(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 May 2016 (19.05.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/077759 A1

(51) International Patent Classification:
A61B 17/34 (2006.01)

(21) International Application Number:
PCT/US2015/060685

(22) International Filing Date:
13 November 2015 (13.11.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/079,822 14 November 2014 (14.11.2014) US

(71) Applicant: **CYTRELLIS BIOSYSTEMS, INC.** [US/US]; 655 Summer Street, Boston, MA 02210 (US).

(72) Inventors: **GINGGEN, Alec**; 6 Murray Street, Plymouth, MA 02360 (US). **LEVINSON, Douglas**; 1 Lake Street, Sherborn, MA 01770 (US).

(74) Agents: **ELBING, Karen, L.** et al.; Clark & Elbing LLP, 101 Federal Street, 15th Floor, Boston, MA 02110 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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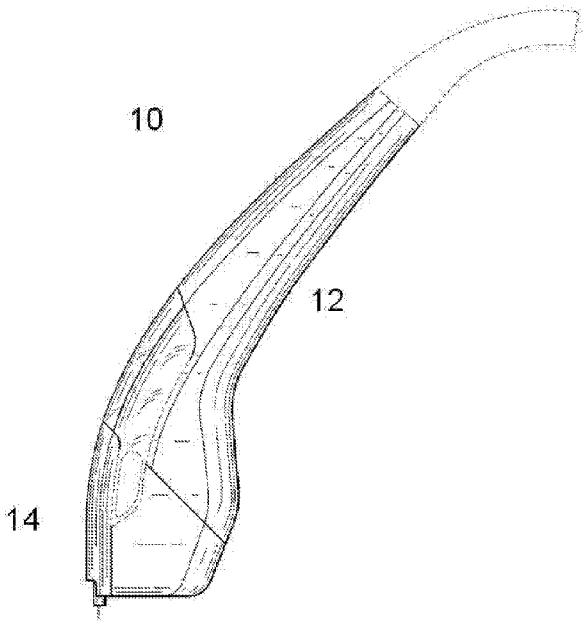
(54) Title: DEVICES AND METHODS FOR ABLATION OF THE SKIN

(57) Abstract: Disclosed herein are apparatuses, systems, kits, and methods for treating skin, such as skin tightening or for treating diseases, disorders, and conditions that would benefit from tissue area or volume reduction, skin restoration, skin tightening, skin lifting, and/or skin repositioning and/or for generally improving skin function or appearance (e.g., the removal of unwanted skin features or irregularities such as sebaceous glands, sweat glands, hair follicles, necrosis, and fibrosis). Such apparatuses, systems, kits, and methods comprise an apparatus having a hand-held main body and a detachably attachable tip comprising one or more needles.

Fig. 2



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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

DEVICES AND METHODS FOR ABLATION OF THE SKIN

Field of the Invention

The field of the present invention relates to treatments for skin and proximal tissue layers (e.g., skin tightening, treating diseases, disorders, and conditions of the skin, skin restoration, skin lifting, skin repositioning, and tattoo removal).

Background of the Invention

Many human health issues arise from the damage or loss of tissue due to disease, advanced age, and/or injury. In aesthetic medicine, elimination of excess tissue and/or skin laxity is an important concern that affects more than 25% of the U.S. population. Conventional surgical therapies (e.g., a face lift, brow lift, or breast lift) can be effective but are often invasive, inconvenient, and expensive, while scarring limits the applicability of surgery to certain treatment sites.

Although minimally invasive methods are available, such methods are generally less effective than surgical methods. Methods using energy sources (e.g., laser, non-coherent light, radiofrequency, and ultrasound) can be effective at improving the architecture and texture of the skin but are much less effective at tightening the skin or reducing skin laxity. Neurotoxins, such as botulinum toxin, reduce the formation of dynamic wrinkles by paralysis of the injected muscles, but such toxins have minimal or no direct effect on skin tightness or laxity. Finally, dermal fillers, such as hyaluronic acid, can be injected in the dermal layer to smooth out wrinkles and improve contours, but such fillers do not directly tighten or reduce laxity of the skin. Thus, surgical therapies remain the gold standard for lifting and/or tightening skin, as compared to energy-based techniques (e.g., laser, radiofrequency, and ultrasound) and injection-based techniques (e.g., botulinum toxin and fillers such as hyaluronic acid- and collagen-based fillers).

Tissue ablative methods such as ablative fractional laser treatment create micro-ablations with photo-thermal energy. The use of such energy generates a coagulation zone in tissue that interferes with closure of the ablation zones thereby inhibiting tissue tightening. These methods also require longer patient healing times due to the biological reparative response to coagulated and dead tissue during the remodeling process. Laser ablation depth is typically limited by the depth of the laser beam focus. Ablation of deeper tissue layers than is possible with available laser systems is desirable for the treatment of scars, for example.

Accordingly, there is a need for improved methods and devices that provide increased effectiveness over currently available minimally-invasive techniques while maintaining convenience, affordability, and accessibility to patients desiring tissue restoration.

Summary of the Invention

This invention relates to apparatuses, systems, kits, and methods for non-thermal tissue ablation. The invention features a device for non-thermal tissue ablation including a skin-penetrating component and a mechanism for removing ablated tissue.

In one aspect, the invention features an apparatus for non-thermal tissue ablation having a main body configured for handheld operation, a tip (e.g., in the form of a detachable cartridge) including a skin-

penetrating component with one or more ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and/or blades) configured for penetration into and retraction from skin, and, optionally, a pressure generating source. The ablation members may be configured to penetrate into the skin to a depth in the range of about 0.01 mm to about 15 mm and/or to produce an ablated tissue portion that results in the removal of an area or volumetric fraction of tissue (e.g., skin) in the range of about 5% to about 70%. If the pressure generating source is present, the ablation members are configured to be in fluid communication therewith (e.g., the ablation members can be connected, e.g., via one or more connectors, such as a tube, to the pressure generating source). The tip may be detachably attached to the main body. The pressure generating source, if present, may be a source of high or low pressure and may, for example, be disposed within the main body of the apparatus. For example, the pressure generating source may produce vacuum or suction to convey one or more ablated tissue portions produced by the one or more ablation members (e.g., needles, such as hollow coring needles) through the ablation members and away from the skin or proximal tissue layer or it may produce a force that injects a fluid (e.g., including one or more of a therapeutic agent, saline, a filler, and other material) into the skin or proximal tissue layers. The pressure generating source, if present, may remove waste materials (e.g., tissue, blood, and/or interstitial fluids) from one or more ablation members to prevent clogging, facilitate detachment of ablated tissue portions from surrounding tissue in a treatment area, and/or remove waste materials from a treatment area. In some embodiments, the apparatus may additionally include a reservoir for collecting waste materials. The reservoir may be disposed within the tip or main body of the apparatus or it may be separate from the apparatus. The reservoir may also be configured to be in fluid communication with the ablation members of the tip. In an embodiment, the pressure generating source is configured to exert force that conveys one or more ablated tissue portions produced by the one or more ablation members through the ablation members and into the reservoir.

In a second aspect, the invention features an apparatus for non-thermal tissue ablation having a main body configured for handheld operation, a tip (e.g., in the form of a detachable cartridge) including a skin-penetrating component with one or more ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and/or blades) configured for penetration into and retraction from skin, and a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids), in which the needles are configured to be in fluid communication with the reservoir. The ablation members may be configured to penetrate into the skin to a depth in the range of about 0.01 mm to about 15 mm and/or to produce an ablated tissue portion that results in the removal of an area or volumetric fraction of tissue (e.g., skin) in the range of about 5% to about 70%. The tip may be detachably attached to the main body. The reservoir may be disposed within the tip or main body of the apparatus or it may be separate from the apparatus. The apparatus may further include a pressure generating source that is a source of high or low pressure and may be disposed within the main body of the apparatus. For example, the pressure generating source may produce vacuum or suction to convey one or more ablated tissue portions produced by the one or more ablation members (e.g., needles, such as hollow coring needles) through the ablation members and into the reservoir or it may produce a force that injects a fluid (e.g., including one or more of a therapeutic agent, saline, a filler, and other material) into the skin or proximal tissue layers. The pressure generating source may remove waste materials from one or more

ablation members to prevent clogging, facilitate detachment of ablated tissue portions from surrounding tissue in a treatment area, and/or remove waste materials from a treatment area.

In a third aspect, the invention features an apparatus for non-thermal tissue ablation having a main body configured for handheld operation and a tip (e.g., in the form of a detachable cartridge) including a skin-penetrating component with one or more ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and/or blades) configured for penetration into and retraction from skin, in which the tip is detachably attached to the main body. The ablation members may be configured to penetrate into the skin to a depth in the range of about 0.01 mm to about 15 mm and/or to produce an ablated tissue portion that results in the removal of an area or volumetric fraction of tissue (e.g., skin) in the range of about 5% to about 70%. The ablation members may further be configured to be in fluid communication with a pressure generating source (e.g., the ablation members can be connected, e.g., via one or more connectors, such as a tube, to the pressure generating source). For example, the pressure generating source may produce vacuum or suction to convey one or more ablated tissue portions produced by the one or more ablation members (e.g., needles, such as hollow coring needles) through the ablation members and away from the skin surface or it may produce a force that injects a fluid (e.g., including one or more of a therapeutic agent, saline, a filler, and other material) into the skin or proximal tissue layers. The pressure generating source may remove waste materials (e.g., tissue, blood, and/or interstitial fluids) from one or more ablation members to prevent clogging, facilitate detachment of ablated tissue portions from surrounding tissue in a treatment area, and/or remove waste materials from a treatment area.

In a fourth aspect, the invention features a system for non-thermal tissue ablation including an apparatus of the invention (e.g., an apparatus of the first, second, and third aspects, and any apparatus described herein) and a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids) that is in fluid communication with the apparatus. The system may further have a base unit (e.g., a dock, computer, control center, and/or charging station) and/or a pressure generating source. The reservoir may be disposed within the tip, the main body, the base unit (if present), or a separate module, or it may be external to these components. A pressure generating source may be a source of high or low pressure (e.g., a vacuum pump or fluid jet), and may be disposed within the main body or the base unit (if present), or it may be separate from the system. For example, the ablation members (e.g., needles, such as hollow coring needles), reservoir, and pressure generating source may be in fluid communication such that generation of vacuum by the pressure generating source draws ablated tissue portions produced by the one or more ablation members through the ablation members and into the reservoir.

In a fifth aspect, the invention features a kit for non-thermal tissue ablation including an apparatus or system of the invention (e.g., an apparatus of the first, second, third, and fourth aspects, and any apparatus described herein) having a main body configured for handheld operation and a tip (e.g., a cartridge) including a skin-penetrating component with one or more ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and/or blades), in which the tip is detachably attached to the main body and the ablation members are configured to be in fluid communication with a pressure generating source. The kit may further include a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids) that is configured to be in fluid

communication with the ablation members. For example, a pressure generating source may provide vacuum or suction to draw one or more ablated tissue portions produced by one or more ablation members (e.g., needles, such as hollow coring needles) through the ablation members and into the reservoir. The kit may include the pressure generating source that may be a source of high or low pressure (e.g., a vacuum pump or fluid jet). The kit may also feature a base unit (e.g., a dock, computer, control center, and/or charging station). The reservoir may be disposed within the tip, the main body, the base unit (if present), or a separate module, or it may be external to these components. The pressure generating source may be disposed within the main body or the base unit (if present), or it may be external to these components.

In some embodiments, the main body and/or base unit may further include one or more user interfaces (e.g., one or more buttons, toggles, spin-wheels, dials, cursors, screws, keys, screens, touch screens, computers, displays, and/or switches) that may include indicators of device configurations, powered status, and/or other information including operation mode and needle number and arrangement. The user interface(s) of the main body and/or base unit may allow for control of device parameters, operation mode, and other features.

In some embodiments, the base unit of a system or kit includes a power source (e.g., one or more alternators, generators, power cords, connections to mains electricity, and/or battery charging stations). In some embodiments, the base unit is electrically coupled to the apparatus. The base unit may be coupled to the apparatus via a cable that provides power, information, fluid flow, and/or vacuum or suction. In other embodiments, the base unit may be wirelessly coupled to the apparatus.

In some embodiments, systems and kits of the invention additionally include a positioning apparatus for positioning skin (e.g., tensioning rods, adhesives, vacuum grippers, and needle or hook grippers).

In some embodiments, the skin-penetrating component of the apparatus includes 1-100 ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and/or blades) (e.g., 1-10, 1-20, 1-30, 1-40, 1-50, 1-60, 1-70, 1-80, 1-90, 1-100, 3-10, 3-20, 3-30, 3-40, 3-50, 3-60, 3-70, 3-80, 3-90, 3-100, 5-10, 5-20, 5-30, 5-40, 5-50, 5-60, 5-70, 5-80, 5-90, 5-100, 10-20, 10-40, 10-60, 10-80, 10-100, 20-40, 20-60, 20-80, 20-100, 40-60, 40-80, 40-100, 60-80, 60-100, and 80-100 needles). In some embodiments, 3-50 ablation members may be present. The ablation members may be arranged in a 1- or 2-dimensional array. In some embodiments, the minimum distance between ablation members may be between about 0.1 mm to about 50 mm (e.g., from 0.1 mm to 0.2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 2 mm, 0.1 mm to 5 mm, 0.1 mm to 10 mm, 0.1 mm to 15 mm, 0.1 mm to 20 mm, 0.1 mm to 30 mm, 0.1 mm to 40 mm, 0.1 mm to 50 mm, 0.2 mm to 0.5 mm, 0.2 mm to 1 mm, 0.2 mm to 2 mm, 0.2 mm to 5 mm, 0.2 mm to 10 mm, 0.2 mm to 15 mm, 0.2 mm to 20 mm, 0.2 mm to 30 mm, 0.2 mm to 40 mm, 0.2 mm to 50 mm, 0.5 mm to 1 mm, 0.5 mm to 2 mm, 0.5 mm to 5 mm, 0.5 mm to 10 mm, 0.5 mm to 15 mm, 0.5 mm to 20 mm, 0.5 mm to 30 mm, 0.5 mm to 40 mm, 0.5 mm to 50 mm, 1 mm to 2 mm, 1 mm to 5 mm, 1 mm to 10 mm, 1 mm to 15 mm, 1 mm to 20 mm, 1 mm to 30 mm, 1 mm to 40 mm, 1 mm to 50 mm, 2 mm to 5 mm, 2 mm to 10 mm, 2 mm to 15 mm, 2 mm to 20 mm, 2 mm to 30 mm, 2 mm to 40 mm, 2 mm to 50 mm, 5 mm to 10 mm, 5 mm to 15 mm, 5 mm to 20 mm, 5 mm to 30 mm, 5 mm to 40 mm, 5 mm to 50 mm, 10 mm to 15 mm, 10 mm to 20 mm, 10 mm to 30 mm, 10 mm

to 40 mm, 10 mm to 50 mm, 15 mm to 20 mm, 15 mm to 30 mm, 15 mm to 40 mm, 15 mm to 50 mm, 20 mm to 30 mm, 20 mm to 40 mm, 20 mm to 50 mm, 30 mm to 40 mm, 30 mm to 50 mm, and 40 mm to 50 mm). In some embodiments, the minimum distance between ablation members is about 0.5 mm to about 2 mm apart. The minimum distance between ablation members may correspond to the minimal size of the array of a plurality of ablation members. For example, an array including 10 ablation members each spaced about 1 mm apart may form a 1-dimensional array that is about 10 mm long or a 2-dimensional array arranged as 2 ablation members by 5 ablation members that is about 2 mm wide and about 5 mm long. The size of an array may correspond to the size of a skin region (e.g., a treatment area). For example, a 2 mm by 5 mm array may be used on a 2 mm by 5 mm treatment area. The skin-penetrating component may be applied more than one time to treat a larger region of skin. For example, a skin-penetrating component including a 2 mm by 5 mm array of ablation members may be applied three times to treat a 6 mm by 5 mm skin region.

In some embodiments, one or more (e.g., all of) of the ablation members may be hollow needles (e.g., hollow coring needles). One or more of the needles may have one or more holes (e.g., at one or both ends or along the shaft of the needle). The needles may be made of metal or plastic and/or may be sharpened at one end. In some embodiments, the needles may be of any gauge between 19 and 26 (e.g., 19, 20, 21, 22, 23, 24, 25, and 26 gauge). In some embodiments, the needles may be 22 or 24 gauge needles.

The apparatus, system, or kit may be used to produce one or more tissue portions. For example, penetration into tissue by the ablation members (e.g., needles, drill bits, abrading elements, punches, and/or blades) of the apparatus may produce one or more tissue portions that are separated from the surrounding tissue. Retraction of the ablation members from tissue may facilitate the separation of the tissue portions from the surrounding tissue, and/or may allow treatment of another area of tissue. The number of tissue portions produced may correspond to the number of ablation members used. For instance, penetration into and retraction from tissue by a single ablation member (e.g., a hollow coring needle) may produce a single tissue portion, while penetration into and retraction from tissue by ten ablation members may produce ten tissue portions. Similarly, a single ablation member used ten times may produce ten tissue portions. A tissue portion produced by the apparatus may have specific dimensions. For example, the depth of penetration by the ablation members (e.g., hollow coring needles) may correspond to the depth or length of a tissue portion produced. In some embodiments, a tissue portion has at least one dimension in a range of about 10 μm to about 2 mm (e.g., about 10 μm to 500 μm, about 10 μm to 100 μm, 10 μm to 250 μm, 10 μm to 500 μm, 10 μm to 750 μm, 10 μm to 1 mm, 10 μm to 1.5 mm, 10 μm to 2 mm, about 50 μm to 100 μm, 50 μm to 250 μm, 50 μm to 500 μm, 50 μm to 750 μm, 50 μm to 1 mm, 50 μm to 1.5 mm, 50 μm to 2 mm, 100 μm to 250 μm, 100 μm to 500 μm, 100 μm to 750 μm, 100 μm to 1 mm, 100 μm to 1.5 mm, 100 μm to 2 mm, 250 μm to 500 μm, 250 μm to 750 μm, 250 μm to 1 mm, 250 μm to 1.5 mm, 250 μm to 2 mm, 500 μm to 750 μm, 500 μm to 1 mm, 500 μm to 1.5 mm, 500 μm to 2 mm, 750 μm to 1 mm, 750 μm to 1.5 mm, and 750 μm to 2 mm); between about 0.1 mm to about 0.8 mm (e.g., 0.1 mm to 0.8 mm, 0.1 mm to 0.6 mm, 0.1 mm to 0.4 mm, 0.1 mm to 0.2 mm, 0.2 mm to 0.8 mm, 0.2 mm to 0.6 mm, 0.2 mm to 0.4 mm, 0.2 mm to 0.3 mm, 0.3 mm to 0.8 mm, 0.3 mm to 0.6 mm, 0.3 mm to 0.4 mm, 0.4 mm to 0.8 mm, 0.4 mm to 0.6 mm, 0.4 mm to 0.5 mm, 0.5 mm to

0.8 mm, 0.5 mm to 0.6 mm, 0.6 mm to 0.8 mm, 0.6 mm to 0.7 mm, and 0.7 mm to 0.8 mm); between about 0.9 mm to about 20 mm (e.g., 0.9 mm to 20 mm, 0.9 mm to 17 mm, 0.9 mm to 14 mm, 0.9 mm to 11 mm, 0.9 mm to 8 mm, 0.9 mm to 5 mm, 0.9 mm to 3 mm, 3 mm to 20 mm, 3 mm to 17 mm, 3 mm to 14 mm, 3 mm to 11 mm, 3 mm to 8 mm, 3 mm to 5 mm, 5 mm to 20 mm, 5 mm to 17 mm, 5 mm to 14 mm, 5 mm to 11 mm, 5 mm to 8 mm, 8 mm to 20 mm, 8 mm to 17 mm, 8 mm to 14 mm, 8 mm to 11 mm, 11 mm to 20 mm, 11 mm to 17 mm, 11 mm to 14 mm, 14 mm to 20 mm, 14 mm to 17 mm, and 17 mm to 20 mm); between about 0.01 mm to 0.25 mm (e.g., 0.01 mm to 0.25 mm, 0.02 mm to 0.25 mm, 0.03 mm to 0.25 mm, 0.05 mm to 0.25 mm, 0.075 mm to 0.25 mm, 0.1 mm to 0.25 mm, 0.15 mm to 0.25 mm, 0.2 mm to 0.25 mm, 0.01 mm to 0.2 mm, 0.02 mm to 0.2 mm, 0.03 mm to 0.2 mm, 0.05 mm to 0.2 mm, 0.075 mm to 0.2 mm, 0.1 mm to 0.2 mm, 0.15 mm to 0.2 mm, 0.01 mm to 0.15 mm, 0.02 mm to 0.15 mm, 0.03 mm to 0.15 mm, 0.05 mm to 0.15 mm, 0.075 mm to 0.15 mm, 0.1 mm to 0.15 mm, 0.01 mm to 0.1 mm, 0.02 mm to 0.1 mm, 0.03 mm to 0.1 mm, 0.05 mm to 0.1 mm, 0.075 mm to 0.1 mm, 0.01 mm to 0.075 mm, 0.02 mm to 0.075 mm, 0.03 mm to 0.075 mm, 0.05 mm to 0.075 mm, 0.01 mm to 0.05 mm, 0.02 mm to 0.05 mm, 0.03 mm to 0.05 mm, 0.01 mm to 0.03 mm, 0.02 mm to 0.03 mm, 0.03 mm to 0.03 mm, 0.01 mm to 0.03 mm, 0.02 mm to 0.03 mm, and 0.01 mm to 0.02 mm); between about 0.01 mm to about 20 mm (e.g., 0.01 mm to 1 mm, 0.01 mm to 2 mm, 0.01 mm to 5 mm, 0.01 mm to 10 mm, 0.01 mm to 15 mm, 0.05 mm to 1 mm, 0.05 mm to 2 mm, 0.05 mm to 5 mm, 0.05 mm to 10 mm, 0.05 mm to 15 mm, 0.05 mm to 20 mm, 0.1 mm to 1 mm, 0.1 mm to 2 mm, 0.1 mm to 5 mm, 0.1 mm to 10 mm, 0.1 mm to 15 mm, 0.1 mm to 20 mm, 0.5 mm to 1 mm, 0.5 mm to 2 mm, 0.5 mm to 5 mm, 0.5 mm to 10 mm, 0.5 mm to 15 mm, 0.5 mm to 20 mm, 1 mm to 2 mm, 1 mm to 5 mm, 1 mm to 10 mm, 1 mm to 15 mm, 1 mm to 20 mm, 2 mm to 5 mm, 2 mm to 10 mm, 2 mm to 15 mm, 2 mm to 20 mm, 5 mm to 10 mm, 5 mm to 15 mm, and 5 mm to 20 mm); or between about 0.01 mm to about 2 mm (e.g., 0.01 mm to 0.1 mm, 0.01 mm to 0.5 mm, 0.01 mm to 1 mm, 0.01 mm to 1.5 mm, 0.01 mm to 1.75 mm, 0.05 mm to 0.1 mm, 0.05 mm to 0.5 mm, 0.05 mm to 1 mm, 0.05 mm to 1.5 mm, 0.05 mm to 1.75 mm, 0.05 mm to 2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 1.5 mm, 0.1 mm to 1.75 mm, 0.1 mm to 2 mm, 0.3 mm to 0.5 mm, 0.3 mm to 1 mm, 0.3 mm to 1.5 mm, 0.3 mm to 1.75 mm, 0.3 mm to 2 mm, 0.5 mm to 1 mm, 0.5 mm to 1.5 mm, 0.5 mm to 1.75 mm, 0.5 mm to 2 mm, 0.7 mm to 1 mm, 0.7 mm to 1.5 mm, 0.7 mm to 1.75 mm, 0.7 mm to 2 mm, 1 mm to 1.5 mm, 1 mm to 1.75 mm, 1 mm to 2 mm, 1.5 mm to 1.75 mm, 1.5 mm to 2 mm, and 1.75 mm to 2 mm).

In some embodiments, a tissue portion produced by an ablation member (e.g., needle, drill bit, abrading element, punch, and blade) of the apparatus has an area dimension less than about 2 mm^2 and/or a volumetric dimension that is less than about 6 mm^3. A tissue portion may have an area dimension in a range of about 0.001 mm^2 to about 2 mm^2 (e.g., 0.001 mm^2 to 0.005 mm^2, 0.001 mm^2 to 0.01 mm^2, 0.001 mm^2 to 0.05 mm^2, 0.001 mm^2 to 0.1 mm^2, 0.001 mm^2 to 0.5 mm^2, 0.001 mm^2 to 1 mm^2, 0.001 mm^2 to 1.5 mm^2, 0.001 mm^2 to 2 mm^2, 0.005 mm^2 to 0.01 mm^2, 0.005 mm^2 to 0.05 mm^2, 0.005 mm^2 to 0.1 mm^2, 0.005 mm^2 to 0.5 mm^2, 0.005 mm^2 to 1 mm^2, 0.005 mm^2 to 1.5 mm^2, 0.005 mm^2 to 2 mm^2, 0.01 mm^2 to 0.02 mm^2, 0.01 mm^2 to 0.05 mm^2, 0.01 mm^2 to 0.1 mm^2, 0.01 mm^2 to 0.5 mm^2, 0.01 mm^2 to 1 mm^2, 0.01 mm^2 to 1.5 mm^2, 0.01 mm^2 to 2 mm^2, 0.05 mm^2 to 0.1 mm^2, 0.05 mm^2 to 0.5 mm^2, 0.05 mm^2 to 1 mm^2, 0.05 mm^2 to 1.5 mm^2, 0.05 mm^2 to 2 mm^2, 0.1 mm^2 to 0.2 mm^2, 0.1 mm^2 to 0.5 mm^2, 0.1 mm^2 to 1 mm^2, 0.1 mm^2 to 1.5 mm^2, 0.1 mm^2 to 2 mm^2, 0.5 mm^2 to 1 mm^2, 0.5 mm^2 to 1.5 mm^2, 0.5

mm^2 to 2 mm^2, 1 mm^2 to 1.5 mm^2, 1 mm^2 to 2 mm^2, and 1.5 mm^2 to 2 mm^2).

In some embodiments, the volume of a tissue portion formed by use of the apparatus is between about 0.001 mm^3 and about 6 mm^3 (e.g., 0.001 mm^3 to 0.01 mm^3, 0.001 mm^3 to 0.1 mm^3, 0.001 mm^3 to 0.5 mm^3, 0.001 mm^3 to 1 mm^3, 0.001 mm^3 to 2 mm^3, 0.001 mm^3 to 3 mm^3, 0.001 mm^3 to 4 mm^3, 0.001 mm^3 to 5 mm^3, 0.001 mm^3 to 6 mm^3, 0.005 mm^3 to 0.01 mm^3, 0.005 mm^3 to 0.1 mm^3, 0.005 mm^3 to 0.5 mm^3, 0.005 mm^3 to 1 mm^3, 0.005 mm^3 to 2 mm^3, 0.005 mm^3 to 3 mm^3, 0.005 mm^3 to 4 mm^3, 0.005 mm^3 to 5 mm^3, 0.005 mm^3 to 6 mm^3, 0.01 mm^3 to 0.1 mm^3, 0.01 mm^3 to 0.5 mm^3, 0.01 mm^3 to 1 mm^3, 0.01 mm^3 to 2 mm^3, 0.01 mm^3 to 3 mm^3, 0.01 mm^3 to 4 mm^3, 0.01 mm^3 to 5 mm^3, 0.01 mm^3 to 6 mm^3, 0.1 mm^3 to 0.5 mm^3, 0.1 mm^3 to 1 mm^3, 0.1 mm^3 to 2 mm^3, 0.1 mm^3 to 3 mm^3, 0.1 mm^3 to 4 mm^3, 0.1 mm^3 to 5 mm^3, 0.1 mm^3 to 6 mm^3, 0.5 mm^3 to 1 mm^3, 0.5 mm^3 to 2 mm^3, 0.5 mm^3 to 3 mm^3, 0.5 mm^3 to 4 mm^3, 0.5 mm^3 to 5 mm^3, 0.5 mm^3 to 6 mm^3, 1 mm^3 to 2 mm^3, 1 mm^3 to 3 mm^3, 1 mm^3 to 4 mm^3, 1 mm^3 to 5 mm^3, 1 mm^3 to 6 mm^3, 2 mm^3 to 3 mm^3, 2 mm^3 to 4 mm^3, 2 mm^3 to 5 mm^3, 2 mm^3 to 6 mm^3, 3 mm^3 to 4 mm^3, 3 mm^3 to 5 mm^3, 3 mm^3 to 6 mm^3, 4 mm^3 to 5 mm^3, 4 mm^3 to 6 mm^3, and 5 mm^3 to 6 mm^3).

In some embodiments, the dimensions, geometry, number, and other characteristics of a tissue portion may correspond to the dimensions, geometry, number, and other characteristics of an ablation member (e.g., needle, drill bit, abrading element, punch, and blade) of the skin penetrating component of the apparatus of the invention. For example, the use of an apparatus of the invention may form one or more holes in a region of skin and/or proximal tissue layers (e.g., a treatment area) by producing one or more tissue portions with the dimensions, geometry, and other characteristics of the holes. The diameter and/or width of a tissue portion may be between about 0.01 mm to about 2 mm (e.g., as described herein). The diameter and/or width of a tissue portion generally correspond to the diameter and/or width of an ablation member of the invention used to produce the tissue portion. The diameter and/or width of an ablation member of an apparatus of the invention at its widest points may be about 0.01 mm to about 2 mm (e.g., as described herein). For example, an apparatus including hollow coring needles with inner (lumen) diameters in the range of about 0.01 mm to about 2.0 mm can be used to provide tissue portions having a corresponding diameter in the range of about 0.01 mm to about 2.0 mm, respectively.

