Emerging Technologies in Scar Management: Remodeling of Post-surgical Linear Scar Using Microplasma Radiofrequency

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53.1 Introduction

A strategy of remodeling of an existed scar is by changing its tissue architecture that can eventually lead to a grossly non-visible or minimally visible scar. Since some years, mechanical or energetic manipulation of scarred skin has received considerable attention in attempts to improve scar quality. Next to techniques as dermabrasia, CO₂ laser, or microneedling, microplasma technology might represent a new technique in this field [1].

53.1.1 Fractional Microplasma Radiofrequency Technology

There are four formats of matter: solid, liquid, gas, and plasma. With energy, solid can be converted into liquid and liquid into gas. Similarly, gas can also be transformed into plasma with energy input. The fractional microplasma radiofrequency technology (FMRT) employs the energy of radiofrequency to act on nitrogen of the air in the narrow space between the therapy tip and the treated skin, and thus to form a grid of high-energy focal-led plasma sparks, which result in ionization of a portion of the atoms. With this physical effect, the FMRT can cause mild ablation of the epidermis

with the formation of micro-channels in a fractional way (■ Fig. 53.1).

The device we used in the past 13 years for patient treatment was a product from Alma Lasers (Caesarea, Israel) called Pixel^{RF} with both roller and stationary tips. ■ Figure 53.1 demonstrates its working mechanism of the device. In general, this device creates the depth of ablative point in 100–150 μm , and the size of ablative point 80–120 μm in diameter, and heating effect with a unipolar can reach the depth of 1000 μm , depending on the radiofrequency power and pulse duration. However, the ablative depth could reach to the upper part of the dermis with increasing energy, and thus to remodel a superficial layer of dermis. By this way, the FMRT can remodel tissue structure via ablative microchannel of epidermis and controlled thermal modification of the underlying dermis, with new collagen synthesis and collagen remodeling [2, 3]. With this type of working mechanism, the created micropore wound can be healed in 7 days (■ Fig. 53.2) and thus repeated treatments can be applied.

Although this particular device was used because of its availability to the author at that time, the effect of wound/scar remodeling is also likely to be achieved by other devices such as CO₂ fractional laser or others made by Lumenis, Cynosure, Alma, or Syneron, depending on physicians' clinical expertise (■ Fig. 53.3).

■ Fig. 53.1 The schematic picture of FMRT working mechanism. **a** Radiofrequency energy acts on nitrogen to create plasma particles. **b** Plasma particles penetrate epidermis in a fractional way. (Photo courtesy from Alma Lasers. © All rights reserved)

Fig. 53.2 Histological demonstration of microplasma working depth and healing process. **a** Acute wound immediately after microplasma. **b** Healing at day 3. **c** Healing at day 14. (Photo courtesy from Alma Lasers. © All rights reserved)

53.2 Procedures: Clinical Protocol for Microplasma-Based Tissue Remodeling (Fig. 53.3)

53.2.1 Pre-therapy Preparation

1. Patients with skin lesions at the treating area should be advised not to receive the treatment before the cure of these lesions, including infectious skin lesions caused by both virus and bacteria, dermatitis, psoriasis, eczema, and urticaria.
2. Patients should be advised for proper management of the micropore wound post-therapy and potential side effects with signed written informed consent.
3. Photography before the treatment. Be sure that it is taken before topical anesthesia and it is in the same conditions of environment such as light, focus, and positions.
4. Topical application of 5% lidocaine hydrochloric gel under plastic wrap for 60–90 minutes before the treatment followed by thorough cleaning and sterilization with 70% alcohol.
5. Non-treated skin should be protected with paper tape surrounding the treated skin if the tip is larger than the area to be treated.

53.2.2 Microplasma Treatment

1. Fractional microplasma radiofrequency treatment was performed with the device of Pixel RF (Alma Lasers, Caesarea, Israel).
2. A roller tip was used with the power setting at 60–90 watts, and 3–4 passes were usually made in different directions.

53.2.3 Post-therapy Wound Care

1. Patients are advised for comprehensive instructions of post-procedure care.
2. Sterile saline cleaning and erythromycin eye ointment were topically applied daily for 6 days to prevent infection.
3. Patients are advised not to be exposed to sunlight to avoid post-therapy pigmentation.
4. Patients are advised to protect the treating area by avoiding scratching or rubbing.

Fig. 53.3 Microplasma procedure. **a** Paper taping is applied to protect untreated skin and 2–3 mm skin surrounding the healed wound tissue is also included in the procedure. **b** A roller tip is

applied to perform the procedure. **c** The gross view of the treated wound/skin tissue immediately after the procedure

5. Patients are advised to have the follow-up regularly.
6. In the case of early wound remodeling, anti-tension type or device should be applied before and after the treatment.

