Complications of Laser Dermatologic Surgery

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Background and Objective: Innovations in lasers, light and radiofrequency devices have allowed for improved therapeutic efficacy and safety and the ability to treat patients with an ever-increasing number of medical and aesthetic indications. Safety remains a primary concern and the timely communication of complications and their management is vital to insure that treatments be as safe as possible. The purpose of this report on the Proceedings of the First International Laser Surgery Morbidity Meeting is to provide laser experts the opportunity to present and discuss complications that their patients have experienced and how they were successfully managed.
Methods: Laser experts were invited to present complications of laser, light, and radiofrequency treatments that their patients have experienced and to discuss the potential mechanisms leading to the complications their management and final outcomes.
Results: Nineteen unique cases are presented and the clinical management of each case discussed. Eighteen sets of pre- and post-operative photos are presented.
Conclusion: This report shows that even experts, with extensive experience using light-based therapies, can and do have patients who develop complications. Sound clinical judgment, and knowing how to avoid complications and their timely post-operative management, is essential to insure optimal therapeutic outcome. Lasers Surg. Med. 38:1–15, 2006. © 2006 Wiley-Liss, Inc.

Key words: complications; safety

INTRODUCTION

Laser dermatologic surgery has rapidly advanced since the first device was introduced more than four decades ago [1]. Continued innovations in optical technology and refinement of existing devices have allowed for new developments to meet growing consumer demands for effective and safe laser therapies [2]. Such innovations include: (1) the expanding use of specific wavelengths, pulse durations and cooling strategies; (2) introduction of non-ablative rejuvenation techniques, including radiofrequency, intense pulsed light and other light sources; and (3) combinations of laser, light, and radiofrequency technologies, all of which have provided dermatologic laser surgeons with the ability to treat patients with an ever-increasing number of medical and aesthetic indications. Constant, however, has been the emphasis on safety in the application of both new and old laser technologies. In the hands of knowledgeable and well-trained practitioners, complication rates with the use of lasers remain low. However, when complications do occur, timely communication of the occurrence and skillful management are

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TABLE 1. Symbols Representing Treatment Parameters

λ	Wavelength
F	Fluence
t_p	Pulse duration
SS	Spot size
RR	Repetition rate
t_c	Cryogen spurt duration
t_d	Delay between cryogen spurt and laser pulse

essential to insure that the use of lasers in medicine and surgery remains as safe as possible. The purpose of the First International Laser Surgery Morbidity Meeting held at Minnesuing Acres Lake Nebagamon, WI, on June 18–20, 2004 was to provide laser experts around the world the opportunity to present and discuss complications that their patients experienced and how they were successfully managed post treatment.

METHODS

Laser experts were invited to present complications of laser treatments that their patients have experienced in recent years and to discuss the potential mechanisms leading to the complication and its successful clinical management. Complications were reported using a standard format, including a description of the patient, indication for treatment, device used, treatment parameters (Table 1), complications that occurred, their management, final outcomes, and a brief discussion of the cause of the complication and potential methods of prevention. Nineteen unique cases are presented and the clinical management of each case discussed.

RESULTS

Summary of Cases Presented and Discussion

Pulsed Dye Laser (PDL)

Case 1: Pulsed dye laser (PDL)-induced scars due to intermittent cryogen spray cooling (CSC) device failure. Three pediatric patients presented on the same day for pulsed dye laser (PDL) therapy of their facial port wine stains (PWS) birthmarks. The patients were treated with a PDL in conjunction with cryogen spray cooling (CSC) under general anesthesia using the following treatment parameters: λ, 595 nm; F, 9–14 J/cm^2; t_p, 1.5 milliseconds; SS, 7 mm; CSC t_c, 30–60 milliseconds; t_d, 20 milliseconds. Within a few days post-operatively, all three patients developed scattered ~7 mm round erosions, equivalent in size and shape to the laser treatment spot diameter, followed several weeks later by hemorrhagic crusting and atrophic scars.

The complication occurred as a result of intermittent failure of the CSC device caused by bubbles present in the supply line between the cryogen canister and laser hand piece. Several weeks post-operatively, the cryogen bubble detector in the hand piece was found to be defective, which resulted in the intermittent loss of CSC. The complication is not easily avoidable given the absence of signs of device malfunction during treatment.

Millisecond Pulsed 1,064-nm Nd:YAG Laser

Case 2: Scarring following long pulsed 1,064 nm Nd:YAG laser treatment of port wine stain (PWS). The patient was a 55-year-old male who presented with a PWS with long-standing blebs on the neck and ear. The patient's PWS was treated with a Nd:YAG laser using the following treatment parameters: λ, 1,064 nm; F, 100 J/cm^2; t_p, 40 milliseconds; SS, 7 mm; Zimmer air cooling. Intra-operatively, the patient developed immediate tissue graying within the test spot (Fig. 1A), which resulted in a white scar (Fig. 1B). Intravascular coagulation was observed without tissue graying immediately following the laser pulse using the following treatment parameters: λ, 1,064 nm; F, 60 J/cm^2; t_p, 40 milliseconds; SS, 10 mm. The PWS was then treated with a PDL at the following treatment parameters: λ, 595 nm; F, 10 J/cm^2; t_p, 40 milliseconds; SS, 10 mm; Zimmer air cooling (set at unit 4) followed 1 minute later by treatment with a Nd:YAG laser using the test parameters (F, 60 J/cm^2; t_p, 40 milliseconds; SS, 10 mm).

The complication occurred as a result of thermal injury associated with the high fluence used to achieve photocoagulation with deeply penetrating 1,064 nm wavelength. Placement of test spots to determine the minimal purpuric threshold [7] or use of initial treatment with a PDL to allow for reduced fluences of the 1,064 nm laser may minimize this complication.

Case 3: Ulceration and scarring following long pulsed 1,064 nm Nd:YAG laser treatment of a proliferating hemangioma. The patient was a 3-month-old female with a rapidly growing hemangioma on the left cheek with combined superficial and deep components (Fig. 2A). The patient's hemangioma was treated with a Nd:YAG laser using the following treatment parameters: λ, 1,064 nm; F, 56 J/cm^2; t_p, 3 milliseconds; SS, 10 mm; RR, 1 Hz; CSC t_c, 50 milliseconds; t_d 50 milliseconds. One day post-operatively, four blisters developed in the areas of greatest apparent vascularity (Fig. 2B) which crusted over and were tender for several days. The deep component of the hemangioma decreased at least one-third in size over the following month. Superficial crusting was noted on one spot for almost a month as the lesion continued to regress (Fig. 2C). The crusting was initially managed with petrolatum ointment. Three areas, including the area of prolonged crusting, healed with hypopigmentation and slight scarring. To avoid further blistering, subsequent treatments were continued with a PDL using the following treatment parameters: λ, 595 nm; F, 7.5 J/cm; t_p, 1.5 milliseconds; SS, 10 mm; RR, 1 Hz; CSC t_c, 30 milliseconds; t_d, 30 milliseconds. The hemangioma slowly decreased in size by an additional 25% after the next three PDL treatments.

The complication occurred as a result of deep thermal injury associated with the use of highly penetrating near infrared wavelengths. Starting at a lower fluence may have minimized this complication. Only experienced laser surgeons should use 1,064 nm lasers for congenital vascular lesions in children and in adults.

