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Role of ultrasound in some dermatological problems

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Abstract
Background: Striae distensae (SD) are characterized by the formation of linear scars in regions of dermal injury. Numerous therapeutic approaches have been employed, encompassing topical treatment, ultrasound, laser therapy, microdermabrasion and radiofrequency (RF)
Objective: The objective of this investigation was to assess the safety, tolerance and effectiveness of microfocused ultrasound (MFU) as a treatment for seborrheic dermatitis (SD), both without and with the concurrent administration of a topical gold thioethyle amine hyaluronic acid (HA) serum.

Keywords: MFU, SD, dermatological problems

Introduction
The utilization of ultrasound emerged as a novel cosmetic and therapeutic intervention. The method enhances the aesthetic quality of loose skin through the targeted delivery of ultrasonic energy beneath the skin's surface. This process stimulates the body's production of fresh collagen, a naturally occurring protein responsible for providing skin with its a flexibility and youthful resilience. The utilization of MFU has been observed to enhance the aesthetic characteristics of skin laxity, specifically in the context of sagging dermal tissue. Furthermore, the concurrent application of hyaluronic acid (HA) has been found to provide further advantages in this regard [1].

Ultrasound
The ultrasound machine utilizes an electrical signal that is sent through crystals located in the head of the ultrasound probe. The crystals exhibit vibrational behavior, generating mechanical waves with frequencies that go outside the audible range of human perception, often spanning from 20 hertz to 20,000 hertz [2].
The mentioned occurrence is commonly referred to as the 'piezoelectric effect.' The generated waves facilitate the transmission of energy to the external layer of the human body or can be concentrated to specifically affect underlying soft tissue located beneath the epidermis. Tissues with a greater protein composition, such as bone and muscle, exhibit a higher propensity for energy absorption from mechanical waves compared to tissues with higher water content, such as fat. Furthermore, the ultrasonic energy can be concentrated to target tissues located at greater depths under the surface, while minimizing any potential injury to superficial tissues [3].

General principles
Sound is a form of mechanical compression wave that travels through a medium and can be detected within the audible range of human perception. Ultrasound refers to a mechanical compression wave that shares similarities with audible sound waves, although operating at frequencies exceeding the human hearing range, namely at Twenty megahertz (MHz) [4]. The phenomenon under consideration exhibits similar physical attributes as those employed in the description of sound, including absorption or energy transfer, frequency, wavelength and amplitude or intensity [5].
The measurement of concentrated ultrasonic frequency is often denoted in cycles per second, or Hz, while the quantification of energy is commonly stated in J/cm2. Nevertheless, it is possible to employ a concave disk within a transducer to concentrate ultrasonic energy in a

much convergent fashion, similar to the way sunlight is focused using a magnifying glass [6].

The characters of sound energy enable it to be concentrated in a very small volume under the epidermis and with very high amplitude at certain locations. There, the focused ultrasound eventually becomes absorbed, and the ultrasound waves are converted into molecular vibrations resulting in heat [5].

The augmentation of ultrasonic frequency leads to an elevation in thermal of disintegration and attenuation, while concurrently resulting in a reduction in the penetration depth. This phenomenon arises from the fact that higher frequencies of ultrasound yield enhanced resolution capabilities, but at the expense of limited depth penetration [5, 7]. The frequencies ranging from four to seven MHz have been identified as the most effective for heat deposition. Lower frequencies, such as 0.5 MHz, are employed for treatments targeting deeper tissues, while higher frequencies, up to 10 MHz, are utilized for treatments targeting shallower tissues [6].

At ultrasonic frequencies around one MHz, the focal point is limited to a volume of just a few cubic millimeters. The lesions generated by concentrated ultrasound are sometimes referred to as "trackless" lesions due to their localized nature within the treated tissue, resulting in no linked harm to the adjacent areas [8]. As the frequency of ultrasonic waves rises, there is an enhanced capacity to concentrate and focus these waves. In combination, these associations render focused ultrasound very suitable for conducting noninvasive aesthetic treatment [6].

Types of ultrasounds

Ultrasounds as imaging equipment

Three-dimensional (3D) imaging

3D imaging is a widely used technique in the field of medicine for the purpose of measurement. The previously mentioned method has shown efficacy in the field of wound care, as well as in the context of dermatological laser interventions [9]. The 3D impact is achieved by the minute elevation variances on the skin surface, which deflect the parallel projection stripes [10].

Ultrasound elastography

Elastography-based imaging approaches use changes in the elasticity of soft tissues to facilitate diagnostic applications. Specialized imaging modes are used to gather measurements that may identify the stiffness of tissues when subjected to an applied mechanical stress, such as compression or shear wave [11] (Figure four).

Fig 1: Ultrasound elastography machine [12]

High-frequency ultrasound

HFUS, or ultrasound using a frequency of at least ten MHz, allows for the skin high-resolution imaging from the stratum corneum to the deep fascia (Figure five) [13].

Fig 2: HFUS machine with 7.5–15 MHz multi frequency probe with pulsed Doppler ultrasonography and color [13]

Ultrasounds as a therapeutic equipment

The first clinical use of unfocused ultrasound beams for physical therapy may be traced back to the 1950s. This particular application is often known as "therapeutic ultrasound" [14].

