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(71) Applicant: **SIANO MOBILE SILICON LTD.** [IL/IL]; P.O. Box 3525, 4059300 Kfar Netter (IL).

(72) Inventors: **LEVI, Itzhak**; 18 Yahalom Street, 3088900 Caesarea (IL). **IRONI, Alon**; 24 Hague Street, 3498030 Haifa (IL). **VOLOKH, Lana**; 27/5 HaRoffe Zlochisti Street, 3436717 Haifa (IL). **JASHEK, Ronen**; 151 Yasmin Street, 6081840 Shoham (IL). **HARPAK, Amnon**; 3/3 Uzi Narkis Street, 5845127 Holon (IL). **TAIEB, Avner**; 6 Rachel Hameshoreret Street, 4950406 Petach Tikva (IL). **RAAB, Hamutal**; 4 Zoran Street, Hod Hasharon (IL). **YABLONKA, Tomer**; 17/4 Onkelos Street, 6291616 Tel Aviv (IL). **BARABASH, Rostislav**; 7/4 Globerman Street, 3499801 Haifa (IL).

(74) Agent: **D. KLIGLER I.P. SERVICES LTD.**; P.O. Box 57651, 61576 Tel Aviv (IL).

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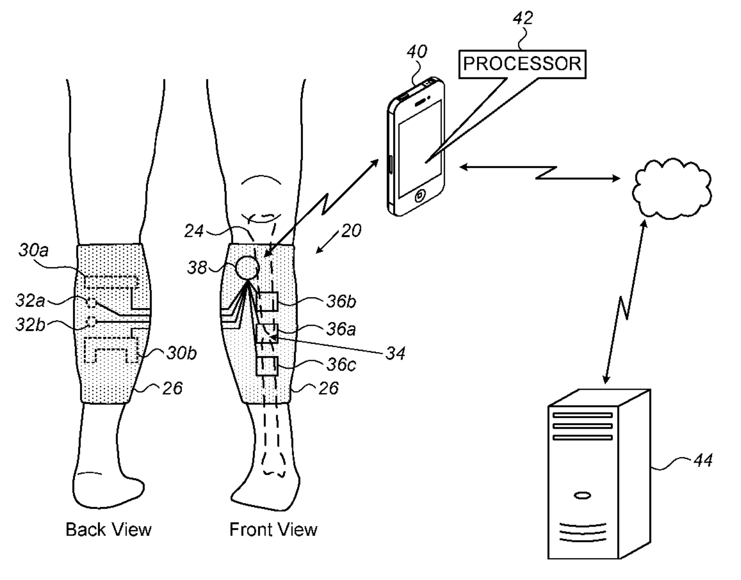
(54) Title: TREATMENT OF BONE FRACTURES

FIG. 1



(57) Abstract: Apparatus and methods are described, including apparatus that comprises a band (26). One or more ultrasonic transducers (36a, 36b, 36c), and a controller (38), are coupled to the band. The controller is configured to cause at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture (34) of a bone (24) of a subject. Other embodiments are also described.

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TREATMENT OF BONE FRACTURES

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of US Provisional Application 62/119,827, filed February 24, 2015, whose disclosure is incorporated herein by reference.

FIELD OF THE INVENTION

Embodiments of the present invention relate generally to the field of medical devices, and in particular, to apparatus and methods for the treatment of bone fractures.

BACKGROUND

The use of Low-Intensity Pulsed Ultrasound (LIPUS) in treating bone fractures, such as tibial fractures, has been documented. For example, the following journal articles are relevant in this regard:

(i) Heckman, James D., et al, "Acceleration of tibial fracture-healing by non-invasive, low-intensity pulsed ultrasound," The Journal of Bone & Joint Surgery 76.1 (1994): 26-34;

(ii) Leung, Kwok-Sui, et al, "Complex tibial fracture outcomes following treatment with low-intensity pulsed ultrasound," Ultrasound in medicine & biology 30.3 (2004): 389-395;

(iii) Walker, Nicol A., Craig R. Denegar, and Jody Preische, "Low-intensity pulsed ultrasound and pulsed electromagnetic field in the treatment of tibial fractures: a systematic review," Journal of athletic training 42.4 (2007): 530; and

(iv) Mundi, Raman, et al. "Low-intensity pulsed ultrasound: Fracture healing," Indian journal of orthopaedics 43.2 (2009): 132.