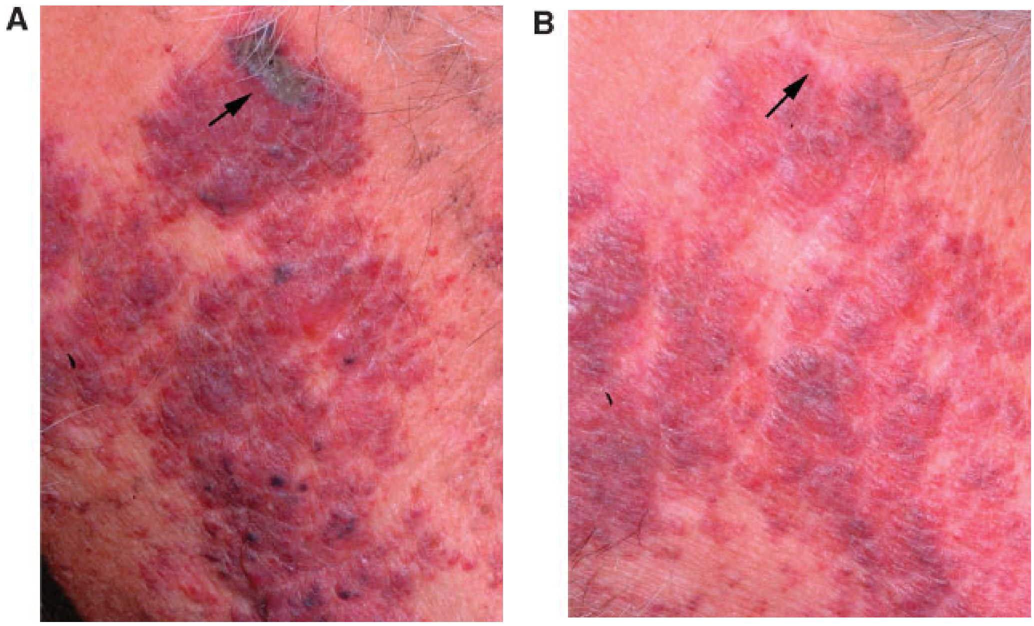

Fig. 1. **A**: PWS with immediate graying of test spot treated with a 1,064 nm Nd:YAG laser. **B**: PWS with scarring of test spot and improvement of remaining lesion following treatment with 595 nm PDL and 1,064 nm Nd:YAG lasers.

Case 4: Textural changes following long pulsed 1,064 nm Nd:YAG laser treatment of perinasal vessels. The patient was a 27-year-old Caucasian male who presented with perinasal telangiectasia (Fig. 3A). The patient's perinasal blood vessels were treated with a Nd:YAG laser using the following treatment parameters: λ, 1,064 nm; F, 380 J/cm^2; t_p, 13 milliseconds; SS, 1.5 mm; sapphire tip parallel contact cooling. The treatment was uneventful and resulted in lesion clearing; however, 2 months post-operatively the patient developed cutaneous indentations within the treated areas (Fig. 3B). The complication was managed by watchful waiting. Spontaneous resolution of these types of indentations may occur after a period of 6–10 months. Non-ablative dermal remodeling may be attempted to improve the indentations with infrared or visible light lasers. If the indentations do not resolve, ablative laser resurfacing also may be employed.

The complication occurred as a result of heat diffusion and thermal injury to tissue surrounding vessels. This complication may have been avoided by using lower fluences, however, even with the appropriate selection of laser treatment parameters, as in this case, patients can develop cutaneous indentations.

Case 5: Scarring following long pulsed 1,064 nm Nd:YAG laser treatment of excess facial hair. The patient was a 17-year-old female who presented with excess facial hair. The patient's excess hair was treated with a Nd:YAG laser using the following treatment parameters: λ, 1,064 nm; F, 100 J/cm^2; t_p, 50 milliseconds; SS, 10 mm hexagonal; sapphire tip contact cooling 5°C on the pre-auricular cheek. Two days post-operatively, the patient developed blistering at the treatment sites with subsequent scarring (Fig. 4A). The complication was managed by treatment of the facial scars with a Candela VBeam PDL using the following treatment parameters: λ, 595 nm; F, 6–7 J/cm^2; t_p, 10 milliseconds; SS, 10 mm; CSC t_c, 30 milliseconds; t_d, 30 milliseconds for two sessions without improvement. The final treatment outcome was hypertrophic scarring that persisted at 4 years follow-up (Fig. 4B).

The complication occurred as a result of excessive heating due to overlapping pulses or failure of the cooling system due to inadequate contact of the cooled tip. Avoiding overlapping pulses, checking the tip for adequate cooling prior to laser treatment, insuring good contact between the cooled tip and the skin surface may have avoided this complication. Future considerations to improve the scarring include Er:YAG or fractional laser skin resurfacing.

Case 6: Ulceration and scarring following long pulsed 1,064 nm Nd:YAG laser treatment of leg veins. The patient was a 67-year-old female who presented with ectatic leg veins. The patient's leg veins were treated with a Nd:YAG laser for twelve treatments over a 2-year period using the following treatment parameters: λ, 1,064 nm; F, 270 J/cm^2; t_p, 50 milliseconds; SS, 3 mm; RR, 2 Hz; contact cooling. Intra-operatively, during the 12th treatment session, the patient experienced pain with subsequent ulceration and scarring at the treatment sites (Fig. 5A). Seven months later, the scarring was treated with a PDL using the following parameters: λ, 595 nm; F, 6.5–7 J/cm^2; t_p, 6–10 milliseconds; SS, 10 mm; CSC t_c, 30 milliseconds; t_d, 30 milliseconds, for a total of eight sessions separated by

