0%. The explanation of such difference can be attributed to the use of different mode (they used thermal mode with sub-ablative fluences of 2.1 and 3.1 J/cm2).

A study was performed by Elliot et al. [37] to investigate ablative fractional laser CO2 which included 15 patients having post-operative and traumatic scars. Each scar received 3 AFR treatments at 1- to 4-month intervals; at six month follow up investigator assessment was graded as 16% of the treated scars achieving excellent 76% or greater overall improvement and 89% of treated scars achieving 51% or greater overall improvement. In the present work, at 3 month follow up 40% of patients had excellent improvement 76% or greater and 90% of patients had 50% or greater improvement. Such difference may be explained by the fact that, we used more number of sessions of laser treatment (up to five treatment sessions at monthly interval) and they used different laser type.

Regarding occurrence of side effects, in the present work, Treatments were well tolerated by all patients no pain to sever pain was reported with a mean1.65±0.88. All patients stated that discomfort ceased upon removal of the light, which was observed by Ane M et al. [38] who recorded that the treatment was well tolerated, without the need for oral analgesic or anxiolytic medication.

Treatment-induced erythema was characterized by all subjects as being both mild and transient and lasted about one to three days with a mean 2.3±0.66. In this respect similar results reported by Hui et al [39].

After treatment, immediate post procedure erythema was noted lasted about three days with a mean 3.6±1.6. Regarding oedema in this study, it persisted for (1 to 2 days) and a mean 1.2±0.41. This was similar to that reported by Elliot et al. [37]. Regarding crust formation, in this study, it persisted for about 4 to 7 days with a mean 6.05±1.10. Similar results reported by Hui et al. [39].

In the present work, no patients reported blistering, persistent swelling or any other adverse events. Of the 20 patients who returned for follow-up three months after their last treatment, none reported any delayed-onset changes in skin pigmentation, erythema, and increased skin sensitivity. No bacterial infections or episodes of viral reactivation occurred during the study.

Karen et al [36] reported that one patient with a history of herpes simplex, a reactivation of latent labial herpes simplex virus infection occurred after the first laser treatment. When acyclovir was given prophylactically before the second treatment, another outbreak could be prevented.

On contrary Rostan et al. [40] reported that ablative resurfacing with the CO2 or Er:YAG laser is associated with considerable downtime and a risk of prolonged erythema, infection, scarring, and delayed hypopigmentation. Moreover, it is painful and usually requires general anesthesia. This was not noted in our study, although the follow-up was relatively short. We speculate that the microscopic pattern of injury induced by the 2,490-nm laser caused only minimal inflammation and therefore led to fewer clinically evident pigmentary changes.

Joy et al. [41] Patients reported moderate pain during treatment. After the procedure, moderate to severe erythema and edema typically resolved within 24 to 48 hours. No additional adverse effects were observed. These findings could be explained by The laser used by Joy et al. [41] was fractional non ablative Erbium-doped fiber laser.

Concerning patients' satisfaction most cases were satisfied at the end of the study period. The degree of patient satisfaction differed from one case to another. Seven patients were slightly satisfied (35%), one patient was satisfied (5%), five patients were very satisfied (25%), seven patients were extremely satisfied (35%). Even, the majority of patients including those who were slightly satisfied asked for more session which explains the psychological aspect of therapy.

Hei et al. [42] found that patient satisfaction with treatment was found to be high, with Five patients stated they were highly satisfied (71.4%) and the remaining two were somewhat satisfied (28.6%).

The clinical improvement according to blinded dermatologist assessment revealed there was no significant difference between it and investigatent.

Histopathology

The scar tissue has histologically improved by two weeks post-treatment as evidenced by a thickened epidermis with normal rete ridge pattern and reduced number of hyperplastic collagen bundles and collagen regrowth as highlighted by Masson's trichrome stain. Orecin staining of untreated scar tissue reveals thin, frayed elastic fibers arranged in a parallel orientation, compared to normal tissue where elastic fibers are thicker in the reticular dermis and more randomly distributed. Two weeks after treatment with the 2940 nm laser, there is an increase in elastic fibers particularly in the upper dermis and they appear thicker and more randomly distributed than in the untreated scar tissue.

In the study conducted by Moshe et al. [32], the biopsy samples clearly showed the thickened epidermis with normal rete ridge pattern and remodeling of scar tissue with renewal and reorganization of collagen and elastic tissue.

These findings support the findings of David et al. [43] who did serial biopsies immediately post-treatment, at 72 hour and two weeks post treatment. The author reported immediate vacuole formation at the dermoepidermal junction is seen with sub-epidermal cleft formation and an underlying zone of dermal coagulation. By 72 hours, the coagulation zone is less defined and complete re-epithelialization has occurred. Although necrotic debris is extruded from the epidermis, it remains entrapped under the stratum corneum and a mild inflammatory reaction is observed. Remodeling of scar tissue with renewal and reorganization of collagen fibers in the dermis was noted two weeks post-treatment.