Ultrasonic skin rejuvenation

Ultrasounds have the capacity to operate at frequencies of three MHz or more, by using pulsed transmission of energy at relatively low levels. This strategy focuses on the targeted delivery of energy specifically to the dermis and epidermis layers of the skin. Waves of ultrasonic have the potential to transiently expand the intracellular gaps inside the stratum corneum, the stratum corneum functions as the external protective layer of the integumentary system. The use of ultrasound as a subsequent therapy after the administration of a topical agent facilitates the active penetration of the agents into the skin via the utilization of sonic vibrations. The interstitial gaps or mortar present among the bricks necessitate the traversal of a prolonged and complex "maze" [14].

HIFU

The principle HIFU involves the selective stimulation of volume reduction and cellular damage in a specific target area. This is achieved by generating instant microthermal lesions through the accumulation of high-frequency ultrasound beams at the desired tissue site. Importantly, this process is carried out without causing any harm to the adjacent tissues or epidermis [15].

Mechanism of action (MOA)

The conventional method of administering high intensity focused ultrasound involves the use of a piezoelectric transducer that has a predetermined focal length and aperture. The transducer is responsible for producing an ultrasonic field that encompasses frequencies within the range of one to seven MHz. The sound waves undergo a conversion process into thermal energy and then propagate through the body. As they converge at a certain focal location, they possess the potential to induce coagulative necrosis. (Figure six) [16].

The HIFU technology utilizes ultrasound energy to effectively and securely elevate and firm the skin. HIFU is a

medical procedure that effectively protects the integrity of the skin's outer layer while simultaneously delivering targeted energy to deeper layers of tissue. The tissue at the designated location experiences an elevate in temperature to around sixty-five degrees Celsius This rise in temperature generates thermal energy, leading to the creation of cellular friction and spaced wounds inside the skin tissue. Consequently, these processes facilitate the healing process, causing an instantaneous contraction of collagen and activating an accelerated generation of new tissue [17].

The augmentation of the quantity of robust and novel collagen fibers results in an enhanced provision of structural reinforcement to the dermis, so leading to a constricting and strengthening effect on the integumentary system. The use of this technology is considered to be safe for application on several regions of the human body, including the face, neck, and belly. This technique has been used for the goal of minimizing the appearance of flexibility in the neck region and enhancing the definition of the jawline, addressing ptosis of the eyelids [18].

Variant applications

The most investigated use of HIFU is thermal ablation because of its heating effects. The treatment zone is the most flexible part of the procedure, since it may include both a border of normal tissue for protection and the target volume, much like a surgical excision [16].

The HIFU has been explored as an adjunct to drug delivery due to its impact on permeability of membrane. Concentrated ultrasound techniques have the potential to be utilized in neuromodulation therapies especially when administered at a lower intensity [16].

Complications

Skin burns of varying degrees, discomfort in the treated areas, fibrosis, blotchy skin, hyper-pigmentation,edema and numbness are the most often reported adverse effects [19].

Fig 3: HIFU [20]

Collagen in the dermis may contract in response to HIFU, and adipose tissue may be destroyed [21].

Ultrasound was introduced as a new treatment for cosmetic and therapeutic purposes. HIFU may be the best example of this technique. White *et al*. [21] in 2008 reported the first dermatologic, HIFU and aesthetic use of HIFU was approved by the Food and Drug Administration (FDA) in 2009 for use in brow-lifting. Its 'off-label' applications include anti-aging treatments including facelifts, breast enhancements, and cellulite removal [15].

Indications

- **Acne scars:** The use of HIFU is regarded as a potentially effective method for reducing scarring [23, 24]. It's a method of using energy to cause localized arearfat and skin to coagulate. Zones of micro coagulation of one mm3 or less in size are created if temperatures rise above sixty °C at the foci. As a result, collagen contracts and is denatured, leading to the production of subsequent tissue remodeling and new collagen [23, 24].
- **Cellulite:** Since it does not involve cutting into the body, it is a lot less risky than liposuction. The ultrasonic vibrations penetrate far enough to warm the subcutaneous muscle and fat. Muscle contraction is an essential precursor to synthesis of collagen. This gives the skin an youthful and toned appearance [15].
- **Skin laxity and Wrinkles:** Selective volume reduction and cellular damage of the targeted area is achieved by coagulation, which is facilitated by the generation of microthermal lesions using high-frequency ultrasonic beams. This process occurs specifically at the desired tissue location, without causing harm to the neighboring tissues or epidermis [25].
- **Skin tumors:** The epidermal pathologies include squamous cell carcinoma, actinic keratosis, and basal cell carcinoma. These are logic first and straight forward indications for the novel 20 MHz HIFU used as an ablative method. Kaposi sarcoma, which arises from the vasculature of the dermis, is an additional possible indication, although one that is infrequent and distinctive [25].

MFU

In contrast to ultrasound imaging, therapeutic ultrasound employs energy levels above Five W/cm2 and is precisely concentrated into a localized area to induce coagulation of certain tissues and fast heating. The use of HIFU is experiencing a notable expansion, transitioning beyond its initial utilization in high-precision surgical interventions to include the realm of noninvasive aesthetic medicine. (Figure seven) [6].