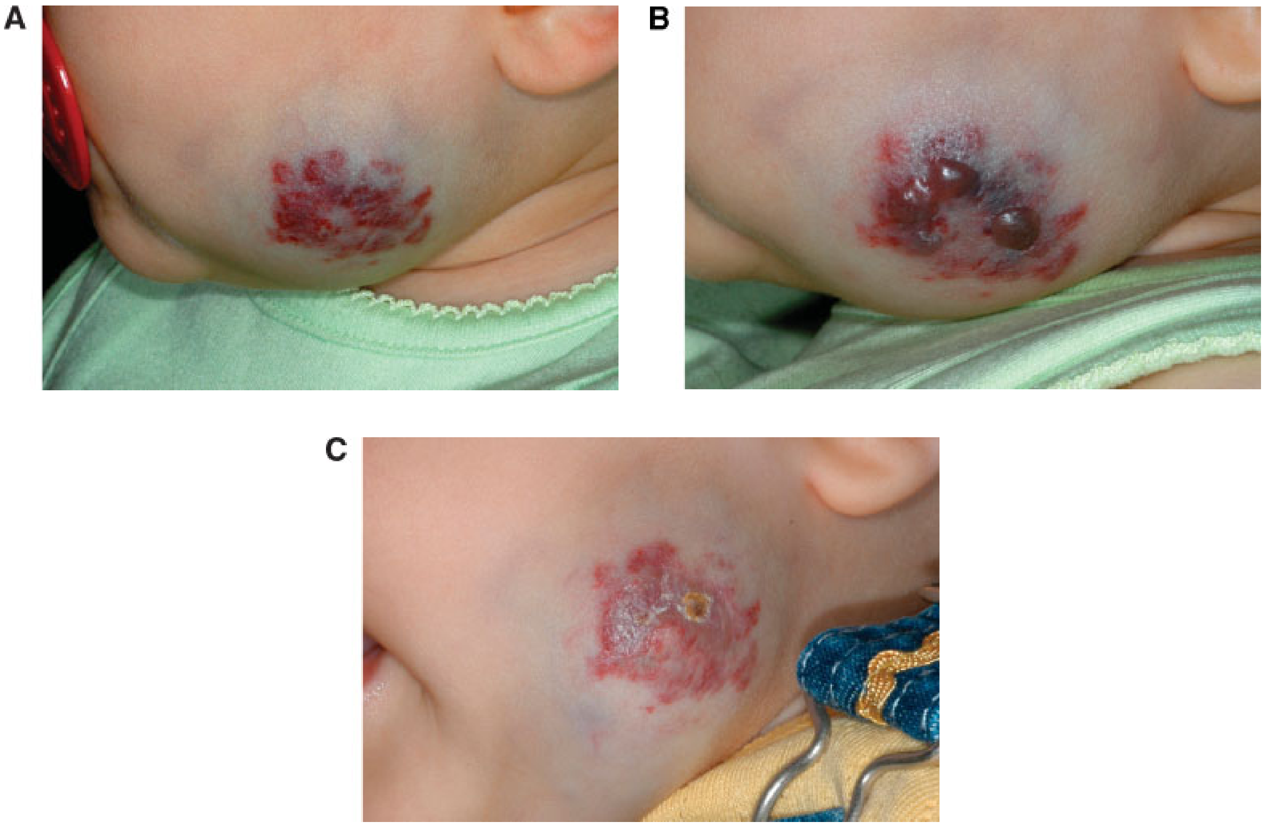

Fig. 2. **A**: Rapidly proliferating hemangioma before laser treatment. **B**: Blistering 1 day following treatment with 1,064 nm Nd:YAG laser. **C**: One month following treatment with 1,064 nm Nd:YAG laser.

1–2 months. The final treatment outcome was some improvement of the scarring.

The complication may have occurred as a result of inadequate contact of the cold tip with the skin surface during laser treatment. Pain during treatment may have indicated inadequate cooling, which may have been avoided by maintaining adequate contact of the sapphire tip with the skin surface during laser treatment.

532-nm KTP Laser

Case 7: Cutaneous depressions following 532 nm KTP laser treatment of facial telangiectasia. The patient was a 44-year-old female who presented with facial telangiectasia

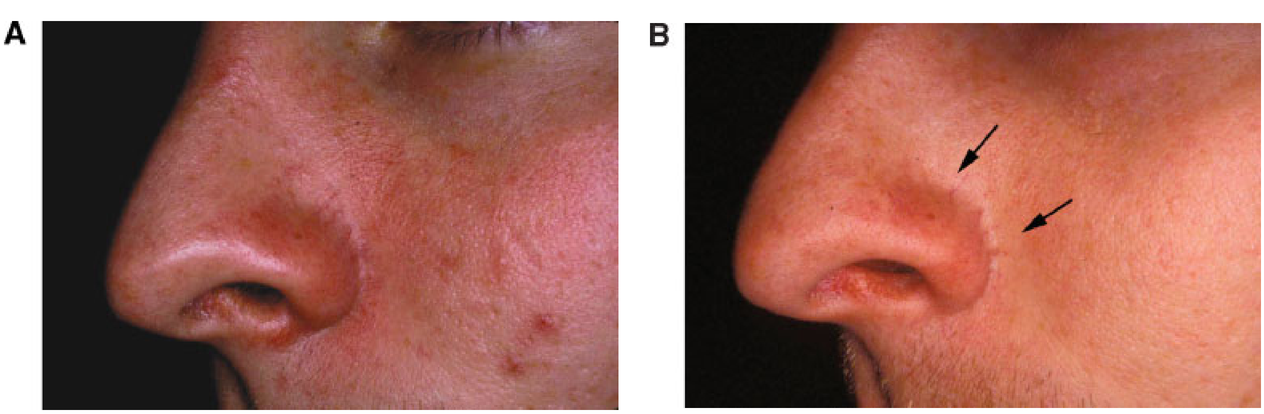

Fig. 3. **A**: Perinasal vessels before laser treatment. **B**: Cutaneous depressions following treatment with a 1,064 nm Nd:YAG laser.

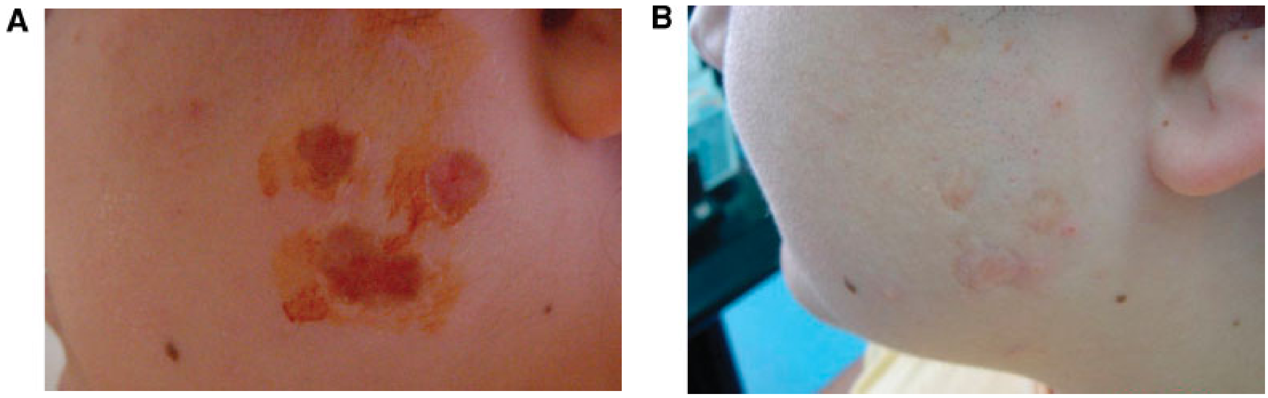

Fig. 4. **A**: Blistering and erythema 48 hours following laser epilation with a 1,064 nm Nd:YAG laser. **B**: Persistent scars 4 years following laser treatment.

(Fig. 6A). The patient's telangiectasia was treated with a KTP laser using the following treatment parameters: λ, 532 nm; F, 15 J/cm^2; t_p, 40 milliseconds; SS, 5 mm; with sapphire tip contact cooling, followed by a second pass using the following treatment parameters: F, 9 J/cm^2; t_p, 10 milliseconds; SS, 4 mm. Post-operatively, the patient developed erythema and swelling in the treated areas, followed 1 month later by hyperpigmentation over the larger vessels. The final treatment outcome was cutaneous depression and scarring at 3 months (Fig. 6B).

The complication occurred as a result of overheating of larger vessels with inadequate time allowed for heat dissipation required for larger vessels. The lack of blistering indicates adequate cooling of the sapphire tip. This complication may have been avoided by using caution in treating larger vessels and increasing the time interval between successive passes.

Fig. 5. Ulceration following treatment of leg veins with a 1,064 nm Nd:YAG laser.

Intense Pulse Light

Case 8: Inadequate cooling with intense pulsed light (IPL) treatment of melasma. The patient was a 40-year-old female who presented with mild melasma. The patient's melasma was treated with an IPL device using the following treatment parameters: λ, 520–1,200 nm; F, 21 J/cm^2; t_p, 20 milliseconds; SS, 12×12 mm^2; button 4. A cold aluminum roller was applied to the skin approximately after every 15 pulses on the right forehead. Intra-operatively, the patient experienced moderate to severe pain, and developed immediate erythema, gray discoloration and blistering, with crusting over the next 4 days (Fig. 7A). At the same visit, subsequent treatment of the left forehead using the same parameters with more frequent cooling (use of roller every five pulses) resulted in no pain or complications (Fig. 7B).

The complication was managed by early application of antibiotic ointment. To "feather" the perimeter of the eroded sites, the surrounding hyperpigmentation was retreated with conservative IPL parameters and adequate cooling 2 months later. The final treatment outcome was mild hypopigmentation that persisted at the site of deepest injury 10 months after treatment (Fig. 7C).