An apparatus of the invention may be configured to provide one or more tissue portions having a change in width as a function of depth (e.g., length). For example, the outer structure and/or inner structure (e.g., for a hollow ablation member) of one or more ablation members (e.g., needles, such as hollow coring needles) of the apparatus may be tapered, having a narrower width at either end, and/or may vary regularly or irregularly along their lengths and so may produce one or more tissue portions having a narrower width at one end and/or regularly or irregularly varying widths along their lengths. The change in width of a tissue portion may be between about 100 μm to about 500 μm as a function of depth (e.g., 100 μm to 200 μm, 100 μm to 300 μm, 100 μm to 400 μm, 100 μm to 500 μm, 200 μm to 300 μm, 200 μm to 400 μm, 200 μm to 500 μm, 300 μm to 400 μm, 300 μm to 500 μm, and 400 μm to 500 μm). The width to depth ratio of a tissue portion may be between about 1:0.3 to about 1:75. For example, the width to depth radio of a tissue portion may be between about 1:0.3 to about 1:1 (e.g., 1:0.3 to 1:1, 1:0.35 to 1:1, 1:0.4 to 1:1, 1:0.45 to 1:1, 1:0.5 to 1:1, 1:0.55 to 1:1, 1:0.6 to 1:1, 1:0.65 to 1:1, 1:0.7 to 1:1, 1:0.75 to 1:1, 1:0.8 to 1:1, 1:0.85 to 1:1, 1:0.9 to 1:1, 1:0.95 to 1:1, 1:0.3 to 1:0.95, 1:0.35 to 1:0.95, 1:0.4 to 1:0.95, 1:0.45 to 1:0.95, 1:0.5 to 1:0.95, 1:0.55 to 1:0.95, 1:0.6 to 1:0.95, 1:0.65 to 1:0.95, 1:0.7 to 1:0.95,

1:0.75 to 1:0.95, 1:0.8 to 1:0.95, 1:0.85 to 1:0.95, 1:0.9 to 1:0.95, 1:0.3 to 1:0.9, 1:0.35 to 1:0.9, 1:0.4 to 1:0.9, 1:0.45 to 1:0.9, 1:0.5 to 1:0.9, 1:0.55 to 1:0.9, 1:0.6 to 1:0.9, 1:0.65 to 1:0.9, 1:0.7 to 1:0.9, 1:0.75 to 1:0.9, 1:0.8 to 1:0.9, 1:0.85 to 1:0.9, 1:0.3 to 1:0.85, 1:0.35 to 1:0.85, 1:0.4 to 1:0.85, 1:0.45 to 1:0.85, 1:0.5 to 1:0.85, 1:0.55 to 1:0.85, 1:0.6 to 1:0.85, 1:0.65 to 1:0.85, 1:0.7 to 1:0.85, 1:0.75 to 1:0.85, 1:0.8 to 1:0.85, 1:0.3 to 1:0.8, 1:0.35 to 1:0.8, 1:0.4 to 1:0.8, 1:0.45 to 1:0.8, 1:0.5 to 1:0.8, 1:0.55 to 1:0.8, 1:0.6 to 1:0.8, 1:0.65 to 1:0.8, 1:0.7 to 1:0.8, 1:0.75 to 1:0.8, 1:0.3 to 1:0.75, 1:0.35 to 1:0.75, 1:0.4 to 1:0.75, 1:0.45 to 1:0.75, 1:0.5 to 1:0.75, 1:0.55 to 1:0.75, 1:0.6 to 1:0.75, 1:0.65 to 1:0.75, 1:0.7 to 1:0.75, 1:0.3 to 1:0.65, 1:0.35 to 1:0.65, 1:0.4 to 1:0.65, 1:0.45 to 1:0.65, 1:0.5 to 1:0.65, 1:0.55 to 1:0.65, 1:0.6 to 1:0.65, 1:0.3 to 1:0.65, 1:0.35 to 1:0.65, 1:0.4 to 1:0.65, 1:0.45 to 1:0.65, 1:0.5 to 1:0.65, 1:0.55 to 1:0.65, 1:0.6 to 1:0.65, 1:0.3 to 1:0.6, 1:0.35 to 1:0.6, 1:0.4 to 1:0.6, 1:0.45 to 1:0.6, 1:0.5 to 1:0.6, 1:0.55 to 1:0.6, 1:0.3 to 1:0.55, 1:0.35 to 1:0.55, 1:0.4 to 1:0.55, 1:0.45 to 1:0.55, 1:0.5 to 1:0.55, 1:0.3 to 1:0.5, 1:0.35 to 1:0.5, 1:0.4 to 1:0.5, 1:0.45 to 1:0.5, 1:0.5 to 1:0.5, 1:0.3 to 1:0.45, 1:0.35 to 1:0.45, 1:0.4 to 1:0.45, 1:0.3 to 1:0.4, 1:0.35 to 1:0.4, and 1:0.3 to 1:0.35); between about 1:1 to about 1:20 (e.g., 1:1 to 1:2, 1:1 to 1:3, 1:1 to 1:4, 1:1 to 1:5, 1:1 to 1:6, 1:1 to 1:7, 1:1 to 1:8, 1:1 to 1:9, 1:1 to 1:10, 1:1 to 1:11, 1:1 to 1:12, 1:1 to 1:13, 1:1 to 1:14, 1:1 to 1:15, 1:1 to 1:16, 1:1 to 1:17, 1:1 to 1:18, 1:1 to 1:19, 1:1 to 1:20, 1:2 to 1:3, 1:2 to 1:4, 1:2 to 1:5, 1:2 to 1:6, 1:2 to 1:7, 1:2 to 1:8, 1:2 to 1:9, 1:2 to 1:10, 1:2 to 1:11, 1:2 to 1:12, 1:2 to 1:13, 1:2 to 1:14, 1:2 to 1:15, 1:2 to 1:16, 1:2 to 1:17, 1:2 to 1:18, 1:2 to 1:19, 1:2 to 1:20, 1:3 to 1:4, 1:3 to 1:5, 1:3 to 1:6, 1:3 to 1:7, 1:3 to 1:8, 1:3 to 1:9, 1:3 to 1:10, 1:3 to 1:11, 1:3 to 1:12, 1:3 to 1:13, 1:3 to 1:14, 1:3 to 1:15, 1:3 to 1:16, 1:3 to 1:17, 1:3 to 1:18, 1:3 to 1:19, 1:3 to 1:20, 1:4 to 1:5, 1:4 to 1:6, 1:4 to 1:7, 1:4 to 1:8, 1:4 to 1:9, 1:4 to 1:10, 1:4 to 1:11, 1:4 to 1:12, 1:4 to 1:13, 1:4 to 1:14, 1:4 to 1:15, 1:4 to 1:16, 1:4 to 1:17, 1:4 to 1:18, 1:4 to 1:19, 1:4 to 1:20, 1:5 to 1:6, 1:5 to 1:7, 1:5 to 1:8, 1:5 to 1:9, 1:5 to 1:10, 1:5 to 1:11, 1:5 to 1:12, 1:5 to 1:13, 1:5 to 1:14, 1:5 to 1:15, 1:5 to 1:16, 1:5 to 1:17, 1:5 to 1:18, 1:5 to 1:19, 1:5 to 1:20, 1:6 to 1:7, 1:6 to 1:8, 1:6 to 1:9, 1:6 to 1:10, 1:6 to 1:11, 1:6 to 1:12, 1:6 to 1:13, 1:6 to 1:14, 1:6 to 1:15, 1:6 to 1:16, 1:6 to 1:17, 1:6 to 1:18, 1:6 to 1:19, 1:6 to 1:20, 1:7 to 1:8, 1:7 to 1:9, 1:7 to 1:10, 1:7 to 1:11, 1:7 to 1:12, 1:7 to 1:13, 1:7 to 1:14, 1:7 to 1:15, 1:7 to 1:16, 1:7 to 1:17, 1:7 to 1:18, 1:7 to 1:19, 1:7 to 1:20, 1:8 to 1:9, 1:8 to 1:10, 1:8 to 1:11, 1:8 to 1:12, 1:8 to 1:13, 1:8 to 1:14, 1:8 to 1:15, 1:8 to 1:16, 1:8 to 1:17, 1:8 to 1:18, 1:8 to 1:19, 1:8 to 1:20, 1:9 to 1:10, 1:9 to 1:11, 1:9 to 1:12, 1:9 to 1:13, 1:9 to 1:14, 1:9 to 1:15, 1:9 to 1:16, 1:9 to 1:17, 1:9 to 1:18, 1:9 to 1:19, 1:9 to 1:20, 1:10 to 1:11, 1:10 to 1:12, 1:10 to 1:13, 1:10 to 1:14, 1:10 to 1:15, 1:10 to 1:16, 1:10 to 1:17, 1:10 to 1:18, 1:10 to 1:19, 1:10 to 1:20, 1:11 to 1:12, 1:11 to 1:13, 1:11 to 1:14, 1:11 to 1:15, 1:11 to 1:16, 1:11 to 1:17, 1:11 to 1:18, 1:11 to 1:19, 1:11 to 1:20, 1:12 to 1:13, 1:12 to 1:14, 1:12 to 1:15, 1:12 to 1:16, 1:12 to 1:17, 1:12 to 1:18, 1:12 to 1:19, 1:12 to 1:20, 1:13 to 1:14, 1:13 to 1:15, 1:13 to 1:16, 1:13 to 1:17, 1:13 to 1:18, 1:13 to 1:19, 1:13 to 1:20, 1:14 to 1:15, 1:14 to 1:16, 1:14 to 1:17, 1:14 to 1:18, 1:14 to 1:19, 1:14 to 1:20, 1:15 to 1:16, 1:15 to 1:17, 1:15 to 1:18, 1:15 to 1:19, 1:15 to 1:20, 1:17 to 1:18, 1:17 to 1:19, and 1:17 to 1:20); between about 1:1 to about 1:75 (e.g., 1:1 to 1:2, 1:1 to 1:5, 1:1 to 1:10, 1:1 to 1:20, 1:1 to 1:30, 1:1 to 1:40, 1:1 to 1:50, 1:1 to 1:60, 1:1 to 1:75, 1:2 to 1:5, 1:2 to 1:10, 1:2 to 1:20, 1:2 to 1:30, 1:2 to 1:40, 1:2 to 1:50, 1:2 to 1:60, 1:2 to 1:75, 1:5 to 1:10, 1:5 to 1:20, 1:5 to 1:30, 1:5 to 1:40, 1:5 to 1:50, 1:5 to 1:60, 1:5 to 1:75, 1:10 to 1:20, 1:10 to 1:30, 1:10 to 1:40, 1:10 to 1:50, 1:10 to 1:60, 1:10 to 1:75, 1:20 to 1:30, 1:20 to 1:40, 1:20 to 1:50, 1:20 to 1:60, 1:20 to 1:75, 1:30 to 1:40, 1:30 to 1:50, 1:30 to 1:60, 1:30 to 1:75, 1:40 to 1:50, 1:40 to 1:60, 1:40 to 1:75, 1:50 to 1:60, 1:50 to 1:75, and 1:60 to 1:75); between about 1:25 to about 1:75 (e.g., 1:25 to 1:75,

1:30 to 1:75, 1:35 to 1:75, 1:40 to 1:75, 1:45 to 1:75, 1:50 to 1:75, 1:55 to 1:75, 1:60 to 1:75, 1:65 to 1:75, 1:70 to 1:75, 1:25 to 1:70, 1:30 to 1:70, 1:35 to 1:70, 1:40 to 1:70, 1:45 to 1:70, 1:50 to 1:70, 1:55 to 1:70, 1:60 to 1:70, 1:65 to 1:70, 1:25 to 1:65, 1:30 to 1:65, 1:35 to 1:65, 1:40 to 1:65, 1:45 to 1:65, 1:50 to 1:65, 1:55 to 1:65, 1:60 to 1:65, 1:25 to 1:60, 1:30 to 1:60, 1:35 to 1:60, 1:40 to 1:60, 1:45 to 1:60, 1:50 to 1:60, 1:55 to 1:60, 1:25 to 1:55, 1:30 to 1:55, 1:35 to 1:55, 1:40 to 1:55, 1:45 to 1:55, 1:50 to 1:55, 1:25 to 1:50, 1:30 to 1:50, 1:35 to 1:50, 1:40 to 1:50, 1:45 to 1:50, 1:25 to 1:45, 1:30 to 1:45, 1:35 to 1:45, 1:40 to 1:45, 1:25 to 1:40, 1:30 to 1:40, 1:35 to 1:40, 1:25 to 1:35, 1:30 to 1:35, and 1:25 to 1:30); or between about 1:03 to about 1:75 (e.g., 1:0.3 to 1:0.5, 1:0.3 to 1:1, 1:0.3 to 1:2, 1:0.3 to 1:5, 1:0.3 to 1:10, 1:0.3 to 1:20, 1:0.3 to 1:30, 1:0.3 to 1:40, 1:0.3 to 1:50, 1:0.3 to 1:60, 1:0.3 to 1:75, 1:0.5 to 1:1, 1:0.5 to 1:2, 1:0.5 to 1:5, 1:0.5 to 1:10, 1:0.5 to 1:20, 1:0.5 to 1:30, 1:0.5 to 1:40, 1:0.5 to 1:50, 1:0.5 to 1:60, and 1:0.5 to 1:75).

In all aspects of the invention, the apparatus may be configured to provide from about 10 to about 10000 tissue portions per cm^2 area (e.g., 10 to 50, 10 to 100, 10 to 200, 10 to 300, 10 to 400, 10 to 500, 10 to 600, 10 to 700, 10 to 800, 10 to 900, 10 to 1000, 10 to 2000, 10 to 4000, 10 to 6000, 10 to 8000, 10 to 10000, 50 to 100, 50 to 200, 50 to 300, 50 to 400, 50 to 500, 50 to 600, 50 to 700, 50 to 800, 50 to 900, 50 to 1000, 50 to 2000, 50 to 4000, 510 to 6000, 50 to 8000, 50 to 10000, 100 to 200, 100 to 300, 100 to 400, 100 to 500, 100 to 600, 100 to 700, 100 to 800, 100 to 900, 100 to 1000, 100 to 2000, 100 to 4000, 100 to 6000, 100 to 8000, 100 to 10000, 200 to 300, 200 to 400, 200 to 500, 200 to 600, 200 to 700, 200 to 800, 200 to 900, 200 to 1000, 200 to 2000, 200 to 4000, 200 to 6000, 200 to 8000, 200 to 10000, 300 to 400, 300 to 500, 300 to 600, 300 to 700, 300 to 800, 300 to 900, 300 to 1000, 300 to 2000, 300 to 4000, 300 to 6000, 300 to 8000, 300 to 10000, 400 to 500, 400 to 600, 400 to 700, 400 to 800, 400 to 900, 400 to 1000, 400 to 2000, 400 to 4000, 400 to 6000, 400 to 8000, 400 to 10000, 500 to 600, 500 to 700, 500 to 800, 500 to 900, 500 to 1000, 500 to 2000, 500 to 4000, 500 to 6000, 500 to 8000, 500 to 10000, 600 to 700, 600 to 800, 600 to 900, 600 to 1000, 600 to 2000, 600 to 4000, 600 to 6000, 600 to 8000, 600 to 10000, 700 to 800, 700 to 900, 700 to 1000, 700 to 2000, 700 to 4000, 700 to 6000, 700 to 8000, 700 to 10000, 800 to 900, 800 to 1000, 800 to 2000, 800 to 4000, 800 to 6000, 800 to 8000, 800 to 10000, 900 to 1000, 900 to 2000, 900 to 4000, 900 to 6000, 900 to 8000, 900 to 10000, 1000 to 2000, 1000 to 4000, 1000 to 6000, 1000 to 8000, 1000 to 10000, 2000 to 4000, 2000 to 6000, 2000 to 8000, 2000 to 10000, 4000 to 6000, 4000 to 8000, 4000 to 10000, 6000 to 8000, 6000 to 10000, and 8000 to 10000 tissue portions per cm^2 area) of a skin region to which the apparatus is applied (e.g., a treatment area). The invention features an apparatus configured to remove about 5%-70% (e.g., 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, and 70%) of tissue within a treatment area. In some embodiments, about 10% of tissue within a treatment area is removed by the apparatus. In an embodiment, the apparatus may be configured to remove about 10% of the tissue within a treatment area using 24 gauge needles. For example, penetration into and retraction from tissue within a treatment area by an array of 24 gauge hollow coring needles may result in the removal of about 10% of the tissue within the treatment area.

Any of the apparatuses, systems, and kits of the invention may further include an actuation mechanism for driving penetration into the skin by the ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and blades) of the skin-penetrating component. The actuation mechanism may be mechanically or electrically coupled to the ablation members. In some

embodiments, the actuation mechanism is configured to allow penetration into the skin by the ablation members to a depth of about 0.1 mm to about 15 mm (e.g., 0.1 mm to 0.2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 2 mm, 0.1 mm to 5 mm, 0.1 mm to 10 mm, 0.1 mm to 15 mm, 0.2 mm to 0.5 mm, 0.2 mm to 1 mm, 0.2 mm to 2 mm, 0.2 mm to 5 mm, 0.2 mm to 10 mm, 0.2 mm to 15 mm, 0.5 mm to 1 mm, 0.5 mm to 2 mm, 0.5 mm to 5 mm, 0.5 mm to 10 mm, 0.5 mm to 15 mm, 1 mm to 2 mm, 1 mm to 5 mm, 1 mm to 10 mm, 1 mm to 15 mm, 2 mm to 5 mm, 2 mm to 10 mm, 2 mm to 15 mm, 5 mm to 10 mm, 5 mm to 15 mm, and 10 mm to 15 mm). In some embodiments, the actuation mechanism is configured to allow penetration into the skin by the ablation members to a depth of about 10 mm to about 15 mm. In other embodiments, the actuation mechanism is configured to allow penetration into the skin by the ablation members to a depth of about 2 mm to about 5 mm. The actuation mechanism may be selected from the group consisting of a pneumatic actuator, an electromagnetic actuator, a motor with a cam, a piezoelectric actuator, and a motor with a lead screw (e.g., a stepper motor). The actuation mechanism may drive penetration of the needles into the skin with a force of about 0.5 N to about 20 N per needle (e.g., 0.5 N to 0. 75 N, 0.5 N to 1 N, 0.5 N to 1.25 N, 0.5 N to 1.5 N, 0.5 N to 2 N, 0.5 N to 5 N, 0.5 N to 10 N, 0.5 N to 12 N, 0.5 N to 15 N, 0.5 N to 20 N, 0. 75 N to 1 N, 0.75 N to 1.25 N, 0.75 N to 1.5 N, 0.75 N to 2 N, 0.75 N to 5 N, 0.75 N to 10 N, 0.75 N to 12 N, 0.75 N to 15 N, 0.75 N to 20 N, 1 N to 1.25 N, 1 N to 1.5 N, 1 N to 2 N, 1 N to 5 N, 1 N to 10 N, 1 N to 12 N, 1 N to 15 N, 1 N to 20 N, 1.25 N to 1.5 N, 1.25 N to 2 N, 1.25 N to 5 N, 1.25 N to 10 N, 1.25 N to 12 N, 1.25 N to 15 N, 1.25 N to 20 N, 1.5 N to 2 N, 1.5 N to 5 N, 1.5 N to 10 N, 1.5 N to 12 N, 1.5 N to 15 N, 1.5 N to 20 N, 2 N to 5 N, 2 N to 10 N, 2 N to 12 N, 2 N to 15 N, 2 N to 20 N, 5 N to 10 N, 5 N to 12 N, 5 N to 15 N, 5 N to 20 N, 10 N to 12 N, 10 N to 15 N, 10 N to 20 N, 12 N to 15 N, 12 N to 20 N, and 15 N to 20 N). The actuation mechanism may also drive retraction of the needles from the skin.

Any of the apparatuses, systems, and kits of the invention may further have an actuation or translation mechanism for driving the ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and blades) across the skin. A translation mechanism may include wheels (e.g., coupled to the main body and/or tip of the apparatus to permit wheels to translate across a skin surface). An actuation mechanism may be mechanically or electrically coupled to one or more ablation members. The actuation mechanism may be selected from the group consisting of a pneumatic actuator, an electromagnetic actuator, a motor with a cam, a piezoelectric actuator, and a motor with a lead screw (e.g., a stepper motor).

In some embodiments, the apparatuses, systems, and kits of the invention may further include a position detection mechanism (e.g., an optical tracking mechanism to guide manual translation of the apparatus across a skin surface). In apparatuses, systems, and kits having one or more actuation, translation, and/or position detection mechanisms, one or more activation mechanisms may activate the components. These activation mechanisms may include toggles, spin-wheels, buttons, screws, switches, cursors, dials, and/or keys. Actuation, translation, position detection, and/or activation mechanisms may be disposed on or within the main body (e.g., on the user interface) or the tip of the apparatus or on or within a base unit (e.g., on the user interface), if present.

In some embodiments, the apparatus has a release mechanism for detaching the tip. In another embodiment, the tip is designed for a single use. Tips may have varying numbers of ablation members

(e.g., needles, drill bits, abrading elements, punches, and blades) and ablation member configurations, and tips of varying ablation members and ablation member configurations may be detachably attachable to the main body of the apparatus.

In some embodiments, the apparatus is battery powered or is powered by a cord that can be plugged into an outlet (e.g., an outlet providing a standard mains power). When battery powered, the main body of the apparatus may have a release mechanism for gaining access to the battery (e.g., to replace a depleted battery and/or remove a battery for charging). Alternatively, the apparatus may have a battery that is built into the main body that is not designed to be replaceable.

The invention also features methods of treating a skin condition, which include a) forming a plurality of tissue portions by contacting the ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and blades) of any of the apparatuses or systems of the first-fourth aspects to the skin of a subject, and b) removing the resultant plurality of tissue portions from the skin. In an embodiment of the invention, penetration into the skin by the ablation members forms the plurality of tissue portions. The tissue portions may be removed from the ablation members and/or skin by the use of a pressure source (e.g., a vacuum applied, e.g., through the ablation members).

In some embodiments, the method of the invention may involve treatment of the dermis and/or epidermis. The method may involve treatment of the skin and/or proximal tissue layers. In some embodiments, the method of the invention may be used to treat one or more diseases, disorders, or conditions in underlying skin layers, such as fat, muscle, and facial SMAS (superficial muscular aponeurotic system). In such embodiments, the apparatus of the invention may include a skin-penetrating component configured to provide a tissue portion having an appropriate depth (e.g., 0.1-15 mm) to reach the targeted underlying skin layers (e.g., fat, muscle, and facial SMAS).

In any embodiment described herein, the apparatuses, systems, kits, and methods may be used to eliminate tissue volume or area of the skin and/or proximal tissue layers, promoting one or more of the following effects: tissue growth, skin tightening, skin rejuvenation, improved skin texture or appearance, decreased skin laxity, lifting of skin, skin repositioning, tattoo removal, and/or an expansion of tissue volume or area. In some embodiments, the devices, apparatuses, and methods are useful for treating one or more diseases, disorders, or conditions of the skin to improve skin appearance, to rejuvenate skin, and/or to tighten skin. Diseases, disorders, or conditions may include removal of pigment, veins (e.g., spider veins or reticular veins), glands (e.g., sebaceous glands or sweat glands), hair follicles, and/or vessels in the skin, as well as treatment of acne, allodynia, blemishes, ectopic dermatitis, hyperpigmentation, hyperplasia (e.g., lentigo or keratosis), loss of translucency, loss of elasticity, melasma (e.g., epidermal, dermal, or mixed subtypes), photodamage, rashes (e.g., erythematous, macular, papular, and/or bullous conditions), psoriasis, rhytides (or wrinkles, e.g., lateral canthal lines ("crow's feet"), age-related rhytides, sun-related rhytides, or heredity-related rhytides), sallow color, scar contracture (e.g., relaxation of scar tissue), scarring (e.g., due to acne, surgery, or other trauma), skin aging, skin contraction (e.g., excessive tension in the skin), skin irritation/sensitivity, skin laxity (e.g., loose or sagging skin or other skin irregularities), striae (or stretch marks), vascular lesions (e.g., angioma, erythema, hemangioma, papule, port wine stain, rosacea, reticular vein, or telangiectasia), or any other unwanted skin irregularities (e.g., areas of fibrosis and /or necrosis).

In other embodiments, the apparatuses, systems, kits, and methods described herein allow for treatment of uneven surfaces (e.g., the face). In particular, large area ablation techniques can be difficult to apply in a conformal or uniform manner to uneven skin surfaces. Thus, the apparatus is configured such that it can conform to the skin surface, even if the surface is uneven.

In some embodiments, a compressive force may be applied to the treatment area prior to treatment. The compressive force may be applied with the hands or with a positioning apparatus, which can be integrated into the main body of the apparatus or used as a standalone device.

In other embodiments, the apparatuses, systems, kits, and methods described herein allow for immediate assessment of the expected or approximate outcome of the treatment. In contrast to energy-based methods, the expected or approximate outcome of the treatment performed with the apparatus of the present invention can be immediately visible. For instance, treatment with conventional energy-based devices activates remodeling of the tissue and the end-result is only visible weeks to months after treatment. The outcome of treatment with the apparatus of the present invention may be assessed within minutes to hours to days after treatment as the treatment involves surgical removal of a portion of the skin.

In other embodiments, the apparatuses, systems, kits, and methods described herein allow for rapid healing. For instance, compared to surgery, the treatment can be much less invasive and the healing can be, therefore, much faster. In some embodiments, a non-compressive bandage may be applied to the skin after the removal of tissue portions to promote healing. In other embodiments, a bandage may be applied to promote healing in a preferred direction.

In some embodiments, the treatment results in a reduction of skin surface area. In particular, the reduction in skin surface area may occur in a direction orthogonal to Langer lines.

In some embodiments, the treatment may not leave lasting changes in the architecture of the skin such that the same skin region may be treated multiple times. Treatment of the same area multiple times may permit sequential tissue area and/or volume reduction without any adverse changes in skin architecture, function, or appearance. In contrast, treatment with energy-based methods results in changes at the ultrastructural level which are likely to be additive with each subsequent treatment, potentially limiting the number of times in which such a treatment can be applied.

Definitions

By “tissue portion” is meant that portion of skin and/or proximal tissue layers (e.g., fat, muscle, and/or facial superficial muscular aponeurotic system) that is ablated, cut, abraded, damaged, and/or removed (e.g., as a plug) by an ablation member (e.g., needle) of the apparatus. A tissue portion may have particular dimensions, geometry, and other characteristics that correspond to the particular dimensions, geometry, and other characteristics of an ablation member of the skin penetrating component of the invention.

By “about” is meant +/- 10% of the recited value.

By “non-thermal tissue ablation” is meant a tissue ablation (e.g., destruction or removal) technique that does not transfer substantial thermal energy to the surrounding non-ablated tissue (e.g., as opposed to thermal and photo-thermal tissue ablation techniques, such as laser ablation techniques). For example, non-thermal tissue ablation does not produce a coagulation zone in tissue, or produces a

substantially reduced (e.g., >90% reduction, as compared to thermal ablation techniques) coagulation zone in tissue, which can prevent and/or slow closure and/or healing of an ablated zone (e.g., a hole).

By "non-thermal ablation apparatus" is meant a device capable of performing non-thermal tissue ablation.

By "skin-penetrating component" is meant an element that includes one or more ablation members (e.g., needles, drill bits, abrading elements, punches, blades, fluid jets, and/or probes) that are capable of puncturing the skin. The skin-penetrating component may alone be capable of creating a tissue portion or, when combined with a pressure generating source, may be capable of producing a tissue portion.

By "subject" is meant a mammal (e.g., a human or non-human mammal).

By "treating" a disease, disorder, or condition in a subject is meant reducing at least one symptom of the disease, disorder, or condition, e.g., a skin condition, such as treatment of acne, allodynia, blemishes, ectopic dermatitis, hyperpigmentation, hyperplasia (e.g., lentigo or keratosis), loss of translucency, loss of elasticity, melasma (e.g., epidermal, dermal, or mixed subtypes), photodamage, rashes (e.g., erythematous, macular, papular, and/or bullous conditions), psoriasis, rhytides (or wrinkles, e.g., lateral canthal lines ("crow's feet"), age-related rhytides, sun-related rhytides, or heredity-related rhytides), sallow color, scar contracture (e.g., relaxation of scar tissue), scarring (e.g., due to acne, surgery, or other trauma), skin aging, skin contraction (e.g., excessive tension in the skin), skin irritation/sensitivity, skin laxity (e.g., loose or sagging skin or other skin irregularities), striae (or stretch marks), vascular lesions (e.g., angioma, erythema, hemangioma, papule, port wine stain, rosacea, reticular vein, or telangiectasia), irregular veins (e.g., spider veins or reticular veins), or any other unwanted skin irregularities (e.g., areas of fibrosis and /or necrosis, undesirable pigmentation, undesirable glands (e.g., sebaceous glands or sweat glands), hair follicles, and undesirable vessels).

Other features and advantages of the invention will be apparent from the following Detailed Description and the claims.

Brief Description of the Drawings

Figures 1A and 1B show schematic views of two handheld apparatuses **10** of the invention.

Figure 2 is an illustration showing an apparatus **10** of the invention including main body **12** and tip **14**.

Figure 3A and 3B are illustrations showing perspective and side views, respectively, of an apparatus of the invention including user interface **16**. Figure 3C is an illustration showing user interaction with user interface **16**.