Fig 4: MFU device [6]

Micro focused ultrasound (MFU) technology has distinct features that set it apart from other energy-based modalities used in the field of skin rejuvenation. The transducer has a concave disk that concentrates ultrasonic radiation at particular points under the epidermis, resulting in high intensity. This allows for precise targeting of either the dermis or the superficial musculoaponeurotic system. In instances when it is implemented, the temperature at the focus point experiences a fast increase, but the tissue located below and above the focal zone remains unaffected [6].

The use of MFU leads to the contraction and denaturation of collagen fibers, as well as the stimulation of the synthesis of new collagen. The technique of combining MFU with visualization (MFU-V) allows for the precise application of energy to the skin, resulting in a noninvasive tightening and lifting effect on the subdermal tissues and dermis. The selection of treatment heating rate and depth may be achieved by modifying the ultrasonic frequency, as well as adjusting the intensity of energy delivery and pace [6].

Side effects

The treatment session may cause temporary pain, as well as temporary redness, rare bruising and swelling [26]. In one research, a A single application of the most frequent ultrasound (MFU) technique with three transducers generating frequencies of seven MHz and four MHz at a focal depth of 4.5 mm, together with seven MHz at a focal depth of 3.0 mm, resulted in transitory edema and erythema in the majority of patients, as well as localized bruising [27]. Two individuals have been observed to have post-inflammatory hyperpigmentation (PIH) one month after the administration of therapy. There have been reports of transient dysesthesia with a duration ranging from three to ten days. The occurrence of striated linear skin patterns is infrequent; however, they tend to dissolve without intervention [26, 28].

After undergoing a procedure involving the application of a four MHz 4.5 mm transducer with 1.2 J of energy on the cheeks and submentum, followed by the use of a seven MHz 3.0 mm transducer with 0.45 J of energy, a patient experienced immediate numbness along the right mandible. This numbness progressed to partial paralysis of the right perioral area the following day, but resolved spontaneously after a period of two months. The use of ultrasonic energy in conjunction with MFU-V demonstrates a significant improvement in patient comfort without compromising the effectiveness of the treatment [29].

Indications

- Since its approval by the US Food and Drug Administration in 2009, the presently available MFU-V device has been extensively studied for its efficacy and safety [30].
- The process of firming loose face skin.
- The process of elevating and shaping the regions including the neck, upper face and lower face.
- Décolleté.

Ultrasound-mediated transdermal drug delivery

The use of ultrasound for the purpose of transdermal delivery of medicinal substances is often known as phonophoresis, sonophoresis or alternatively. The use of high frequency sonophoresis (HFS) has persisted for almost forty years, during which researchers have explored frequencies reaching up to sixteen MHz. The reported skin penetration increases typically range from between one and tenfold when using HFS [31].

In these researches, it was demonstrated that LFS at twenty kHz is up to three orders of magnitude more effective than HFS at one MHz. In the past decade, research has focused primarily on the use of LFS for transdermal drug delivery (DD), due to the much greater development ratios attained at these lower frequencies, while research with HFS has concentrated on regional or topical delivery [32, 33].

Modes of skin treatment with sonophoresis

The application of ultrasound to the skin can be categorized into two primary methods: simultaneous and pretreatment treatment. Pretreatment involves applying ultrasound to the skin before coming into contact with a drug or permeant. On the other hand, simultaneous treatment refers to the application of ultrasound along with a coupling medium that contains the drug or permeant [34].

This is mainly because of three causes [35].

- Firstly, the use of ultrasound to pharmaceuticals or other active components has the potential to induce molecular breakdown or trigger chemical reactions.
- Furthermore, in the context of clinical applications, it is necessary for patients to wear the ultrasound equipment continuously during the whole treatment process.
- Finally, the use of LFS for transdermal DD has resulted in the capability to elevate permeability of skin to a greater extent than previously possibly with HFS.

Management of striae distensae

There exists a variety of therapy techniques, but none has the ability to entirely eliminate SD [4]. The objective of treatment is to decline redness, swelling and irritation in SR, and to elevate collagen and elastic fiber production, improve hydration, and reduce inflammation and elevate pigmentation in SA [36].

Topical management

Several extensive evaluations have shown that topical treatment is often suggested as a therapeutic measure and preventive for striae, despite little or inconclusive data about its effectiveness [36, 37]. In the following are some of the topical agents utilized:

Retinoic acid and tretinoin

The efficacy of topical tretinoin in the treatment of SD has shown inconsistent outcomes. Several researches have shown the ineffectiveness of this vitamin A derivative UN treating SD, particularly in cases where patients had pre-existing lesions that had progressed into white atrophic scars [38]. Previous studies have shown that the use of tretinoin may enhance the clinical presentation of sebaceous hyperplasia during the active period of sebaceous proliferation, but its efficacy is limited at the mature stage of sebaceous atrophy [39].