The complication occurred as a result of infrequent application of the cold aluminum roller and could have been avoided by more frequent application of the cold rolling system and/or by suspending treatment to assess the skin surface. The pain response alone should have alerted the treating physician that there might be excessive heat generation due to inadequate skin cooling. In the absence of integration, cooling is operator dependent, and successful treatment requires careful real-time attention to the pain response as well as the skin surface color. Erythema that sharply mirrors the IPL footprint, graying of the skin, or frank blistering indicates excessive fluence or inadequate cooling.

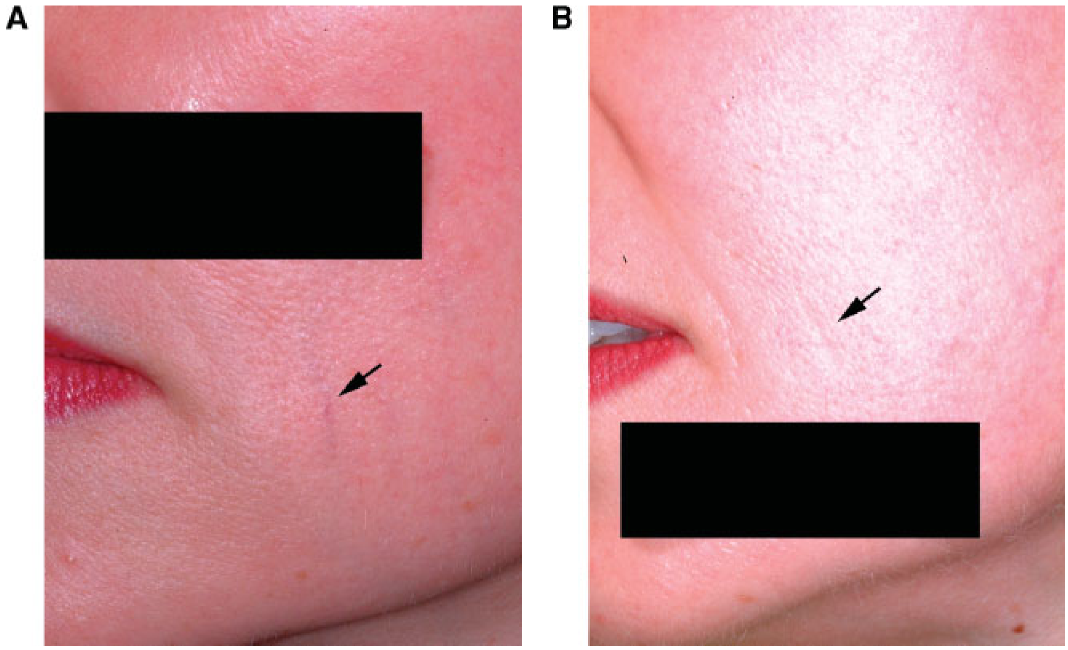

Fig. 6. **A**: Facial vessels before laser treatment. **B**: Cutaneous depression 3 months following treatment with a Q-switched Nd:YAG laser.

Intense Pulsed Light and Frequency Doubled 532-nm Nd:YAG Laser

Case 9: Dyschromia following sequential IPL and frequency doubled Nd:YAG for photoaging. The patient was a 42-year-old female (skin type II) who presented with diffuse Fitzpatrick Class II photo aging manifested by mild wrinkling, increased vascularity and pigment dyschromia. The patient's wrinkling, increased vascularity, and dyschromia were treated with a Q-switched Nd:YAG laser using the following treatment parameters: λ, 532 nm; F, 1.1 J/cm^2; SS, 4 mm; RR; 10 Hz. On the same day, the patient's clinical manifestations were treated with an IPL device using the following treatment parameters λ, 560–1,200 nm; F, 28 J/cm^2; SS, 10 $\times$35 mm^2; t_p, 2.4 milliseconds pass one, 4.2 milliseconds pass two. Post-operatively, the patient developed IPL "foot-printing" the size of the IPL crystal and persistent pigment dyschromia over Nd:YAG treated sites (Fig. 8). The complication was managed by application of increasing concentrations of a topical cream consisting of 5%–20% glycolic acid with 4% hydroquinone applied nightly, and biweekly microdermabrasions alternating with 20%–30% salicylic acid peels. The final outcome was marked improvement noted 4.5 months after treatment.

The complication occurred as a result of thermal injury following treatment with two pigment specific lasers in the same day, which may increase the risk of skin hypersensitivity and pigment dyschromia. Performing the procedures on separate days may have minimized this complication.

Combination Radiofrequency and Broad Spectrum Light

Case 10: Dyschromia following treatment of facial photoaging. The patient was a 47-year-old female (skin type II) who presented with diffuse Fitzpatrick Class II photo aging manifested by mild wrinkling, increased vascularity and pigment dyschromia. The patient was treated with a combination bi-polar radiofrequency energy and broad spectrum light device using the following treatment parameters: λ, 580–980 nm; F, 20 J/cm^3 RF energy, and 15 J/cm^2 broad spectrum light; two to three passes to the face without sequelae. A second treatment was performed 1 month later using the following treatment parameters: F, 25 J/cm^3 RF energy and 25 J/cm^2 broad-spectrum light. Post-operatively after the second treatment, the patient developed footprinting and persistent dyschromia at the treated sites (Fig. 9). The complication was managed with topical application of 2% hydrocortisone cream with 4% hydroquinone in addition to biweekly microdermabrasions, alternating with 20%–30% salicylic peels and 5% glycolic acid and nightly 2% hydroquinone cream. The final treatment outcome was gradual improvement of the dyschromia over 6 months.

The complication occurred as a result of an excessive increase in fluence leading to thermal injury. Using conservative treatment parameters in early treatment sessions, performing a test spot, and slowly increasing fluences by 10% may have minimized this complication.

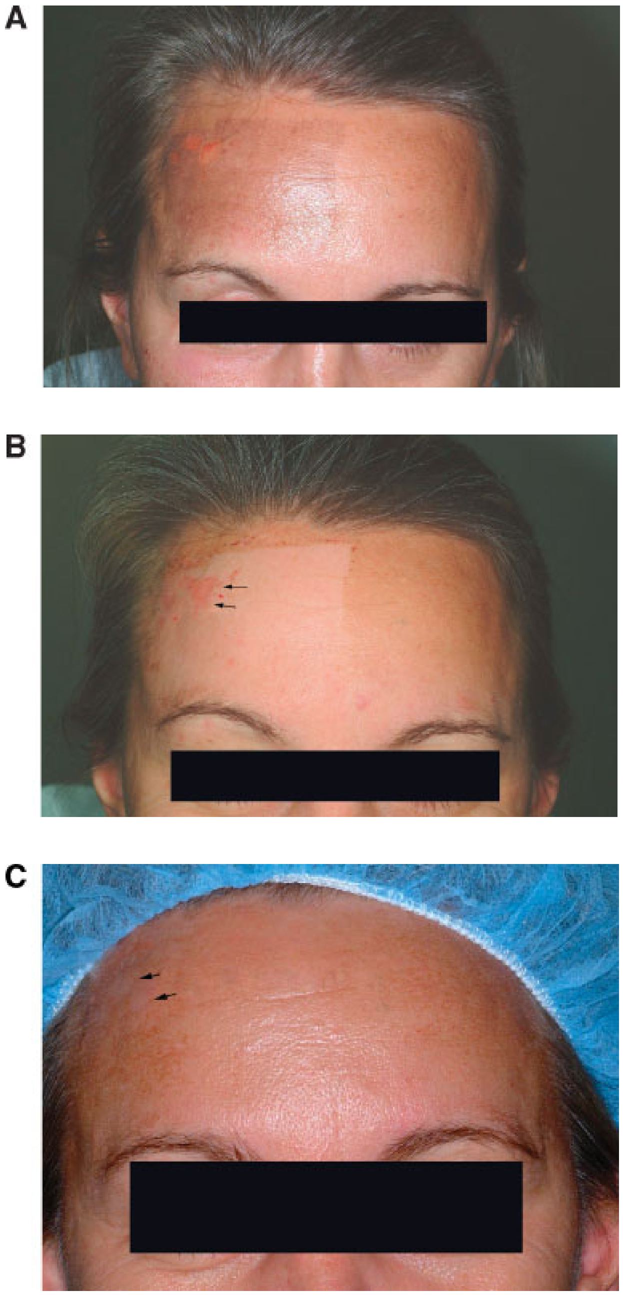

Fig. 7. **A**: One day after IPL treatment: the patient's right side shows effect of inadequate cooling; the left side was treated with same parameters but with more aggressive cooling. **B**: Healing wound 2 weeks following IPL burn. **C**: Focal hypopigmentation 10 months following IPL burn. Note the melasma has returned.