In addition, US Patent Application Publication 2008/0021327, whose disclosure is incorporated herein by reference, discloses ultrasound stimulation devices and related techniques. An ultrasound transducer for generating ultrasound energy is carried by a transducer housing that seals the transducer and may also include a positioning element for positioning the transducer proximate an application area to which generated ultrasound energy is to be applied. The transducer housing may also carry such components as a battery, a wireless receiver, and a controller. The same housing or a separate sensor housing may include an ultrasound sensor that provides feedback to the ultrasound transducer or its controller, illustratively through a wireless transmitter.

Ultrasound may also be used to monitor bone fracture healing. Protopappas, Vasilios C., et al, "Ultrasonic monitoring of bone fracture healing," Ultrasonics, Ferroelectrics, and Frequency Control, IEEE Transactions on 55.6 (2008): 1243-1255, reviews the relevant literature in this regard.

Additionally, Al-Nashash, Hasan, et al, "Quantification of the bone healing process using information of B-Mode ultrasound image," Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE, IEEE, 2012, develops a quantitative measure towards assessment and monitoring of the bone healing process. Information theoretic criterion (KLD) was used to quantify the degree of bone healing using the intensity histogram of the callus region obtained from B-Mode ultrasound.

SUMMARY OF THE INVENTION

There is provided, in accordance with some embodiments of the present invention, apparatus that includes a band, one or more ultrasonic transducers coupled to the band, and a controller coupled to the band. The controller is configured to cause at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture of a bone of a subject.

In some embodiments, a thickness of each of the ultrasonic transducers is less than 1 cm.

In some embodiments, a surface area of a front face of each of the ultrasonic transducers is less than 2 cm^2.

In some embodiments, the band is configured to wrap around a limb of the subject that contains the bone.

In some embodiments, a combined thickness of the band, the transducers, and the controller is less than 1 cm.

In some embodiments, the ultrasonic wave has a frequency of between 800 kHz and 1.5 MHz.

In some embodiments, the ultrasonic wave has a frequency of between 3 and 5 MHz.

In some embodiments, the one or more ultrasonic transducers include:

a first ultrasonic transducer, which is configured to transmit the ultrasonic wave; and

a second ultrasonic transducer, configured to:

receive a reflection of the ultrasonic wave, and

in response to the reflection, generate a signal.

In some embodiments, the controller is further configured to:

receive the signal from the second ultrasonic transducer, and

in response to the signal from the second ultrasonic transducer, generate a wireless signal.

In some embodiments, the controller is further configured to, by processing the signal from the second ultrasonic transducer, derive an indication of a status of the fracture, and the wireless signal includes the indication.

In some embodiments, the apparatus further includes at least one processor configured to:

receive the wireless signal, and

in response to the wireless signal, generate an output that indicates a status of the fracture.

In some embodiments, the apparatus further includes a mobile device, the processor being a processor of the mobile device.

In some embodiments, the band includes a material selected from the group consisting of: spandex and cotton.

In some embodiments, the apparatus further includes a plurality of electrodes coupled to the band, the controller being further configured to cause the electrodes to pass an electric current between the electrodes.

There is further provided, in accordance with some embodiments of the present invention, a method that includes placing a band on a portion of a body of a subject, one or more ultrasonic transducers being coupled to the band, and subsequently, causing at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture of a bone that is contained within the portion of the body of the subject.

In some embodiments, the bone is a tibia of the subject.

In some embodiments, the method further includes placing a cast over the band.

In some embodiments, placing the cast over the band includes placing the cast over the band such that the ultrasonic transducers are embedded in the cast.

In some embodiments, the at least one of the ultrasonic transducers includes an array of ultrasonic transducers, and the method includes causing the at least one of the ultrasonic transducers to transmit the ultrasonic wave by causing the array of ultrasonic transducers to transmit an ultrasonic beam.

There is further provided, in accordance with some embodiments of the present invention, a method of manufacture. The method includes coupling, to a band, one or more ultrasonic transducers, and a controller, configured to cause at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture of a bone of a subject. The method further includes connecting the ultrasonic transducers to the controller.

The present invention will be more fully understood from the following detailed description of embodiments thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic illustration of apparatus for treating a bone fracture, in accordance with some embodiments of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

OVERVIEW

In many cases, to treat a fractured bone, a cast is placed over the limb that contains the bone. The cast stabilizes the bone, thus promoting the healing process. For example, a fractured tibia may be treated by placing a cast over the lower leg of the subject.