Figure 4 shows an apparatus of the invention in which tip **14** is detachable from main body **12** by quick-release mechanism **18**. The main body also includes user interface **16**.

Figures 5A and 5B are illustrations showing two perspective views of an apparatus of the invention in which tip **14** is detachable from main body **12** by quick-release mechanism **18**. The arrow in Figure 5B is for illustration purposes only.

Figure 6 shows tip **14** of an apparatus of the invention with skin penetrating components **20**. Also shown are tips having a variable number and configuration of ablation members.

Figure 7 is an illustration showing apparatus **10** of the invention featuring user interface **16** to activate penetration into the tissue with skin penetrating component **20**. The inset shows the ablation members of skin penetrating component **20** in extended and retracted configurations.

Figure 8 is an illustration showing a system of the invention that includes base unit **30** with user interface **32** coupled to a handheld apparatus by cable **34**. The cable carries one or more of power, information, and suction to and/or from the handheld apparatus.

Figures 9A and 9B are illustrations of two base units **30** of the invention including user interfaces **32** and cables **34**.

Figure 10 shows a skin positioning apparatus **40** of the invention that includes skin tensioning rods **42**. The skin positioning apparatus may position skin for treatment of tissue layers such as dermis **52**, subcutaneous fat **54**, and muscle **56**, e.g., using an apparatus of the invention.

Figure 11 shows a system of the invention that includes a tip **14** with an integrated reservoir for waste collection **60**, a handheld main body **12** with a user interface **16**, a cable **34** for carrying one or more of power, information, and suction, and a base unit **30** that includes a user interface **32**.

Figure 12 shows a system of the invention that includes a tip **14**, a handheld main body **12** with a user interface **16**; one or more cables **34** for carrying one or more of power, information, and suction, and a base unit **30** that includes a user interface **32** and a reservoir for waste collection **60**.

Figure 13 shows a system of the invention that includes a tip **14**, a module including a reservoir for waste collection **60**, a handheld main body **12** with a user interface **16** and a miniature vacuum source **70**, a cable **34** for carrying one or more of power, information, and suction, and a base unit **30** that includes a user interface **32**.

Figure 14 shows a system of the invention includes a tip **14**, a module including a reservoir for waste collection **60**, a handheld main body **12** with a user interface **16** and a miniature vacuum source **70**, a battery unit **36**, and a base unit **30** that includes a user interface **32**.

Figure 15 shows possible needle tip configurations for the ablation members of the tip of the apparatus of the invention.

Figure 16 is a schematic depicting reduction of tissue in a treated area by closure of ablations in a preferred direction.

Figure 17 is a schematic depicting the architecture of a “stamping” device. The “stamping” device of the invention includes z-actuator **84**, x-actuator **82**, control electronics **38**, array gripper **22**, skin-penetrating component **20**, tubing **24**, reservoir for waste collection **60**, vacuum source **70**, and skin positioning apparatus **40**.

Figures 18A, 18B, and 18C illustrate operation of a device with a “stamping” architecture (18A) and automatic (18B) and manual (18C) operation of a device with a “brushing” architecture.

Figure 19 is a schematic depicting the architecture of a “brushing” device. The “brushing” device of the invention includes z-actuator **84**, translating mechanism **86**, position detection mechanism **88**, control electronics **38**, array gripper **22**, skin-penetrating component **20**, tubing **24**, reservoir for waste collection **60**, vacuum source **70**, and skin positioning apparatus **40**.

Detailed Description

This invention relates to apparatuses, systems, kits, and methods for treating skin (e.g., eliminating tissue volume, tightening skin, lifting skin, and/or reducing skin laxity) by ablating tissue without substantial thermal energy being imparted to the surrounding (e.g., non-ablated) tissue. In particular, the invention relates to apparatuses, systems, kits, and methods that include skin-penetrating components with ablation members (e.g., needles, drill bits, abrading elements, punches, blades, fluid jets, and/or probes) capable of mechanical fractional ablation of the epidermal, dermal, and proximal tissue layers (e.g., fat, muscle, and SMAS (superficial muscular aponeurotic system)).

In particular embodiments, the present invention provides one or more of the following advantages. First, the non-thermal fractional ablation apparatuses, systems, kits, and methods herein allow for skin tightening, skin lifting, and/or reduction of skin laxity without inducing coagulation in the surrounding tissue. In contrast, thermal ablation techniques prevent and/or inhibit skin tightening by allowing coagulation of the tissue and formation of rigid tissue cores that cannot be compressed. Second, the handheld, compact, modular, and versatile apparatuses and systems herein facilitate ease of use and sterilization and permit treatment of varied skin regions and conditions with a single instrument. For example, a tip of an apparatus having an array with a particular number and configuration of ablation members (e.g., needles) can be used to treat a particular skin region and/or condition and, if desired, the tip may be exchanged during the treatment for a different tip having a different number and configuration of ablation members (e.g., needles) for treatment of a different skin region and/or condition. This adaptability may allow for treatment of multiple skin regions and/or conditions within a single treatment session. Third, the apparatuses, systems, and kits include micro-sized features, which can be beneficial for controlling the extent of skin treatment and for ease of handling the apparatus. Fourth, the apparatuses, systems, kits, and methods described herein may require less skill than that of a surgeon to operate and/or perform. For example, treatment of patients can occur in an outpatient setting, rather than in an inpatient, surgical setting. Fifth, the apparatuses, systems, kits, and methods herein constitute minimally invasive techniques that can provide more predictable results and/or minimize risk factors to a greater degree than that for more invasive techniques (e.g., plastic surgery) or non-invasive energy-based techniques (e.g., laser, radiofrequency, and ultrasound). Sixth, the apparatuses, systems, kits, and methods herein can allow for rapid closing of holes or slits after treating the skin (e.g., within a few seconds or minutes after treating skin, such as within about ten to about sixty seconds), thereby minimizing the extent of bleeding and/or clotting within the holes or slits and/or scar formation. Seventh, the apparatuses, systems, kits, and methods herein can be useful for maximizing the tightening effect while minimizing healing time by optimizing tightening (e.g., by controlling the extent of skin pleating, such as by increasing the extent of skin pleating for some applications or skin regions and by decreasing the extent of skin pleating for other applications or skin regions, as described herein). Eighth, the apparatuses, systems, kits, and methods for tissue removal described herein provide efficient clearance of partially ablated tissue and debris from ablated tissue portions, thus reducing the time for healing and improving the skin tightening treatment. Ninth, the apparatuses, systems, kits, and methods herein allow visualization of results in real time during the course of the treatment. For example, the operator can ask the patient for feedback in real time during the treatment and can adjust the treatment course according

to the patient's preference. These and other advantages are facilitated by the handheld, compact, versatile, easy to use, and easy to sterilize apparatuses of the invention.

In some embodiments, apparatuses, systems, kits, and methods of the invention allow for the treatment of skin with varied thickness. Skin regions vary in thickness depending on the location on the body. For example, Kakasheva-Mazenkovska et al., (Contributions, Soc. Biol. Med. Sci., MASA, XXXII, 2, p. 119-128 (2011), incorporated by reference herein in its entirety) describes thin skin regions for 23-53 year old adults as including the anterior lower leg (average skin thickness of 1.7 mm) and the cheeks (average skin thickness of 2.1 mm) and thick skin regions as the anterior leg (average skin thickness of 4.9 mm, e.g., in the anterior upper leg) and the gluteus (average skin thickness of 5.2 mm).

In addition to variations in skin thickness, different regions of the body present issues of accessibility with known treatments. The versatility of the apparatuses of the present invention, which can be configured to treat skin of varying thicknesses at various locations on a subject, is therefore desirable.

Ablation Apparatus

The invention features an apparatus including a main body for handheld operation and a tip (e.g., configured as a detachable cartridge) that can be attached and detached (e.g., by a quick release mechanism) to the main body. The tip includes a skin-penetrating component with one or more ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, and/or blades) configured for penetration into and retraction from skin that may also be configured to be in fluid communication with a pressure generating source (e.g., a vacuum pump, suction source, or fluid injection component (e.g., a high pressure fluid jet)). Such an apparatus provides many benefits including ease of use, ease of clean up and sterilization, disposability of components (e.g., the tip), rapid treatment of the skin, lower skill level required for use, and the potential for outpatient treatment with rapid healing times.

Main body

Figures 1A, 1B, and 2 show schematics of apparatuses **10** of the invention each including main body **12** and tip **14**. Main body **12** is configured for handheld operation, which facilitates ease of use. Main body **12** may feature a contoured design to permit comfortable, ergonomic operation. Such a design may also permit treatment of multiple areas of a subject without forcing the subject to move, in contrast to other, larger medical treatment systems. Main body **12** may be readily cleaned and sterilized (e.g., by steam sterilization).

Main body **12** of apparatus **10** may include additional components, such as a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids), a pressure generating source (e.g., a vacuum pump, suction source, or high pressure fluid jet), tubing and/or cables to couple various components, device control electronics and actuation mechanisms, activation mechanisms, a power supply (e.g., an alternator and/or battery component), and/or a user interface. The components of the apparatus may be provided to an operator (e.g., a doctor or surgeon) in sterile condition prior to use on a patient and many, if not all, of the components can be re-sterilized or replaced with sterile components prior to a subsequent use. For example, tubing components may be readily removable from the device

for sterilization or replacement after use of the apparatus.

Figures 3A and 3B are illustrations of different views of an apparatus of the invention with user interface **16**, while Figure 3C demonstrates user interaction with user interface **16**. User interface **16** of main body **12** may include indicators that the tip is properly coupled to main body **12**, that the device is charged or otherwise powered (e.g., the amount of battery life remaining), that the ablation members (e.g., needles) are in an extended or retracted position, that a pressure generating source is coupled to the device, the fill level of a reservoir for collecting waste materials, and/or other useful information. User interface **16** may include information about the apparatus, such as the number of ablation members of the apparatus, the arrangement of the ablation members, the potential depth of tissue penetration by the ablation members, the mechanism or mode of operation, and/or other useful information. User interface **16** may include buttons, keys, switches, toggles, spin-wheels, LED displays, and/or touch screens that allow the user to observe and change various parameters or configurations during operation of the apparatus, to activate the high or low pressure generating source, and/or to initiate penetration into the skin by the ablation members. User interface **16** may be configured and disposed to allow a user to access buttons, keys, switches, toggles, spin-wheels, LED displays, and/or touch screens with the hand holding the apparatus or with the free hand (Figure 3C). For example, a button for activating the high or low pressure generating source may be disposed on the one side of the main body such that it is can be depressed by one or more fingers of the user during operation. User interface **16** may also be configured to transmit and/or receive information from another unit, such as a computer or base unit (see Figures 8 and 9).

Main body **12** may feature additional buttons, keys, switches, toggles, spin-wheels, and/or touch screens to initiate penetration into the skin by the needles and/or translation of the device across the skin. These features may be components of user interface **16**.

Main body **12** is configured to couple with a tip including a skin-penetrating component with ablation members (e.g., needles). Main body **12** may have a locking mechanism to secure the tip in place during operation. The locking mechanism may allow mechanical and/or electrical connection of additional components (e.g., one or more actuators that can be used to operate the components of the tip). In some embodiments, locking main body **12** and tip **14** may be used to establish fluidic connection between, e.g., the ablation members, a reservoir, and/or a pressure generating source. The main body-tip locking mechanism may be engaged and disengaged repeatably. The main body-tip locking mechanism may include one or more of adhesive, magnetic, electrical, and/or mechanical components (e.g., one or more gaskets, o-rings, septa, springs, clasps, and other engagement members). In some embodiments, the main body may include a groove or depression for placement of an o-ring (e.g., a viton o-ring, a nitrile rubber o-ring, and a thermoplastic polyurethane o-ring) that will allow for a seal to form between main body **12** and tip **14**. The portion of tip **14** engineered to engage with main body **12** may include a corresponding groove or depression. In other embodiments, a locking mechanism may involve mated pieces made of molded plastic. Figures 5A and 5B show two views of main body **12** and mated tip **14**. As an example, the body of tip **14** may be formed to fit as a sheath over a rim of main body **12**, or vice versa, such that one component may form a seal by sliding partway into the other component. In the instance that tip **14** fits over the edge of main body **12**, the inner surface of the housing of tip **14** may

include a ridge formed as a stop to facilitate the seal. Main body **12** and tip **14** may also include interlocking ridges (e.g., made of plastic, rubber, or other material) to enhance or form a seal between the components. Main body **12** may also feature a mechanism to activate detachment of the tip from the main body. This mechanism may include one or more of a button, key, switch, toggle, spin-wheel, touch screen, and/or sliding lock. The detachment mechanism may be a quick-release mechanism. Figure 4 shows an apparatus of the invention with quick-release mechanism **18** to separate tip **14** from main body **12**. In some embodiments, one component (e.g., main body **12**) includes a depressible portion that engages a seal when the other component (e.g., tip **14**) is slid around the rim of the other. Depression of the portion may be disengaged by activation of a sliding lock, eliminating the seal between the components to allow their separation and, e.g., removal and replacement of tip **14**.

Main body **12** may also include a power supply. For example, main body **12** may have a housing for batteries that power operation of the device or may be configured to receive an element including batteries (see Figure 14). The housing may be configured to charge the batteries (e.g., when depleted) with a paired charging station, without requiring removal of the batteries, or the batteries may be removed from the device for replacement or charging. In another embodiment, main body **12** may include electronics and components (e.g., a power cord) that allow it to be powered from an external power supply, such as a direct or alternating current supply or a generator.

Tip

Tip **14** (e.g., configured as a detachable cartridge; see e.g., Figures 1-5) of apparatus **10** of the invention includes a skin-penetrating component (e.g., one or more needles, such as one or more hollow coring needles) and may be detachably attached to main body **12**. The detachability of tip **14** provides an advantage in that the component that interacts with the skin can be easily removed from apparatus **10**, thereby minimizing the cleaning and sterilization of apparatus **10**. In some embodiments, tip **14** is designed for a single use. For example, tip **14** may be disposable. Alternatively, tip **14** may be cleaned and sterilized for reuse.

The detachability of tip **14** also facilitates the design and use of tips having varying numbers and configurations of ablation members (e.g., coring needles) and provides for quick interchangeability of apparatus architectures and applications. Different tip geometries may be useful for treatment of different regions of the skin. For example, a small tip may be useful for treatment of a limited surface area (e.g., the peri-oral area) while a large tip may be useful for treatment of a large surface area (e.g., the abdomen). A small tip may have a small number of ablation members (e.g., as few as 1) that may be arranged in a 1-dimensional array (e.g., a linear array), while a large tip may have many ablation members (e.g., up to or more than 100) that may be arranged in a 2-dimensional array (e.g., a rectangular array). Figure 6 shows several different tips **14** with skin-penetrating components **20** of different geometries.

Tip **14** may further include elements for coupling the ablation members therewith. Such an element may have magnetic, adhesive, electrical, and/or mechanical components. For example, the coupling element may include one or more plastic connectors configured to couple to one or more ablation members. The ablation members may be joined to a coupling element by a molded plastic

connection. Tip **14** may further feature an element coupling the ablation members fluidly to other components of the system such as a reservoir for collecting waste materials and/or a pressure generating source. This element may be a tube or series of tubes. In one embodiment, a seal formed by mechanically mating main body **12** and tip **14** may also be the seal establishing fluid connectivity with other components. In other embodiments, one or more tubes coupled to skin-penetrating component **20** of tip **14** must be mated (e.g., via one or more o-ring, gasket, KF, LF, QF, quick coupling, Swagelok, and other sealing mechanisms) to establish fluid connection between components of tip **14** and other components of the system.

Tip **14** may further couple with a detachable cover piece to cover the ablation members when the device is not in use in order to keep the components clean and/or sterile.

In some embodiments, tip **14** may include a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids) that is in fluid communication with the ablation members. The reservoir may further be in fluid communication with a pressure generating source (e.g., a vacuum pump). Tip **14** may have a filter, membrane, or other physical element that maintains separation between materials that enter the tip, such as collected waste materials, and other components of the system.

Reservoir

The apparatus may include or be otherwise coupled to a reservoir for collecting tissue, fluids (e.g., blood and/or interstitial fluids), and other waste. The collection of tissue and fluid allows skin tightening, minimizes the risk of infection, and maintains a clear treatment field for the operator of the apparatus.

The reservoir may be in fluid communication with the ablation members of the tip. The reservoir may be disposed within the tip or the main body of the apparatus, or it may be external to these components. Alternatively, a separate module of the apparatus may contain the reservoir. This module may be disposed between the tip and the main body, such that the module containing the reservoir is coupled to both components. The coupling elements may include mechanical and other components as described above. The module and/or its components may be designed for a single use; for example, the reservoir may be disposable. Alternatively, the reservoir may be easily removed from the system for cleaning (e.g., sterilization) and reuse.

The reservoir may be detachably attached to the tip and/or main body of the apparatus. The reservoir may be readily removable from the system (e.g., for ease of sterilization or disposability). The reservoir may be made of materials that are chemically and/or thermally resistant, and may feature chemically and/or thermally resistant coatings.

Sterilizing chemicals may be stored within the reservoir during, prior to, or after use of the apparatus. Sterilizing chemicals may include ethylene oxide, chlorine bleach, formaldehyde, hydrogen peroxide, peracetic acid, or other chemicals.

The reservoir may further be in fluid communication with a pressure generating source. For example, the reservoir may be in fluid communication with a vacuum pump. Transfer of ablated tissue and other materials may be achieved by applying a differential pressure across the circuit including the needles and reservoir. A filter, membrane, or other physical element may prevent suction of materials out

of the reservoir toward the vacuum pump. Such a filter, membrane, or physical element may be disposed within the reservoir. A filter, membrane, or physical element may also be detachable from the reservoir, pressure generating source, and/or their coupling elements for sterilization and/or disposal.

Pressure Generating Source

The apparatus may further include or be otherwise coupled to a pressure generating source. In some embodiments, a separate tissue removal apparatus may include the pressure generating source. The tissue removal apparatus could additionally include a reservoir for collecting waste materials and a component to prevent material from the reservoir from contaminating the pressure generating source. In other embodiments, the pressure generating source may be configured to be in fluid communication with the ablation members of the tip and/or with a reservoir for collecting waste materials. Materials may be separated from the pressure generating source with one or more filters, membranes, and/or other physical elements known in the art.

The pressure generating source may be a low pressure generating source. For example, the pressure generating source may be capable of providing vacuum and/or suction. Vacuum sources may include one or more rotary pumps, momentum transfer pumps, diffusion pumps, scroll pumps, and/or diaphragm pumps. In some embodiments, a low pressure generating source may include a house or central vacuum system. In other embodiments, a suction source may include a wall or portable suction device. In some embodiments, a vacuum source provides an absolute pressure less than about 6.3 kPa (e.g., from about 0.1 kPa to about 6 kPa, such as from 0.1 kPa to 6 kPa, 0.1 kPa to 5 kPa, 0.1 kPa to 4 kPa, 0.1 kPa to 3 kPa, 0.1 kPa to 2 kPa, 0.1 kPa to 1 kPa, 0.5 kPa to 6 kPa, 0.5 kPa to 5 kPa, 0.5 kPa to 4 kPa, 0.5 kPa to 3 kPa, 0.5 kPa to 2 kPa, 0.5 kPa to 1 kPa, 1 kPa to 6 kPa, 1 kPa to 5 kPa, 1 kPa to 4 kPa, 1 kPa to 3 kPa, 1 kPa to 2 kPa, 1.5 kPa to 6 kPa, 1.5 kPa to 5 kPa, 1.5 kPa to 4 kPa, 1.5 kPa to 3 kPa, and 1.5 kPa to 2 kPa).

A low pressure generating source may be configured to remove tissue portions and other waste materials formed by penetration into tissue by ablation members. For example, suction and/or vacuum may be applied to remove waste materials from the ablation members (e.g., from the cores of coring needles) to prevent clogging during operation, to facilitate the separation of ablated tissue portions from surrounding tissue in a treatment area, and/or to remove waste materials from the treatment area. Suction and/or vacuum may be applied via the ablation members (e.g., needles) of the apparatus. The ablation members and low pressure generating source may be configured to remove tissue portions and other waste materials by providing suction and/or vacuum after penetration into the skin by but before removal of the needles. For example, a pressure generating source, such as a vacuum pump, may be coupled to needles that include holes as well as a reservoir for waste collection. Following penetration into the tissue by the ablation members, vacuum may be applied to draw waste materials from a treated skin area through holes in the ablation members and though tubing coupling the ablation members to the reservoir. A filter may prevent waste materials from leaving the reservoir and possibly aspirating within the pressure generating source (e.g., vacuum pump). In other embodiments, the pressure generating source (e.g., vacuum pump) may be activated after the ablation members (e.g., hollow coring needles) have been removed from the skin to clear any waste materials from the hollows of the ablation members

and prevent clogging to allow for effective continued treatment. Alternatively, the pressure generating source (e.g., vacuum pump) may be integrated with a separate tissue removal apparatus. Such an apparatus may be configured with an array of small access ports along the bottom of a chamber which may be applied to a skin region. The access ports that contact a treated skin area may be configured to form a seal with the tissue such that, upon separation of the tissue removal apparatus from the skin region, ablated tissue portions and other waste materials may also be removed.

In an alternative configuration, the pressure generating source (e.g., vacuum pump) may be configured to directly ablate and/or facilitate ablation of the skin. For example, the ablation members (e.g., hollow needles) may be configured to apply a high level of vacuum (e.g., a vacuum with an absolute pressure less than about 6.3 kPa) to the skin, thereby directing tissue removal via either a suctioning mechanism or through conveyance of damage to the tissue that is targeted for removal or destruction. The size of an ablated tissue portion may be controlled by the level of vacuum, the duration of exposure, and the dimensional size (e.g., area or volume) over which the vacuum is applied. In one embodiment, vacuum may be used to ablate tissue by causing local boiling off or vaporization of tissue at ambient temperatures. In another embodiment, vacuum may ablate tissue by causing desiccation or freeze-drying of tissue.

The pressure generating source may alternatively facilitate exposure of a treatment area to fluid or gas and/or injection of fluid or gas into a treatment area. For example, the pressure generating source may be a fluid injection component (e.g., a high pressure fluid jet or an array of high pressure fluid jets). In some embodiments, a fluid jet or an array of fluid jets may be configured to ablate tissue non-thermally. For example, a jet with fluid pressure greater than about 200 psi may be positioned external to the skin surface, such that interaction between the fluid jet and the skin produces a hole in the skin. The size of the hole may be determined by the fluid jet size and length of exposure. For example, to provide an ablated skin portion with a shallower depth, the fluid jet may be applied for a shorter time. Alternatively, to provide an ablated skin portion with a greater depth or diameter, the fluid jet may be applied to the skin region for a longer time. A high pressure fluid jet for tissue ablation is a non-thermal ablative mechanism and does not generate a thermal injury to the surrounding tissue. In other embodiments, fluid jets may be used to clear clogs in ablation members. Alternatively, fluid jets may be configured to facilitate the removal of waste materials from a treatment area (e.g., by rinsing and/or otherwise dislodging waste materials). In other embodiments, one or more fluid jets may be used to expose the treatment area to one or more chemicals (e.g., medicaments, botulinum toxin, and fillers, such as hyaluronic acid- and collagen-based fillers). For example, fluid jets may be used to flush a treatment area with a collagen-based filler following ablation of the skin by the ablation members (e.g., needles) of the apparatus.

Non-limiting possible pressures for a fluid injection component (e.g., a fluid jet) include from about 200 psi to about 100000 psi (e.g., from 200 psi to 1000 psi, 200 psi to 5000 psi, 200 psi to 10000 psi, 200 psi to 50000 psi, 200 psi to 100000 psi, 500 psi to 1000 psi, 500 psi to 5000 psi, 500 psi to 10000 psi, 500 psi to 50000 psi, 500 psi to 100000 psi, 750 psi to 1000 psi, 750 psi to 5000 psi, 750 psi to 10000 psi, 750 psi to 50000 psi, 750 psi to 100000 psi, 1000 psi to 5000 psi, 1000 psi to 10000 psi, 1000 psi to 50000 psi, 1000 psi to 100000 psi, 1500 psi to 5000 psi, 1500 psi to 10000 psi, 1500 psi to 50000 psi, 1500 psi to 100000 psi, 2000 psi to 5000 psi, 2000 psi to 10000 psi, 2000 psi to 50000 psi, 2000 psi to 100000 psi,

2500 psi to 5000 psi, 2500 psi to 10000 psi, 2500 psi to 50000 psi, 2500 psi to 100000 psi, 4000 psi to 5000 psi, 4000 psi to 10000 psi, 4000 psi to 50000 psi, 4000 psi to 100000 psi, 5000 psi to 10000 psi, 5000 psi to 50000 psi, 5000 psi to 100000 psi, 7500 psi to 10000 psi, 7500 psi to 50000 psi, 7500 psi to 100000 psi, 10000 psi to 50000 psi, 10000 psi to 100000 psi, 50000 psi to 100000 psi, and 75000 psi to 100000 psi) and from about 15 psi to about 200 psi (e.g., 15 psi to 20 psi, 15 psi to 50 psi, 15 psi to 75 psi, 15 psi to 100 psi, 15 psi to 125 psi, 15 psi to 150 psi, 15 psi to 175 psi, 15 psi to 200 psi, 20 psi to 50 psi, 20 psi to 75 psi, 20 psi to 100 psi, 20 psi to 125 psi, 20 psi to 150 psi, 20 psi to 175 psi, 20 psi to 200 psi, 50 psi to 75 psi, 50 psi to 100 psi, 50 psi to 125 psi, 50 psi to 150 psi, 50 psi to 175 psi, 50 psi to 200 psi, 75 psi to 100 psi, 75 psi to 125 psi, 75 psi to 150 psi, 75 psi to 175 psi, 75 psi to 200 psi, 100 psi to 125 psi, 100 psi to 150 psi, 100 psi to 175 psi, 100 psi to 200 psi, 125 psi to 150 psi, 125 psi to 175 psi, 125 psi to 200 psi, 150 psi to 175 psi, 150 psi to 200 psi, and 175 psi to 200 psi).

In one embodiment, an apparatus containing one or more fluid jets may be configured for insertion into the fatty layer or under the dermis or epidermis. The array of fluid jets may be configured to emit fluid at very high pressure to ablate the tissue above. A low pressure out-flow tube may be positioned on the surface of the skin for removal of fluid and debris. In another embodiment, a fluid jet or an array of fluid jets may be configured for discontinuous fluid flow to allow removal of fluid and debris before reactivating the jet. In another embodiment, a fluid jet or an array of fluid jets may be configured to move (e.g., in a circular fashion) in relation to the skin, e.g., to produce an array of cylindrical ablations.

Fluid jets of the invention may be continuous or discontinuous fluid streams, and may feature turbulent and/or laminar flow. One or more nozzles may be configured to form a fluid jet. For example, a convergent nozzle may be used which reduces the diameter of the outlet, thus increasing the velocity of the fluid jet. In some embodiments, the ablation members of the tip (e.g., hollow needles) may be conduits for fluid streams.

Fluid jets may include one or more fluids. Non-limiting examples of fluids for use in a fluid jet or fluid jet array include aqueous and non aqueous solutions, such as isotonic and non isotonic buffers, and saline solutions. Fluid jets may include additional ingredients that have a desirable medical or aesthetic activity or utility (e.g., therapeutic agents, such as heparin, fibrin, antibiotics, lidocaine, and other analgesics, and/or botulinum toxin, and fillers, such as hyaluronic acid- and collagen-based fillers).

Alternatively, a fluid jet may be a gas jet such as an air jet. In some embodiments, a fluid jet or an array of fluid jets may be configured to remove tissue, fluids, and/or other debris generated during ablation of the skin. For example, a pressurized air stream may be applied to the skin following ablation via the ablation members (e.g., needles).

A pressure generating source may include a venturi-effect element at an end of an ablation member (e.g., a hollow needle). The venturi-effect element may convert a high pressure air stream into a vacuum. This conversion would push ablated tissue and other waste materials into a collection reservoir after exiting the end of the ablation member.

Actuation, Translation, and Position Detection Mechanisms

The apparatus may further include actuation mechanisms to drive ablation members (e.g., needles, such as hollow coring needles) into or across skin. A “z” actuator may drive penetration into the

skin by the ablation members and/or retraction of the ablation members after insertion. The apparatus may include a feature or setting that has the ability to control or change the depth of penetration of the ablation members into the skin. For example, a scroll wheel on a user interface of a main body may adjust the allowed depth of penetration by the ablation members by physically retracting the ablation members and/or providing an electrical signal to a z-actuator. Alternatively, digital controls on the user interface of the base unit may control the depth and/or timing of penetration into and retraction out of the skin by the ablation members (e.g., needles). For example, an operator may program a computer component of the base unit to require a certain displacement of the ablation members (e.g., needles) into the skin based upon the area being treated. The z-actuator may be programmed or otherwise set to displace the ablation members (e.g., needles) up to about 15 mm into thick skin (e.g., on a patient's back) or about 2 mm into thin skin (e.g., on a patient's cheeks), for instance. The z-actuator may also be capable of operating at a high speed to minimize treatment time and deflection of the skin during the penetration of the ablation members and penetration force. The z-actuator may further be capable of operating with relatively high force. Preferably, a force of about 0.5 N to about 20 N (e.g., 0.5 N to 0. 75 N, 0.5 N to 1 N, 0.5 N to 1.25 N, 0.5 N to 1.5 N, 0.5 N to 2 N, 0.5 N to 5 N, 0.5 N to 10 N, 0.5 N to 12 N, 0.5 N to 15 N, 0.5 N to 20 N, 0. 75 N to 1 N, 0.75 N to 1.25 N, 0.75 N to 1.5 N, 0.75 N to 2 N, 0.75 N to 5 N, 0.75 N to 10 N, 0.75 N to 12 N, 0.75 N to 15 N, 0.75 N to 20 N, 1 N to 1.25 N, 1 N to 1.5 N, 1 N to 2 N, 1 N to 5 N, 1 N to 10 N, 1 N to 12 N, 1 N to 15 N, 1 N to 20 N, 1.25 N to 1.5 N, 1.25 N to 2 N, 1.25 N to 5 N, 1.25 N to 10 N, 1.25 N to 12 N, 1.25 N to 15 N, 1.25 N to 20 N, 1.5 N to 2 N, 1.5 N to 5 N, 1.5 N to 10 N, 1.5 N to 12 N, 1.5 N to 15 N, 1.5 N to 20 N, 2 N to 5 N, 2 N to 10 N, 2 N to 12 N, 2 N to 15 N, 2 N to 20 N, 5 N to 10 N, 5 N to 12 N, 5 N to 15 N, 5 N to 20 N, 10 N to 12 N, 10 N to 15 N, 10 N to 20 N, 12 N to 15 N, 12 N to 20 N, and 15 N to 20 N) per ablation member (e.g., needle) can be applied to ensure insertion of the ablation member into the skin. Actuator types having these characteristics include pneumatic actuators, electromagnetic actuators, motors with cams, motors with lead screws (e.g., stepper motors), and piezoelectric actuators. The insertion force may be inversely correlated with needle gauge. For example, a 24 gauge needle may be operated with an insertion force of 12 N, while a 20 gauge needle may be operated with a higher insertion force.