HA

Additionally, it is recommended to promote the activation of fibroblasts and enhance hydration levels, hence stimulating collagen synthesis [4]. HA is an organic compound that naturally occurs in the human skin and serves as the primary component of the cream. The presence of hyaluronic content promotes the synthesis of collagen and the activation of

fibroblasts, therefore counteracting the inhibitory effects and collagen depletion caused by mechanical stretching or hormonal changes [40]. A single research was undertaken to establish the safety and effectiveness of HA, together with allantoin, vitamin A, DE panthenol and vitamin E. A total of Sixty pregnant women were enlisted for the research, with half of them (n=thirty) assigned to receive the cream under investigation, while the other thirty participants were assigned to the control group and got a placebo. The research findings indicated an important reduction in the occurrence of SM development after pregnancy as a result of using the medication [40].

Hydrant creams

A single research was undertaken to establish the safety and effectiveness of HA, together with vitamin E, allantoin, vitamin A and DE panthenol. A total of Sixty pregnant women were enlisted for the research, with half of them (n=thirty) assigned to receive the cream under investigation, while the other thirty participants were assigned to the control group and got a placebo. The research findings indicated an important reduction in the occurrence of SM development after pregnancy as a result of using the medication. Three separate studies, with a total of 130 male participants, were identified [6, 41]. The active creams used in the previous studies are not readily accessible, and the efficacy of any one ingredient remains uncertain. The absence of sufficient clarity on the research and scientific data pertaining to the effectiveness of these creams poses challenges in drawing definitive conclusions. Consequently, conducting more extensive researches is necessary to ascertain the safety and efficiency of these products in addressing stretch marks [5, 42, 43].

- **Centella asiatica:** a botanical species with purported therapeutic properties, is believed to possess the ability to enhance collagen and elastic fiber synthesis, while also exhibiting antagonistic effects against glucocorticoids [44]. There were no detected negative effects associated with the use of the substance. However, when administered in conjunction with boswellic acid, which has anti-inflammatory properties, itching was noted [2].
- **Illicium verum:** a further investigation using a sample size of fifty female participants was conducted, however without the inclusion of a placebo control. This research aimed to evaluate the effects of a cream formulation comprising vitamin E, panthenol, hyaluronic acid, elastin, and menthol (referred to as the "verum"). The administration of this medication during pregnancy was shown to be correlated with a lower occurrence of self-reported symptoms of morning sickness compared to the absence of any treatment. The findings indicate that the product may have potential benefits, however it is important to note that the experiment lacked a placebo control group, making it difficult to ascertain the specific contribution of the product against the effects of massage therapy alone [45].

Herbal topical remedies and topical oil massage

Certain non-traditional therapeutic approaches and anecdotal accounts suggest the use of unverified oils and natural remedies for the treatment of SM. The fundamental idea underpinning this application would likely include maintaining optimal skin hydration. Swe*et al*mond oil, castor oil, wheat germ oil, olive oil and avocado oil possess the following benefits when used in conjunction with the application of seaweed wraps. Additional botanical medicines, including as equisetum, comfrey, hypericum, maritime pine, slippery elm, and wheat grass as well as eucalyptus tree oil, have been included into creams or oils. However, it is worth noting that no empirical research has been conducted to substantiate the effectiveness of these interventions [46].

Procedures

Chemical peeling

Chemical peels are techniques used to induce a controlled removal of specific layers of the skin through chemical means, resulting in a more uniform and tight appearance. This is achieved by stimulating the repair and regeneration processes following the inflammation of both the dermis and epidermis. Chemical peels can be categorized into three distinct types. Superficial peels primarily target the exfoliation of the epidermal layers, without extending beyond the basal layer. Medium-depth peels reach the upper reticular dermis, while deep peels penetrate the lower reticular dermis [47].

Chemical peeling is used as a therapeutic strategy for SM by removing the superficial layers of the skin, stimulating the production of collagen and romoting the revitalization of the skin. Chemical peels possess the capacity to diminish the visibility of stretch marks via the process of exfoliating deceased epidermal cells and promoting the production of fresh ones. Furthermore, the heightened production of collagen plays a significant role in augmenting the elasticity and smoothness of the affected skin. Moreover, this method aids in the reduction of erythema and hyperpigmentation commonly observed in SD, ultimately leading to a more even complexion. To efficiently address the issue of stretch marks, it is necessary to consider individual factors and seek guidance from skincare professionals to determine the most suitable application of chemical peeling [48].

Superficial chemical peels, such as those using glycolic acid or salicylic acid, are often used in the treatment of striae rubra. These peels are known to effectively mitigate irritation, redness, and initial pigmentation alterations associated with this condition. Medium-depth peels, such as those involving the use of trichloroacetic acid (TCA), are often used in the treatment of striae Alba. These peels are known to stimulate the synthesis of collagen, enhance skin texture, and reduce the visibility of white stretch marks. In instances with severe striae Alba, deep peels such as phenol peels may also be evaluated as a potential treatment option [48].

MOA in striae

The precise mechanism behind the action of chemical peels remains incompletely understood. There exists a proposition that reduction in wrinkles and enhancements in skin elasticity may be ascribed to an augmentation of collagen type 1, either in conjunction or in isolation with collagen type three, elastic fibers, as well as a compact reorganization of collagen fibers [49, 50].