Fig. 8. Dyschromia following treatment with IPL and 532 nm frequency-doubled Nd:YAG laser.

CO_2 and Erbium:YAG Laser Resurfacing

Case 11: Actinic bronzing in "Skipped Areas" following CO_2 resurfacing for photoaging. The patient was a 52-year-old Caucasian female who presented with mild photo damage. The patient underwent uneventful full face laser skin resurfacing using a standard pulsed CO_2 laser and the following treatment parameters: λ, 10.6 μm; F, 300 mJ; SS, 2.25 mm. A single pass was applied with a computer pattern scanner (CPG) density of 6 (35% overlap between spots within the scan). Re-epithelialization was complete in 10 days. Erythema diminished significantly over 2–4 weeks; diffuse erythema persisted for 12 weeks. Eighteen months post-operatively the patient developed brown "stripes" on her cheeks that were coincident with "skip" areas between the initial individual square CPG scans (Fig. 10A,B).

The complication was managed with treatment of the actinically bronzed skip areas with a long pulsed 532-nm KTP laser without improvement. Full-face laser resurfacing with the treatment parameters previously used is planned. The complication occurred as a result of inadvertently skipped areas between scans at the time of resurfacing and could have been avoided by meticulous attention to laying down perfectly contiguous scans (using magnifying loupes during resurfacing). In the absence of complete skin coverage, the physician can use a "freehand" hand piece with independent pulses to "fill in" skip areas between scans at the time of initial resurfacing.

Case 12: Enterobacter cloacae infection following CO_2 laser resurfacing. The patient is a 38-year-old female who presented increased tenderness under one eye 1 week following CO_2 laser resurfacing. Yellowish discharge with erythema and swelling consistent with an infection were noted. Cultures were taken and the complication was managed with dilute vinegar soaks, and the oral antibiotic prescribed was changed from cephalexin to ciprofloxacin 500 mg twice daily. Bacterial culture grew *enterobacter cloacae* sensitive to ciprofloxacin. The patient's symptoms improved within the next 2 days.

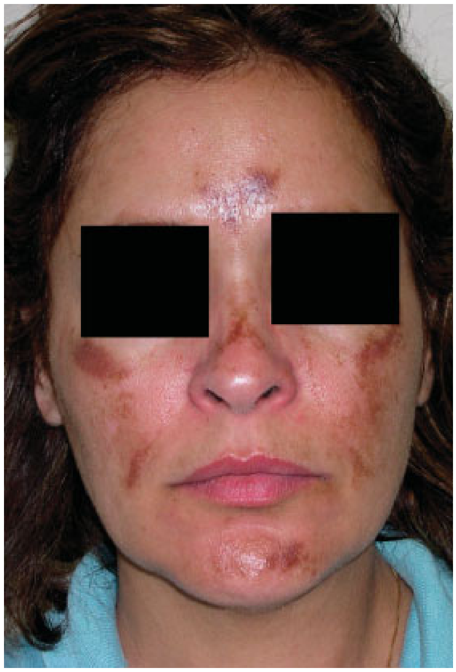

Fig. 9. Dyschromia following treatment with bi-polar radiofrequency energy and broad spectrum light.

The patient had children ages 2 and 5 years. Neither child was still in diapers, however children are typically not as careful with hand washing and hands may be contaminated with fecal flora. Practitioners should be careful to warn mothers of young children (as well as those with pets) to be aware of this potential contamination and to always wash their hands before touching their face to help control spread of bacteria. If a patient presents with post-operative pain, erythema, or discharge it is imperative to culture non-healing areas for fungus, viruses, and bacteria.

Case 13: Pseudomonas aeruginosa infection following CO_2 laser resurfacing leading to extensive scarring. The patient was a 50-year-old female who presented 1 year after CO_2 laser skin resurfacing with full face and anterolateral neck hypertrophic scarring and dyspigmentation (Fig. 11). The patient had been treated with three full passes with a CO_2 laser using the following treatment parameters: λ, 10.6 μm; F, 200 mJ; t_p, 80–520 milliseconds; SS, 4–9 mm. The entire area was treated with identical settings. Post-operative wound care included open wound healing with saline soaks and aquaphor healing ointment. During the first week post-operatively, the patient developed increasing pain and purulent discharge; cultures grew *Pseudomonas aeruginosa*. Antimicrobial therapy was initiated and the infection subsided. However, healing and full re-epithelialization was delayed for several weeks, with subsequent hypertrophic scarring and dyspigmentation. The scarring was treated with a PDL using the following treatment parameters: λ, 595 nm; F, 7.5 J/cm^2; t_p, 0.45 milliseconds; SS, 7 mm. In addition, the complication was managed with pressure dressings, intralesional steroids, potent topical steroids, and daily occupational therapy. The final outcome was extensive hypertrophic scarring and dyspigmentation.

The complication occurred as a result of overly aggressive CO_2 laser skin resurfacing and delayed diagnosis of a post-operative wound infection, both of which contributed to the final outcome. This complication could have been prevented

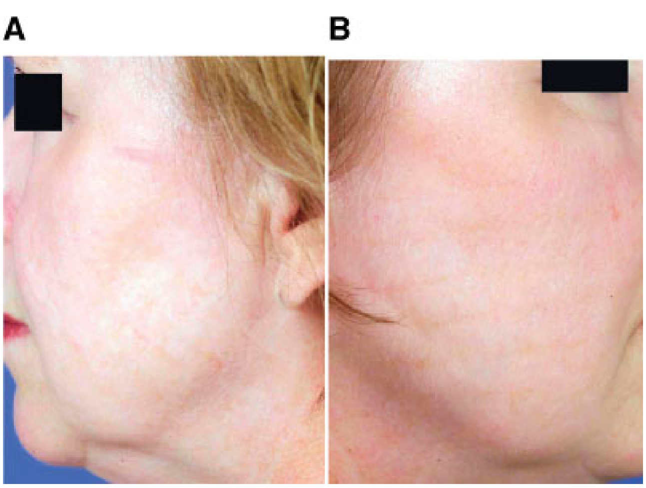

Fig. 10. **A**, **B**: Streaks of retained pigment (brown) in "skip areas" 18 months following single pass CO_2 laser resurfacing.

Fig. 11. Extensive hypertrophic scarring following CO_2 laser resurfacing complicated by infection.

by performing two rather than three passes, varying the treatment parameters depending on the facial area treated, avoiding the neck except in occasional circumstances with very gentle low fluences and one pass only. Earlier diagnosis may have limited the extent of scarring, but would not have eliminated the risk in this individual. The treatment of the scarring with the PDL, pressure dressings and topical and intralesional steroids was appropriate.