Although helpful in promoting the healing of the fracture, the application of a cast presents certain challenges. First, the cast may inhibit the use of the LIPUS techniques outlined above in the Background, in that it may not be possible to transmit ultrasound waves through the cast. Moreover, the immobilization of the limb may lead to muscle atrophy, and/or deep vein thrombosis (DVT), in which dangerous blood clots form. (The latter risk is especially relevant to the legs.)

To address the above challenges, embodiments of the present invention provide a thin band that has one or more ultrasonic transducers, such as piezoelectric or capacitive transducers, coupled thereto. The band is placed around the limb of the subject, prior to placement of the cast over the band. Subsequently, to promote healing of the fracture, the ultrasonic transducers are used to apply LIPUS therapy. Typically, in addition, electrodes coupled to the band are used to electrostimulate the muscles of the subject, thus helping to prevent muscle atrophy, and/or increasing blood flow, thus helping to prevent the formation of blood clots.

In some embodiments, the ultrasonic transducers are, alternatively or additionally, used to monitor the healing process, such as by acquiring ultrasound images of the fracture site, or by use of non-imaging ultrasound techniques. Such monitoring allows the physician to treat the fracture more effectively, thus facilitating a faster and more complete healing process. In addition, such monitoring may allow the physician to properly time the removal of the cast.

A controller, which is also coupled to the band, controls the operation of the ultrasonic transducers and electrodes. In some embodiments, the controller is configured to wirelessly communicate with a mobile device. The mobile device may, for example, provide relevant firmware updates to the controller, and/or communicate instructions to the controller regarding the therapeutic programs and/or parameters to use. Conversely, the controller may communicate, to the mobile device, information received from the ultrasonic transducers and/or electrodes.

APPARATUS DESCRIPTION

Reference is made to Fig. 1, which is a schematic illustration of apparatus 20 for treating a bone fracture, in accordance with some embodiments of the present invention. Fig. 1 shows a front view and a back view of a leg 22 of a subject, leg 22 having a fractured tibia 24. As described in detail below, apparatus 20 may be used to treat such a fracture, along with other types of bone fractures in any relevant portion of a body of a subject, including, for example, an arm, a wrist, or an ankle.

Apparatus 20 comprises a band 26, which has one or more ultrasonic transducers coupled thereto. For example, Fig. 1 shows three such ultrasonic transducers 36a, 36b, and 36c. Prior to placing a cast over the leg, band 26 is placed around the leg, such that the ultrasonic transducers are near the fracture 34 in tibia 24. Subsequently, if required, a cast, and/or other stabilizing apparatus (such as a brace), may be placed over the band. Apparatus 20 is typically relatively thin, such that the apparatus does not inhibit the placement of a cast around the fracture. For example, the combined thickness of the band and all of the components coupled thereto (e.g., the controller, the transducers, and the electrodes) may be less than 1 cm. More specifically, the thickness of the band itself may be less than 5 mm, e.g., around 2 mm. Although the transducers protrude from the band (thus bringing the combined thickness of the apparatus closer to 1 cm), the transducers may be embedded in the cast, such that less than 5 mm, e.g., only around 2 mm, separate between the cast and the skin.

In general, the term "band," as used throughout the present application (including the claims), refers to any suitable strip of material to which the relevant components described herein (such as ultrasonic transducers 36a-c) may be coupled. Band 26 may be embodied, for example, as a sleeve, a cuff, a sock, a wrap, a brace, a bracelet, a bandage, a strip, a thimble, a glove, or a patch. Band 26 may be made of any suitable material(s), including, for example, cotton and/or spandex (also known as elastane), such as a blend of cotton and spandex. (In other words, the band may consist entirely of such materials, or at least most of the band - e.g., at least 50%, 80%, or 90% of the band - may consist of such materials.) The band is typically sized in proportion to the portion of the subject's body over which the band is intended to be placed. For example, a band that is designated for placement around the lower leg may have a length and/or width of between 5 and 30 cm.

In some embodiments, band 26 is wrapped (partially, or fully) around the relevant portion of the subject's body, such as a limb of the subject (e.g., the subject's leg). In some embodiments, the band is then fastened to itself. For example, band 26 may comprise snap fasteners, hook-and-loop fasteners, and/or ties, which allow band 26 to be fastened to itself, thus facilitating a secure fit around the leg. Alternatively or additionally, a secure fit may be achieved by virtue of the band being stretchable, and/or by use of an adhesive material to secure the band to the skin.