The apparatus may include an "x" and/or "y" actuator for driving the ablation members (e.g., needles) across the skin. The x/y-actuator may be used to establish the treatment coverage by defining the distance between two applications of an array of ablation members. The x/y-actuator may be characterized by a relatively large displacement range (e.g., up to about 30 mm). The x/y-actuator may also operate at a relatively high speed to minimize treatment time. Actuator types having these characteristics include pneumatic actuators, electromagnetic actuators, motors with cams, piezoelectric actuators, and motors with lead screws (e.g., stepper motors).

Actuation components may be disposed in the main body of the apparatus or external to the main body. The z-, x-, and y- actuators may be activated independently or together by one or more buttons, keys, toggles, switches, screws, dials, cursors, spin-wheels, or other components. In an embodiment, each of the z-, x-, and y- actuators can be separately controlled (e.g., using separate activation components, such as a button, or by using separate controls in a user interface). Figure 7 is an illustration of an apparatus of the invention with the ablation members (e.g., needles) of the skin-

penetrating component **20** in both retracted and extended positions. Z-actuation may be activated by a trigger button element disposed on the main body of the apparatus that is accessible to the index finger of the operator. Alternatively, digital controls on user interface **32** of base unit **30** or user interface **16** of main body **12** may control the depth and/or timing of penetration into and retraction out of the skin by the ablation members (e.g., needles) and/or translation of the apparatus across the skin surface.

The apparatus may further include a translation mechanism to drive ablation members across the skin (e.g., x- and y- translation). A translation mechanism may include, e.g., driving wheels or rods. A translation mechanism may permit automatic or manual translation of the apparatus across the skin. Translating components (e.g., wheels) may be disposed in or on the main body, be detachably attachable to the tip, or be disposed external to the main body. The translating mechanism may be activated by an activator, such as a button, key, toggle, switch, screw, cursor, dial, spin-wheel, or other component, and/or may be digitally controlled at user interface **32** of base unit **30** or user interface **16** of main body **12**.

The apparatus may also include a position detection mechanism, such as an optical tracking mechanism. A position detection mechanism (e.g., a camera, infrared sensor, photodiode, and LED and detector) may assist in tracking movement of the apparatus in relation to a patient or a treatment area. The optical tracking mechanism may also facilitate placement of the skin-penetrating component on the skin surface in the instance of manual translation of the device across the skin. Control electronics for a position detection mechanism may be disposed in the main body of the apparatus or external to the main body (e.g., in a base unit or separate computer). For example, the position detection mechanism may monitor the distance between the previous needle insertion and the current device position and send a signal to the control electronics to actuate the skin penetration mechanism when the device has reached the desired position (e.g., a position a defined distance from the position where the needles were last inserted). Desired distances and/or positions may be controlled at user interface **32** or user interface **16**.

Materials

The apparatuses, systems, kits, and methods of the invention can include any useful materials.

For example, the main body, tip, and other components may include and/or be formed from any useful polymer or plastic. Such materials may include alginate, benzyl hyaluronate, carboxymethylcellulose, cellulose acetate, chitosan, collagen, dextran, epoxy, gelatin, hyaluronic acid, hydrocolloids, nylon (e.g., nylon 6 or PA6), pectin, poly (3-hydroxyl butyrate-co- poly (3-hydroxyl valerate), polyalkanes, polyalkene, polyalkynes, polyacrylate (PA), polyacrylonitrile (PAN), polybenzimidazole (PBI), polycarbonate (PC), polycaprolactone (PCL), polyester (PE), polyethylene glycol (PEG), polyethylene oxide (PEO), PEO/polycarbonate/polyurethane (PEO/PC/PU), poly(ethylene-co-vinyl acetate) (PEVA), PEVA/polylactic acid (PEVA/PLA), polyethylene, polypropylene, poly (ethylene terephthalate) (PET), PET/poly (ethylene naphthalate) (PET/PEN) polyglactin, polyglycolic acid (PGA), polyglycolic acid/polylactic acid (PGA/PLA), polyimide (PI), polylactic acid (PLA), poly-L-lactide (PLLA), PLLA/PC/polyvinylcarbazole (PLLA/PC/PVCB), poly (β-malic acid)-copolymers (PMLA), polymethacrylate (PMA), poly (methyl methacrylate) (PMMA), polystyrene (PS), polyurethane (PU), poly (vinyl alcohol) (PVA), polyvinylcarbazole (PVCB), polyvinyl chloride (PVC), polyvinylidenedifluoride (PVDF),

polyvinylpyrrolidone (PVP), silicone, rayon, polytetrafluoroethylene (PTFE), polyether ether ketone (PEEK), or combinations thereof. Polymers and/or plastics of the invention may be composite materials in which additives to the polymers and/or plastics, such as ceramics or particles, alter the mechanical properties.

Elements of the invention (e.g., all or a portion of the apparatus, such as all or a portion of the main body, tip, or other components) may also include and/or be formed from any useful metal or metal alloy. For example, in some embodiments, the ablation members may be metallic needles. Metals and alloys featured in the invention include stainless steel; titanium; a nickel-titanium (NiTi) alloy; a nickel-titanium-niobium (NiTiNb) alloy; a nickel-iron-gallium (NiFeGa) alloy; a nickel-manganese-gallium (NiMnGa) alloy; a copper-aluminum-nickel (CuAlNi) allow; a copper-zinc (CuZn) alloy; a copper-tin (CuSn) alloy; a copper-zinc-aluminum (CuZnAl) alloy; a copper-zinc-silicon (CuZnSi) alloy; a copper-zinc-tin (CuZnSn) alloy; a copper-manganese alloy; a gold-cadmium (AuCd) alloy; a silver-cadmium (AgCd) alloy; an iron-platinum (FePt) alloy; an iron-manganese-silicon (FeMnSi) alloy; a cobalt-nickel-aluminum (CoNiAl) alloy; a cobalt-nickel-gallium (CoNiGa) alloy; or a titanium-palladium (TiPd) alloy. Elements of the invention may also include and/or be formed from glass. For example, an apparatus of the invention may include glass needles.

Apparatuses, systems, kits, and methods of the invention may use one or more adhesives. An adhesive may be located on a surface, between elements, or otherwise adhered to an element of the invention. Useful adhesives include a biocompatible matrix (e.g., those including at least one of collagen (e.g., a collagen sponge), low melting agarose (LMA), polylactic acid (PLA), and/or hyaluronic acid (e.g., hyaluranon); a photosensitizer (e.g., Rose Bengal, riboflavin-5-phosphate (R-5-P), methylene blue (MB), N-hydroxypyridine-2-(1H)-thione (N-HTP), a porphyrin, or a chlorin, as well as precursors thereof); a photochemical agent (e.g., 1,8 naphthalimide); a synthetic glue (e.g., a cyanoacrylate adhesive, a polyethylene glycol adhesive, or a gelatin-resorcinol-formaldehyde adhesive); a biologic sealant (e.g., a mixture of riboflavin-5-phosphate and fibrinogen, a fibrin-based sealant, an albumin-based sealant, or a starch-based sealant); or a hook or loop and eye system (e.g., as used for Velcro®). In particular embodiments, adhesives are biodegradable.

Adhesives may be pressure-sensitive adhesives (PSAs). The properties of pressure sensitive adhesives are governed by three parameters: tack (initial adhesion), peel strength (adhesion), and shear strength (cohesion). Pressure-sensitive adhesives can be synthesized in several ways, including solvent-borne, water-borne, and hot-melt methods. Tack is the initial adhesion under slight pressure and short dwell time and depends on the adhesive's ability to wet the contact surface. Peel strength is the force required to remove the PSA from the contact surface. The peel adhesion depends on many factors, including the tack, bonding history (e.g. force, dwell time), and adhesive composition. Shear strength is a measure of the adhesive's resistance to continuous stress. The shear strength is influenced by several parameters, including internal adhesion, cross-linking, and viscoelastic properties of the adhesive. Permanent adhesives are generally resistant to debonding and possess very high peel and shear strength. Pressure-sensitive adhesives may include natural rubber, synthetic rubber (e.g., styrene-butadiene and styrene-ethylene copolymers), polyvinyl ether, polyurethane, acrylic, silicones, and ethylene-vinyl acetate copolymers. A copolymer's adhesive properties can be altered by varying the

composition (via monomer components) changing the glass transition temperature (Tg) or degree of cross-linking. In general, a copolymer with a lower Tg is less rigid and a copolymer with a higher Tg is more rigid. The tack of PSAs can be altered by the addition of components to alter the viscosity or mechanical properties. Pressure sensitive adhesives are further described in Czech et al., "Pressure-Sensitive Adhesives for Medical Applications," in Wide Spectra of Quality Control, Dr. Isin Akyar (Ed., published by InTech), Chapter 17 (2011), which is hereby incorporated by reference in its entirety.

The apparatuses, systems, kits, and methods of the invention may include one or more useful therapeutic agents. For example, the ablation members (e.g., needles) of the apparatus of the invention may be configured to administer one or more therapeutic agents to the skin. Examples of such agents include one or more growth factors (e.g., vascular endothelial growth factor (VEGF), platelet-derived growth factor (PDGF), transforming growth factor beta (TGF-β), fibroblast growth factor (FGF), epidermal growth factor (EGF), and keratinocyte growth factor); one or more stem cells (e.g., adipose tissue-derived stem cells and/or bone marrow-derived mesenchymal stem cells); one or more skin whitening agents (e.g., hydroquinone); one or more vitamin A derivatives (e.g., tretinoin), one or more analgesics (e.g., paracetamol/acetaminophen, aspirin, a non-steroidal antiinflammatory drug, as described herein, a cyclooxygenase-2-specific inhibitor, as described herein, dextropropoxyphene, co-codamol, an opioid (e.g., morphine, codeine, oxycodone, hydrocodone, dihydromorphine, pethidine, buprenorphine, tramadol, or methadone), fentanyl, procaine, lidocaine, tetracaine, dibucaine, benzocaine, p-butylaminobenzoic acid 2-(diethylamino) ethyl ester HCl, mepivacaine, piperocaine, dyclonine, or venlafaxine); one or more antibiotics (e.g., cephalosporin, bactitracin, polymyxin B sulfate, neomycin, bismuth tribromophenate, or polysporin); one or more antifungals (e.g., nystatin); one or more antiinflammatory agents (e.g., a non-steroidal antiinflammatory drug (NSAID, e.g., ibuprofen, ketoprofen, flurbiprofen, piroxicam, indomethacin, diclofenac, sulindac, naproxen, aspirin, ketorolac, or tacrolimus), a cyclooxygenase-2-specific inhibitor (COX-2 inhibitor, e.g., rofecoxib (Vioxx®), etoricoxib, and celecoxib (Celebrex®)), a glucocorticoid agent, a specific cytokine directed at T lymphocyte function), a steroid (e.g., a corticosteroid, such as a glucocorticoid (e.g., aldosterone, beclometasone, betamethasone, cortisone, deoxycorticosterone acetate, dexamethasone, fludrocortisone acetate, hydrocortisone, methylprednisolone, prednisone, prednisolone, or triamcinolone) or a mineralocorticoid agent (e.g., aldosterone, corticosterone, or deoxycorticosterone)), or an immune selective antiinflammatory derivative (e.g., phenylalanine-glutamine-glycine (FEG) and its D-isomeric form (feG))); one or more antimicrobials (e.g., chlorhexidine gluconate, iodine (e.g., tincture of iodine, povidone-iodine, or Lugol's iodine), or silver, such as silver nitrate (e.g., as a 0.5% solution), silver sulfadiazine (e.g., as a cream), or Ag^+ in one or more useful carriers (e.g., an alginate, such as Acticoat® including nanocrystalline silver coating in high density polyethylene, available from Smith & Nephew, London, U.K., or Silvercel® including a mixture of alginate, carboxymethylcellulose, and silver coated nylon fibers, available from Systagenix, Gatwick, U.K.; a foam (e.g., Contreet® Foam including a soft hydrophilic polyurethane foam and silver, available from Coloplast A/S, Humlebæk, Denmark); a hydrocolloid (e.g., Aquacel® Ag including ionic silver and a hydrocolloid, available from Conva Tec Inc., Skillman, NJ); or a hydrogel (e.g., Silvasorb® including ionic silver, available from Medline Industries Inc., Mansfield, MA)); one or more antiseptics (e.g., an alcohol, such as ethanol (e.g., 60-90%), 1-propanol (e.g., 60–70%), as well as mixtures of 2-propanol/isopropanol;

boric acid; calcium hypochlorite; hydrogen peroxide; manuka honey and/or methylglyoxal; a phenol (carbolic acid) compound, e.g., sodium 3,5-dibromo-4-hydroxybenzene sulfonate, trichlorophenylmethyl iodosalicyl, or triclosan; a polyhexanide compound, e.g., polyhexamethylene biguanide (PHMB); a quaternary ammonium compound, such as benzalkonium chloride (BAC), benzethonium chloride (BZT), cetyl trimethylammonium bromide (CTMB), cetylpyridinium chloride (CPC), chlorhexidine (e.g., chlorhexidine gluconate), or octenidine (e.g., octenidine dihydrochloride); sodium bicarbonate; sodium chloride; sodium hypochlorite (e.g., optionally in combination with boric acid in Dakin's solution); or a triarylmethane dye (e.g., Brilliant Green)); one or more antiproliferative agents (e.g., sirolimus, tacrolimus, zotarolimus, biolimus, or paclitaxel); one or more emollients; one or more hemostatic agents (e.g., collagen, such as microfibrillar collagen, chitosan, calcium-loaded zeolite, cellulose, anhydrous aluminum sulfate, silver nitrate, potassium alum, titanium oxide, fibrinogen, epinephrine, calcium alginate, poly-N-acetyl glucosamine, thrombin, coagulation factor(s) (e.g., II, V, VII, VIII, IX, X, XI, XIII, or Von Willebrand factor, as well as activated forms thereof), a procoagulant (e.g., propyl gallate), an anti-fibrinolytic agent (e.g., epsilon aminocaproic acid or tranexamic acid), and the like); one or more procoagulative agents (e.g., any hemostatic agent described herein, desmopressin, coagulation factor(s) (e.g., II, V, VII, VIII, IX, X, XI, XIII, or Von Willebrand factor, as well as activated forms thereof), procoagulants (e.g., propyl gallate), antifibrinolytics (e.g., epsilon aminocaproic acid), and the like); one or more anticoagulative agents (e.g., heparin or derivatives thereof, such as low molecular weight heparin, fondaparinux, or idraparinux; an anti-platelet agent, such as aspirin, dipyridamole, ticlopidine, clopidogrel, or prasugrel; a factor Xa inhibitor, such as a direct factor Xa inhibitor, e.g., apixaban or rivaroxaban; a thrombin inhibitor, such as a direct thrombin inhibitor, e.g., argatroban, bivalirudin, dabigatran, hirudin, lepirudin, or ximelagatran; or a coumarin derivative or vitamin K antagonist, such as warfarin (coumadin), acenocoumarol, atromentin, phenindione, or phenprocoumon); one or more immune modulators, including corticosteroids and non-steroidal immune modulators (e.g., NSAIDS, such as any described herein); one or more proteins; and/or one or more vitamins (e.g., vitamin A, C, and/or E). One or more of botulinum toxin, fat (e.g. autologous), hyaluronic acid, a collagen-based filler, or other filler may also be administered to the skin.

A therapeutic agent may include anticoagulative and/or procoagulative agents. For instance, by controlling the extent of bleeding and/or clotting in treated skin regions, a skin tightening effect may be more effectively controlled. Thus, in some embodiments, the methods and devices herein include or can be used to administer one or more anticoagulative agents, one or more procoagulative agents, one or more hemostatic agents, one or more fillers, or combinations thereof. In particular embodiments, the therapeutic agent controls the extent of bleeding and/or clotting in the treated skin region, including the use one or more anticoagulative agents (e.g., to inhibit clot formation prior to skin healing or slit/hole closure) and/or one or more hemostatic or procoagulative agents.

Ablation System

Any of the apparatuses of the invention described herein may be components of a system for non-thermal tissue ablation. In addition to the main body and tip of the apparatus, a system for non-thermal tissue ablation may include additional elements, such as a reservoir for collecting waste materials

(e.g., tissue, blood, and/or interstitial fluids), a pressure generating source (e.g., a vacuum pump), mechanisms for actuation (e.g., pneumatic and/or electromagnetic actuators), translation (e.g., driving wheels), and position detection (e.g., a camera), a base unit, and a skin positioning apparatus. Any or all of the components may be readily sterilized prior to and/or after treatment of a patient or, if desired, replaced with sterile components.

Base Unit

A system for non-thermal tissue ablation may have a base unit that may include, e.g., a user interface, a power supply, control electronics, mechanisms to drive operation of the apparatus, and other components. The base unit may feature a computer, which may be programmed to operate and/or control any or all aspects of an apparatus of the invention.

A user interface of a base unit may include buttons, keys, switches, toggles, spin-wheels, screens, touch screens, keyboards, cursors, dials, indicators, displays, and/or other components. The user interface may be configured to indicate proper coupling of the tip and/or reservoir module to the main body, charged and/or powered status of the apparatus, the mode and/or position of ablation members (e.g., needles), coupling of a pressure generating source (e.g., a vacuum pump) to the apparatus, the application of low or high pressure, the fill level of a waste-collecting reservoir, actuation of system components, and/or other useful indicia. The user interface may be configured to provide information about the number and kind of ablation members of the apparatus, the treatment area, the treatment coverage (e.g., percentage of skin surface area ablated) the arrangement of the ablation members, the potential depth of penetration by the ablation members (if relevant), the mechanism or mode of operation, use count of the tip and/or reservoir, and other useful information. The user interface may allow adjustment of parameters and/or operation mode, application of high or low pressure, and/or activation of penetration into the skin by the ablation members. The user interface may also be configured to transmit and/or receive information from another unit. For example, user actions at a user interface on the main body of the apparatus may be reflected by a user interface of the base unit, or vice versa.

The base unit may include buttons, keys, switches, toggles, spin-wheels, and/or other activation mechanisms to allow adjustment of parameters and/or operation mode, application of high or low pressure, penetration into the skin by the ablation members, and/or powering on or off of the base unit, pressure generating source, apparatus, and/or other system components. These components may be integrated into the user interface.

The base unit may further include electronics to control operation of the apparatus, pressure generating source, and/or other components of the system. For example, the base unit may include one or more microcontrollers, programmable logic, discrete elements, and/or other components. The base unit may further have one or more power supplies. Power supplies may include batteries, alternators, generators, and/or other components. The base unit may be configured to allow conversion of main power to DC for system operation, for example. In some embodiments, the base unit has a battery charging station for use with a battery-powered apparatus.

The base unit may include a reservoir for collecting waste materials, a pressure generating source, mechanisms to drive ablation members into or across the skin, a position detection mechanism,

and other components, as provided above.

One or more cables may couple the base unit to the main body. The cable or cables may carry power and/or electrical signals to permit operation of the apparatus and its components. The cable or cables may be capable of carrying high pressure, vacuum, and/or suction. Multiple cables may be joined together. For example, tubing or wrapping material may be placed around multiple cables to effectively create a single cable linking the base unit and the apparatus. Figure 8 shows a system of the invention that includes a main body coupled to base unit **30** by cable **34** capable of carrying one or more of power, information, and suction. The base unit shown also includes user interface **32**. In addition to or in place of coupling via a cable, the base unit and the main body may be wirelessly coupled. The base unit may also have a power cord that can be plugged into a wall, floor, or ceiling power source and/or a tube for connection to an external pressure generating source (e.g., a house or medical suction system). Figures 9A and 9B illustrate examples of base unit configurations. For example, the base unit of Figure 9A is a small docking station, while the base unit of Figure 9B is a larger, portable station.

Skin Positioning Apparatus

A non-thermal tissue ablation system may further include a skin positioning apparatus. A skin positioning apparatus should be configured to allow for efficient and effective positioning of skin prior to, during, and after ablation and/or tissue removal. Positioning the skin provides control to the direction of skin-tightening subsequent to treatment and ensures that ablation occurs in the desired location and with the desired dimensions.

An apparatus capable of gripping and/or lifting the skin provides numerous advantages: it holds the skin in place during the introduction of the ablation members (e.g., needles), minimizes deflection of the skin when embedding more than one needle at a time ("needle-bed effect"); reduces the risk of the user moving the apparatus during treatment, which could result in unpredictable treatment coverage; allows lifting of the skin (reducing the risk of ablation members damaging underlying structures, such as blood vessels, nerves, muscle, and bone); and allows tensioning of the skin to permit generation of non-circular ablations. A skin gripping and/or lifting apparatus should have high gripping force to sustain the insertion force of the ablation members, permit gripping of wet skin that may be covered with blood and/or interstitial fluids, minimize damage to the skin, and permit fast gripping and release to minimize treatment duration. Skin positioning mechanisms include, e.g., penetrating needle grippers, rollers pinching the skin, adhesives, freezing grippers, and vacuum grippers (including Coanda and Bernouilli grippers). Figure 10 shows skin positioning apparatus **40** of the invention that includes tensioning rods **42**. Tensioning rods **42** are used to apply force to the skin surface by moving the rods toward each other, thus pinching the skin to elevate the dermis **52** and subcutaneous fat **54** away from the underlying structures (e.g., sub-dermal muscle layer **56**, blood vessels, and nerve fibers). Additional examples and details of skin positioning apparatuses are provided in PCT/US14/50426, "Methods and Apparatuses for Skin Treatment Using Non-Thermal Tissue Ablation," which is herein incorporated by reference in its entirety.

Tissue Removal

A system or kit of the invention may further include components to aid in the removal of tissue and/or fluids, such as blood and interstitial fluids. Tissue removal components may include a low or high pressure generating source as described above. In addition to or instead of these components, tissue removal components may include adhesive materials, temperature controllers, and/or other elements. For example, a heating element coupled to the needles of the skin-penetrating component may be actuated which causes the needles to heat up to facilitate separation of ablated tissue portions from the skin. A vacuum source may then be applied to remove the heated ablated tissue portions and fluids. Additional examples and details of tissue removal components and apparatuses are provided in PCT/US14/50426.

Additional Components

A system of the invention may include additional components, such as a camera and/or viewing station. A camera may be used to image a treatment area before, during, or after treatment. In some embodiments, a camera may be disposed in or on the apparatus. The camera may transmit signal to a viewing station, such as a computer, that may be disposed in the line of sight of the device operator. The image or images transmitted by the camera may assist the operator in treating the skin.

A system may further include a fluid system coupled to the ablation members to facilitate removal of tissue portions or to irrigate the skin portion, e.g., with saline or a phosphate buffered solution; a heat source (e.g., a resistive heater or current) in communication with one or more ablation members to promote cauterization of ablation of tissue portions; and/or an optical element (e.g., a lens, a prism, a reflector, etc.) to facilitate viewing of the skin.

Configurations

Systems of the invention may include a variety of components in different configurations. For example, systems may include a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids) as well as a base unit. The reservoir may be disposed in the base unit, in the main body, in the tip, or in a separate module disposed between the tip and the main body or external to the apparatus and base unit components. Similarly, a pressure generating source (e.g., a vacuum pump) may be disposed external to other components or may be integrated into the main body or the base unit. Mechanisms for actuation, translation, and/or position detection; control electronics; and/or user interface(s) may be included in the main body and/or the base unit. These configurations facilitate the sterilization of the apparatus and/or system components as needed for patient treatment.

Figure 11 is a schematic illustrating a possible configuration of a system including reservoir **60**, main body **12** with user interface **16**, base unit **30** with user interface **32**, and cable **34**. In this system, the reservoir is integrated into detachably attachable tip **14**, which is designed for a single use. The needles included in tip **14** are hollow and include one or more holes that are in fluid communication with reservoir **60**. Reservoir **60** is further in fluid communication with a vacuum pump, such as an oil-free scroll pump, disposed in the base unit via tubing (e.g., nylon or Teflon tubing). A filter, such as a stainless steel sterilizing grade filter membrane (Mott Corporation), can be used to prevent materials from exiting the

reservoir and aspirating in the vacuum pump. The base unit may include control electronics, a power supply, and a user interface that permit powering of the base unit and apparatus; activation of actuators disposed in the main body that cause translation of the skin-penetrating component across the skin and/or penetration into the skin by the needles; control of the displacement and speed of translation across the skin and the depth of penetration into the skin by the needles; the application of vacuum; and other parameters. The cable coupling the base unit and the apparatus is capable of carrying power, information, and vacuum, and facilitates interaction between the user interfaces of the main body and the base unit. Activators, such as buttons and scroll wheels on the handheld main body, can be used to activate the device by the operator with his or her hand(s) to allow easy and controlled operation. The actuators may also be digitally controlled (e.g., at a user interface). As such, operation of the system may be entirely or almost entirely controllable by features of the apparatus.

Treatment of a region of skin of a patient may proceed by supplying power to the vacuum pump, if present, and other components of the system, preparing the skin region for treatment (e.g., sterilizing and/or positioning the skin), placing the skin-penetrating component of the apparatus upon the skin in the treatment region, and activating the mechanism that drives penetration of the ablation members (e.g., needles, such as hollow coring needles) of the skin-penetrating component into the skin. The operator may activate the vacuum source, if present, to remove waste materials (e.g., tissue, blood, and/or interstitial fluids) from the treatment area and/or ablation members with an activator, such as a button, e.g., disposed on the main body. Alternatively, the activation of the vacuum source, if present, may be automatically trigged by the apparatus when the ablation members are inserted into or retracted from the skin. Removal of waste materials may proceed by suctioning the waste materials into the reservoir via holes in the ablation members (e.g., through the hollow lumen of a coring needle). Application of vacuum may be ceased prior to translation of the skin-penetrating component to an adjacent skin region for further treatment. The process may be repeated until the entire skin region of interest has been treated, at which point the tip can be detached from the main body via a quick-release mechanism, the tip disposed of, and the other components of the system sterilized as needed. Such treatment may provide a plurality of tissue portions with dimensions, geometries, and other characteristics corresponding to the dimensions, geometries, and other characteristics of the ablation members. For example, hollow coring needles inserted about 2 mm into the skin may provide tissue portions having a depth or length of about 2 mm.

A system of the invention with a similar configuration might, alternatively, integrate a miniature vacuum pump into the main body of the apparatus. In this instance, a cable coupling the main body and the base unit might be used to carry power and information but not suction. A miniature vacuum pump may have lower power requirements than a larger vacuum pump. In another related embodiment, actuation and/or translation mechanisms may be disposed in or on the main body instead of in or on the base unit.

In another embodiment, the reservoir may be a component of the base unit. This configuration of the system permits collection of a larger volume of waste. Figure 12 is a schematic of such a system that includes main body **12** with user interface **16** that couples to base unit **30** with user interface **32** and reservoir **60** via one or more cables **34** (note that here, as in all other figures, components may not be drawn to scale). Main body **12** further couples to detachably attachable tip **14**.

In this system, one or more cables capable of providing power, information, and/or suction or vacuum act as conduits for waste between the handheld apparatus and the base unit. The cable or tubing for waste extends through the main body and is configured to be in fluid communication with the ablation members of the skin-penetrating component of the tip, which may be hollow needles having one or more holes (e.g., a central, longitudinal hole along the axis of the needle). The vacuum source may be disposed in the base unit or external to the system; for example, the vacuum source may be a medical or house vacuum source. Alternatively, the vacuum source may be a pump, such as a scroll, momentum transfer, rotary, diffusion, or diaphragm pump disposed within the base unit. The base unit of a system, such as that shown in Figure 12, may further include a power supply, control electronics, and/or actuation, translation, and/or position detection mechanisms. Actuation, translation, and/or position detection mechanisms may, alternatively, be disposed within main body **12**. User interfaces **16** and **32** may interact and/or reflect changes made at the other user interface. User action at user interface **16**, including depression or activation of buttons, key switches, toggles, touch screens, scroll wheels, and/or other components may be performed with the hands.