Case 14: Herpes simplex infection and staphylococcal ecthyma following CO_2 laser resurfacing. The patient was a 40-year-old female who presented with photo aging (Fig. 12A). The patient underwent CO_2 laser resurfacing with uneventful healing until the 8th post-operative day when she presented with a number of vesicles and erosions on the right cheek (Fig. 12B). Oral valacyclovir 500 mg twice a day was started 2 days pre-operatively and taken until post-operative day 7. Ten days post-operatively increasing vesicles and erosions developed (Fig. 12C). A Tzanck preparation and viral cultures for herpes simplex virus (HSV) were positive. The patient was admitted to hospital and treated with intravenous acyclovir. Fifteen days post-operatively, after 7 days of intravenous acyclovir and 2 days following hospital discharge, the patient presented with purulent erosions in many of the previously eroded areas that coalesced into superficial purulent ulcers (Fig. 12D). Wound cultures grew *Staphylococcus aureus* and oral dicloxacillin 500 mg four times daily was initiated. Twenty days post-operatively, the infection appeared to be resolving (Fig. 12E). The final treatment outcome was complete healing with no textural change several weeks following timely management of HSV and staphylococcal infections, and a very happy patient who remained remarkably optimistic throughout the post-operative course (Fig. 12F).

The complication occurred as a result of facial HSV infection that developed immediately after discontinuation of antiviral therapy and upon facial re-epithelialization. Intravenous acyclovir effectively treated the HSV infection, but by not continuing the dicloxacillin, a bacterial super infection developed. This complication may have been avoided by extending the antiviral prophylactic therapy, and contemporaneous antibiotic upon diagnosing the HSV infection may have prevented the secondary bacterial infection. Early diagnosis, appropriate therapy, and a positive patient attitude helped to prevent scarring in this case.

Case 15: Hypopigmentation and scarring following CO_2 resurfacing for exogenous ochronosis. The patient was a 60-year-old Southern African black female who presented with exogenous ochronosis predominantly affecting her malar areas and upper lip. Test spots were performed with a CO_2 laser using the following treatment parameters: λ, 10.6 μm; 40 W, 200 mm hand piece; 6 mm square pattern, using single, double, and triple passes. After 12 months, the test areas resolved to form a single uniformly hypopigmented patch which was nevertheless cosmetically pleasing to the patient (Fig. 13A). Test spots were also performed with a Q-Switched 694 nm Ruby laser and showed no lessening of the ochronosis. The patient was treated with single pass CO_2 laser resurfacing using the above treatment parameters. Post-operatively, the patient developed marked hyperpigmentation of lesional skin and hypopigmentation of other resurfaced areas, the latter characterized by delayed and incomplete re-pigmentation. In addition, at 12–16 weeks there was incipient, erythematous scarring on the right cheek and upper lip (Fig. 13B).

The complication was managed by treatment of scarring with a PDL using the following treatment parameters: λ, 585 nm; F, 7 J/cm^2, t_p, 1.5 milliseconds; SS, 7 mm; CSC t_c, 30 milliseconds; t_d, 30 milliseconds delay. The final treatment outcome was improvement of the ochronosis, however, with persistent patterning and hypopigmentation at 2 years. The complication may have occurred as a result of compromised healing in the presence of dermal changes associated with exogenous ochronosis that led to exaggerated fibrosis and consequent hypopigmentation and scarring. Avoiding ablative resurfacing in the presence of exogenous ochronosis may have prevented the complication.

Case 16: Hypertrophic scarring following Erbium:YAG laser resurfacing. The patient was a 51-year-old female referred for evaluation and treatment of hypertrophic scarring that resulted from variable pulsed Er:YAG laser resurfacing (Fig. 14A). In areas of ongoing healing, an erythematous, almost eczematous plaque was evident. Other areas had thickened hypertrophic red scars. All areas were treated with a PDL using the following parameters: λ, 595 nm; F, 7.0–7.5 J/cm^2; t_p, 6 milliseconds; SS, 10 mm; CSC t_c, 30 milliseconds; t_d, 30 milliseconds. The thickened areas were also injected with intralesional triamcinolone at concentrations of 5–20 mg/ml depending on the thickness of the scars. Eight laser treatments were performed at 1–2 month intervals, with more frequent treatments earlier on. As the progression of new scarring slowed, longer intervals between treatments were allowed. The final treatment outcome was marked improvement in scarring, with some persistent scars in the areas of greatest hypertrophy 2 years after initiation of therapy (Fig. 14B).

The complication occurred as a result of aggressive ablation and a tendency toward hypertrophic scarring. Careful attention to any non-healing areas, which are a sign of potential scarring, could have minimized this complication. An erythematous, eczematous region unrelated to a contact allergic or irritant dermatitis may be a precursor to scarring. If topical modalities do not improve the area, the PDL may be used to help halt the scar progression. In some cases, several treatments may be needed to obtain the best possible cosmetic result.

Monopolar Radiofrequency Device

Case 17: Textural changes following radiofrequency treatment facial tissue laxity. The patient was a 57-year-old Caucasian presented with mild facial laxity. The patient was treated with a monopolar radiofrequency device. A full-face procedure was performed with no anesthesia using a grid and the following treatment parameters: SS, 1×1 cm^2; lower face F, 124 J/cm^2 the first pass and then 106–89 J/cm^2 the second pass; upper neck and forehead F, 106–89 J/cm^2; and selected double passes of the sub-mental and jowl areas. A total of 200 pulses were

Fig. 12. **A**: Before CO_2 laser resurfacing. **B**: 7 days following CO_2 laser resurfacing. **C**: Vesicles and erosions ten days following CO_2 laser resurfacing. **D**: Purulent erosions and ulcers 15 days following CO_2 laser resurfacing. **E**: Resolving infection 20 days following CO_2 laser resurfacing. **F**: Complete healing several weeks following timely management of HSV and staphylococcal infections.

used. The treatment was tolerated by the patient with a pain score of 2 on a scale of 0–4. There were no immediate side effects except transient erythema and swelling.

One month post-operatively, the patient developed mild cutaneous depressions on the cheeks (Fig. 15). The complication was managed by instructing the patient to massage the skin daily and two treatments with a PDL using the following treatment parameters: λ, 595 nm; F, 6 J/cm^2; t_p, 6 milliseconds; SS, 10 mm; CSC t_c, 40 milliseconds; t_d, 30 milliseconds. The final treatment

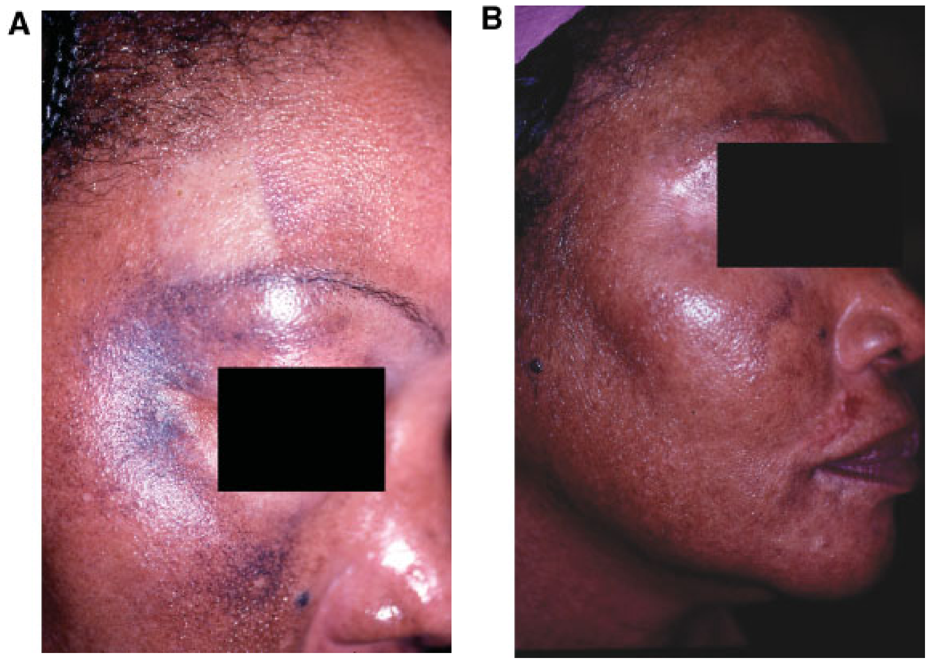

Fig. 13. **A**: Patient with exogenous ochronosis showing uniform hypopigmentation following test spots using one, two, and three passes with a CO_2 laser. **B**: Incomplete facial repigmentation, together with scarring on the lip and cheek 16 weeks after resurfacing.