In some embodiments, apparatus 20 comprises a single ultrasonic transducer, which performs both the transmitting and receiving functions described below. Typically, however, apparatus 20 comprises a plurality of ultrasonic transducers, with one of the transducers being used as a transmitting transducer, and one or more other transducers being used as receiving transducers. In such embodiments, the band is placed around the leg such that the transmitting transducer is directly over (or at least immediately adjacent to) the fracture, with the receiving transducers being disposed adjacent to the transmitting transducer, near the fracture. Thus, for example, Fig. 1 shows a transmitting transducer 36a directly over fracture 34, with receiving transducers 36b and 36c adjacent to transducer 36a, on opposite sides of the fracture. (It is noted that the transducers are typically structurally identical to each other, and that a transmitting transducer may be used for receiving, and *vice versa*.) Typically, upon placing the band around the leg, the physician aligns the transducers with respect to the fracture, by referring to radiological images (e.g., X-ray images) of the leg. Additionally, the transducers may be aligned based on ultrasound reflections received from the fracture site. Such reflections also provide baseline information that can later be used for monitoring the healing process.

In general, the ultrasonic transducers coupled to the band are miniature in size. For example, the thickness of each of the transducers may be less than 1 cm, and/or the surface area of the front face of each of the transducers (i.e., the face of the transducer that faces the skin of the subject and performs transmitting and/or receiving functions) may be less than 2 cm^2.

Apparatus 20 further comprises a controller 38, which is also coupled to the band.

Controller 38 comprises circuitry configured to control the ultrasonic transducers, and/or receive data from the transducers, via wired connections between the controller and the transducers. For example, as further described below, the controller causes transmitting transducer 36a to transmit ultrasonic waves toward the bone fracture. Controller 38 typically further comprises a wireless transceiver, such as a Bluetooth Low Energy (BLE) transceiver, and an antenna, which allow the controller to wirelessly communicate with other devices, as further described below. Typically, the circuitry of controller 38 is fabricated on a printed circuit board (PCB), e.g., in an Application-Specific Integrated Circuit (ASIC), such as a system-on-chip (SoC). Alternatively, controller 38 may be implemented as a combination of separate components, including at least a microcontroller and suitable analog-to-digital and digital-to-analog conversion circuitry for interfacing between the microcontroller and the transducers and electrodes. In any case, the controller circuitry typically includes a processor (e.g., a firmware-based processor), configured to execute program instructions (provided, for example, in microcode) that cause the processor to carry out the various tasks described herein.

The controller further comprises a power source, configured to provide power to the controller. Typically, the controller consumes relatively little power, such that the power source need not be recharged for the entire duration of the healing process, assuming that the apparatus is used "normally" as described hereinbelow. For example, the power source may power the controller for at least 60 days, which, for most bone fractures, is sufficient time for completion of the healing process.

Typically, apparatus 20 further comprises a plurality of electrodes, which are used for electrostimulating the subject, and/or acquiring physiological measurements. For example, Fig. 1 shows two stimulating electrodes 30a and 30b, and two sensing electrodes 32a and 32b. Electrodes 30a-b and 32a-b are coupled to the band such that, upon the band being placed over the lower leg as shown, the electrodes are positioned over the calf of the leg. The controller, via wired connections to the electrodes, controls the electrodes, and/or receives data from the electrodes. In some embodiments, an adhesive material is used to adhere the electrodes to the skin.

It is noted that, in some embodiments, at least some of the connections between the controller and the transducers, and/or between the controller and the electrodes, are wireless connections. It is further noted that the scope of the present disclosure includes coupling any suitable number of transducers, and/or any suitable number of electrodes, to the band.

To manufacture apparatus 20, the ultrasonic transducers, electrodes, and controller are coupled to the band, and the controller is connected to each of the transducers and electrodes. Typically, the transducers and controller are coupled to the band by an adhesive material, and/or by fasteners, such as hook-and-loop fasteners. The electrodes may be similarly coupled to the band. Alternatively, the electrodes may be printed onto, or woven into, the band.