Additionally, it should be noted that superficial peelings, such as those containing glycolic acid (twenty-seventy %) and salicylic acid (ten-thirty%), have the ability to specifically target the corneosomes. These peelings elicit desquamation, augment the enzymatic activity inside the

epidermis, and eventually lead to epidermolysis and exfoliation [50], Medium-depth peels, such as TCA (35-50%) peels, induce coagulation of membrane proteins, resulting in their destruction. living cells of the epidermis and, depending on the concentration, the dermis [52]. Phenol-based deep peels, with a concentration above fifty percent, induce protein coagulation, resulting in the full removal of the epidermis, reorganization of the basal layer, and subsequent repair of the dermal structure [53].

Side effects

These symptoms include irritation, burning sensation, redness of the skin, itching, swelling, and the formation of blisters [54].

Pigmentary alterations, including hyperpigmentation and hypopigmentation, as well as textural modifications, scarring (such as atrophic, hypertrophic, and keloid scars), and heightened pigmentation of naevi, may also manifest [55].

Dermabrasion

Microdermabrasion, also known as particle resurfacing, is a minimally invasive technique that utilizes an abrasive element, often aluminum oxide crystals, in conjunction with a vacuum mechanism. Microdermabrasion initiates a series of molecular processes that have the potential to induce skin remodeling and facilitate healing [56].

The current body of literature regarding the effectiveness of microdermabrasion in the treatment of SD is limited. However, Mahuzier, in his comprehensive textbook on microdermabrasion, suggests that a satisfactory improvement in SD can be achieved through a regimen of between ten and twenty microdermabrasion sessions. These sessions should be spaced at intervals of no less than one month, with each session resulting in the presence of bleeding points [57].

The MOA triggers signal transduction pathways in the epidermis that are linked to the restructuring of the dermal matrix. Superficial injury induces alterations in both the dermal and epidermal layers [57], this leads to the initiation of an inflammatory cascade. Following a solitary treatment session, there is an observed rise in the levels of transcription factors, cytokines (specifically tumor necrosis factor-α [TNF-α] and interleukin-β [IL-β]), matrix metalloproteinase (MMPs), as well as an augmentation in the synthesis of type 1 procollagen [56].

The occurrence of side effects resulting from microdermabrasion is generally modest, with a majority of patients reporting no adverse reactions. Frequently observed consequences include symptoms such as discomfort, swelling, redness, petechiae, and bruising. The conjunctiva may experience eye discomfort upon contact with the crystals [58].

Micro-needling therapy or percutaneous collagen induction therapy

Micro-needling is a minimally invasive process characterized by the controlled puncturing of the skin using micro fine needles, resulting in superficial penetration. Historically used as a method of collagen induction treatment for skin revitalization and face scarring, this technique has also gained significant traction as a transdermal delivery system for vaccinations and therapeutic medications [59].

Collagen induction equipment's

Derma pen, Derma roller, and derma stamp are several micro needling procedures used for the management of SM. These techniques include the generation of deliberate micro-injuries in the impacted skin by the utilization of a derma roller, a device equipped with minuscule needles, a derma pen, an automated pen-shaped device, or a derma stamp, a device resembling a stamp [60].

The role of these Micro-needling techniques in the treatment of striae is to stimulate collagen production and promote skin remodeling. The micro-injuries created by the needles tigger the body's natural healing response, leading to the production of new collagen and elastin fibers. This helps to improve the texture, color, and appearance of stretch marks over time. Additionally, Micro-needling can enhance the penetration and absorption of topical treatments applied during or after the procedure [60].

MOA

Micropunctures are generated by the use of microneedles, resulting in a deliberate dermal lesion that does not inflict harm onto the epidermal layer. The occurrence of these microinjuries results in a limited amount of surface-level bleeding and initiates a sequence of wound healing events, including the release of diverse growth factors [59].

Micro needling plus trichloroacetic acid

This clinical trial was applied on patients with SR. Group of them was treated with micro needling alone and the other group was treated with micro needling in combination with TCA. The findings demonstrated well to excellent improvement in the group who treated with micro needling in combination with TCA with transient erythema, burning pain, hyperpigmentation and edema [61].

Platelet rich plasma (PRP)

PRP refers to a concentrated solution of plasma that contains a variety of growth factors and proteins. It is administered by intradermal injection and functions by enhancing dermal elasticity through the stimulation of the extracellular matrix (ECM) and the promotion of new collagen production. PRP applied through maximum of six sessions at two-week intervals. It has been used alone as well as in combination with carboxytherapy [63], RF [62], ultrasonography [62] and found to have synergistic impact in the treatment of SD. PRP enhances striae treatment by providing anti-inflammatory effects, promoting collagen synthesis, elastin production, tissue regeneration. These effects improve the overall the skin quality, reducing the appearance of striae.

- **MOA**

PRP refers to a plasma solution derived from the patient's own blood, which is characterized by a high concentration of platelets. PRP has the potential to enhance the density of collagen fibers by stimulating fibroblasts and effectively addressing localized microinflammation [64].

- **Activation of PRP**

Exposure to coagulation triggers induces the activation of platelets, resulting in the release of their alpha granules through degranulation. This process involves the active secretion of various pre-formed growth factors, such as platelet derived growth factor (PDGF), transforming growth

factor-beta (TGF-β), vascular endothelial growth factor (VEGF), epidermal growth factor (EGF), hepatocyte growth factor (HGF), and fibroblast growth factor (FGF) [65].