outcome was 80% improvement in the skin indentations at 12 months follow-up.

Although, biopsies were not obtained, the complication most likely occurred as a result of selective heating of the subcutaneous fat layer by radiofrequency energy. Despite the appropriate level of patient discomfort on a subjective pain scale using no anesthesia during the two passes, the procedure produced cutaneous depressions. Using lower fluences with multiple passes may help to eliminate this type of complication.

Case 18: Textural changes following radiofrequency treatment of periorbital tissue laxity. The patient was a 56-year-old female who presented with periorbital tissue laxity. The patient was treated with a monopolar radiofrequency device using the following treatment parameters: *F*, 14.5 J/cm^2; SS, 1×1 cm^2; RR, *5* min. Two months post-operatively, the patient developed cutaneous depressions in the both temple areas (Fig. 16). The complication was managed by watchful waiting. The complication occurred as a result of excessive heating by radiofrequency energy and may have been minimized by use of lower energy with multiple passes.

Fractional Resurfacing Prototype Device

Case 19: Persistent hypopigmentation following evaluation of microscopic thermal zone densities after fractional laser skin resurfacing. The patient was a 36-year-old male (skin type II) who was exposed to test spots for evaluation of the effects of different microscopic thermal zone (MTZ) densities for a fractional resurfacing prototype device emitting at 1,450 nm and an energy per MTZ of 3 mJ. The test site treated with 10,000 MTZ/cm^2 (100 μm between MTZ); *F*, 30 J/cm^2 developed immediate whitening, followed by marked erythema persistent for several weeks after exposure, while the test sites with lower MTZ densities of 2,500 MTZ/cm^2 (200 μm between MTZ); *F*, 7.5 J/cm^2 and 625 MTZ/cm^2 (400 μm between MTZ); *F*, 1.9 J/cm^2 were well-tolerated (Fig. 17A). The final treatment outcome was persistent hypopigmentation at the test site with the highest MTZ density (10,000 MTZ/cm^2), while the lower MTZ densities did not exhibit any dyspigmentation 2 years post-operatively (Fig. 17B).

The complication occurred with excessively high MTZ densities (approximately five times the total MTZ density as applied with the currently available fractional resurfacing device after multiple passes). Such high densities result in confluent bulk heating of the skin and as they lack of undamaged tissue between individual MTZs, they are not consistent with the concept of "fractional" resurfacing anymore. This complication can be prevented by strictly avoiding the use of excessively high MTZ densities with fractional resurfacing devices.

DISCUSSION

Innovations in lasers, light and radiofrequency devices have allowed for improved therapeutic efficacy and safety and the ability to treat patients with an ever-increasing number of medical and aesthetic indications. [2]. As such

Fig. 14. **A**: Hypertrophic scarring following Er:YAG laser resurfacing. **B**: Marked improvement following eight treatments with a 595 nm PDL and intralesional corticosteroids.

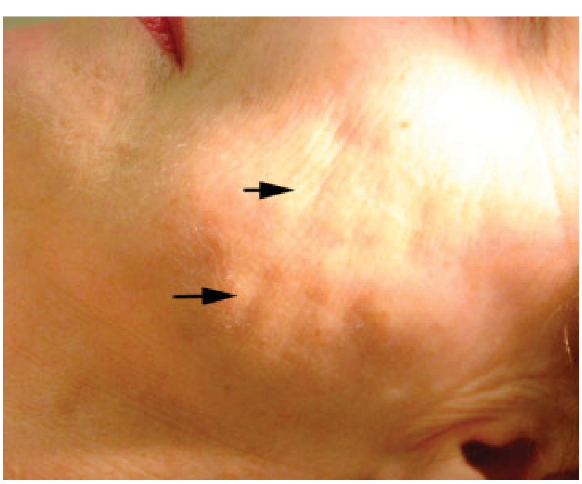

Fig. 15. Textural changes following treatment with a monopolar radiofrequency device.

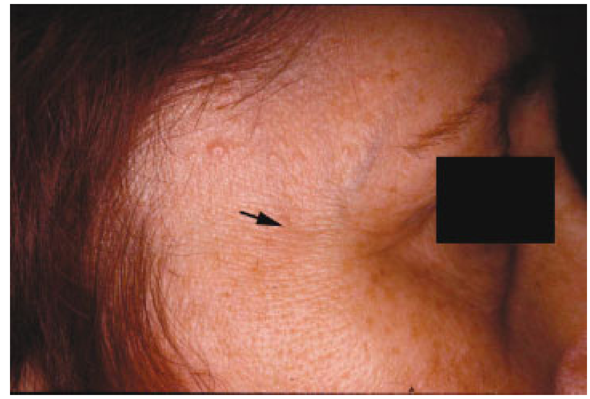

Fig. 16. Cutaneous depressions 4 months following treatment with a monopolar radiofrequency device.

innovations continue to develop, techniques continue to evolve to achieve optimal efficacy and minimal side effects. Because many laser and light based devices receive food and drug administration approval with a relatively simple 510 K application, determination of the exact parameters for achieving the best results with minimal side effects is left to the experience of clinical investigators and practitioners. Furthering this difficulty, many new devices allow for the ability to modify multiple treatment parameters, requiring considerable knowledge for safe operation. The complications presented at this meeting demonstrate that

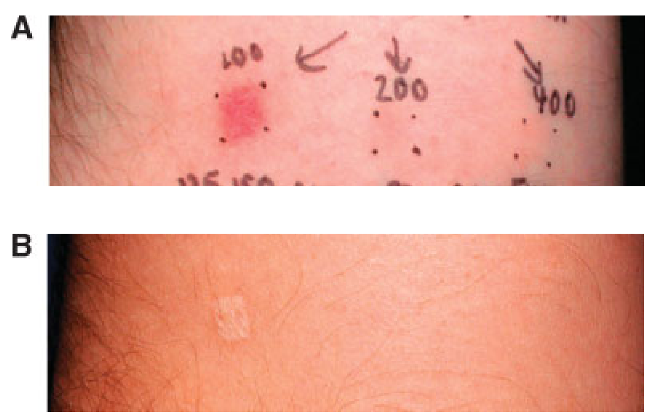

Fig. 17. **A**: Effects of three different MTZ densities§ for a constant MTZ energy of 3 mJ 17 days post-exposure. There is marked erythema within the test site with excessively high MTZ density. The remaining test sites do not exhibit any erythema. §100 μm distance between center of adjacent MTZ is equivalent to 10,000 MTZ/cm^2 (F, 30 J/cm^2); 200 μm is equivalent to 2,500 MTZ/cm^2 (F, 7.5 J/cm^2); 400 μm is equivalent to 625 MTZ/cm^2 (F, 1.9 J/cm^2). **B**: Effects of three different MTZ densities§ for a constant MTZ energy of 3 mJ 2 years post-exposure. The test site with excessive high MTZ density presents persistent hypopigmentation while the remaining test sites do not exhibit any pigment disturbance.

even experts with decades of experience can and do have patients with complications associated with light-based treatments, emphasizing the importance of timely and skillful management.