TREATMENT AND MONITORING

As described above, the controller causes transmitting transducer 36a to transmit ultrasonic waves toward the facture. For example, the controller may cause the transmitting transducer to periodically provide LIPUS treatment, by transmitting relatively low-frequency ultrasound waves toward the fracture. Thus, for example, ultrasonic pulses having a frequency of between 800 kHz and 1.5 MHz may be applied to the fracture, once a day, for approximately 20-30 minutes, to expedite the healing process. Such pulses may be delivered, for example, at a pulse repetition frequency (PRF) of approximately 1 kHz, with a duty cycle of approximately 20%. (Alternatively, any other suitable PRF and duty cycle may be used.) Typically, in providing such treatment, the emitted power is on the order of 30 mW/cm^2.

Alternatively or additionally, the controller may cause the transmitting transducer to, at regular intervals and/or on an *ad-hoc* basis (e.g., in response to instructions communicated wirelessly to the controller), transmit higher-frequency (e.g., 3-5 MHz, such as approximately 3.5 MHz) ultrasound waves toward the fracture. (Typically, the transmitting transducer is positioned such that the fracture is located at the beginning of the far field of these higher-frequency ultrasound waves.) These ultrasound waves "probe" the fracture site, in that reflections of these waves from bone tissue at the site of the fracture give indication as to the status of the fracture. The reflections are received by receiving transducers 36b and 36c, which generate electric signals in response to the reflections. The controller receives these signals, and, typically, processes the signals such as to derive an indication of the status of the fracture. The controller then generates a wireless signal, which includes the indication of the status of the fracture.

Typically, the wireless signal is received by a processor 42 of a mobile device 40, such as a smartphone or tablet computer belonging to the subject. In response to the wireless signal, processor 42 generates an output (e.g., a visual output displayed on the mobile device) that indicates the status of the fracture. For example, the output may show a particular quantitative metric that describes the current status of the fracture, along with a baseline value for the metric (e.g., a baseline value that was computed upon the initial placement of the apparatus over the fracture), such that the subject may assess any improvement relative to the baseline.

More specifically, the probing may be performed in accordance with either one of the following two methods:

(i) In some embodiments, apparatus 20 comprises an array of transmitting transducers, i.e., transmitting transducer 36a is actually an array of transducers. In such embodiments, the transmitting array may be used (by alternatingly enabling and disabling the transducers in the array, and/or by using beamforming techniques) to direct ultrasound beams to various portions of the fracture site, thus allowing for acquisition of an ultrasound image. (The beams typically have a frequency of 3-5 MHz, e.g., approximately 3.5 MHz.) Based on the acquired image, the status of the fracture may be ascertained, using, for example, techniques described in the above-cited reference to Al-Nashash et al, which is incorporated herein by reference.

(ii) In other embodiments, a non-imaging ultrasound technique, such as the axial transmission technique described in the above-cited reference to Protopappas et al, which is incorporated herein by reference, is employed. In brief, the axial transmission technique measures the time required for an ultrasound wave to pass through the fracture site. (This time is known as the transit time of the first-arriving signal (FAS).) A decrease in this time indicates progress in the healing of the fracture. To use the axial transmission technique, ultrasound pulses may be transmitted, for example, at a frequency of approximately 100 kHz. A single transmitting transducer may be used for this purpose.

Typically, as noted above, the controller processes the received signals from the ultrasonic transducers such as to derive the indication of the status of the fracture, in accordance with one of the two methods described above. Alternatively, the wireless signal from the controller may include merely the "raw" information received from the transducers, and another processor - such as processor 42 - may perform the relevant processing.

Typically, the controller also causes electric currents to be passed between stimulating electrodes 30a and 30b. When the band is worn as shown in Fig. 1, such currents may stimulate activity of the muscle fibers in the gastrocnemius, soleus, tibialis anterior, and/or tibialis posterior muscles, thus causing, for example, contractions of these muscles. The stimulated activity helps prevent muscle atrophy, and/or helps prevent the formation of blood clots. Thus, for example, an atrophy-prevention stimulation session may be conducted twice daily, and/or a blood-clot-prevention stimulation session may be conducted every few hours. The duration of each such session may be, for example, on the order of 20 minutes. Some other example electrostimulation parameters include a modulated frequency of 1-10 Hz (i.e., 1-10 pulses per second), a current of 10-25 mA, and a pulse width of approximately 400 microseconds.

Alternatively, any other suitable parameters may be used. (It is noted that the electrostimulation parameters do not necessarily differ between the atrophy-prevention stimulation sessions and the blood-clot-prevention stimulation sessions.) Typically, electrostimulation and LIPUS treatment are not applied at the same time.