53.3 Application Areas for FMRT-Mediated Tissue Remodeling

53.3.1 Microplasma Therapy for Post-scar Revision Skin to Enhance Cosmetic Result

Brief descriptions of the procedures for treating a linear scar for cosmetic reasons are as follows:

1. In general, a patient will visit our clinics and seek a consultation through discussing what a patient is expected and what can be achieved from the procedures. Then the patient will make an appointment for a scar revision surgical procedure.
2. In the surgical procedure, the patient is given a local injection of 1–2% lidocaine for anesthesia. In most cases, a w-plasty procedure will be applied along with the surgical excision of a linear scar to prevent linear tension, which usually causes observable scarring after the scar revision. To reduce wound tension, wound edge flap should be freed before wound closure. In addition, suturing of wound tissue at various levels also helps reducing wound tension, including subcutaneous, dermal, and epidermal tissues. For patients who are prone to scarring, wound irrigation with triamcinolone acetonide (5 mg/mL) or 5-fluorouracil (2–4 mg/mL) or both combined should be applied before wound closure to prevent scar formation.
3. After the surgical procedure, tension-reduction tape (such as 3 M tape) should be applied to keep the wound in a tension-free state. Patients are advised to have the tape changed every 2–3 days and maintained for at least 6 months post-surgery. The stitches are removed at day 5 or 6 post-surgery for head and neck regions, and stitch removal can be postponed for 1 or 2 days at other regions. In case of the scar-prone patients who were treated for hypertrophic scar or keloid, an injection of triamcinolone acetonide (5 mg/mL) or 5-fluorouracil (2–4 mg/mL) or both combined with lidocaine into the healed wound can be administered at 1 or 2 months post-suturing.
4. In most cases, Pixel RF microplasma is applied to the healed incisional wound at 8 weeks post-surgery. Generally, the therapy should include 2–3 mm normal skin on both sides of the linear wound. The procedure is usually applied with a roller tip at 60–70 watts with 3–4 passes (Fig. 53.2).
5. Pixel RF microplasma therapy should be repeated for 3–5 times with 8–12 weeks' interval in general and patients should be closely followed up every 4–8 weeks until a linear wound mark and stitch marks are completely removed. By this procedure, the linear scar resulting from scar revision procedure can be largely removed and the fine linear scar becomes grossly less visible or non-visible.

Fig. 53.4 Case presentation of microplasma remodeling of a linear scar resulting from surgical scar revision procedure. **a** Before surgery. **b** The gross view of a linear scar at 8 weeks after the first microplasma remodeling on a post-scar revision scar. **c** After 3

microplasma remodeling, the gross view reveals complete scar remodeling and no visible linear scar at the time points of 8 weeks after the third remodeling

Fig. 53.5 Case presentation of microplasma remodeling of a linear scar resulting from surgical scar revision procedure. **a** Before surgery. **b** The gross view of a linear scar at 8 weeks post-surgical scar revision. **c** Gross view of a remodeled linear scar at 8 weeks after

the first microplasma remodeling. **d** After 3 microplasma remodeling, the gross view reveals complete scar remodeling and no visible linear scar at the time points of 8 weeks after the third remodeling. However, erythema resulting from tissue remodeling remains visible

The following are the case presentations.

■ ■ Case 1

A 32-year-old female patient visited our clinic to request for forehead scar treatment solely for cosmetic reason. Physical examination showed a red-colored linear scar with a length of 2 cm and a width of 0.2 cm. In addition, the linear scar was also a bit elevated and with a few stitch marks scar on both sides (■ Fig. 53.4a). The patient received a scar revision surgery along with w-plasty procedure. After the surgery, the patient wore 3 M anti-tension paper tape vertical to the incisional line. Later, silicone gel was also applied topically on the incisional line, and then 3 M paper was used. At 8 weeks post-surgery, she received microplasma therapy with an energy of 65 watts and 4–6 passes of rolling therapy. At 8 weeks after the first treatment, the follow-up photo showed significant improvement of the gross view of her forehead scar, although a fine linear scar remains

when observed closely (■ Fig. 53.4b). Then, the patient received another two treatments with 8 weeks' interval between them. At 8 weeks after the third therapy, the follow-up photo shows no visible linear scar on her head (■ Fig. 53.4c), and the patient was completely satisfied as the result match her original request of removing her forehead scar completely.