Histopathological finding in the present study support the previous evidences that the columns of thermal injury characterized by localized epidermal necrosis and collagen denaturation initiate a cascade of events that leads to a normalization of the collagenesis–collagenolysis cycle. This was consistent with Tannous et al. [44] who correlated the histopathological finding and Clinical improvement of pigmented lesions to the formation of microscopically small areas of epidermal necrotic debris and dermal contents containing melanin.

Those necrotic contents migrate and are progressively eliminated, resulting in release of pigment and improvement of pigmented lesions. Also, Goldberg et al [45] who did histologic and ultrastructural analysis reported a decrease in the number of melanocytes and the amount of melanin granules within keratinocytes, consistent with this elimination process. They did not observe post inflammatory hyperpigmentation even in patients with Fitzpatrick skin type IV. It is possible that the micro-beam-composed laser avoids bulk heating of the skin dermis, reducing the risk of post inflammatory hyperpigmentation

Concolusion

From the previous results of this study and in addition to reviewing related internationally published literature, we have the following conclusions and recommendations:

- Scars cause significant impact on the quality of life of the affected patients and compel the search for more effective treatments.
- The ablative fractional laser treatments represent a safe, effective and a promising treatment modality for improving scars due to surgery or trauma with reduced risk and downtime compared to existing laser methods.
- Detailed medical history and drug history should be taken for any case before performing laser treatment.
- Controlled studies are warranted to better understand the efficacy of ablative fractional photothermolysis for the treatment and prevention of scars and to determine optimal parameters.
- Further histopathological studies should be done for more understanding of mechanism of action of laser beam in scar tissue.

REFERENCES

1. Lupton JR, Alster TS: Laser scar revision. Dermatol Clin. 2002; 20: 55-65.
2. English RS, Shenefelt PD: Keloids and hypertrophic scars. Dermatol Surg. 1999; 25: 631-638.
3. Linares HA: From wound to scar. Burns. 1996; 22: 339-352.
4. Alster TS, Tanzi EL, Lazarus M: The use of fractional laser photothermolysis for the treatment of atrophic scars. Dermatol Surg. 2007; 33: 295-299.
5. Atkinson JA, McKenna KT, Barnett AG: A randomized, controlled trial to determine the efficacy of paper tape in preventing hypertrophic scar formation in surgical incisions that traverse Langer's skin tension lines. Plast Reconstr Surg. 2005; 116: 1648-1656.
6. Baisch A, Riedel F: Hyperplastic scars and keloids. Part I: Basics and prevention. HNO. 2006; 54: 893-904.
7. O'Brien L, Pandit A: Silicon gel sheeting for preventing and treating hypertrophic and keloid scars. Cochrane Database Syst Rev. 2006; 25: 246-274.
8.Van Loey NE, Son MJ: Psychopathology and psychological problems in patients with burn scars: Epidemiology and management. Am J Clin Dermatol. 2003; 4: 245-272.
9. Bock O, Schmid-Ott G, Malewski P, Mrowietz U: Quality of life of patients with keloid and hypertrophic scarring. Arch Dermatol Res. 2006; 297: 433-238.
10. Kerckhove E, Stappaerts K, Boeckx W: Silicones in the rehabilitation of burns: A review and overview. Burns. 2001; 27: 205-214.
11. Nouri K, Vidulich K, Rivas MP: Lasers for scars: A review. J Cosmet Dermatol. 2006; 5: 14-22.
12. Alster TS: Laser treatment of hypertrophic scars, keloids, and striae. Dermatol Clin. 1997; 15: 419-429.
13. Atiyeh BS: Nonsurgical management of hypertrophic scars: Evidence-based therapies, standard practices, and emerging methods. Aesthetic Plast Surg. 2007; 31: 468-492.
14. Bernstein LJ, Kauvar AN, Grossman MC, Geronemus RG: The short- and long-term side effects of carbon dioxide laser resurfacing. Dermatol Surg. 1997; 23: 519-525.
15. Nanni CA, Alster TS: Complications of carbon dioxide laser resurfacing. An evaluation of 500 patients. Dermatol Surg. 1998; 24: 315-320.
16. Eberlein A, Schepler H, Spilker G: Erbium: YAG laser treatment of post-burn scars: Potentials and limitations. Burns. 2005; 31: 15-24.
17. Bouzari N, Davis SC, Nouri K: Laser treatment of keloids and hypertrophic scars. Int J Dermatol. 2007; 46: 80-88.
18. Alster TS: Improvement of erythematous and hypertrophic scars by the 585-nm flashlamp-pumped pulsed dye laser. Ann Plast Surg. 1994; 32: 186-190.
19. Alster TS, Williams CM: Treatment of keloid sternotomy scars with 585 nm flashlamp-pumped pulsed-dye laser. Lancet 1995; 345: 1198-1200.
20. Alster TL: aser scar revision: Comparison study of 585-nm pulsed dye laser with and without intralesional corticosteroids. Dermatol Surg. 2003; 29: 25-29.
21. Kono T, Ercocen AR, Nakazawa H: The flashlamp-pumped pulsed dye laser (585 nm) treatment of hypertrophic scars in Asians. Ann Plast Surg. 2003; 51: 366-371.
22. Dierickx C, Goldman MP, Fitzpatrick RE: Laser treatment of erythematous/hypertrophic and pigmented scars in 26 patients. Plast Reconstr Surg. 1995; 95: 84-90.
23. Goldman MP, Fitzpatrick RE: Laser treatment of scars. Dermatol Surg. 1995; 21: 685-687.
24. Manstein D, Herron GS, Sink RK: Fractional photothermolysis: a new concept for cutaneous remodeling using microscopic patterns of thermal Injury Lasers Surg Med. 2004; 34: 426-438.
25. Geronemus RG: Fractional photothermolysis: current and future applications. Lasers Surg Med. 2006; 38: 169-176.
26. Rokhsar CK, Fitzpatrick RE: The treatment of melasma with fractional photothermolysis: a pilot study. Dermatol Surg. 2005; 31: 1645-1650.
27. Hasegawa T, Matsukura T, Mizuno Y: Clinical trial of a laser device called fractional photothermolysis system for acne scars. J Dermatol. 2006; 33: 623-637.
28. Behroozan DS, Goldberg LH, Dai T: Fractional photothermolysis for the treatment of surgical scars: a case report. J Cosmet Laser Ther. 2006; 8: 35-38.
29. Behroozan DS, Goldberg LH, Glaich AS: Fractional photothermolysis for treatment of poikiloderma of Civatte. Dermatol Surg. 2006; 32: 298-301.
30. Hantash BM, Bedi VP, Kapadia B: In vivo histological evaluation of a novel ablative fractional resurfacing device. Lasers Surg Med. 2007; 39: 96-107.
31. Hantash BM, Bedi VP, Chan KF, Zachary CB: Ex vivo histological characterization of a novel ablative fractional resurfacing device. Lasers Surg Med. 2007; 39: 87-95.
32. Moshe L, Marina EY, Lilian MO: Novel use of Erbium: YAG (2940-nm) lasers for fractional ablative photothermolysis in the treatment of photodamaged fascial skin. Dermatol Surg. 2008; 34: 1023-1053.