One of the greatest advances in laser surgery in recent years has been the development of skin cooling technologies, which protect the epidermis from heat injury and allow for the use of higher fluences [3,4]. Failure of skin cooling, whether due to device or operator error, poses risks of thermal injury: misalignment of the cryogen spray tip, angling of the hand piece, and inadequate duration of cryogen spray have been described [5]. Misalignment of the cryogen spray tip causes crescent-shaped hypopigmentation [5], unlike the round scars in Case 1. Intermittent failure of the cryogen spray due to air bubbles in the line between the cryogen canister and the laser hand piece is a rare complication that may lead to PDL-induced scarring, especially when fluences greater than 10 J/cm^2 are used. Awareness of this type of device malfunction is important given that the associated complications may be inconspicuous at the time of treatment.

All methods of skin cooling (evaporative, contact, or convective) may have unique complications if improperly utilized. Infrequent application of aluminum rollers (Case 8), failure of water chilling, inadequate contact, and/or retrograde motion of copper tips can result in inadequate cooling with increased pain and undesirable tissue reactions at the time of treatment. These immediate reactions can herald post-operative blistering, ulceration, and scarring; careful real-time attention to the patient's pain response and the skin surface color immediately after treatment is required to insure adequate skin cooling (Cases 6 and 8). Additional measures include familiarity with the specific device, feeling the cooled tip prior to initiation of therapy, appropriate use of pre, parallel, and post-cooling methods, optimal duration of cryogen spray for a given fluence and spot diameter [6], and increasing fluences slowly with the initiation of cooling methods.

Because absorption of both oxyhemoglobin and melanin is reduced in the near infrared region of the electromagnetic spectrum, significantly higher fluences are required for photocoagulation of deeper vessels. The use of proper cooling methods and avoidance of overlapping pulses is essential with long-pulsed 1,064 nm lasers to prevent injury associated with inadequate dissipation of heat (Cases 5 and 6). Immediate blanching of target vessels with no change in the overlying epidermis should be observed to insure appropriate treatment parameters are used. In the absence of epidermal injury, cutaneous depressions can occur 1–2 months following laser treatment due to diffusion of heat beyond the target vessel (Cases 4 and 7).

Recent work evaluating the efficacy of long pulsed 1,064 nm lasers for the treatment of PWS demonstrated a steep fluence-response relationship much like that observed in Case 2 [7]. In addition, great variation in the minimal purpuric threshold (MTP) observed, suggests that the skin response changes rapidly at fluences greater than the MPT. Determination of MPT is recommended with use of the 1,064 nm Nd:Yag laser to treat PWS. In addition, Black et al. demonstrated increased absorption during coagulation with the 1,064 nm laser associated with the formation of methemoglobin that may lead to "runaway" heat deposition and burns, suggesting the safety profile of long pulsed 1,064 nm lasers may be improved by initial treatment with a 532 nm laser followed by a 1,064 nm laser at lower fluences as demonstrated in Case 2 [8,9]. The use of longer wavelengths and higher fluences to treat vascular lesions may be best reserved for laser experts familiar with the complexities of these lesions and devices (Cases 2,3, and 6).

Innovations in the treatment of photo aging have greatly expanded in recent years to include broad-spectrum IPL sources that allow for simultaneous treatment of vascular and pigmentary changes. Early complications with IPL devices have been reduced with the use of cooling methods, selective filters [10–12], light guide positioning, lower fluences for the neck and chest, reducing fluence with progression of treatment, caution in darker and tanned skin, and treating only cosmetic units to avoid irregular treatment delineation. Additive thermal injury may occur with the use of combinations of laser, light, and radiofrequency therapies (Cases 9 and 10), which may increase the risk of epidermal injury. With careful attention to the time allowed between passes, use of lower fluences and multiple passes may improve efficacy and safety.

Complications associated with CO_2 resurfacing have been well described [13–19]. The use of aggressive techniques, including use of high energy densities, multiple passes, and overlapping spots or scans can increase the risk of hypertrophic scarring and infections (Cases 13 and 16). The management of infection risk has been controversial, and various regimens of prophylaxis against viral, bacterial, fungal infections, and post-operative wound care have been recommended [20–39]. Ideally, antimicrobial prophylaxis should be tailored to individual risks (Case 12) and the timely management can minimize adverse outcomes (Cases 12, 13, and 14). Further, Case 15 raises the possibility that exogenous ochronosis may interfere with normal wound healing suggesting that ochronosis may be a relative contraindication for ablative resurfacing.

It is important to treat signs of potential scar formation early. Increased or prolonged erythema or eczematous changes can be a sign of potential trouble. Potent topical corticosteroids and treatment with the PDL may improve scarring (Cases 13 and 16); intralesional steroids may be required for hypertrophic scars. The patient should be followed closely and treated at 3–6 week intervals depending on scar progression. If there is any question as to the best way to proceed, the patient should be referred to a skin laser expert for management.

Growing demand for non-invasive rejuvenation of photo aged skin has led to the expansion of non-ablative techniques [40], including monopolar radiofrequency devices that induce collagen remodeling and selective heating of the fibrous septae [41–46] and fractional resurfacing devices that induce spatially selective dermal injury with minimal epidermal damage [47]. The use of radiofrequency devices with excessive energies and overlapping pulses may lead to cutaneous depressions that may or may not be associated with excessive pain (Cases 17 and 18). Even so, excessive pain during treatment is an important indicator of thermal injury. Cutaneous depressions may spontaneously improve over 6–12 months. Gentle dermal massage, non-ablative remodeling, and dermal fillers may be beneficial. Avoiding inadvertent overlapping of volumetric areas and the use of lower energies with multiple passes may improve efficacy and minimize the risk of unintended thermal injury.

A recently developed fractional resurfacing device (Fraxel™) may offer a promising alternative to non-ablative resurfacing methods [47]. A microscopic pattern of laser-induced epidermal and dermal thermal injury provides partial epidermal replacement and collagen remodeling with minimal downtime. Optimal pattern densities allow for sufficient spacing of MTZs and therefore avoid confluence of thermal injury. The operator should avoid very high MTZ densities and should also provide sufficient time for the skin to cool down between multiple passes. This is especially important when small areas are covered with multiple passes. In order to provide a relatively homogeneous MTZ density over the entire treatment area, the operator should keep the hand piece perpendicular to the skin surface and should carefully track the number of passes performed within each area. Immediate skin whitening during treatment should be strictly avoided as it indicates excessive thermal injury that may be associated with persistent hypopigmentation (Case 19).

CONCLUSION

Complications such as scarring, dyspigmentation, and textural changes can occur with any laser, light, or radiofrequency based treatment, even in the hands of the most experienced laser surgeons. Such complications may result from diverse causes, including device malfunction, poor patient selection, operator error, post-treatment mismanagement, or simple misfortune. Many recent advances in laser surgery take advantage of energy sources and treatment parameters that do not strictly adhere to the principles of selective photothermolysis and require increasing knowledge and skill of the laser surgeon. As continued innovations attempt to improve upon existing techniques and technologies, awareness of potential complications, early recognition when problems do arise, and knowledge of how to skillfully manage complications is essential to insure patient safety.

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