■ ■ Case 2

A 27-year-old female patient visited our clinic for cosmetic treatment of a linear scar on her left face. Physical examination showed a mature flatten linear scar with a length of 6 cm and a width of 0.5 cm as shown in ■ Fig. 53.5a. The patient received a surgery of scar revision plus w-plasty. The follow-up photo at 8 weeks post-surgery showed an apparent linear scar resulting from scar surgical revision, with which the patient was significantly unsatisfied despite the fact that an original wide and flatten scar has been transformed into a fine

linear scar (■ Fig. 53.5b). At this time point, microplasma tissue remodeling procedure was applied to the patient with an energy of 70 watts and six passes using a roller tip. Interestingly, at 8 weeks after the first therapy, the linear scar has already been significantly remodeled with the previous linear scar obscured; however, the linear scar remained obviously visible (■ Fig. 53.5c). Thereafter, the patient was given another two microplasma therapies with 8 weeks' interval between them. At 8 weeks after the third therapy, the follow-up photo showed that a linear scar resulting from scar revision surgery was almost completely remodeled with no apparently visible linear scar (■ Fig. 53.5d). Due to the thorough tissue remodeling process, in which the tissue structure of a healed linear wound has been significantly changed along with a regenerative skin repair, angiogenesis apparently occurred with manifestation of skin redness (■ Fig. 53.5d), which will disappear in 3–6 months after the discontinuation of the treatment. The patient was very satisfied with the end result, in which microplasma tissue remodeling played a role significantly more important than the surgical procedure.

53.3.2 Microplasma for Early Wound Intervention to Prevent Scar Formation

With the success of remodeling healed linear wound tissue, we wondered if such a concept could be applied to tissue remodeling of an early incisional wound to prevent scar formation. The scenario is that linear wounds of non-elected surgical procedures such as trauma and wounding are usually difficult to prepare an optimal condition for their healing, and thus these linear wounds are more likely to form an obvious linear scar than the wounds created by elected surgical procedure of scar revision.

Due to the non-optimal healing condition, the wound tissue remodeling procedure should be applied at an early-stage wound. In addition, improvement of wound healing conditions by other wound manipulation methods should also be applied comprehensively including anti-tension, silicone product, drug local injection, or even re-suturing of an already sutured wound. Following are the general principles:

1. When a patient with an acute linear skin wound visits the clinic, proper wound cleaning should be the first consideration. In case of severe wounds or appearance of early signs of wound infection, antibiotics should be applied either locally or systemically or both.
2. Anti-tension tape or device should be applied before and after stitch removal, such as 3 M tape, Zipline™

or Neodyne™ or other tension reduction device in order to maximally reduce the tension-induced scarring during wound healing process.

3. Silicone product should be applied as early as possible, such as Dermatrix™, Kelo-cote™ or other products. This should be applied along with taping or tension-reduction device and wound tension-free procedure should not be compromised by other procedures.
4. Proper surgical procedures for wound closing is important as a thick scar will be too difficult to be remodeled for achieving a desirable effect. When decided to perform, proper debridement, wound edge preparation as well as fine suturing should all be included.
5. The timing for microplasma procedure can be decided on the basis of the wound condition. If an injured wound is properly managed with a condition similar to that of elected surgical procedure, the remodeling procedure can be performed at time point about 8 weeks post-wound closure to give a wound sufficient time to heal as a very fine linear immature scar, which can be completely remodeled with microplasma procedure. If a wound is improperly closed with a thick linear wound mark and obvious other stitch marks, then the procedure should be applied as early as 1–4 weeks post-wound closure.
6. The energy of microplasma remodeling can be adjusted according to the wound condition. For example, a wound of a child or a wound with fine closure technique, then the wound can be treated with a relative low energy; whereas a wound is closed unprofessionally or in a poor condition, a relatively high energy should be applied and the treatment should be repeated until a desirable result can be achieved.
7. The comprehensive scar-reduction management should be continually applied after the remodeling and maintained for at least for 6 months post-wound closure.

The following are the case presentations.