In an alternative embodiment, a module coupling to the tip and/or handheld device may include the reservoir. This module may be an element of the tip. A system of the invention having reservoir **60** disposed in such a module is schematically depicted in Figure 13. In the system shown, the module is detachably attached to both tip **14** and main body **12** via, e.g., a quick-release mechanism to allow for easy sterilization and/or disposal of both the tip and the reservoir. The reservoir may be an element or the entirety of the module. A miniature vacuum source **70** may be disposed in the main body of the apparatus. The ablation members of the skin-penetrating component, the reservoir, and the vacuum source are all in fluid communication; a filter may be disposed in the reservoir, module, and/or main body to block waste materials, such as tissue, from aspirating into the vacuum source. The base unit may include a user interface as well as control electronics and actuation, translation, and/or position detection mechanisms. Cable **34** couples main body **12** and base unit **30** and carries power and information therebetween. In some embodiments, cable **34** is not present and the apparatus is powered by batteries that may be disposed in main body **12**. Figure 14 schematically depicts a system of the invention that includes battery pack **36** that may insert into main body **12**. The apparatus may be charged by either removing the batteries from their housing, e.g., to be charged in a battery charging unit, or by placing the device in a battery charging station of the system. The apparatus and/or base unit **30** may also include components that allow for wireless communication therebetween.

Ablation Members

The invention features a tip and/or cartridge having one or more ablation members (e.g., needles (e.g., hollow coring needles), drill bits, abrading elements, punches, blades, and/or fluid jets) configured for penetration into and retraction from skin. These ablation members may be of varying number and characteristics and may be arranged in various configurations.

Needles

Ablation members of the invention are preferably needles. Needles of the invention may include

and/or be formed of a variety of materials (e.g., any described herein). For example, the needles may be made of molded plastic, metal, or glass. The needles may also have coatings including chemical coatings. Such coatings may include therapeutic agents as described above.

Needles may be of varying sizes and geometries. For example, needles may be hollow coring needles. Needles may be of any gauge, including gauges between 19 and 26 (e.g., 19, 20, 21, 22, 23, 24, 25, and 26 gauge). In a preferred embodiment, the needles are 24 gauge needles. In another preferred embodiment, the needles are 22 gauge needles. The outer and/or inner diameter of the needles may vary across their lengths, such that the diameter of one region of a needle may be different from the outer and/or inner diameter of another region of said same needle. The change in a diameter across the needles may or may not be continuous. The outer and/or inner diameter of the needles at their widest point may be between about 0.01 mm to about 2 mm (e.g., 0.01 mm to 0.1 mm, 0.01 mm to 0.5 mm, 0.01 mm to 1 mm, 0.01 mm to 1.5 mm, 0.01 mm to 1.75 mm, 0.05 mm to 0.1 mm, 0.05 mm to 0.5 mm, 0.05 mm to 1 mm, 0.05 mm to 1.5 mm, 0.05 mm to 1.75 mm, 0.05 mm to 2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 1.5 mm, 0.1 mm to 1.75 mm, 0.1 mm to 2 mm, 0.3 mm to 0.5 mm, 0.3 mm to 1 mm, 0.3 mm to 1.5 mm, 0.3 mm to 1.75 mm, 0.3 mm to 2 mm, 0.5 mm to 1 mm, 0.5 mm to 1.5 mm, 0.5 mm to 1.75 mm, 0.5 mm to 2 mm, 0.7 mm to 1 mm, 0.7 mm to 1.5 mm, 0.7 mm to 1.75 mm, 0.7 mm to 2 mm, 1 mm to 1.5 mm, 1 mm to 1.75 mm, 1 mm to 2 mm, 1.5 mm to 1.75 mm, 1.5 mm to 2 mm, and 1.75 mm to 2 mm). The needles may or may not be entirely partially cylindrical. For example, one or more needles may be rectangular, serrated, scalloped, and/or irregular in one or more dimension and along some or all of their lengths. In some embodiments, the inner lumen diameter may vary along the length of a needle. For example, the inner diameter may be wider at the distal end of the needle (e.g., away from the tip that penetrates the skin). This may facilitate the removal of tissue from the treatment area and/or the needles themselves and may limit the need for clearing of the ablation member using a pressure generating source (e.g., a vacuum source).

The needles may be configured to provide tissue portions. For example, penetration into and/or retraction from tissue by the needles may result in ablated tissue portions. The dimensions, geometry, number, and other characteristics of a tissue portion should correspond to the dimensions, geometry, number, and other characteristics of the skin penetrating component of the invention (e.g., the needle or array of needles). For example, a tissue portion created by penetration into the skin with a cylindrical, coring needle may have a cylindrical geometry, while a tissue portion created by penetration into the skin with a serrated ablation member may have a serrated or irregular geometry.

Needles of the invention may be configured to provide tissue portions having a change in width as a function of depth. For example, the part of an ablated tissue portion that originates from deeper tissue may be narrower than that part that originates from tissue closer to the skin surface. This change in width may be between about 100 μm to about 500 μm as a function of depth (e.g., 100 μm to 200 μm, 100 μm to 300 μm, 100 μm to 400 μm, 100 μm to 500 μm, 200 μm to 300 μm, 200 μm to 400 μm, 200 μm to 500 μm, 300 μm to 400 μm, 300 μm to 500 μm, and 400 μm to 500 μm). The needles may be configured to provide ablated tissue portions having a width to depth ratio between about 1:0.3 to about 1:75. For example, the width to depth radio of a tissue portion may be between about 1:0.3 to about 1:1 (e.g., 1:0.3 to 1:1, 1:0.35 to 1:1, 1:0.4 to 1:1, 1:0.45 to 1:1, 1:0.5 to 1:1, 1:0.55 to 1:1, 1:0.6 to 1:1, 1:0.65

to 1:1, 1:0.7 to 1:1, 1:0.75 to 1:1, 1:0.8 to 1:1, 1:0.85 to 1:1, 1:0.9 to 1:1, 1:0.95 to 1:1, 1:0.3 to 1:0.95, 1:0.35 to 1:0.95, 1:0.4 to 1:0.95, 1:0.45 to 1:0.95, 1:0.5 to 1:0.95, 1:0.55 to 1:0.95, 1:0.6 to 1:0.95, 1:0.65 to 1:0.95, 1:0.7 to 1:0.95, 1:0.75 to 1:0.95, 1:0.8 to 1:0.95, 1:0.85 to 1:0.95, 1:0.9 to 1:0.95, 1:0.3 to 1:0.9, 1:0.35 to 1:0.9, 1:0.4 to 1:0.9, 1:0.45 to 1:0.9, 1:0.5 to 1:0.9, 1:0.55 to 1:0.9, 1:0.6 to 1:0.9, 1:0.65 to 1:0.9, 1:0.7 to 1:0.9, 1:0.75 to 1:0.9, 1:0.8 to 1:0.9, 1:0.85 to 1:0.9, 1:0.3 to 1:0.85, 1:0.35 to 1:0.85, 1:0.4 to 1:0.85, 1:0.45 to 1:0.85, 1:0.5 to 1:0.85, 1:0.55 to 1:0.85, 1:0.6 to 1:0.85, 1:0.65 to 1:0.85, 1:0.7 to 1:0.85, 1:0.75 to 1:0.85, 1:0.8 to 1:0.85, 1:0.3 to 1:0.8, 1:0.35 to 1:0.8, 1:0.4 to 1:0.8, 1:0.45 to 1:0.8, 1:0.5 to 1:0.8, 1:0.55 to 1:0.8, 1:0.6 to 1:0.8, 1:0.65 to 1:0.8, 1:0.7 to 1:0.8, 1:0.75 to 1:0.8, 1:0.3 to 1:0.75, 1:0.35 to 1:0.75, 1:0.4 to 1:0.75, 1:0.45 to 1:0.75, 1:0.5 to 1:0.75, 1:0.55 to 1:0.75, 1:0.6 to 1:0.75, 1:0.65 to 1:0.75, 1:0.7 to 1:0.75, 1:0.3 to 1:0.65, 1:0.35 to 1:0.65, 1:0.4 to 1:0.65, 1:0.45 to 1:0.65, 1:0.5 to 1:0.65, 1:0.55 to 1:0.65, 1:0.6 to 1:0.65, 1:0.3 to 1:0.65, 1:0.35 to 1:0.65, 1:0.4 to 1:0.65, 1:0.45 to 1:0.65, 1:0.5 to 1:0.65, 1:0.55 to 1:0.65, 1:0.6 to 1:0.65, 1:0.3 to 1:0.6, 1:0.35 to 1:0.6, 1:0.4 to 1:0.6, 1:0.45 to 1:0.6, 1:0.5 to 1:0.6, 1:0.55 to 1:0.6, 1:0.3 to 1:0.55, 1:0.35 to 1:0.55, 1:0.4 to 1:0.55, 1:0.45 to 1:0.55, 1:0.5 to 1:0.55, 1:0.3 to 1:0.5, 1:0.35 to 1:0.5, 1:0.4 to 1:0.5, 1:0.45 to 1:0.5, 1:0.5 to 1:0.5, 1:0.3 to 1:0.45, 1:0.35 to 1:0.45, 1:0.4 to 1:0.45, 1:0.3 to 1:0.4, 1:0.35 to 1:0.4, and 1:0.3 to 1:0.35); between about 1:1 to about 1:20 (e.g., 1:1 to 1:2, 1:1 to 1:3, 1:1 to 1:4, 1:1 to 1:5, 1:1 to 1:6, 1:1 to 1:7, 1:1 to 1:8, 1:1 to 1:9, 1:1 to 1:10, 1:1 to 1:11, 1:1 to 1:12, 1:1 to 1:13, 1:1 to 1:14, 1:1 to 1:15, 1:1 to 1:16, 1:1 to 1:17, 1:1 to 1:18, 1:1 to 1:19, 1:1 to 1:20, 1:2 to 1:3, 1:2 to 1:4, 1:2 to 1:5, 1:2 to 1:6, 1:2 to 1:7, 1:2 to 1:8, 1:2 to 1:9, 1:2 to 1:10, 1:2 to 1:11, 1:2 to 1:12, 1:2 to 1:13, 1:2 to 1:14, 1:2 to 1:15, 1:2 to 1:16, 1:2 to 1:17, 1:2 to 1:18, 1:2 to 1:19, 1:2 to 1:20, 1:3 to 1:4, 1:3 to 1:5, 1:3 to 1:6, 1:3 to 1:7, 1:3 to 1:8, 1:3 to 1:9, 1:3 to 1:10, 1:3 to 1:11, 1:3 to 1:12, 1:3 to 1:13, 1:3 to 1:14, 1:3 to 1:15, 1:3 to 1:16, 1:3 to 1:17, 1:3 to 1:18, 1:3 to 1:19, 1:3 to 1:20, 1:4 to 1:5, 1:4 to 1:6, 1:4 to 1:7, 1:4 to 1:8, 1:4 to 1:9, 1:4 to 1:10, 1:4 to 1:11, 1:4 to 1:12, 1:4 to 1:13, 1:4 to 1:14, 1:4 to 1:15, 1:4 to 1:16, 1:4 to 1:17, 1:4 to 1:18, 1:4 to 1:19, 1:4 to 1:20, 1:5 to 1:6, 1:5 to 1:7, 1:5 to 1:8, 1:5 to 1:9, 1:5 to 1:10, 1:5 to 1:11, 1:5 to 1:12, 1:5 to 1:13, 1:5 to 1:14, 1:5 to 1:15, 1:5 to 1:16, 1:5 to 1:17, 1:5 to 1:18, 1:5 to 1:19, 1:5 to 1:20, 1:6 to 1:7, 1:6 to 1:8, 1:6 to 1:9, 1:6 to 1:10, 1:6 to 1:11, 1:6 to 1:12, 1:6 to 1:13, 1:6 to 1:14, 1:6 to 1:15, 1:6 to 1:16, 1:6 to 1:17, 1:6 to 1:18, 1:6 to 1:19, 1:6 to 1:20, 1:7 to 1:8, 1:7 to 1:9, 1:7 to 1:10, 1:7 to 1:11, 1:7 to 1:12, 1:7 to 1:13, 1:7 to 1:14, 1:7 to 1:15, 1:7 to 1:16, 1:7 to 1:17, 1:7 to 1:18, 1:7 to 1:19, 1:7 to 1:20, 1:8 to 1:9, 1:8 to 1:10, 1:8 to 1:11, 1:8 to 1:12, 1:8 to 1:13, 1:8 to 1:14, 1:8 to 1:15, 1:8 to 1:16, 1:8 to 1:17, 1:8 to 1:18, 1:8 to 1:19, 1:8 to 1:20, 1:9 to 1:10, 1:9 to 1:11, 1:9 to 1:12, 1:9 to 1:13, 1:9 to 1:14, 1:9 to 1:15, 1:9 to 1:16, 1:9 to 1:17, 1:9 to 1:18, 1:9 to 1:19, 1:9 to 1:20, 1:10 to 1:11, 1:10 to 1:12, 1:10 to 1:13, 1:10 to 1:14, 1:10 to 1:15, 1:10 to 1:16, 1:10 to 1:17, 1:10 to 1:18, 1:10 to 1:19, 1:10 to 1:20, 1:11 to 1:12, 1:11 to 1:13, 1:11 to 1:14, 1:11 to 1:15, 1:11 to 1:16, 1:11 to 1:17, 1:11 to 1:18, 1:11 to 1:19, 1:11 to 1:20, 1:12 to 1:13, 1:12 to 1:14, 1:12 to 1:15, 1:12 to 1:16, 1:12 to 1:17, 1:12 to 1:18, 1:12 to 1:19, 1:12 to 1:20, 1:13 to 1:14, 1:13 to 1:15, 1:13 to 1:16, 1:13 to 1:17, 1:13 to 1:18, 1:13 to 1:19, 1:13 to 1:20, 1:14 to 1:15, 1:14 to 1:16, 1:14 to 1:17, 1:14 to 1:18, 1:14 to 1:19, 1:14 to 1:20, 1:15 to 1:16, 1:15 to 1:17, 1:15 to 1:18, 1:15 to 1:19, 1:15 to 1:20, 1:17 to 1:18, 1:17 to 1:19, and 1:17 to 1:20); between about 1:1 to about 1:75 (e.g., 1:1 to 1:2, 1:1 to 1:5, 1:1 to 1:10, 1:1 to 1:20, 1:1 to 1:30, 1:1 to 1:40, 1:1 to 1:50, 1:1 to 1:60, 1:1 to 1:75, 1:2 to 1:5, 1:2 to 1:10, 1:2 to 1:20, 1:2 to 1:30, 1:2 to 1:40, 1:2 to 1:50, 1:2 to 1:60, 1:2 to 1:75, 1:5 to 1:10, 1:5 to 1:20, 1:5 to 1:30, 1:5 to 1:40, 1:5 to 1:50, 1:5 to 1:60, 1:5 to 1:75, 1:10 to 1:20, 1:10 to 1:30, 1:10 to 1:40, 1:10 to 1:50, 1:10 to 1:60, 1:10 to

1:75, 1:20 to 1:30, 1:20 to 1:40, 1:20 to 1:50, 1:20 to 1:60, 1:20 to 1:75, 1:30 to 1:40, 1:30 to 1:50, 1:30 to 1:60, 1:30 to 1:75, 1:40 to 1:50, 1:40 to 1:60, 1:40 to 1:75, 1:50 to 1:60, 1:50 to 1:75, and 1:60 to 1:75); between about 1:25 to about 1:75 (e.g., 1:25 to 1:75, 1:30 to 1:75, 1:35 to 1:75, 1:40 to 1:75, 1:45 to 1:75, 1:50 to 1:75, 1:55 to 1:75, 1:60 to 1:75, 1:65 to 1:75, 1:70 to 1:75, 1:25 to 1:70, 1:30 to 1:70, 1:35 to 1:70, 1:40 to 1:70, 1:45 to 1:70, 1:50 to 1:70, 1:55 to 1:70, 1:60 to 1:70, 1:65 to 1:70, 1:25 to 1:65, 1:30 to 1:65, 1:35 to 1:65, 1:40 to 1:65, 1:45 to 1:65, 1:50 to 1:65, 1:55 to 1:65, 1:60 to 1:65, 1:25 to 1:60, 1:30 to 1:60, 1:35 to 1:60, 1:40 to 1:60, 1:45 to 1:60, 1:50 to 1:60, 1:55 to 1:60, 1:25 to 1:55, 1:30 to 1:55, 1:35 to 1:55, 1:40 to 1:55, 1:45 to 1:55, 1:50 to 1:55, 1:25 to 1:50, 1:30 to 1:50, 1:35 to 1:50, 1:40 to 1:50, 1:45 to 1:50, 1:25 to 1:45, 1:30 to 1:45, 1:35 to 1:45, 1:40 to 1:45, 1:25 to 1:40, 1:30 to 1:40, 1:35 to 1:40, 1:25 to 1:35, 1:30 to 1:35, and 1:25 to 1:30); or between about 1:03 to about 1:75 (e.g., 1:0.3 to 1:0.5, 1:0.3 to 1:1, 1:0.3 to 1:2, 1:0.3 to 1:5, 1:0.3 to 1:10, 1:0.3 to 1:20, 1:0.3 to 1:30, 1:0.3 to 1:40, 1:0.3 to 1:50, 1:0.3 to 1:60, 1:0.3 to 1:75, 1:0.5 to 1:1, 1:0.5 to 1:2, 1:0.5 to 1:5, 1:0.5 to 1:10, 1:0.5 to 1:20, 1:0.5 to 1:30, 1:0.5 to 1:40, 1:0.5 to 1:50, 1:0.5 to 1:60, and 1:0.5 to 1:75).

Needles may be of varying lengths and may have varying active lengths (i.e., the length of needle configured to penetrate the skin). Active lengths may vary between about 0.1 mm to about 15 mm (e.g., 0.1 mm to 0.2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 2 mm, 0.1 mm to 5 mm, 0.1 mm to 10 mm, 0.1 mm to 15 mm, 0.2 mm to 0.5 mm, 0.2 mm to 1 mm, 0.2 mm to 2 mm, 0.2 mm to 5 mm, 0.2 mm to 10 mm, 0.2 mm to 15 mm, 0.5 mm to 1 mm, 0.5 mm to 2 mm, 0.5 mm to 5 mm, 0.5 mm to 10 mm, 0.5 mm to 15 mm, 1 mm to 2 mm, 1 mm to 5 mm, 1 mm to 10 mm, 1 mm to 15 mm, 2 mm to 5 mm, 2 mm to 10 mm, 2 mm to 15 mm, 5 mm to 10 mm, 5 mm to 15 mm, and 10 mm to 15 mm) and may be selectable with manual or automatic controls (e.g., a scroll wheel or an actuation mechanism such as an electromagnetic actuator). Needle parameters may be selected based on the area of skin and the condition to be treated. For example, treatment of thin, lax skin on the cheeks may benefit from coring needles having active lengths of about 2 mm and medium gauge (e.g., 22 gauge), while treatment of thick skin on the back may benefit from coring needles having lengths closer to 15 mm and thicker gauges (e.g., 26 gauge).

The needles of the invention may or may not be hollow. Hollow needles may have a plurality of holes. For example, needles may have holes at either end and/or along their lengths. The needles may include and/or be coated with chemical or biological materials to treat skin. In some embodiments, holes in the needles may facilitate the injection of chemical or bioactive agents into tissue. Such agents may be injected at multiple depths or at specific areas along the needles or in specific patterns. The size of the needle holes may control the amount of chemical or bioactive agents delivered to particular locations. In some embodiments, chemical or bioactive agents may be used to destroy or ablate skin tissue. Typical chemical or bioactive agents used include trichloroacetic acid, alpha hydroxy acids, beta hydroxy acids, liquid nitrogen, hypoosmotic fluids, hyperosmotic fluids, and bioactive proteins (e.g., one or more hormones, antibodies, and/or enzymes, such as enzymes that liquefy tissue, such as one or more proteases, DNases, hyaluronidase, and collagenases, or combinations thereof). Chemicals or bioactive agents may be used to create an injury, ablated tissue portion, and/or stimulate new tissue formation. Chemicals or bioactive agents may also include fillers, such as collagen-based fillers.

Needles may include one or more barbs on either their outer or inner surfaces. The ends (tips) of

the needles configured to penetrate the skin may be sharpened to a fine point or otherwise configured. Two possible needle tip configurations are shown in Figure 15.

The needles may be coupled to other components of an apparatus, system, or kit such as a reservoir for collecting waste materials and/or a pressure generating source. Coring needles may be in fluid communication with such components to facilitate the removal of ablated tissue, for example. The needles may also be coupled to a substrate disposed in the tip. The substrate may enforce the needle array configuration and sufficiently bind the needles to prevent the needles from becoming stuck or left behind in the skin upon penetration. A substrate may include adhesive and/or mechanical coupling components and materials such as glues or plastic overmoldings. The needles may further be electrically and/or mechanically coupled to actuation mechanisms to drive the needles across and into the skin surface. A coupling mechanism may include an array gripper.

Arrays

When a tip has more than one ablation member (e.g., needle), the ablation members may be configured to form a one- or two-dimensional array (including linear, radial, rectangular, and irregular arrays). The size and geometry of an array may be selected based on the area of skin and condition being treated. For example, a small array may be selected for treatment of the peri-oral area, while a large array may be suitable for treatment of the abdomen. Arrays of the same size may feature different numbers and/or arrangements of ablation members (e.g., needles). For example, one linear array may include five needles spaced about 2 mm apart while another linear array may include ten needles spaced about 1 mm apart. The main body may be configured for detachable attachment to a variety of tips having different numbers and configurations of ablation members. Also, the tip housing and/or structure may be configured for inclusion of arrays of varying sizes and geometries.

The tip may have as few as 1 or as many as hundreds of ablation members (e.g., needles). In some embodiments, 1-100 ablation members may be present (e.g., 1-10, 1-20, 1-30, 1-40, 1-50, 1-60, 1-70, 1-80, 1-90, 1-100, 3-10, 3-20, 3-30, 3-40, 3-50, 3-60, 3-70, 3-80, 3-90, 3-100, 5-10, 5-20, 5-30, 5-40, 5-50, 5-60, 5-70, 5-80, 5-90, 5-100, 10-20, 10-40, 10-60, 10-80, 10-100, 20-40, 20-60, 20-80, 20-100, 40-60, 40-80, 40-100, 60-80, 60-100, or 80-100 ablation members). In preferred embodiments, the tip may have 3-50 ablation members (e.g., needles). The use of an array of multiple ablation members may facilitate skin treatment over larger areas and in less time.

The minimum distance between two ablation members (e.g., needles) in an array may be between about 0.1 mm to about 50 mm (e.g., from 0.1 mm to 0.2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 2 mm, 0.1 mm to 5 mm, 0.1 mm to 10 mm, 0.1 mm to 15 mm, 0.1 mm to 20 mm, 0.1 mm to 30 mm, 0.1 mm to 40 mm, 0.1 mm to 50 mm, 0.2 mm to 0.5 mm, 0.2 mm to 1 mm, 0.2 mm to 2 mm, 0.2 mm to 5 mm, 0.2 mm to 10 mm, 0.2 mm to 15 mm, 0.2 mm to 20 mm, 0.2 mm to 30 mm, 0.2 mm to 40 mm, 0.2 mm to 50 mm, 0.5 mm to 1 mm, 0.5 mm to 2 mm, 0.5 mm to 5 mm, 0.5 mm to 10 mm, 0.5 mm to 15 mm, 0.5 mm to 20 mm, 0.5 mm to 30 mm, 0.5 mm to 40 mm, 0.5 mm to 50 mm, 1 mm to 2 mm, 1 mm to 5 mm, 1 mm to 10 mm, 1 mm to 15 mm, 1 mm to 20 mm, 1 mm to 30 mm, 1 mm to 40 mm, 1 mm to 50 mm, 2 mm to 5 mm, 2 mm to 10 mm, 2 mm to 15 mm, 2 mm to 20 mm, 2 mm to 30 mm, 2 mm to 40 mm, 2 mm to 50 mm, 5 mm to 10 mm, 5 mm to 15 mm, 5 mm to 20 mm, 5 mm to 30 mm, 5 mm to

40 mm, 5 mm to 50 mm, 10 mm to 15 mm, 10 mm to 20 mm, 10 mm to 30 mm, 10 mm to 40 mm, 10 mm to 50 mm, 15 mm to 20 mm, 15 mm to 30 mm, 15 mm to 40 mm, 15 mm to 50 mm, 20 mm to 30 mm, 20 mm to 40 mm, 20 mm to 50 mm, 30 mm to 40 mm, 30 mm to 50 mm, and 40 mm to 50 mm). The minimum distance may correspond to the minimal size of an array, while the maximum distance may correspond to the maximum size of an array.

Arrays of different sizes and geometries may be selected based on the area of treatment and the skin condition being treated. Arrays may also be selected for compatibility with actuation mechanisms and control electronics of a given apparatus, system, or kit. Alternatively, actuation mechanisms and control electronics of an apparatus, system, or kit may be selected for compatibility with a desired array size and/or geometry. For example, a long, linear array may be used in combination with a translating mechanism with driving wheels, while a large, rectangular array may be used in combination with an x-actuator to drive the ablation members (e.g., needles) across the skin.

In any of the apparatuses, systems, kits, and methods herein, the tip may be configured to provide from about 10 to about 10000 ablated tissue portions per cm^2 area (e.g., 10 to 50, 10 to 100, 10 to 200, 10 to 300, 10 to 400, 10 to 500, 10 to 600, 10 to 700, 10 to 800, 10 to 900, 10 to 1000, 10 to 2000, 10 to 4000, 10 to 6000, 10 to 8000, 10 to 10000, 50 to 100, 50 to 200, 50 to 300, 50 to 400, 50 to 500, 50 to 600, 50 to 700, 50 to 800, 50 to 900, 50 to 1000, 50 to 2000, 50 to 4000, 510 to 6000, 50 to 8000, 50 to 10000, 100 to 200, 100 to 300, 100 to 400, 100 to 500, 100 to 600, 100 to 700, 100 to 800, 100 to 900, 100 to 1000, 100 to 2000, 100 to 4000, 100 to 6000, 100 to 8000, 100 to 10000, 200 to 300, 200 to 400, 200 to 500, 200 to 600, 200 to 700, 200 to 800, 200 to 900, 200 to 1000, 200 to 2000, 200 to 4000, 200 to 6000, 200 to 8000, 200 to 10000, 300 to 400, 300 to 500, 300 to 600, 300 to 700, 300 to 800, 300 to 900, 300 to 1000, 300 to 2000, 300 to 4000, 300 to 6000, 300 to 8000, 300 to 10000, 400 to 500, 400 to 600, 400 to 700, 400 to 800, 400 to 900, 400 to 1000, 400 to 2000, 400 to 4000, 400 to 6000, 400 to 8000, 400 to 10000, 500 to 600, 500 to 700, 500 to 800, 500 to 900, 500 to 1000, 500 to 2000, 500 to 4000, 500 to 6000, 500 to 8000, 500 to 10000, 600 to 700, 600 to 800, 600 to 900, 600 to 1000, 600 to 2000, 600 to 4000, 600 to 6000, 600 to 8000, 600 to 10000, 700 to 800, 700 to 900, 700 to 1000, 700 to 2000, 700 to 4000, 700 to 6000, 700 to 8000, 700 to 10000, 800 to 900, 800 to 1000, 800 to 2000, 800 to 4000, 800 to 6000, 800 to 8000, 800 to 10000, 900 to 1000, 900 to 2000, 900 to 4000, 900 to 6000, 900 to 8000, 900 to 10000, 1000 to 2000, 1000 to 4000, 1000 to 6000, 1000 to 8000, 1000 to 10000, 2000 to 4000, 2000 to 6000, 2000 to 8000, 2000 to 10000, 4000 to 6000, 4000 to 8000, 4000 to 10000, 6000 to 8000, 6000 to 10000, and 8000 to 10000 tissue portions per cm^2 area) of the skin region to which the apparatus is applied (e.g., treatment area). The tip may be configured to remove about 5%-70% (e.g., 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, and 70%) of tissue within a treatment area. In a preferred embodiment, about 10% of tissue within a treatment area is removed.

In any of the apparatuses, systems, kits, and methods herein, one or more components of the device may be selected or designed to secure the ablation member(s) (e.g., one or more needles) and/or prevent or minimize angular movement (e.g., wobbling) of the ablation member(s). The needle(s) may be secured to a substrate so as to minimize or reduce angular movement of the needle(s) during insertion to less than 5 degrees, e.g., less than 4, 3, or 2 degrees. An angular movement of the needle(s) during insertion of ~1-1.5 degrees is within nominal tolerances, whereas an angular movement of the needle(s)

during insertion of ~4-5 degrees or more is to be avoided, if possible. For example, components that join ablation member(s) to other components (e.g., a substrate) may be designed with low mechanical tolerances to firmly secure the ablation member(s). This may reduce the prevalence of or lower the risk of destabilization and/or reduction in the structural integrity of ablation member(s) that may result from repeated use. For example, firmly securing the needle(s) may prevent and/or minimize dulling, bending, and curling of needle tip(s) that could reduce the effectiveness of the needle(s). Firmly securing the needle(s) may also reduce the risk of over-striking (e.g., striking a hole produced by a needle more than once).