33. Tanzi EL, Alster TS: Comparison of a 1450-nm diode laser and a 1320-nm Nd:YAG laser in the treatment of atrophic facial scars: prospective clinical and histologic study. Dermatol Surg. 2004; 30: 152-157.
34. Alster TS, Tanzi EL, Lazarus M: The use of fractional laser photothermolysis for the treatment of atrophic scars. Dermatol Surg. 2007; 295: 9-33.
35. Manuskiatti W, Wanitphakdeedecha R, Fitzpatrick RE: Effect ofpulse width of a 595-nm flashlamp-pumped pulsed dye laser on the treatment response of keloidal and hypertrophic sternotomy scars. Dermatol Surg. 2007; 33: 152-161.
36. Karen KR, Christine CD, Bernard C, Michael D: Minimally Invasive Skin Rejuvenation With Erbium:YAG Laser Used in Thermal Mode. Lasers Surg Med. 2006; 38: 899-907.
37. Weiss ET, Chapas A, Brightman L, Hunzeker C, Hale EK, Karen JK, et al: Successful treatment of atrophic postoperative and traumatic scarring with carbon dioxide ablative fractional resurfacing: quantitative volumetric scar improvement. Arch Dermatol. 2010; 146: 133-140.
38. Niwa AB, Mello AP, Torezan LA, Osório N: Fractional photothermolysis for the treatment of hypertrophic scars :clinical experience of eight cases. Dermatol Surg. 2009: 35: 773-778.
39. Deng H, Yuan D, Yan C, Lin X, Ding X: A 2940 nm fractional photothermolysis laser in the treatment of acne scarring: a pilot study in China. J Drugs Dermatol. 2009; 8: 978-980.
40. Rostan EF: Laser treatment of photodameged skin. Fascial Plast Surg. 2005; 21: 99-109.
41. Joy H, Tracy M, Leonard H, Paul M: Fractional photothermolsis for the treatment of surgical scars .American Society for Dermatologic Surgery. 2010; 36: 538-541.
42. Kim HS, Cho EJ, Park YM, Kim HO, Lee JY: Punch excision combined with erbium:YAG fractional laser ;Its application on different types of scars in Asian patients (pilot study). J Cosmet Laser Ther. 2011; 13: 196-199.
43. Vasily DB, Cerino ME, Ziselman EM, Zeina ST: Non-ablative fractional resurfacing of surgical and post-traumatic scars. J Drugs Dermatol. 2009 Nov; 8: 998-1005.
44. Tannous Z, Laubach HJ, Anderson RR, Manstein D: Changes of epidermal pigment distribution after fractional resurfacing: a clinicopathologic correlation. Lasers Surg Med. 2005; 36: 32-26.
45. Goldberg DJ, Berlin AL, Phelps R: Histological and ultrastructural analysis of melasma after fractional resurfacing. Lasers Surg Med. 2008; 40: 134-138.