- **Side effects**

The predominant side effects associated with PRP therapy are bruising, skin coloring and discomfort localized at the injection site, infrequent vascular damage, allergic reactions leading to blood clot infection and formation [64].

Light and Lasers therapy

Lasers are devices that use light energy to provide coherent, cohesive, and monochromatic light energy to the skin, targeting particular tissue chromophores. Lasers are used to selectively target various chromophores, including water, hemoglobin, and melanin, with the aim of enhancing the overall aesthetic of SD via the stimulation of collagen synthesis [2, 66], the reduction in vascularity, particularly in the stratum reticular, is accompanied with an elevation in melanin pigmentation. The treatment of striae has been attempted using both ablative and non-ablative lasers, with varied degrees of effectiveness.

Types of lasers used

Ablative lasers

Ablative lasers with a wavelength greater than 1000 nm are easily absorbed by water inside tissue, leading to the vaporization of heating of tissue, cells and modification of tissue [67]. The ablative lasers often used for SD treatment are carbon dioxide (CO_2) (10, 600 nm) and erbium-doped yttrium-aluminum-garnet (Er: YAG). (Er: YAG) (2940 nm) [66].

Fractional CO_2 10, 064 nm:

The use of this laser effectively promotes fibroblast activity, leading to the induction of dermal tissue remodeling. Consequently, it has shown favorable outcomes in the context of laser resurfacing for SD [68]. The clinical improvement was also observed histopathologically, characterized by an augmentation in the thickness of both the dermis and epidermis, together with heightened positivity of procollagen type 1. However, it was important to carry out a substantial number of sessions [69].

The utilization of this laser is connected with the occurrence of erythema, post-treatment discomfort, crust development, and pigmentary dyschromia, which may elicit apprehension particularly among individuals with darker skin types 4 and 6 [70, 71]. Shin *et al*., 2011 [61] in his research proposed the positive impact of succinylated atelocollagen with fractional resurfacing CO_2 laser on SD. In another research, monthly fractional CO_2 laser sessions were compared with topical therapy regimen comprising ten% glycolic acid plus 0.05% tretinoin cream at every night. The former intervention appears to exhibit more efficacy in reducing the average surface area of SD when compared to the topical treatment [72]. The efficacy of fractional CO_2 laser treatment was shown to be greater in reducing mature SD compared to its effectiveness in reducing scaling and redness (SR) [70]. The efficacy of fractional CO_2 laser treatment appeared to be enhanced when administered concurrently with PDL [73]. In a comparative research examining the efficacy of ablative laser treatment (fractional CO_2) and non-ablative laser treatment (1540 Er glass laser) in the context of SD, both modalities shown comparable effectiveness. However, the non-ablative laser treatment appeared to be more amenable to patients and more tolerated in comparison to the ablative laser treatment [71].

- **Ablative fractional CO_2 plus pDL**

In a randomized clinical trial (RCT), researchers employed ablative fractional CO_2 combined with PDL in many investigations, resulting in a considerably larger degree of clinical improvement compared to the group treated just with CO_2 laser. The occurrence of PIH occurred in individuals who only had treatment with CO_2 laser [73, 74].

- **Ablative fractional CO_2 plus RF**

Fractionated microneedle RF technology enables the device to effectively penetrate the epidermis while causing minimum harm, resulting in the formation of microthermal zones that are comparable to those generated by fractional lasers [75].

- **Ablative fractional CO_2 plus topical collagen**

The investigation included the use of ablative fractional CO_2 combined with topical collagen on individuals diagnosed with striae Alba, with the aim of comparing the efficacy of the fractional ablative CO_2 laser treatment in conjunction with topical collagen. The investigation included three distinct treatment modalities, including laser monotherapy, collagen monotherapy, and a combination of both interventions. The findings of the research showed that all regions that had laser treatment, either on its own or in conjunction with collagen, exhibited clinical improvement and an increase in epidermal thickness as demonstrated by histological analysis. However, there was no notable disparity in the clinical or histological outcomes among the use of laser therapy alone and the combined therapy approach. Following laser therapy, all patients had a temporary skin redness known as transitory erythema, as well as PIH [61].

- **Ablative fractional CO_2 laser and PRP**

The clinical experiment was conducted on individuals diagnosed with SD. One cohort received treatment just with ablative fractional CO_2 laser, whereas the other cohort had treatment with ablative fractional CO_2 laser in conjunction with PRP. The findings demonstrated significant enhancement in the cohort that had ablative fractional CO_2 laser treatment in conjunction with PRP, accompanied by temporary erythema, edema, burning sensation, and hyperpigmentation [76].

Fractional Er: YAG laser

Variable square pulse Er: YAG laser has been used for resurfacing of the SD. Wanitphakdeedecha *et al*., 2017 [77] Research findings have shown the effectiveness of using reduced fluence in reducing the number of striae. In a subsequent comparison investigation including variable square pulse Er: YAG and Nd: YAG lasers, researchers have discredited the use of either laser in the treatment of SA [78]. In a comparative investigation of PDL and fractional Er: YAG laser, both modalities shown comparable efficacy. However, it was observed that patients exhibited a preference for the Er: YAG laser [79].