Ablated tissue portions

The present invention features apparatuses, systems, kits, and methods for generating ablated tissue portions having various geometric dimensions. The apparatuses, systems, kits, and methods of the invention can be configured to produce tissue portions by producing holes in the skin (e.g., by penetration with ablation members, such as hollow needles). The apparatuses, systems, kits, and methods of the invention can further be configured to provide tissue portions with specific dimensions, geometries, and other characteristics. Characteristics (e.g., dimensions, geometries, and other characteristics) of tissue portions may reflect the characteristics of holes formed in the skin. For example, an apparatus may be configured to produce a hole having a change in width or diameter as a function of depth (e.g., by use of ablation members, such as needles, having changes in width or diameter along their lengths), such that a corresponding tissue portion may also have a change in width or diameter as a function of depth. Certain width or depth ratios of one or more ablation members may allow for improvement of skin tightening (e.g., forming a hole having a larger diameter at the skin surface than at the skin depth may facilitate hole closing via mechanical hole closure or, alternatively, forming a hole having a smaller diameter at the skin surface than at the skin depth may accelerate closure of the epidermal layer (e.g., reepithelialization) and therefore minimize the risk of adverse events, such as infections, and minimize healing time), skin rejuvenation (e.g., skin texture, color, and/or architecture), treatment of thin skin regions (e.g., lower anterior leg and cheeks), and/or treatment of thick skin (e.g., anterior leg and gluteus). Using apparatuses, systems, kits, and methods with certain width to depth ratios may further minimize the risk of scarring while maximizing skin tightening. Such benefits may minimize healing time, improve treatment to abnormal skin areas (e.g., irregularly shaped and/or small treatment areas), and/or increase the ability to tune hole depth and diameter to the treatment objective. A provided tissue portion may have a width to depth ratio of between about 1:0.3 to about 1:75 (e.g., as described herein) and/or have a change in width as a function of depth between about 100 μm to about 500 μm (e.g., as described herein).

In some embodiments, the ablated tissue portions provided by apparatuses, systems, kits, and methods of the invention may have at least one dimension between about 10 μm and about 2 mm (e.g., about 10 μm to 500 μm, about 10 μm to 100 μm, 10 μm to 250 μm, 10 μm to 500 μm, 10 μm to 750 μm, 10 μm to 1 mm, 10 μm to 1.5 mm, 10 μm to 2 mm, about 50 μm to 100 μm, 50 μm to 250 μm, 50 μm to 500 μm, 50 μm to 750 μm, 50 μm to 1 mm, 50 μm to 1.5 mm, 50 μm to 2 mm, 100 μm to 250 μm, 100 μm to 500 μm, 100 μm to 750 μm, 100 μm to 1 mm, 100 μm to 1.5 mm, 100 μm to 2 mm, 250 μm to 500 μm,

250 µm to 750 µm, 250 µm to 1 mm, 250 µm to 1.5 mm, 250 µm to 2 mm, 500 µm to 750 µm, 500 µm to 1 mm, 500 µm to 1.5 mm, 500 µm to 2 mm, 750 µm to 1 mm, 750 µm to 1.5 mm, and 750 µm to 2 mm); between about 0.1 mm to about 0.8 mm (e.g., 0.1 mm to 0.8 mm, 0.1 mm to 0.6 mm, 0.1 mm to 0.4 mm, 0.1 mm to 0.2 mm, 0.2 mm to 0.8 mm, 0.2 mm to 0.6 mm, 0.2 mm to 0.4 mm, 0.2 mm to 0.3 mm, 0.3 mm to 0.8 mm, 0.3 mm to 0.6 mm, 0.3 mm to 0.4 mm, 0.4 mm to 0.8 mm, 0.4 mm to 0.6 mm, 0.4 mm to 0.5 mm, 0.5 mm to 0.8 mm, 0.5 mm to 0.6 mm, 0.6 mm to 0.8 mm, 0.6 mm to 0.7 mm, and 0.7 mm to 0.8 mm); between about 0.9 mm to about 20 mm (e.g., 0.9 mm to 20 mm, 0.9 mm to 17 mm, 0.9 mm to 14 mm, 0.9 mm to 11 mm, 0.9 mm to 8 mm, 0.9 mm to 5 mm, 0.9 mm to 3 mm, 3 mm to 20 mm, 3 mm to 17 mm, 3 mm to 14 mm, 3 mm to 11 mm, 3 mm to 8 mm, 3 mm to 5 mm, 5 mm to 20 mm, 5 mm to 17 mm, 5 mm to 14 mm, 5 mm to 11 mm, 5 mm to 8 mm, 8 mm to 20 mm, 8 mm to 17 mm, 8 mm to 14 mm, 8 mm to 11 mm, 11 mm to 20 mm, 11 mm to 17 mm, 11 mm to 14 mm, 14 mm to 20 mm, 14 mm to 17 mm, and 17 mm to 20 mm); between about 0.01 mm to 0.25 mm (e.g., 0.01 mm to 0.25 mm, 0.02 mm to 0.25 mm, 0.03 mm to 0.25 mm, 0.05 mm to 0.25 mm, 0.075 mm to 0.25 mm, 0.1 mm to 0.25 mm, 0.15 mm to 0.25 mm, 0.2 mm to 0.25 mm, 0.01 mm to 0.2 mm, 0.02 mm to 0.2 mm, 0.03 mm to 0.2 mm, 0.05 mm to 0.2 mm, 0.075 mm to 0.2 mm, 0.1 mm to 0.2 mm, 0.15 mm to 0.2 mm, 0.01 mm to 0.15 mm, 0.02 mm to 0.15 mm, 0.03 mm to 0.15 mm, 0.05 mm to 0.15 mm, 0.075 mm to 0.15 mm, 0.1 mm to 0.15 mm, 0.01 mm to 0.1 mm, 0.02 mm to 0.1 mm, 0.03 mm to 0.1 mm, 0.05 mm to 0.1 mm, 0.075 mm to 0.1 mm, 0.01 mm to 0.075 mm, 0.02 mm to 0.075 mm, 0.03 mm to 0.075 mm, 0.05 mm to 0.075 mm, 0.01 mm to 0.05 mm, 0.02 mm to 0.05 mm, 0.03 mm to 0.05 mm, 0.01 mm to 0.03 mm, 0.02 mm to 0.03 mm, 0.03 mm to 0.03 mm, 0.01 mm to 0.03 mm, 0.02 mm to 0.03 mm, and 0.01 mm to 0.02 mm); between about 0.01 mm to about 20 mm (e.g., 0.01 mm to 1 mm, 0.01 mm to 2 mm, 0.01 mm to 5 mm, 0.01 mm to 10 mm, 0.01 mm to 15 mm, 0.05 mm to 1 mm, 0.05 mm to 2 mm, 0.05 mm to 5 mm, 0.05 mm to 10 mm, 0.05 mm to 15 mm, 0.05 mm to 20 mm, 0.1 mm to 1 mm, 0.1 mm to 2 mm, 0.1 mm to 5 mm, 0.1 mm to 10 mm, 0.1 mm to 15 mm, 0.1 mm to 20 mm, 0.5 mm to 1 mm, 0.5 mm to 2 mm, 0.5 mm to 5 mm, 0.5 mm to 10 mm, 0.5 mm to 15 mm, 0.5 mm to 20 mm, 1 mm to 2 mm, 1 mm to 5 mm, 1 mm to 10 mm, 1 mm to 15 mm, 1 mm to 20 mm, 2 mm to 5 mm, 2 mm to 10 mm, 2 mm to 15 mm, 2 mm to 20 mm, 5 mm to 10 mm, 5 mm to 15 mm, and 5 mm to 20 mm); or between about 0.01 mm to about 2 mm (e.g., 0.01 mm to 0.1 mm, 0.01 mm to 0.5 mm, 0.01 mm to 1 mm, 0.01 mm to 1.5 mm, 0.01 mm to 1.75 mm, 0.05 mm to 0.1 mm, 0.05 mm to 0.5 mm, 0.05 mm to 1 mm, 0.05 mm to 1.5 mm, 0.05 mm to 1.75 mm, 0.05 mm to 2 mm, 0.1 mm to 0.5 mm, 0.1 mm to 1 mm, 0.1 mm to 1.5 mm, 0.1 mm to 1.75 mm, 0.1 mm to 2 mm, 0.3 mm to 0.5 mm, 0.3 mm to 1 mm, 0.3 mm to 1.5 mm, 0.3 mm to 1.75 mm, 0.3 mm to 2 mm, 0.5 mm to 1 mm, 0.5 mm to 1.5 mm, 0.5 mm to 1.75 mm, 0.5 mm to 2 mm, 0.7 mm to 1 mm, 0.7 mm to 1.5 mm, 0.7 mm to 1.75 mm, 0.7 mm to 2 mm, 1 mm to 1.5 mm, 1 mm to 1.75 mm, 1 mm to 2 mm, 1.5 mm to 1.75 mm, 1.5 mm to 2 mm, and 1.75 mm to 2 mm). For instance, the diameter or width of a tissue portion may be between about 0.01 mm and about 2 mm at its widest point (e.g., as described herein). For example, penetration into tissue by about 1 mm with a needle having a diameter of about 2 mm may produce a tissue portion having a depth or length of about 1 mm and a diameter of about 2 mm.

A tissue portion may have an area dimension in a range of about 0.001 mm^2 to about 2 mm^2 (e.g., 0.001 mm^2 to 0.005 mm^2, 0.001 mm^2 to 0.01 mm^2, 0.001 mm^2 to 0.05 mm^2, 0.001 mm^2 to 0.1 mm^2, 0.001 mm^2 to 0.5 mm^2, 0.001 mm^2 to 1 mm^2, 0.001 mm^2 to 1.5 mm^2, 0.001 mm^2 to 2 mm^2, 0.005 mm^2 to

0.01 mm^2, 0.005 mm^2 to 0.05 mm^2, 0.005 mm^2 to 0.1 mm^2, 0.005 mm^2 to 0.5 mm^2, 0.005 mm^2 to 1 mm^2, 0.005 mm^2 to 1.5 mm^2, 0.005 mm^2 to 2 mm^2, 0.01 mm^2 to 0.02 mm^2, 0.01 mm^2 to 0.05 mm^2, 0.01 mm^2 to 0.1 mm^2, 0.01 mm^2 to 0.5 mm^2, 0.01 mm^2 to 1 mm^2, 0.01 mm^2 to 1.5 mm^2, 0.01 mm^2 to 2 mm^2, 0.05 mm^2 to 0.1 mm^2, 0.05 mm^2 to 0.5 mm^2, 0.05 mm^2 to 1 mm^2, 0.05 mm^2 to 1.5 mm^2, 0.05 mm^2 to 2 mm^2, 0.1 mm^2 to 0.2 mm^2, 0.1 mm^2 to 0.5 mm^2, 0.1 mm^2 to 1 mm^2, 0.1 mm^2 to 1.5 mm^2, 0.1 mm^2 to 2 mm^2, 0.5 mm^2 to 1 mm^2, 0.5 mm^2 to 1.5 mm^2, 0.5 mm^2 to 2 mm^2, 1 mm^2 to 1.5 mm^2, 1 mm^2 to 2 mm^2, and 1.5 mm^2 to 2 mm^2) and/or a volume between about 0.001 mm^3 and about 6 mm^3 (e.g., 0.001 mm^3 to 0.01 mm^3, 0.001 mm^3 to 0.1 mm^3, 0.001 mm^3 to 0.5 mm^3, 0.001 mm^3 to 1 mm^3, 0.001 mm^3 to 2 mm^3, 0.001 mm^3 to 3 mm^3, 0.001 mm^3 to 4 mm^3, 0.001 mm^3 to 5 mm^3, 0.001 mm^3 to 6 mm^3, 0.005 mm^3 to 0.01 mm^3, 0.005 mm^3 to 0.1 mm^3, 0.005 mm^3 to 0.5 mm^3, 0.005 mm^3 to 1 mm^3, 0.005 mm^3 to 2 mm^3, 0.005 mm^3 to 3 mm^3, 0.005 mm^3 to 4 mm^3, 0.005 mm^3 to 5 mm^3, 0.005 mm^3 to 6 mm^3, 0.01 mm^3 to 0.1 mm^3, 0.01 mm^3 to 0.5 mm^3, 0.01 mm^3 to 1 mm^3, 0.01 mm^3 to 2 mm^3, 0.01 mm^3 to 3 mm^3, 0.01 mm^3 to 4 mm^3, 0.01 mm^3 to 5 mm^3, 0.01 mm^3 to 6 mm^3, 0.1 mm^3 to 0.5 mm^3, 0.1 mm^3 to 1 mm^3, 0.1 mm^3 to 2 mm^3, 0.1 mm^3 to 3 mm^3, 0.1 mm^3 to 4 mm^3, 0.1 mm^3 to 5 mm^3, 0.1 mm^3 to 6 mm^3, 0.5 mm^3 to 1 mm^3, 0.5 mm^3 to 2 mm^3, 0.5 mm^3 to 3 mm^3, 0.5 mm^3 to 4 mm^3, 0.5 mm^3 to 5 mm^3, 0.5 mm^3 to 6 mm^3, 1 mm^3 to 2 mm^3, 1 mm^3 to 3 mm^3, 1 mm^3 to 4 mm^3, 1 mm^3 to 5 mm^3, 1 mm^3 to 6 mm^3, 2 mm^3 to 3 mm^3, 2 mm^3 to 4 mm^3, 2 mm^3 to 5 mm^3, 2 mm^3 to 6 mm^3, 3 mm^3 to 4 mm^3, 3 mm^3 to 5 mm^3, 3 mm^3 to 6 mm^3, 4 mm^3 to 5 mm^3, 4 mm^3 to 6 mm^3, and 5 mm^3 to 6 mm^3).

The ablated tissue portion can have any combination of the dimensions described herein. For instance, in some non-limiting embodiments, the ablated tissue portion has at least one dimension that is less than about 2 mm and an area dimension that is less than about 2 mm^2. In other embodiments, the ablated tissue portion has at least one dimension that is less than about 2 mm and a volumetric dimension that is less than about 6 mm^3. In yet other embodiments, the ablated tissue portion has at least one dimension that is less than about 2 mm and an area dimension that is less than about 2 mm^2 and a volumetric dimension that is less than about 6 mm^3. In some embodiments, the ablated tissue portion has an aerial dimension that is less than about 2 mm^2 and a volumetric dimension that is less than about 6 mm^3.

Ablation Kit

The invention also features kits for skin tightening and/or for treating diseases, disorders, and conditions that would benefit from skin restoration or tightening. Kits may include one or more tips and or cartridges including skin-penetrating components with one or more ablation members (e.g., coring needles) configured for penetration into and retraction from skin as well as a main body of the apparatus configured for handheld operation. As described above, tips in a kit may be configured to be detachably attached to the main body. The ablation members of a tip may be configured to be in fluid communication with a pressure generating source (e.g., a vacuum pump), such as when a tip is attached to a main body.

Kits of the invention may include additional components, such as a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids); a pressure generating source; mechanisms for actuation, translation, and position detection (e.g., one or more pneumatic, electromagnetic, and/or

piezoelectric actuators; driving wheels; and/or a camera); a base unit; and a skin positioning apparatus (e.g., tensioning rods). In addition, kits of the invention may include any other useful components, such as instructions on how to use the device(s), an air blower, a heating element (e.g., a heat gun or heating pad), one or more therapeutic agents (e.g., any described herein, such as an anticoagulative and/or procoagulative agent, and optionally in combination with a useful dispenser for applying the therapeutic agent, such as a brush, spray, film, ointment, cream, lotion, or gel), one or more wound cleansers (e.g., including any antibiotic, antimicrobial, or antiseptic, such as those described herein, in any useful form, such as a brush, spray, film, ointment, cream, lotion, or gel), one or more compression dressings, one or more closures (e.g., bandage, hemostats, sutures, or adhesives), one or more debriding agents, one or more adhesives (e.g., any described herein), one or more cosmetics (e.g., as described herein), and/or other suitable or useful materials.

Kits of the invention may also feature one or more replacement tips (e.g., one or more tips of a single configuration or of different configurations). Kits may be packaged with the tip in sterile form and with instructions for applying the tip to the main body of an apparatus of the invention.

Kits of the invention may include any of the components provided herein (e.g., tips, reservoir containing modules, and cables) in any number. Kits may also have or be designed to have any of the configurations described herein.

Ablation Method and Treatment

Any of the apparatuses, systems, kits, and methods of the invention may be used for non-thermal tissue ablation. The apparatuses, systems, kits, and methods of the invention can be applied to treat one or more skin regions. In particular embodiments, these regions are treated with one or more procedures to improve skin appearance. Accordingly, the apparatuses, systems, kits, and methods herein can be useful for skin rejuvenation (e.g., removal of pigment, veins (e.g., spider veins or reticular veins), glands (e.g., sebaceous glands or sweat glands), hair follicles, and/or vessels in the skin) or for treating acne, allodynia, blemishes, ectopic dermatitis, hyperpigmentation, hyperplasia (e.g., lentigo or keratosis), loss of translucency, loss of elasticity, melasma (e.g., epidermal, dermal, or mixed subtypes), photodamage, rashes (e.g., erythematous, macular, papular, and/or bullous conditions), psoriasis, rhytides (or wrinkles, e.g., lateral canthal lines ("crow's feet"), age-related rhytides, sun-related rhytides, or heredity-related rhytides), sallow color, scar contracture (e.g., relaxation of scar tissue), scarring (e.g., due to acne, surgery, or other trauma), skin aging, skin contraction (e.g., excessive tension in the skin), skin irritation/sensitivity, skin laxity (e.g., loose or sagging skin or other skin irregularities), striae (or stretch marks), tattoo removal, vascular lesions (e.g., angioma, erythema, hemangioma, papule, port wine stain, rosacea, reticular vein, or telangiectasia), or any other unwanted skin irregularities.

Such treatments may be applied to any part or parts of the body, including the face (e.g., eyelid, cheeks, chin, forehead, lips, or nose), neck, chest (e.g., as in a breast lift), arms, hands, legs, abdomen, and/or back. Accordingly, the apparatuses, systems, kits, and methods of the invention can be configured to be useful for treatment of regions of the body with different sizes and geometries. For example, tips having ablation member arrays of different sizes, geometries, and arrangements may be included in a kit of the invention to allow for treatment of both facial (e.g., with tips having small arrays of

regular or irregular geometries) and abdominal regions (e.g., with tips having large arrays of regular geometries). Such arrangements and configurations can include any useful shape (e.g., linear, curved, or stellate), size, geometry, depth, and/or other characteristics.

Treatment methods may involve forming a plurality of ablated tissue portions by contacting the ablation members (e.g., needles, such as hollow coring needles) of the tip to the skin of a subject and removing the ablated tissue portions from the skin. Penetration into the skin by the ablation members may create small wounds (e.g., microwounds) and/or holes and so effectively reduce tissue volume and/or improve tissue quality upon healing. For example, forming a series of ablated tissue portions (e.g., ablation of about 10% of the total skin area) and corresponding holes in a high laxity skin region and subsequent compression of the skin region to close the holes may promote the growth of new skin (e.g., improved tissue). Healing of the tissue under compression allows for the existing tissue to span the gap introduced by the removal of an ablated tissue portion, thereby reducing the skin volume and area (e.g., by tightening the skin).

Prior to contacting the skin with the ablation members, the skin may be gripped, lifted, and/or positioned to facilitate treatment. For example, tensioning rods may be used to apply a compressive force to the skin as provided in Figure 10. Such a force may be applied throughout the treatment.

Any beneficial area or volumetric fraction of the skin region can be removed. For example, between about 5% to about 70% of tissue may be removed (e.g., as described herein). In some preferred embodiments, about 10% of the treatment area is removed.

Tissue can be removed from the treatment region with various hole density (i.e., the number of holes per unit area) corresponding to the number and geometry of ablation members included in the tip or tips used and the number of applications of the tip or tips to the treatment region. Different hole densities may be desirable for different regions of skin and for different conditions and may be achieved using different tips. For example, 15 holes corresponding to the size of a 19 gauge needle and their corresponding ablated tissue portions may be created in a given treatment area by actuation of a single 19 gauge needle 15 times, or by actuating an array having five 19 gauge needles three times. Spacing the same number of holes further apart will result in a lower hole density per unit area. For example, 15 holes may be created within a 0.5 mm by 0.3 mm region or within a 5 mm by 3 mm region. In particular embodiments, apparatuses, systems, kits, and methods of the invention (e.g., any described herein) are configured to provide from about 10 to about 10000 ablated tissue portions per cm^2 area of the skin region (e.g., as described herein). The array of holes created by ablation of the skin may be created in any beneficial pattern within the skin region. For example, a higher density and/or smaller spacing of tissue portions and corresponding holes can be ablated in the skin in the center of a pattern or in thicker portions of the skin. A pattern may be random or include one or more of staggered rows and/or blocks, parallel rows and/or blocks, a circular pattern, a spiral pattern, a square or rectangular pattern, a triangular pattern, a hexagonal pattern, a radial distribution, or a combination of one or more such patterns. The pattern may arise from the use of one or more tips with one or more configurations and numbers of ablation members applied in any ordered or disordered manner. Modifications to the average length, width, shapes, and/or other characteristics of one or more ablation members used to treat a skin region may also result in a specific pattern of holes in the skin. Such patterns may be optimized to

promote unidirectional, non-directional, or multidirectional contraction or expansion of skin (e.g., in the x-direction, y-direction, x-direction, x-y plane, y-z plane, x-z plane, and/or xyz-plane), such as by modifying the average length, depth, width, density, orientation, and/or spacing between ablations.

Any useful portion of the skin and/or underlying structures (e.g., SMAS) can be ablated. Tissue portions created by penetration into the skin with the ablation members of a tip may include epidermal tissue, dermal tissue, and/or cells or tissue proximal to the dermal/fatty layer boundary (e.g., stem cells). In some embodiments, a tissue portion may have a length that corresponds to a typical total depth of the skin layer (e.g., epidermal and dermal layers). The total depth of the epidermal and dermal layers may vary based on the region and age of the body being treated. In some instances, the depth of the epidermal layer is between about 0.01 mm to 0.2 mm, and/or the depth of the dermal layer is between about 0.3 mm to 6.0 mm. The total depth of the skin layer (e.g., epidermal and dermal layers) may be between about 0.3 mm and 6.2 mm, corresponding to a possible tissue portion having a length between about 0.3 mm and 6.2 mm (e.g., between about 0.3 mm and 0.6 mm, 0.3 mm and 0.9 mm, 0.3 mm and 1.5 mm, 0.3 mm and 2.0 mm, 0.3 mm and 2.5 mm, 0.3 mm and 3.0 mm, 0.3 mm and 3.5 mm, 0.3 mm and 4.0 mm, 0.3 mm and 4.5 mm, 0.3 mm and 5.0 mm, 0.3 mm and 5.5 mm, 0.3 mm and 6.0 mm, 0.3 mm and 6.2 mm, 0.6 mm and 0.9 mm, 0.6 mm and 1.5 mm, 0.6 mm and 2.0 mm, 0.6 mm and 2.5 mm, 0.6 mm and 3.0 mm, 0.6 mm and 3.5 mm, 0.6 mm and 4.0 mm, 0.6 mm and 4.5 mm, 0.6 mm and 5.0 mm, 0.6 mm and 5.5 mm, 0.6 mm and 6.0 mm, 0.6 mm and 6.2 mm, 0.9 mm and 1.5 mm, 0.9 mm and 2.0 mm, 0.9 mm and 2.5 mm, 0.9 mm and 3.0 mm, 0.9 mm and 3.5 mm, 0.9 mm and 4.0 mm, 0.9 mm and 4.5 mm, 0.9 mm and 5.0 mm, 0.9 mm and 5.5 mm, 0.9 mm and 6.0 mm, 0.9 mm and 6.2 mm, 1.5 mm and 2.0 mm, 1.5 mm and 2.5 mm, 1.5 mm and 3.0 mm, 1.5 mm and 3.5 mm, 1.5 mm and 4.0 mm, 1.5 mm and 4.5 mm, 1.5 mm and 5.0 mm, 1.5 mm and 5.5 mm, 1.5 mm and 6.0 mm, 1.5 mm and 6.2 mm, 2.0 mm and 2.5 mm, 2.0 mm and 3.0 mm, 2.0 mm and 3.5 mm, 2.0 mm and 4.0 mm, 2.0 mm and 4.5 mm, 2.0 mm and 5.0 mm, 2.0 mm and 5.5 mm, 2.0 and 6.0 mm, 2.0 mm and 6.2 mm, 2.5 mm and 3.0 mm, 2.5 mm and 3.5 mm, 2.5 mm and 4.0 mm, 2.5 mm and 4.5 mm, 2.5 mm and 5.0 mm, 2.5 mm and 5.5 mm, 2.5 mm and 6.0 mm, 2.5 mm and 6.2 mm, 3.0 mm and 3.5 mm, 3.0 mm and 4.0 mm, 3.0 mm and 4.5 mm, 3.0 mm and 5.0 mm, 3.0 mm and 5.5 mm, 3.0 and 6.0 mm, 3.0 mm and 6.2 mm, 3.5 mm and 4.0 mm, 3.5 mm and 4.5 mm, 3.5 mm and 5.0 mm, 3.5 mm and 5.5 mm, 3.5 and 6.0 mm, 3.5 mm and 6.2 mm, 4.0 mm and 4.5 mm, 4.0 mm and 5.0 mm, 4.0 mm and 5.5 mm, 4.0 and 6.0 mm, 4.0 mm and 6.2 mm, 4.5 mm and 5.0 mm, 4.5 mm and 5.5 mm, 4.5 and 6.0 mm, 4.5 mm and 6.2 mm, 5.0 mm and 5.5 mm, 5.0 mm and 6.0 mm, 5.0 mm and 6.2 mm, 5.5 mm and 6.0 mm, 5.5 mm and 6.2 mm, or 6.0 mm and 6.2 mm). In some instances, the average total depth of the skin layer (e.g., epidermal and dermal layers) may be about 1.5 mm, about 3 mm, or about 6 mm.

In some instances, it may be desirable to configure apparatuses, systems, kits, and methods of the invention to provide one or more tissue portions that do not include significant amounts of subcutaneous tissue, or, in other instances, to provide tissue portions that do include significant amounts of subcutaneous tissue. Electronic and/or physical mechanisms may be used to control the depth of an ablation (i.e., the penetration into the skin by the ablation members) and the corresponding size of an ablated tissue portion and hole. For example, an apparatus may include one or more stop arrangements (e.g., one or more collars and/or sleeves); one or more scroll wheels, buttons, dials, toggles, or other

components to physically retract the skin-penetrating component; a vibrating arrangement (e.g., a piezoelectric element, a solenoid, a pneumatic element, or a hydraulic element) that mechanically couples to at least one ablation member (e.g., to promote insertion of one or more ablation members into the skin region, such as by providing an amplitude of vibration in the range of about 50-500 μm or by providing a frequency of the induced vibrations to be between about 10 Hz and about 10 kHz); a z-actuation mechanism (e.g., a pneumatic, electromagnetic, or piezoelectric actuator or a motor with a cam); and/or one or more sensors (e.g., force sensors, optical sensors, laser fibers, photodetectors, and/or position sensors) in communication with one or more needles, pins, actuators, valves, pressure generating sources, and/or user interfaces to detect the position of ablation members and/or the position of the apparatus relative to the treated skin portion.

Healing of Skin Regions After Removal of Ablated Tissue Portions

A compressive wound dressing may be applied after ablation to promote skin tightening. A hole created by penetration into the skin with the ablation members of the tip may be closed with a suture, staple, dressing, tunable dressing, glue, sealant, and/or other compression retaining devices. Such dressings may be applied in the proximity of the treatment zone or at a distant site provided that it conveys the appropriate mechanical force on the treatment site (e.g., by gluing the surrounding area into a compressed state, which then confers compression to the treated area). Wound dressings may be applied in a preferred direction to promote healing in a particular direction or along particular axes (Figure 16). For example, healing may be engineered to occur along Langer lines. In some embodiments, a photochemical agent may be applied to the tissue and the tissue then irradiated with visible light to produce a seal.

Examples

Example 1: Stamping Mechanism

In one example, a system of the invention includes the apparatus, a reservoir for collecting waste materials (e.g., tissue, blood, and/or interstitial fluids), a low pressure generating source, a skin gripper and/or lifter, a base unit, and a cable coupling the apparatus and the base unit. Figure 17 shows a schematic representation of the components of this system. The handheld apparatus has a separate module disposed between the tip and the main body that includes reservoir **60** for waste collection. This module is detachably attachable to both the tip and the main body via a quick-release mechanism. Both the body of the tip and the waste module are made of plastic materials and are meant to be disposed of after a single use (e.g., after treatment of a distinct region of the skin of a subject) either as a single unit or as two separated components.

Skin-penetrating component **20** of the tip includes an array of hollow, cylindrical, metallic coring needles that are sharpened and open at their tips. The needles are coupled to a substrate and are further coupled to plastic tubing **24** that establishes fluid communication between the needles, reservoir, and low pressure generating source **70** of the system. This low pressure generating source is a scroll-type oil-free vacuum pump disposed in the base unit and separated from the reservoir and needles by a series of filters (e.g., stainless steel 0.2 μm membrane filters) to prevent aspiration of waste materials into

the device. A solenoid valve disposed in the main body of the apparatus allows for separation of the treatment site from the vacuum source without ceasing power supply to the vacuum pump. A user interface disposed on the main body of the apparatus permits a user to activate actuation mechanisms to drive needles into and across the skin as well as to activate the solenoid valve and thus provide suction to the treatment site. The user interface also indicates the number and configuration of needles in the array of the tip, the level of vacuum being supplied to the system and the powered status of the vacuum, the powered status of the apparatus, the mode of operation, and other useful information. The user interface of the main body receives signal from a user interface of the base unit via a cable coupling the apparatus and the base unit, and changes made in one user interface are reflected in the other. The user interface of the base unit includes a touch screen as well as various buttons to provide power to the vacuum source; actuation, translation, and position detection mechanisms of the apparatus; and control electronics **38**. The base unit receives electrical power from a wall unit and transmits power to components of the system via the cable coupling the base unit and the apparatus.