■ ■ Case 3

A 52-year-old male (■ Fig. 53.6) was wounded on his left-side face 3 days before, and he came to our clinic for assistance of the wound management in order to prevent severe scarring. Physical examination showed that there was a linear wound on his left-side face with a length of 3 cm. The wound had been closed unprofessionally by single layer suturing with tight knots that would be bound to form a thick linear scar with obvious stitch marks after the healing of the wound (■ Fig. 53.6a). To better prepare the wound closure, the stitches were removed and the wound was re-opened. After thorough

Fig. 53.6 Case presentation of microplasma intervention of an early stage wound to prevent scar formation. **a** The patient has facial wound 3 days ago with unprofessional wound closure technique. **b** The stitches were removed and the wound was reopened. After wound debridement and proper position of wound tissues, the wound was

properly closed with fine suturing technique, which paved the way for further tissue remodeling. **c** Gross view shows remodeling of a linear scar at 8 weeks after the first microplasma remodeling. **d** Gross view shows that post-wound linear scar is almost completely remodeled with no visible scar

Fig. 53.7 Case presentation of microplasma intervention of an early stage wound to prevent scar formation. **a** The patient has two wounds on her face for 5 days. **b** Early sign of scar formation was observed on her upper face scar at day 12 post-wounding. The arrow shows elevated tissue growth that would develop into hypertrophic

scar, and thus a steroid injection was given. **c** Significant improvement of the linear scar was observed at 8 weeks after the first microplasma remodeling. **d** Gross view shows almost complete remodeling of the linear scar except for minor hyperpigmentation caused by microplasma treatment

wound debridement, wound dermal and epidermal layers were properly positioned and closed with fine suturing (■ Fig. 53.6b). The stitches were removed at day 5 post-surgery and 3 M tape was applied. At 4 weeks post-surgery (31 days after wounding), the patient received his first microplasma remodeling. Eight weeks later (87 days after wounding), the follow-up photo showed significant improved gross view of the healed linear wound (■ Fig. 53.6c). Then the patient was given the second microplasma remodeling. Eight weeks later (143 day after wounding), the patient was followed up with a photo demonstrating that linear wound mark was almost all removed via tissue remodeling (■ Fig. 53.6d). The patient was very satisfied with the wound remodeling result.

■ ■ Case 4

A 11-year-old female was injured on her left-side face and part of nose 5 days before she visited our clinic. She had concern of possible scar formation on her face after wound healing. Physical examination showed that

there was a linear scar on her left-side face starting from suborbital region and extending to the left part of the upper region of the nose. In addition, she also had a curved linear wound at the left side of her left ala nasi as shown in ■ Fig. 53.7a. The patient was asked to remove her stitches and to apply 3 M tape for anti-tension purpose. The patient was given COX-2 inhibitor (oral medicine) for 2 weeks to reduce wound inflammatory process. At day 12 post-wounding, there was an early sign of scar formation as raised tissue was observed on the upper wound of her face (arrow, ■ Fig. 53.7b). The patient was thus given an injection of low concentration steroid to inhibit potential scar formation. Four weeks later, several more injections were given with 4 weeks' interval between them. During the time period, taping and silicone gel were consistently applied. At 3.5 months post-wounding, the patient was given the first microplasma remodeling. Eight weeks after the first therapy (5.5 months post-wounding), the scarring was significantly remodeled with obvious improvement of the gross view as shown in ■ Fig. 53.7c. Afterward,

■ **Fig. 53.8** Case presentation of microplasma remodeling of an existed linear scar. **a** Gross view of an existed linear scar at the region between forehead and nose. **b–d** Gross view of remodeling the scar

at 8 weeks, respectively, after the first, third, and fourth microplasma remodeling. The end result shows almost no visible linear scar in the region

the patient was given three more procedures of microplasma remodeling. The final follow-up photo demonstrated that original scar was barely visible except for minor pigmentation. The patient was extremely satisfied with the results.

53.3.3 Microplasma Remodeling for an Existing Linear Scar

As described previously, scar revision surgery along with microplasma tissue remodeling is a preferred procedure to deal with the significant linear scars in majority cases. However, direct remodeling with microplasma is also a choice for linear scars under certain conditions. These include (1) a superficial linear scar; (2) an irregular shaped linear scar that is difficult to revise with surgical procedure; (3) a linear scar that formed in not too long time; and (4) the scar contains less dense collagen. These linear scars are more likely to be remodeled than other types of linear scars.

The following is a case presentation:

■ ■ Case 5

A 35-year-old female patient had an irregular linear scar caused by trauma in less than 1 year on the region between forehead and nose (■ Fig. 53.8a). The linear

scar was relatively irregular and superficial and was a bit raised above the skin. Microplasma remodeling procedure was applied using a roller tip with 70 watts for 4–6 passes. ■ Figure 53.8 shows the tissue remodeling results after the first (■ Fig. 53.8b), third (■ Fig. 53.8c), and fourth (■ Fig. 53.8d) microplasma treatments, which demonstrated gradual improvement of the gross view of the linear scar, and the scar was barely detectable at the end of the treatment. The patient was very happy with the end result.

Conflict of Interest No conflict of interest.

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