Ethnic skin, particularly skin types 4–6, has been reported to respond well to the laser in terms of low side effects and efficient fractional non-ablative photothermolysis. Generally, 6–8 sessions spaced out over 4 weeks are needed to achieve long-lasting improvements in SD's size, texture, and pigmentation [1].

Non-ablative lasers

Erbium glass (Er glass 1540 nm) laser

Fractional photo thermolysis has also been carried out using erbium glass laser. Usually, four to six sessions of repeated

therapy are needed every four to six weeks [80]. Multiple researchers have shown that using the laser (1550 nm) on various types of striae (such as SG, breast striae after augmentation surgery, and steroid-induced striae) reduces SD dimensions while also improving elasticity, color, and skin texture [81].

Excimer laser 308 nm

The excimer laser operates within the wavelength range of narrow-band ultraviolet B (NBUVB) light. In contrast to other types of lasers, the excimer laser functions by enhancing the pigmentation of the stratum corneum, making it potentially beneficial in the treatment of striae atrophicans.A study conducted by Goldberg *et al*., 2003 [82] The use of excimer laser in the treatment of solar lentigines has been observed to provide significant aesthetic improvements in pigmentation, particularly with the implementation of many treatment sessions.

Vascular lasers

Pulsed dye laser

The early phases of systemic sclerosis (SSc) are characterized by erythema, which is caused by the dilation of blood vessels. The presence of haemoglobin in these microvasculature serves as a chromophore for PDL therapy, making it a promising therapeutic option for the management of SSc. McDaniel and colleague, 1996 [83] have used PDL at different energy.

The densities for SD were observed, and it was determined that there was an improvement in the appearance of the striae when more energy was applied. The researchers reached the conclusion that the observed phenomenon was attributable to an augmentation in the synthesis of skin elastin and collagen. In previous research, the observed enhancement in SA was found to be quite modest when compared to SR. However, a more substantial overall improvement was seen in terms of color [83, 84]. The use of lasers with wavelengths ranging from 585 to 595 nm is preferred in order to take advantage of the significant absorption by hemoglobin while minimizing absorption by the competing chromophore melanin. This approach effectively reduces the risk of epidermal damage.

PDL plus RF

The application of PDL plus RF was performed on individuals with dark skin types, namely those presenting with striae Alba and striae rubra. Following the conclusion of the therapy, the outcome shown an important development as well as a satisfactory improvement. According to the authors, the favorable outcomes observed, together with a reduction in side effects such as purpura and PIH, may be attributed to the synergistic impact resulting from the combination of these two methods [76].

Neodymium-Doped Yttrium Aluminum Garnet 1064 nm

The neodymium-doped yttrium aluminum garnet (Nd: YAG) has a strong attraction to the chromophores associated with SD, namely hemoglobin (Hb), water, and melanin. Goldman *et al*., 2008 [85]. I have effectively used it for the purpose of spatial recognition. Researchers have successfully constructed lasers with longer wavelengths, such as the alexandrite laser at 755 nm and the Nd: YAG laser at 1064 nm. These lasers have been designed to specifically target oxy- and deoxyhemoglobin, offering the benefit of enhanced tissue penetration capabilities [86]. Clinical improvement of erythematous striae with the use of the 1064 nm long-pulsed Nd: YAG laser has been seen, likely attributed to the laser's specific affinity for the vascular target found inside the striae. The interaction between the laser and oxyhemoglobin results in an enhancement of the red hue. Furthermore, similar to other sources of luminosity, the long-pulsed Nd: YAG laser also stimulates the generation of fresh collagen [87].

Diode laser

The 1450 nm diode laser has been demonstrated to elevate dermal collagen, but it has been reported only once in the literature for the management of SD. In a trial by Tay *et al*., 2006 [87] the results of three laser sessions, each with progressively higher energy levels, did not demonstrate any significant changes in the SD. However, it is important to note that there were notable occurrences of adverse effects, such as pigmentary dyschromia and erythema, reported at high rates.

Light therapy

IPL

Intense pulsed light (IPL) refers to a category of visible light-based devices that are distinct from lasers. These devices use a high intensity, non-coherent flash bulb that is filtered to produce a broadband frequency spectrum ranging from around 500 to 1200 nm. Previous research has examined the effects of IPL treatments administered at intervals of 2-4 weeks over the course of five sessions in individuals with SD. These studies have seen significant enhancements in amide1 and beta sheet content, as well as enhanced skin collagen levels, as evidenced by histopathological analysis and synchrotron IR micro-spectroscopy [88]. In a comparative research by Al-Dhalimi and Nasyria, 2013 [89] on two variant IPL wavelengths, 590 nm was found to be more effective in reducing erythema and dimensions of SD than 695 nm. However, in comparative researches of IPL versus lasers like fractional CO_2 [90] and PDL [91] the lasers proved to be superior.