The main body includes the actuation mechanisms to drive needle action. Electromagnetic z-actuator **84** controls the timing and depth of needle penetration as well as the withdrawal of the needles, while electromagnetic x-actuator **82** controls the movement of the apparatus across the treatment surface. Separate buttons disposed on the main body operate the z- and x-actuators. The actuation mechanisms may be configured by the user interface of the base unit (e.g., the depth of penetration into the skin by the needles may be selected from a range of options; controlling the penetration depth may involve supplying electrical signals with different amplitudes to the actuator). Array gripper **22** provides a mechanical connection between the needle array and the actuation mechanisms.

Prior to treatment, the skin region may be sterilized, plucked, shaved, massaged, heated, cooled, treated with chemicals and/or bioactive agents, and/or otherwise prepared. The region of skin is positioned using skin positioning apparatus **40** that utilizes tensioning rods to apply a compressive force. System components are supplied with power, and the desired operating parameters are selected on either user interface (e.g., the depth of penetration by the needles). The skin-penetrating component is placed upon the surface of the skin and the z-actuator is activated to cause the needles to penetrate into the skin. Before the needles are retracted, the solenoid valve is activated and vacuum applied to the treatment area, removing tissue (e.g., ablated tissue portions) from within the needle and waste materials from the area and depositing tissue, blood, interstitial fluids, and/or any other debris within the reservoir. After the valve is closed, activation of the z-actuator causes the needles to withdraw from the skin. Subsequent activation of the x-actuator moves the apparatus to an adjacent treatment area, where the actions may be repeated. The amount of movement caused by activation of the x-actuator depends on the size of the area but may be selected to be as far as 50 mm. The tip and/or reservoir may be replaced at any point during the treatment, though preferably after the treatment of a given region is complete. The system may be configured to remove between about 5% and about 70% of tissue from the treatment area. For example, the system may be configured to remove about 10% of tissue from the treatment area. Accordingly, the system may be configured to produce a particular arrangement, density, and geometry of ablated tissue portions.

Figure 18A demonstrates this treatment method schematically. In the illustration, adjacent areas are treated with a system including a 2-dimensional needle array. This treatment method may be thought of as a "stamping" mechanism.

Example 2: Brushing Mechanism

In a second example, a system of the invention may have substantially the same components and configuration as a system designed to operate with a "stamping mechanism" but may include a translation mechanism in place of an x-actuator. Such a system is schematically represented in Figure 19. In this system, translation mechanism **86** features driving wheels which can be detachably coupled to the tip. The translation mechanism may be nearly continuously activated by means of a button disposed on the main body such that action of the device resembles a "brushing" motion (Figure 18B). The system operator may alternatively select to manually translate the device across the skin surface. Manual translation may be particularly useful in skin regions with small or irregular geometries such as on the face. The system further includes a position detection mechanism (i.e., an optical tracking mechanism) to assist the operator in providing even treatment across a skin surface (Figure 18C). For example, the position detection mechanism may facilitate automatic operation of the apparatus by detecting the distance between the previous needle insertion and the current device position and activating penetration into the skin by the needles when the device has reached the desired position. The system may also include a camera configured to transmit images to a viewing station such as a computer of the base unit. The camera is disposed on the main body of the apparatus and assists the operator in selecting regions for treatment and translating the apparatus across the region.

Example 3: Treatment of skin laxity and/or rhytides in the face

An apparatus or system of the invention may be used to administer treatment to the skin of a subject. Treatment may be performed outside of an operating room environment, thereby minimizing the cost of treatment.

The system used for treatment of the subject may be any of those described herein. For example, the system may be that of Example 1. For treatment of skin laxity in the face, a tip with a rectangular array of, e.g., 50 metallic coring needles may be selected for application to a treatment area of about 4 mm by about 9 mm. The selected needles may be 24 gauge needles and may be affixed to the tip structure by plastic molded around one end of each needle. The other needle ends may be, e.g., sharpened to fine points. The minimum distance between any two needles may be about 0.9 mm. With this tip, about 10% of the area of skin may be ablated upon activation of the device. The needles may be configured to penetrate about 2 mm into the skin. Thus, with this tip, ablated tissue portions may have volumes of about 0.2 mm^3.

As described above, the skin area may first be sterilized, treated with chemicals, and/or otherwise prepared for treatment. The tensioning rods of the optional skin positioning apparatus may subsequently be applied to the skin to position the skin and facilitate ease and effectiveness of device operation. Treatment may proceed with the driving of the needles into the skin by activation of the z-actuator, removal of waste materials by activation of suction, removal of the needles from the skin, and translation

of the device to an adjacent region for treatment. When sufficient tissue area has been treated, the device components may be powered off, any residual fluids and/or debris are removed, the skin surface and/or holes are cleaned and/or flushed with fluid, and a compressive wound dressing applied to the skin to cause the holes to close in a preferred direction. The tip and the separate reservoir module may be disposed of, and other components of the system may be sterilized.

The treatment may be rapid (e.g., less than 30 minutes), minimizing patient downtime and allowing treatment to be carried out as an outpatient procedure. Within days, a reduction in skin laxity and/or rhytides in the treatment area may be observed. The treatment should be more effective at reducing skin laxity, inducing skin tightening, and/or rejuvenating skin (i.e., improving skin architecture, reducing wrinkles) than energy-based skin treatment methods, such as laser, ultrasound, and radio frequency methods, while requiring similar or reduced patient downtime and environmental/training requirements. In certain applications and configurations, the treatment may also allow deeper tissue ablation than is possible with lasers, for example, to permit the treatment of scars and the removal of sub-dermal tissue layers.

Other Embodiments

All publications, patent applications, and patents mentioned in this specification are herein incorporated by reference.

Various modifications and variations of the described apparatuses, systems, kits, and methods of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific desired embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention are intended to be within the scope of the invention.

Claims

1. An apparatus for non-thermal tissue ablation comprising:
    a) a main body configured for handheld operation, and
    b) a tip comprising a skin-penetrating component comprising one or more ablation members, wherein said tip is detachably attached to said main body and said ablation members are configured for penetration into and retraction from skin.

2. The apparatus of claim 1, wherein said one or more ablation members are selected from the group consisting of needles, drill bits, abrading elements, punches, blades, fluid jets, and probes.

3. The apparatus of claim 2, wherein said ablation members are needles.

4. The apparatus of claim 3, wherein said needles are hollow coring needles.

5. The apparatus of any one of claims 2 to 4, wherein one end of said needles is sharpened.

6. The apparatus of any one of claims 1 or 5, wherein said ablation members are configured to be in fluid communication with a pressure generating source.

7. The apparatus of any one of claims 1 to 6, wherein said main body further comprises a user interface.

8. The apparatus of any one of claims 1 to 7, wherein said ablation members are arranged in a 1-dimensional array.

9. The apparatus of any one of claims 1 to 8, wherein said ablation members are arranged in a 2-dimensional array.

10. The apparatus of any one of claims 1 to 9, wherein said skin-penetrating component comprises 1-100 ablation members.

11. The apparatus of claim 10, wherein said skin-penetrating component comprises 3-50 ablation members.

12. The apparatus of any one of claims 1 to 11, wherein said ablation members are spaced about 0.1 mm to about 5 mm apart.

13. The apparatus of claim 12, wherein said ablation members are spaced about 0.5 mm to about 2 mm apart.

14. The apparatus of any one of claims 1 to 13, wherein one or more of said ablation members comprise one or more holes.

15. The apparatus of any one of claims 1 to 14, wherein said ablation members are metallic.

16. The apparatus of any one of claims 2 to 5, wherein said needles are 19-26 gauge needles.

17. The apparatus of claim 16, wherein said needles are 22 or 24 gauge needles.

18. The apparatus of any one of claims 1 to 17, wherein said apparatus is configured to provide an ablated tissue portion having a change in width as a function of depth.

19. The apparatus of claim 18, wherein said change in width is between about 100 μm and about 500 μm as a function of depth.

20. The apparatus of claim 18, wherein the width to depth ratio of said ablated tissue portion is between about 1:0.3 and about 1:75.

21. The apparatus of any of claims 1 to 20, wherein said ablation members have a width at their widest points of about 0.01 mm and about 2 mm.

22. The apparatus of any one of claims 1 to 21, wherein the minimum distance between said ablation members is between about 0.1 mm and about 50 mm.

23. The apparatus of any one of claims 1 to 22, wherein said apparatus is configured to remove about 5% to about 70% of tissue within a treatment area.

24. The apparatus of claim 23, wherein said apparatus is configured to remove about 10% of tissue within a treatment area.

25. The apparatus of claim 24, wherein said ablation members are 24 gauge needles.

26. The apparatus of any one of claims 1 to 25, further comprising an actuation mechanism for driving penetration into skin by said ablation members, wherein said actuation mechanism is mechanically or electrically coupled to said ablation members.

27. The apparatus of claim 26, wherein said actuation mechanism is configured to drive penetration into the skin by said ablation members to a depth of about 0.1 mm to about 15 mm.

28. The apparatus of claim 27, wherein said actuation mechanism is configured to drive penetration into the skin by said ablation members to a depth of about 10 mm to about 15 mm.

29. The apparatus of claim 27, wherein said actuation mechanism is configured to drive penetration into the skin by said ablation members to a depth of about 2 mm to about 5 mm.

30. The apparatus of any one of claims 26 to 29, wherein said actuation mechanism is configured to drive penetration into the skin by said ablation members with a force of about 0.5 N to about 20 N per ablation member.

31. The apparatus of any one of claims 26 to 30, wherein said actuation mechanism is selected from the group consisting of a pneumatic actuator, an electromagnetic actuator, a motor with a cam, a motor with a lead screw, and a piezoelectric actuator.

32. The apparatus of any one of claims 1 to 31, further comprising a translating mechanism for driving said ablation members across skin.

33. The apparatus of claim 32, wherein said translating mechanism comprises wheels or rods.

34. The apparatus of any one of claims 1 to 31, further comprising an actuation mechanism for driving said ablation members across skin, wherein said actuation mechanism is mechanically or electrically coupled to said ablation members.

35. The apparatus of claim 34, wherein said actuation mechanism is selected from the group consisting of a pneumatic actuator, an electromagnetic actuator, a motor with a cam, a motor with a lead screw, and a piezoelectric actuator.

36. The apparatus of any one of claims 26 to 35, wherein said actuation or translating mechanism is activated by one or more activators.

37. The apparatus of claim 36, wherein said one or more activators are independently selected from the group consisting of a toggle, a spin-wheel, a dial, a button, a screw, a switch, a cursor, and a key.

38. The apparatus of any one of claims 1 to 37, further comprising a position detection mechanism.

39. The apparatus of any one of claims 1 to 38, further comprising a release mechanism for detaching said tip.

40. The apparatus of any one of claims 1 to 39, wherein said tip is designed for a single use.

41. The apparatus of any one of claims 1 to 40, wherein said apparatus is battery operated.

42. The apparatus of any one of claims 1 to 41, further comprising a pressure generating source.

43. The apparatus of claim 42, wherein said pressure generating source is capable of producing high pressure.

44. The apparatus of claim 42, wherein said pressure generating source is capable of producing low pressure.

45. The apparatus of claim 44, wherein said pressure generating source produces vacuum.

46. The apparatus of any one of claims 42 to 45, wherein said pressure generating source is disposed within the main body.

47. The apparatus of any one of claims 42 to 45, wherein said pressure generating source is separate from said apparatus.

48. The apparatus of any one of claims 1 to 47, further comprising a reservoir for collecting waste materials.

49. The apparatus of claim 48, wherein said reservoir is separate from said apparatus.

50. The apparatus of claim 48, wherein said reservoir is disposed within the tip or within the main body.

51. A system for non-thermal tissue ablation, said system comprising:
    a) the apparatus of any one of claims 1 to 47, and
    b) a reservoir for collecting waste materials,
    wherein said apparatus is in fluid communication with said reservoir.

52. The system of claim 51, further comprising a base unit.

53. The system of claim 52, wherein said base unit comprises said reservoir.

54. The system of claim 51 or 52, wherein said apparatus comprises said reservoir.

55. The system of claim 54, wherein said main body of said apparatus comprises said reservoir.

56. The system of claim 54, wherein said tip comprises said reservoir.

57. The system of any one of claims 51 to 56, wherein said apparatus comprises a pressure generating source.

58. The system of any one of claims 52 to 56, wherein said base unit comprises a pressure generating source.

59. The system of any one of claims 52 to 58, wherein said base unit is electrically or wirelessly coupled to said apparatus.

60. The system of any one of claims 52 to 59, wherein said base unit comprises a power source.

61. The system of any one of claims 52 to 60, wherein said base unit comprises a user interface.

62. The system of any one of claims 52 to 61, further comprising a cable that couples said main body to said base unit.

63. The system of claim 62, wherein said cable comprises a power cord and a vacuum line.

64. The system of any one of claims 52 to 63, wherein said base unit comprises an actuation mechanism for driving penetration into skin by said ablation members.

65. The system of any one of claims 52 to 64, wherein said base unit comprises an actuation mechanism or a translation mechanism for driving said ablation members across skin.

66. The system of any one of claims 52 to 65, wherein said base unit comprises a position detection mechanism.

67. The system of any one of claims 51 to 66, further comprising a positioning apparatus for positioning skin.

68. A kit comprising a plurality of tips each comprising a skin-penetrating component comprising one or more ablation members, wherein said tips are configured for detachable attachment to a main body, and wherein said ablation members are configured for penetration into and retraction from skin.

69. The kit of claim 68, wherein said ablation members are needles.

70. The kit of claim 69, wherein said needles are hollow coring needles.

71. The kit of any one of claims 68 to 70, wherein each of said tips comprises the same number and configuration of ablation members.

72. The kit of any one of claims 68 to 70, wherein said tips comprise one or more different numbers or configurations of ablation members.

73. A kit comprising:

a) the apparatus of any one of claims 1 to 50, and

b) one or more tips each comprising a skin-penetrating component comprising one or more ablation members,

wherein said tips are configured for detachable attachment to said main body and said ablation members are configured for penetration into and retraction from skin. .

74. A kit comprising:

a) the system of any one of claims 51 to 67, and

b) one or more tips each comprising a skin-penetrating component comprising one or more ablation members,

wherein said tips are configured for detachable attachment to said main body and said ablation members are configured for penetration into and retraction from skin. .

75. The kit of any one of claims 68 to 74, wherein said ablation members are configured for fluid communication with a pressure generating source.

76. A method of treating a skin condition, comprising:

a) forming a plurality of ablated tissue portions by contacting the ablation members of the apparatus of any one of claims 1 to 50 or the system of any one of claims 51 to 67 to the skin of a subject, and

b) removing said plurality of ablated tissue portions from said skin.

77. The method of claim 76, wherein said removing comprises the use of a pressure generating source.

78. The method of claim 76 or 77, wherein penetration into skin by the ablation members forms said plurality of ablated tissue portions

79. The method of any one of claims 76 to 78, wherein said ablated tissue portions comprise the epidermis.

80. The method of any one of claims 76 to 79, wherein said ablated tissue portions comprise the dermis.

81. The method of any one of claims 76 to 80, wherein said ablated tissue portions comprise the skin and proximal tissue layers.

82. The method of claim 81, wherein said proximal tissue layers include fat or muscle.

83. The method of claim 82, wherein said muscle comprises the facial superficial muscular aponeurotic system.

84. The method of any one of claims 76 to 83, wherein said method promotes skin tightening, skin lifting, skin repositioning, or tissue area or volume reduction.

85. The method of any one of claims 76 to 84, wherein said ablated tissue portions are formed from skin of the face, chest, arms, hands, legs, abdomen, and/or back.

86. The method of claim 85, wherein said method comprises forming said ablated tissue portions from an eyelid, cheek, jowl, chin, forehead, lip, peri-oral area, or nose.

87. The method of claim 85, wherein said method results in a breast lift.

88. The method of any one of claims 76 to 86, wherein said skin condition is a tattoo, and wherein said method removes all or a portion of said tattoo.

89. The method of any one of claims 76 to 87, wherein said skin condition is selected from the group consisting of rhytides , hyperpigmentation, acne, allodynia, blemishes, ectopic dermatitis, hyperplasia, loss of translucency, loss of elasticity, melasma, photodamage, rashes, psoriasis, sallow color, scar contracture, scarring, skin aging, skin contraction, skin irritation, skin sensitivity, skin laxity, vascular lesions, striae, or any other unwanted skin features or irregularities.

90. The method of claim 89, wherein

a) said rhytides are selected from the group consisting of lateral canthal lines (“crow’s feet”), age-related rhytides, sun-related rhytides, or heredity-related rhytides;

b) said hyperplasia is selected from the group consisting of lentigo and keratosis;

c) said melasma is selected from the group consisting of epidermal, dermal, and mixed subtypes;

d) said rashes are selected from the group consisting of erthymatous, macular, papular, and/or bullous conditions;

e) said scar contracture comprises relaxation of scar tissue;

f) said scarring is selected from the group consisting of acne-related scars, surgical scars, and other traumatic scars;

g) said skin contraction comprises excessive tension in the skin;

h) said skin laxity comprises loose skin, sagging skin, and other skin irregularities;

i) said vascular lesions are selected from the group consisting of angioma, erythema, hemangioma, papule, port wine stain, rosacea, reticular vein, and telangiectasia; and

j) said other skin features or irregularities are selected from the group consisting of areas of fibrosis, sebaceous glands, sweat glands, hair follicles, and/or necrosis.

91. The method of any one of claims 76 to 88, wherein a compressive force is applied to said skin prior to treatment.

92. The method of claim 91, wherein said compressive force is applied by hand.

93. The method of any one of claims 76 to 92, wherein a non-compressive bandage is applied to said skin after removal of said plurality of ablated tissue portions.

94. The method of claim 93, wherein said non-compressive bandage is applied to promote healing in a preferred direction.

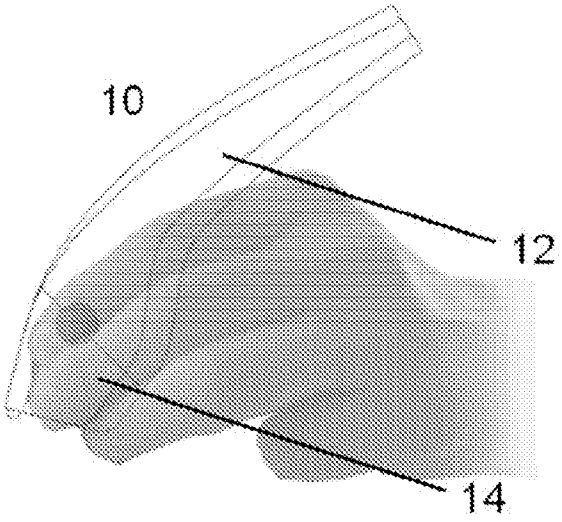


Fig. 1A

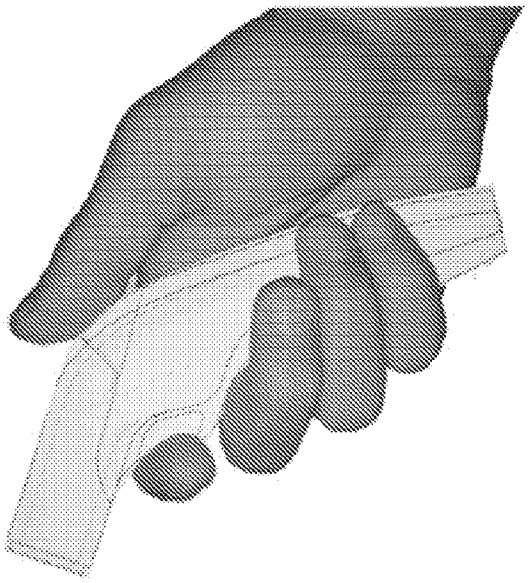
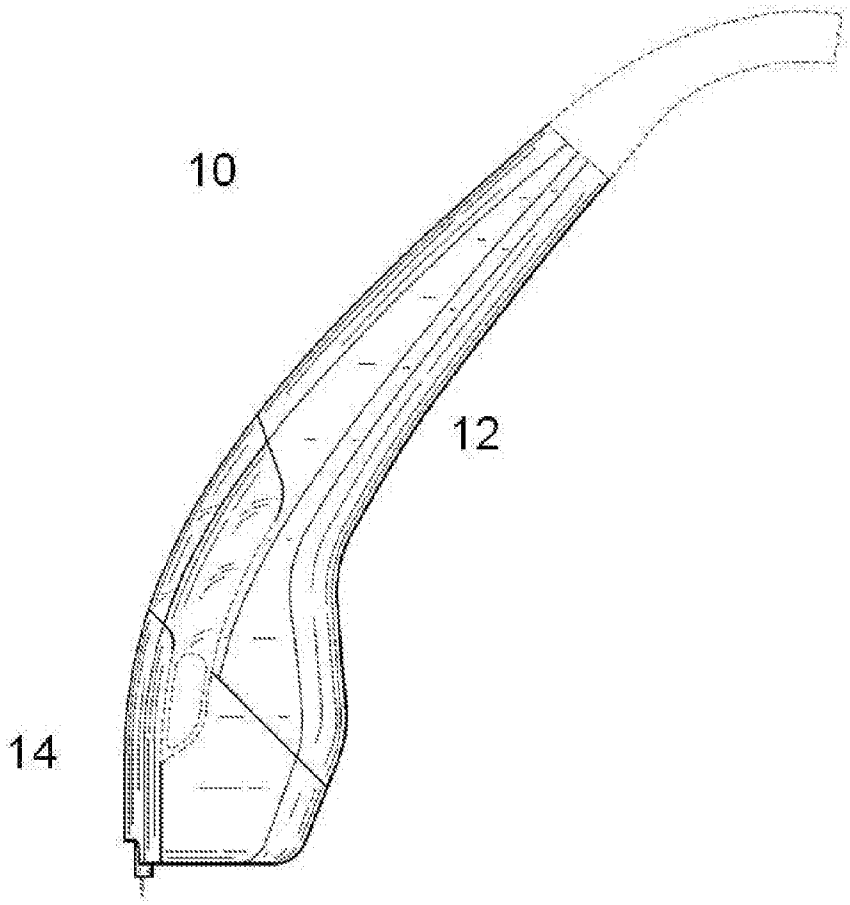


Fig. 1B

Fig. 2



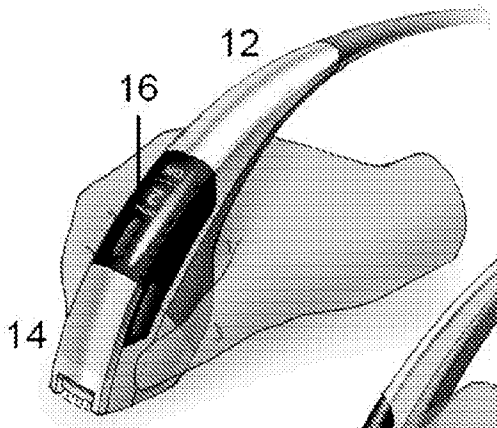


Fig. 3A

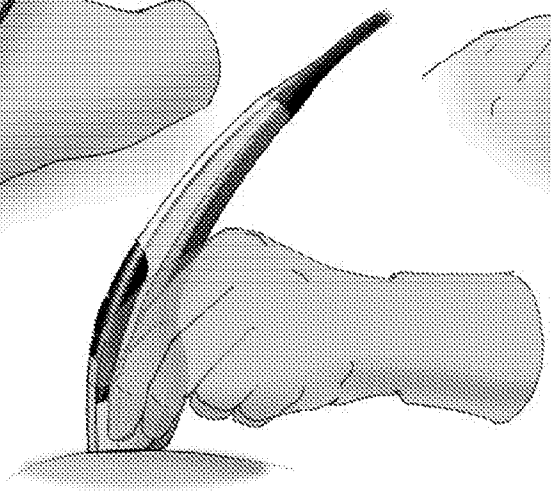


Fig. 3B

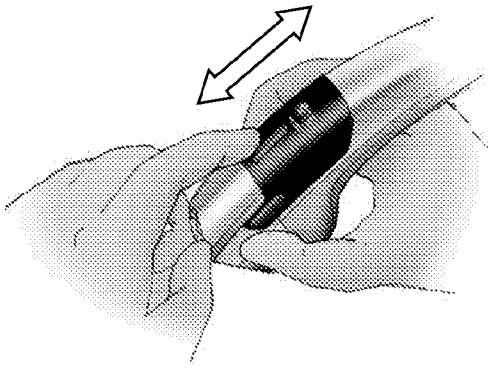
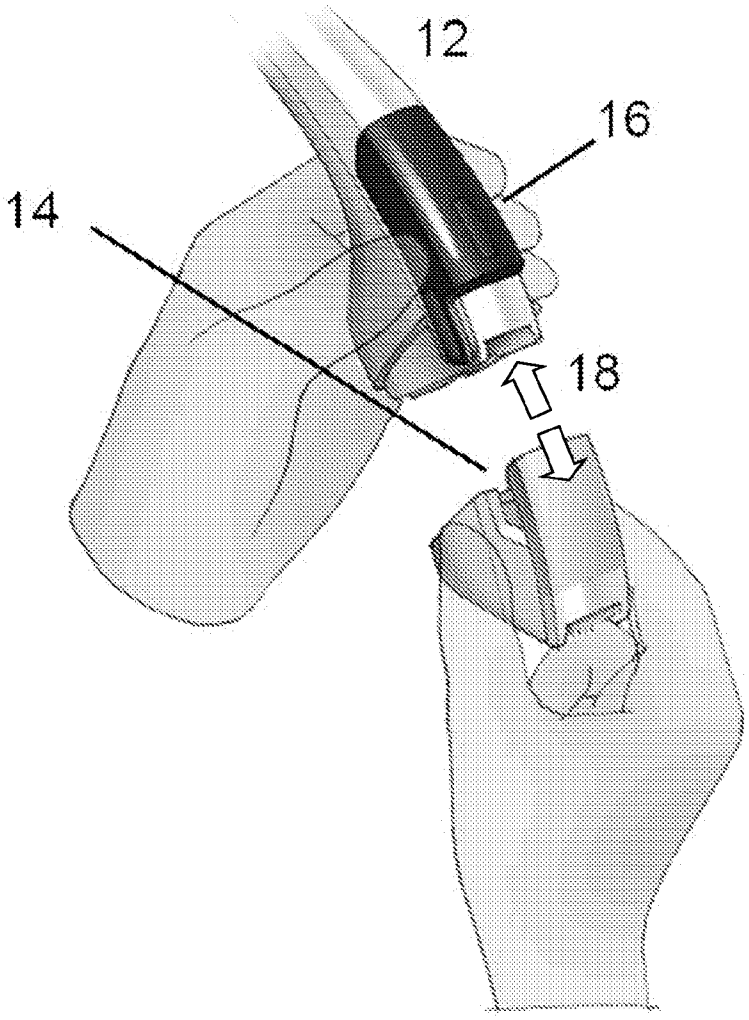