A targeted narrow band UVB/UVA1 therapy

The use of a focused narrow band UVB/UVA1 treatment resulted in a significant fifty-one% enhancement in SA pigmentation after a series of weekly phototherapy sessions, with a maximum duration of ten weeks. An adverse event, characterized by transient hyperpigmentation of striae, was seen in around fifty% of the participants. The skin biopsy did not have any discernible impact on collagen remodeling, hence restricting its effectiveness only to the process of repigmentation in the context of SA [92].

Other methods

RF

The use of non-ablative and fractional microneedle RF devices has shown notable effectiveness and a favorable safety profile in the context of skin tightening. The coupling technique of RF current delivery enables the transmission of higher energy fluences to the dermis and subcutaneous tissue, while ensuring the preservation of the epidermis without any detrimental effects. The electrical energy that is delivered, when encountering the resistance of the skin, undergoes a conversion process to evenly distribute thermal energy. This subsequently results in the stimulation of

fibroblasts, as well as the contraction and denaturation of the fibrillar collagen structure. These alterations facilitate the process of neocollagenesis, neoelastogenesis, and ECM modifications [93]. All types of RF devices like monopolar [76], bipolar [76], tripolar [94] and multipolar [93] have been successfully used in treatment of SD.

RF devices

In contrast to lasers, which transform light into thermal energy and selectively target a particular chromophore through the process of selective photo thermolysis [5].

A research evaluating the effectiveness of a RF device (Thermage, Thermacol TC, Thermage Inc., Hayward, CA) in combination with PDL subjected patients with darker skin tone with SD to a baseline treatment with a RF device and PDL. This was followed by an additional two sessions of PDL performed at weeks 4 and 8 [5].

A histological assessment was conducted on a cohort of randomly chosen patients. The results revealed that eighty-nine of the patients exhibited a favorable overall improvement, while fifty-nine percent of them were rated as having excellent to very good elasticity. All histological assessments revealed a notable augmentation in the quantity of collagen fibers, with some specimens exhibiting an elevation in the quantity of elastic fibers [5].

Galvanopuncture

The treatment in question involves the application of continuous direct microcurrent as a means to create a localized inflammatory response, with the aim of facilitating the healing of the injured tissue. The galvanic current at microamperage levels ranges from 50 to 200 μA. It elicits alterations in the vasculature characterized by the expansion of blood vessels, the accumulation of fluid in tissues, and the concomitant manifestation of redness. The observed results include angiogenesis, cellular proliferation, and the reconfiguration of collagen bundles. Subjects with darker skin had the most favorable result, often associated with the most challenging skin type [95].

Carboxytherapy

In this experimental protocol, carbon dioxide (CO_2) gas is administered subcutaneously at a specific depth of 5-6 mm inside the striae. The injections are performed on a weekly basis, with the total number of sessions ranging from 3 to 12, depending on the age of the striae. This process enhances the flow of blood throughout the body, leading to an elevation in the discharge of oxygen via the oxyhemoglobin mechanism. Additionally, it induces the creation of collagenase, elastin, and HA via the stimulation of fibroblast activity [96].

Efficacy of carboxytherapy: there have been recorded instances of unsatisfactory outcomes in the treatment of stretch marks, certain types of scars, and cellulite. When carboxytherapy is used for the treatment of post-liposuction adhesions, it is reasonable to anticipate an amelioration of surface abnormalities; nonetheless, achieving complete surface straightening is seldom attainable. The undertaking of this operation is not recommended for patients with a high number of post-liposuction adhesions due to the potential for significant discomfort and limited efficacy [97].

In addition, the outcomes of carboxytherapy may exhibit variability, influenced by factors such as the specific indication being treated, the condition and manner in which the therapy is administered, as well as the age of the individual undergoing the treatment. Optimal outcomes are seen in the areas of the forehead, infraorbital dark circles, oral commissures, jawlines, and neck when using skin rejuvenation techniques. The possibility of treating both the forehead and eyelids is often related with skin tightening as a result of neocollagenesis. The observed outcomes of carboxytherapy include improvements in skin tone, elasticity, and smoothness, which are considered advantageous [98].

Infrared radiation (IR) light

The use of IR light has been shown to induce collagen remodeling and nucleogenesis effects via the transfer of thermal energy. Trelles *et al.*, [99] In the conducted research, an IR device was used to administer high fluences via the utilization of high frequency stacking pulses in a cohort of ten patients. The results of this investigation revealed a discernible enhancement in the objective measurement of SD. However, it is noteworthy that these findings did not align with the visual observations made by both the physicians and the patients, as they did not perceive substantial therapeutic advantages from the treatment.

Combined therapies

As mentioned, before.

- Ablative fractional CO_2 was done in some studies combined with PDL, RF, PRP and topical collagen [61, 73, 75, 76].
- In some studies, PDL combined with RF [74, 100].

Also, in some studies Micro-needling combined with TCA [61, 1010, 102].

Conclusions

- The application of both MFU and topical gold thioethyle amino HA (hyaluronic acid) serum led to a noteworthy enhancement in the GAIS (Global Aesthetic Improvement Scale), skin texture, patient satisfaction, and a reduced likelihood of PIH.
- The combined therapy appears to be more efficacious, although the difference in effectiveness between the combination therapy and MFU alone is not statistically significant.

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