Fig. 3C

Fig. 4



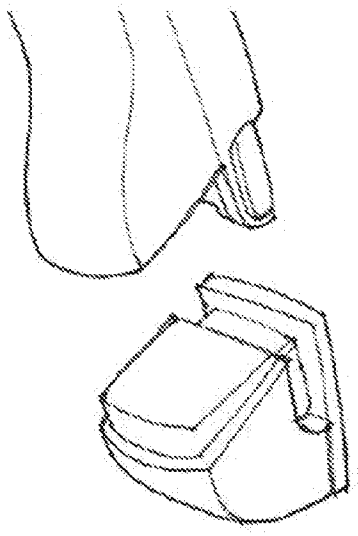


Fig. 5A

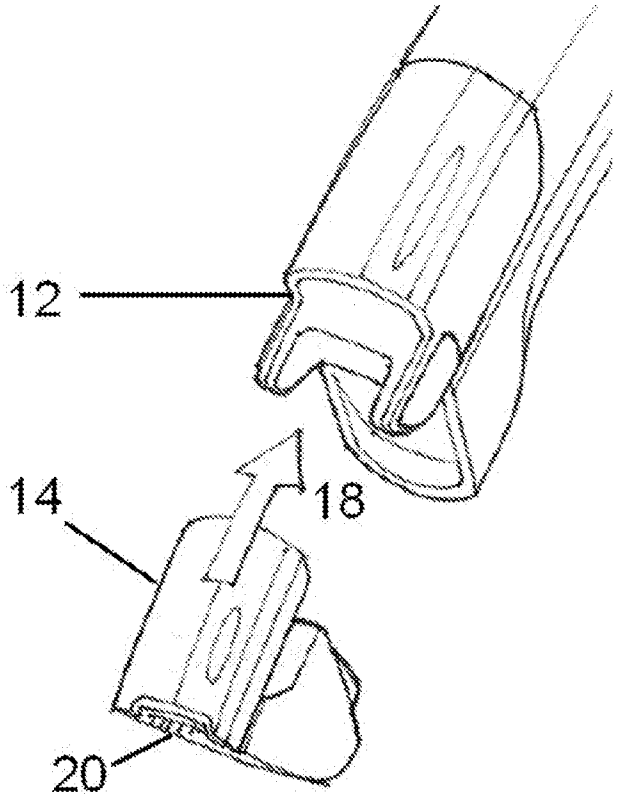


Fig. 5B

Fig. 6

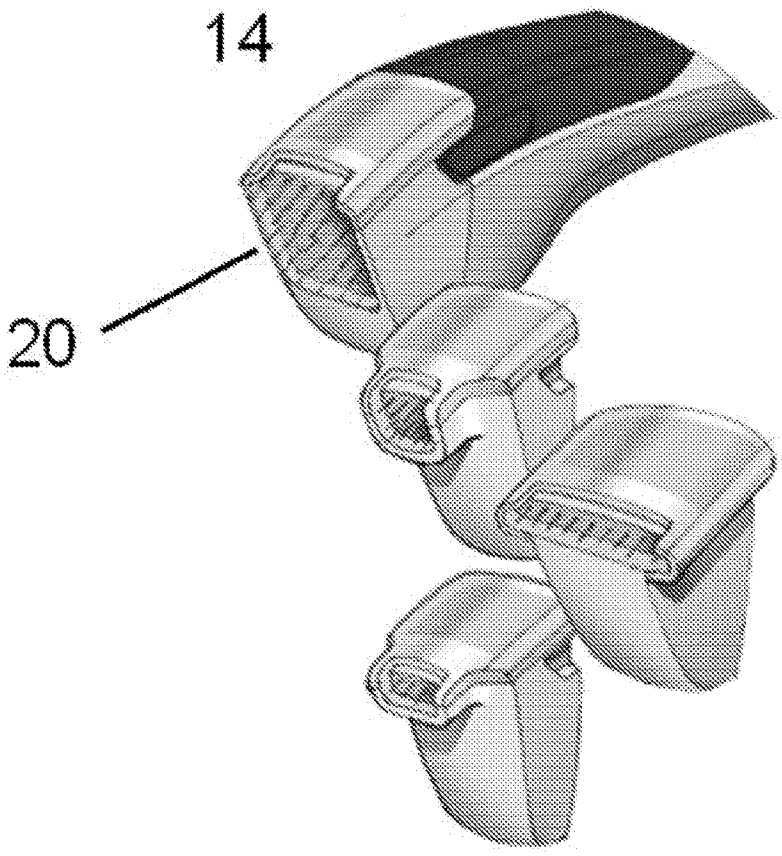


Fig. 7

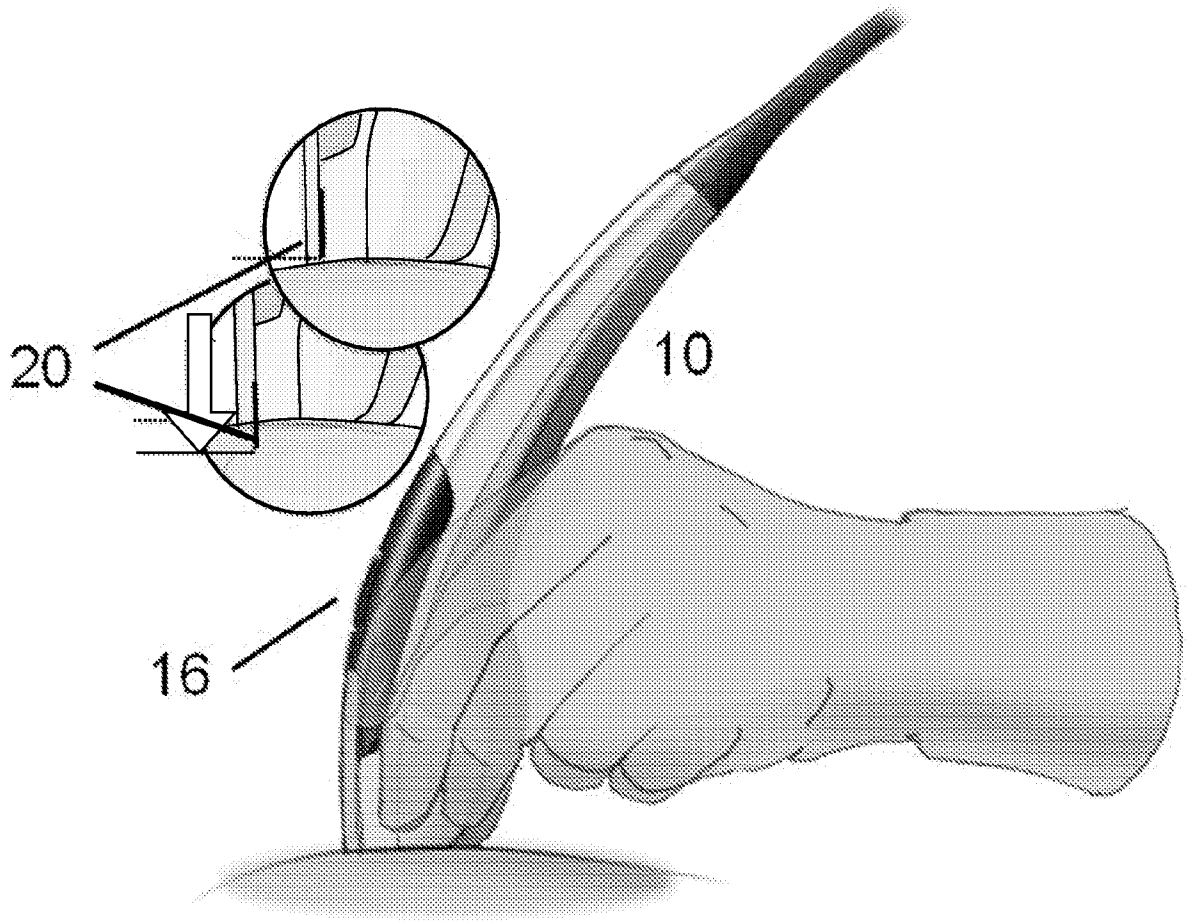
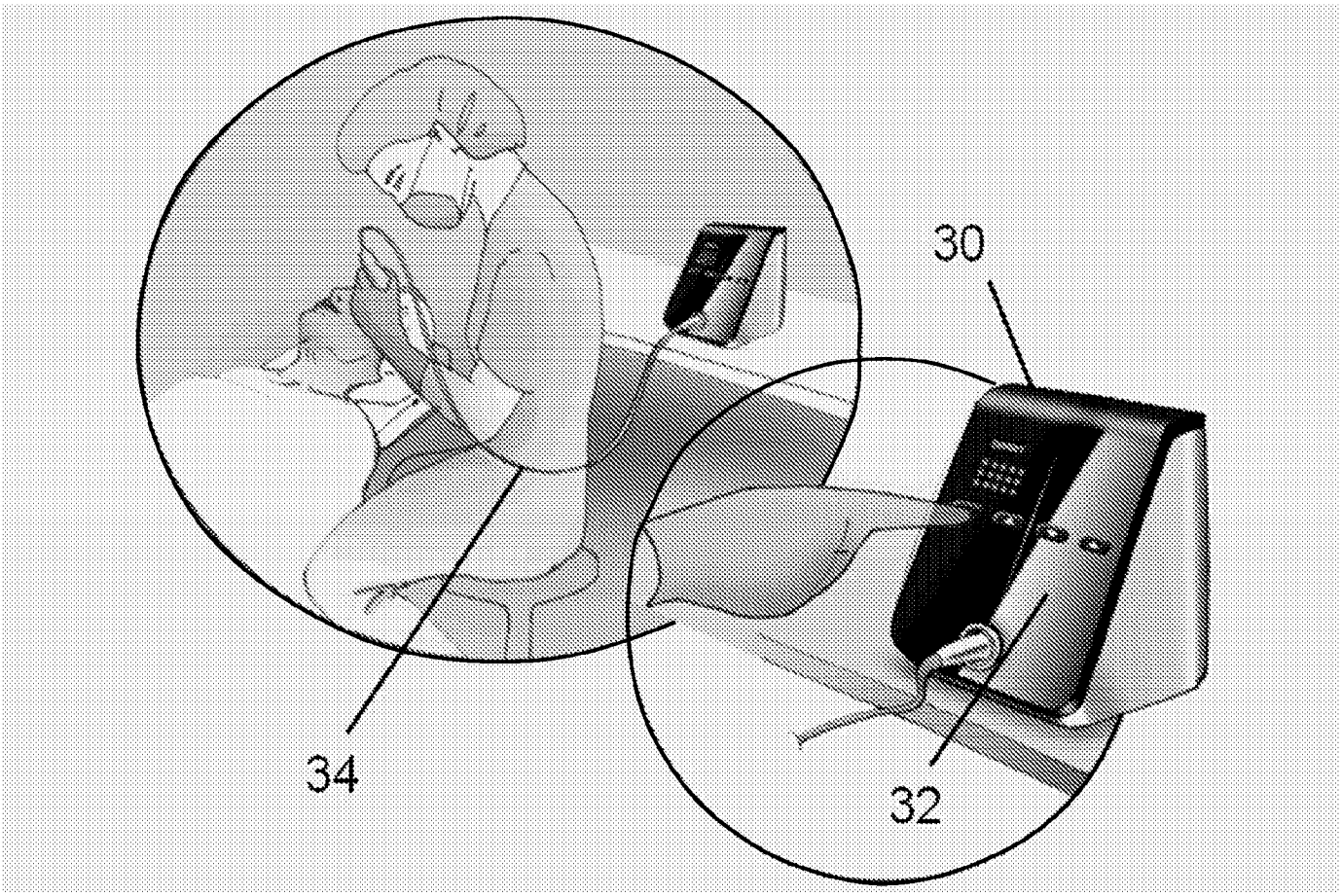


Fig. 8



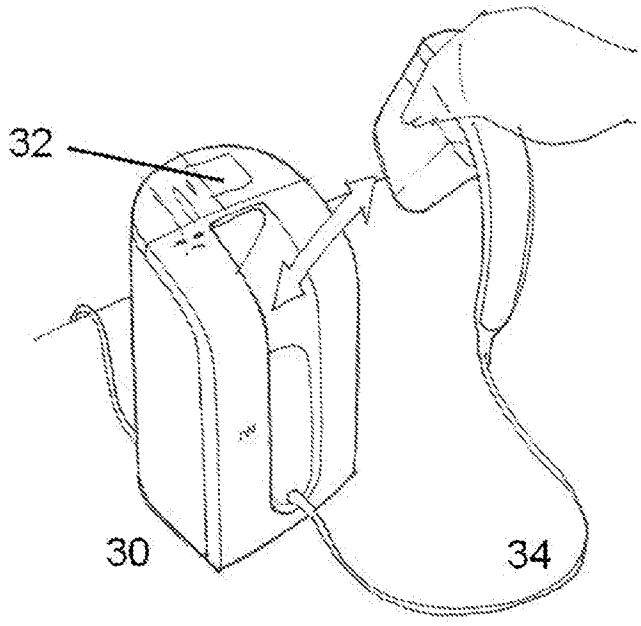


Fig. 9A

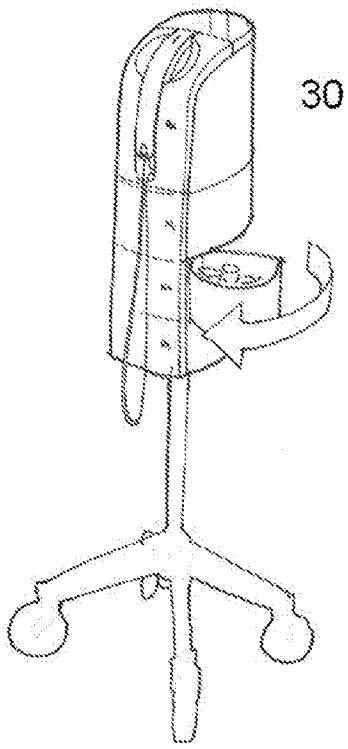


Fig. 9B

Fig. 10

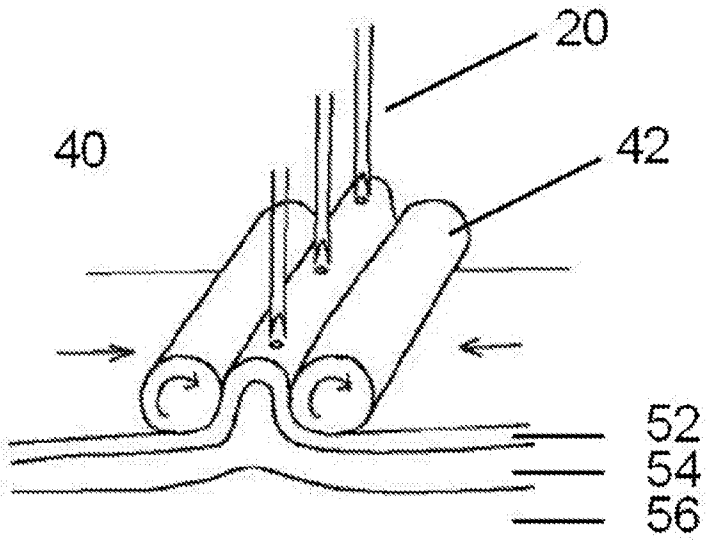


Fig. 11

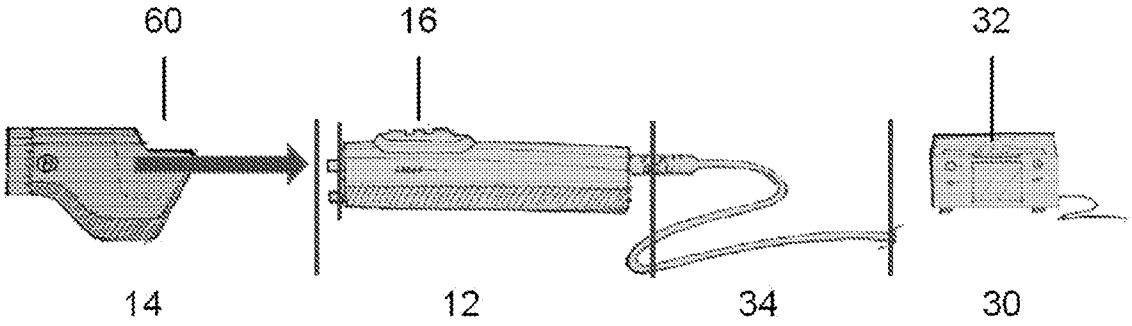


Fig. 12

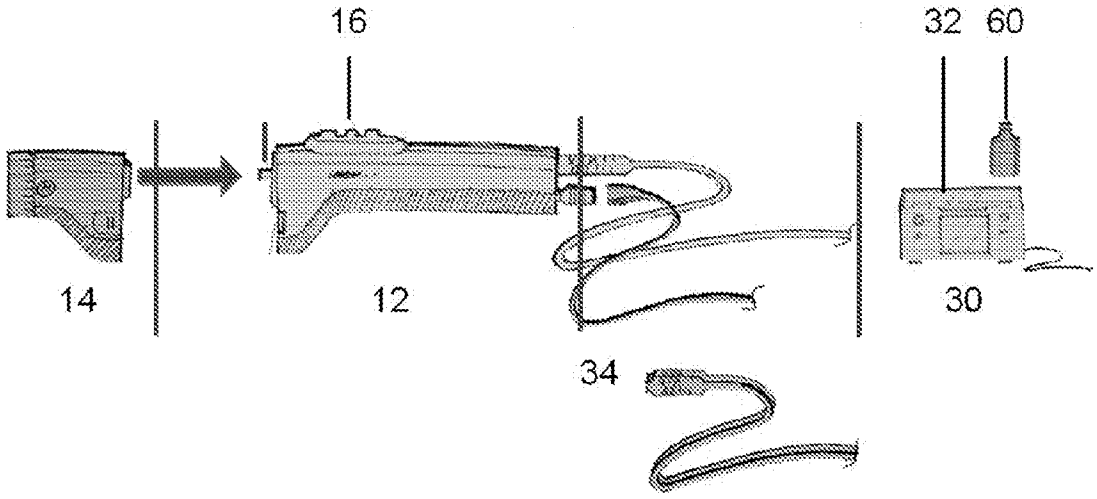


Fig. 13

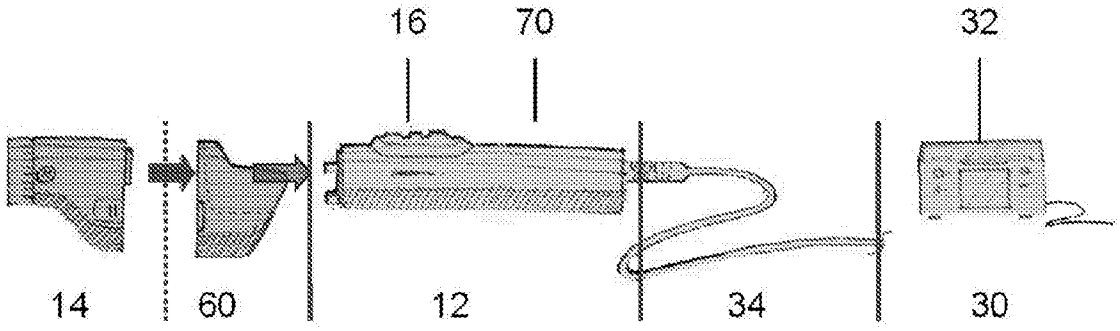


Fig. 14

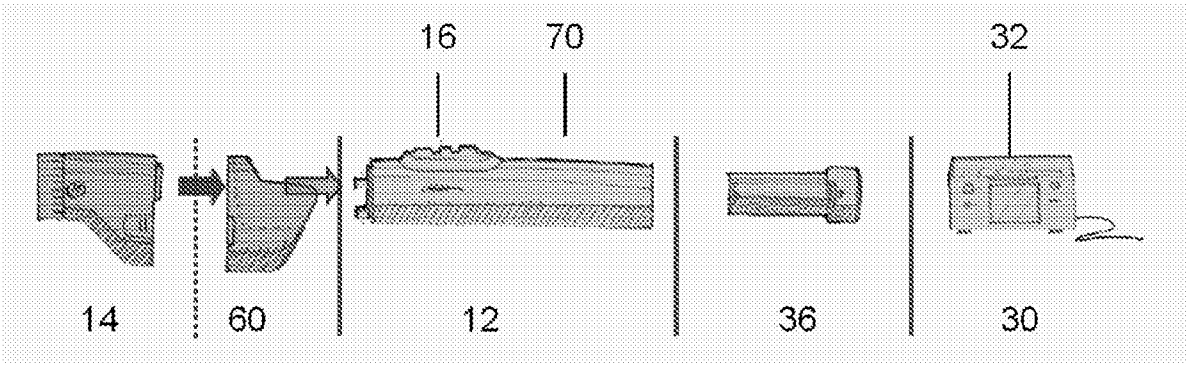


Fig. 15

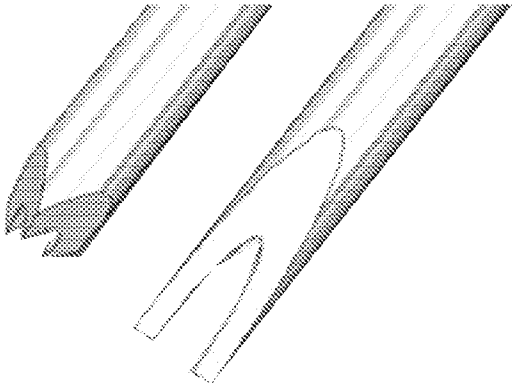


Fig. 16

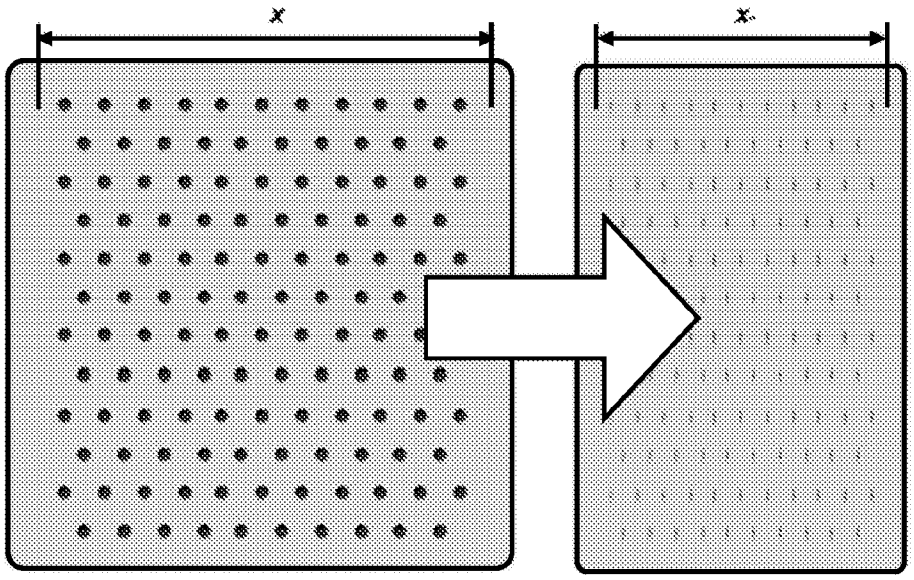
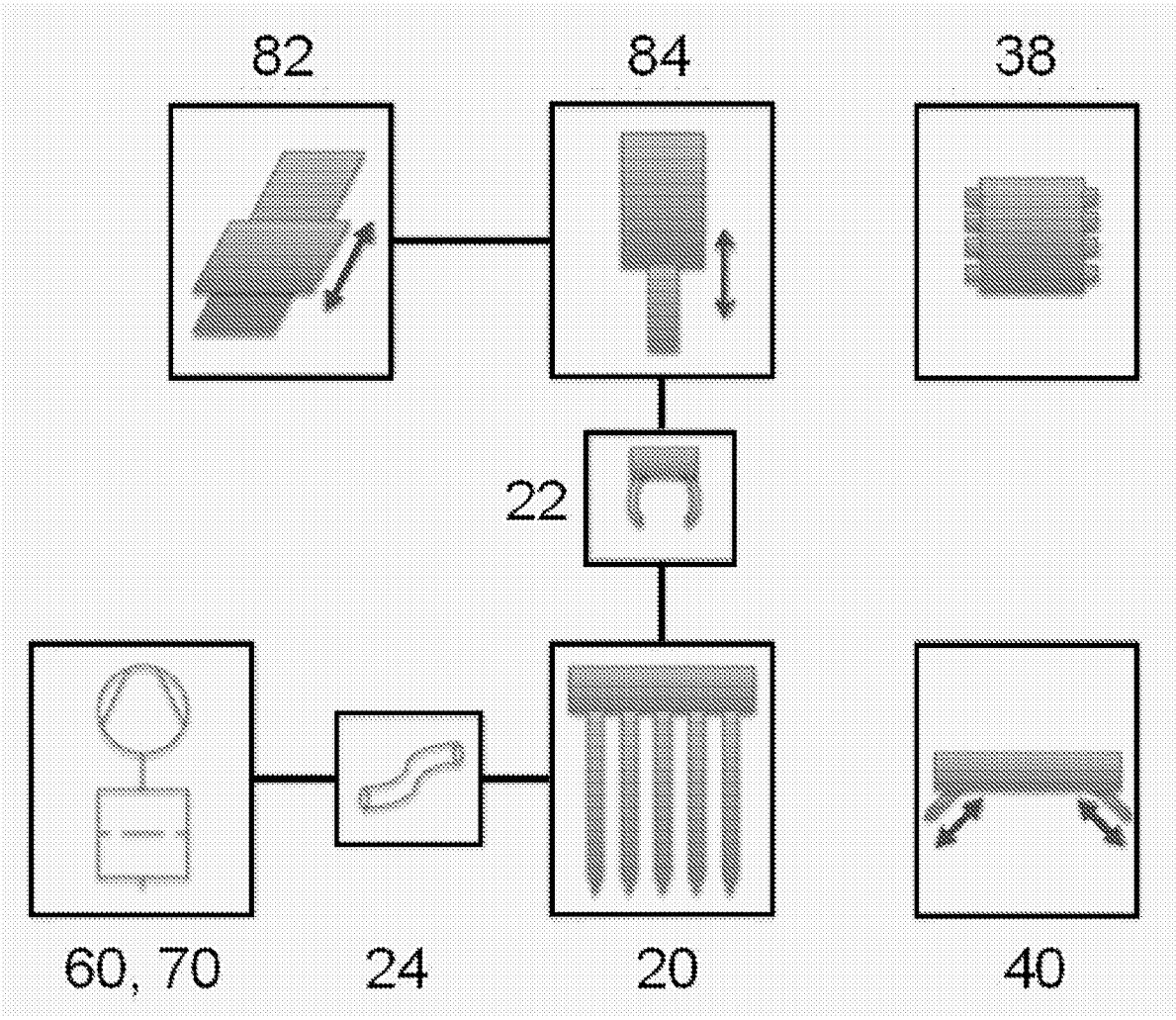


Fig. 17



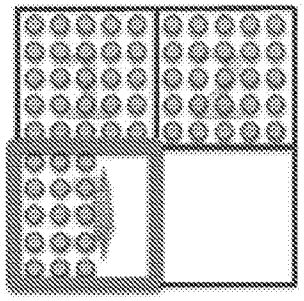


Fig. 18A

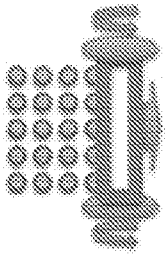


Fig. 18B

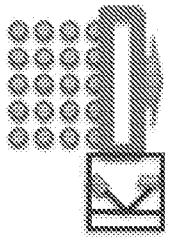
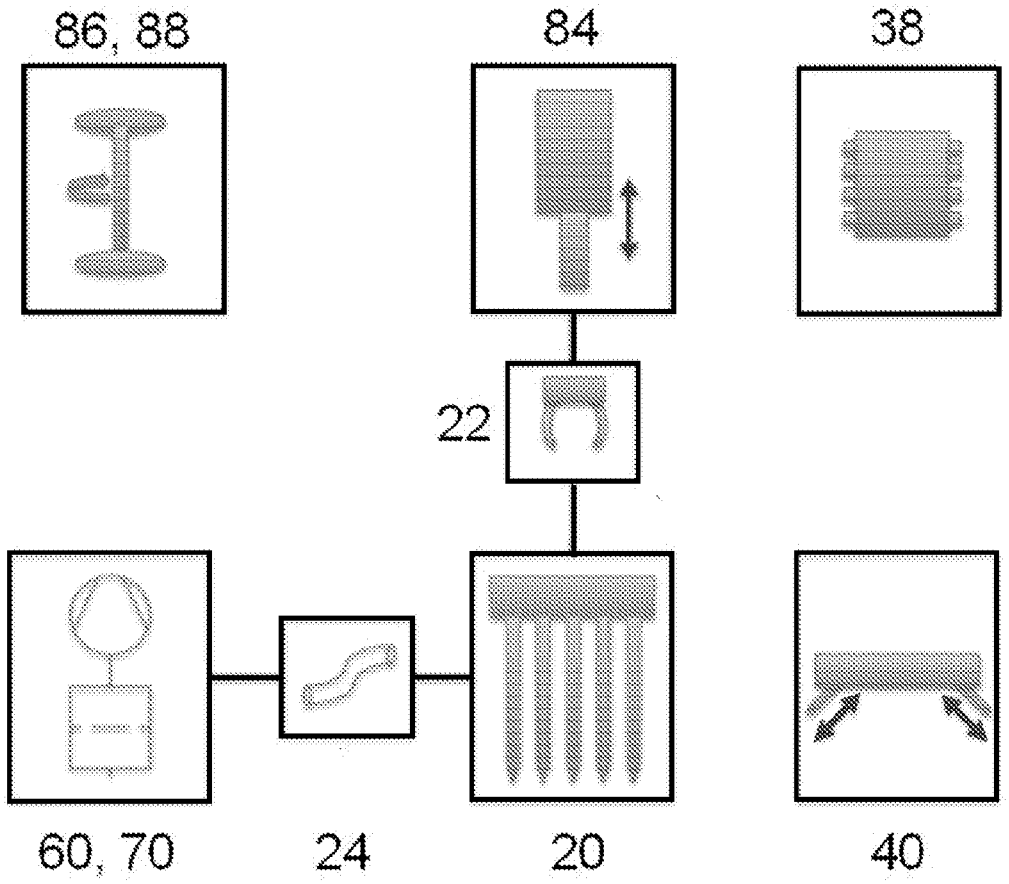


Fig. 18C

Fig. 19



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/060685

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61B 17/34 (2015.01)
CPC - A61B 17/34 (2015.12)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - A61B 17/00, 17/34, 17/39, 17/50, 18/00, 18/02; A61F 7/00; A61M 5/00, 5/31; A61N 5/00, 5/06 (2015.01)
CPC - A61B 17/00, 17/34, 17/39, 17/50, 18/00, 18/02; A61F 7/00;
A61M 5/00, 5/31; A61N 5/00, 5/06 (2015.12)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
US: 604/113; 606/20, 50, 133, 186; 607/88, 99, 116 (Keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, Google Scholar
Search terms used: Ablation, needle, tip, detach, exchange, multiple tip, non-thermal,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0149991 A1 (MULHOLLAND) 28 June 2007 (28.06.2007) entire document	1-5, 68-72
A	US 5,868,744 A (WILLMEN) 09 February 1999 (09.02.1999) entire document	1-5, 68-72
A	US 2004/0220589 A1 (FELLER) 04 November 2004 (04.11.2004) entire document	1-5, 68-72
A	US 2009/0093864 A1 (ANDERSON) 09 April 2009 (09.04.2009) entire document	1-5, 68-72

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 January 2016	02 FEB 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/060685

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 6-67, 73-94
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

摘要

本发明公开了用于治疗皮肤、比如用于使皮肤紧致或用于治疗将从组织面积或体积减小、皮肤修复、皮肤紧致、皮肤抬升和/或皮肤复位中受益的疾病、病症和病况和/或用于大致改善皮肤功能或外观（例如去除不需要的皮肤特征或缺陷，比如皮脂腺、汗腺、毛囊、坏疽和纤维化）的设备、系统、套件和方法。该设备、系统、套件和方法包括具有手持式主要本体以及以可拆卸的方式附接的带有一个或更多个针状件的稍端的设备。