Typically, the sensing electrodes are used to acquire plethysmographic measurements and/or electromyographic measurements. The controller receives the relevant signals from the sensing electrodes, and, in response to the signals, computes relevant parameters, and controls the electrostimulation in response thereto.

For example, International Patent Application PCT/IB2016/050543, whose disclosure is incorporated herein by reference, describes a technique for deriving a measure of blood flow from plethysmographic measurements. In brief, the voltage between the sensing electrodes is measured while a (relatively weak, generally non-stimulating) current is passed between the stimulating electrodes. By dividing the voltage by the amplitude of the current, the impedance between the sensing electrodes is derived. Based on this impedance, the rate of flow of blood between the sensing electrodes is estimated, using a technique that is based on the backward-extrapolation method of Nyboer et al., "Electrical Impedance Plethysmography: A Physical and Physiologic Approach to Peripheral Vascular Study," Circulation 2.6 (1950): 811-821, which is incorporated herein by reference. In response to the estimate of blood flow, the controller may increase or decrease the electrostimulation of the subject. Likewise, based on the level of muscular activity indicated by the electromyographic signals, the controller may increase or decrease the electrostimulation of the subject.

In some embodiments, the same electrodes are used for acquiring both plethysmographic and electromyographic measurements. In other embodiments, separate electrodes are used for each function.

Typically, mobile device 40 communicates with a remote server 44. Remote server 44, via the mobile device, provides firmware updates to the controller, and/or communicates instructions to the controller that cause the controller to start or abort ultrasound transmission or electrostimulation, select particular LIPUS or electrostimulation programs or parameters, and/or perform any relevant tasks. Conversely, the controller, via the mobile device, communicates relevant information concerning the status of the subject, such as the current status of the fracture. The remote server (and/or any other device in communication with the remote server) may present such information for viewing by the subject's physician. In this manner, the physician may monitor the healing process, such as to more effectively (i) decide whether further probing, surgical intervention, or physical therapy is needed, (ii) time the removal of the cast, and/or (iii) make any other relevant decisions. Alternatively or additionally, the remote server may use the information (in combination with similar information from other subjects) to further optimize the LIPUS and/or electrostimulation parameters.

The controller is typically configured (in hardware, firmware, and/or software) to perform any relevant digital signal processing (DSP) functions involved in the probing techniques described above. Alternatively or additionally, such DSP functions may be performed by processor 42, and/or by any other processor, such as a processor of remote server 44. Similarly, any other relevant computational task described herein - such as calculating suitable LIPUS or electrostimulation parameters, or processing feedback from the electrodes - may be assigned to any one of the controller, processor 42, and remote server 44. In some embodiments, some computational tasks may be distributed over two or more of the controller, processor 42, and remote server 44, and/or any other processor(s).

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art, which would occur to persons skilled in the art upon reading the foregoing description.

CLAIMS

1. Apparatus, comprising:

a band;

one or more ultrasonic transducers coupled to the band; and

a controller coupled to the band, the controller being configured to cause at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture of a bone of a subject.

2. The apparatus according to claim 1, wherein a thickness of each of the ultrasonic transducers is less than 1 cm.

3. The apparatus according to claim 1, wherein a surface area of a front face of each of the ultrasonic transducers is less than 2 cm^2.

4. The apparatus according to claim 1, wherein the band is configured to wrap around a limb of the subject that contains the bone.

5. The apparatus according to claim 1, wherein a combined thickness of the band, the transducers, and the controller is less than 1 cm.

6. The apparatus according to claim 1, wherein the ultrasonic wave has a frequency of between 800 kHz and 1.5 MHz.

7. The apparatus according to claim 1, wherein the ultrasonic wave has a frequency of between 3 and 5 MHz.

8. The apparatus according to any one of claims 1-7, wherein the one or more ultrasonic transducers comprise:

a first ultrasonic transducer, which is configured to transmit the ultrasonic wave; and

a second ultrasonic transducer, configured to:

receive a reflection of the ultrasonic wave, and

in response to the reflection, generate a signal.

9. The apparatus according to claim 8, wherein the controller is further configured to:

receive the signal from the second ultrasonic transducer, and

in response to the signal from the second ultrasonic transducer, generate a wireless signal.

10. The apparatus according to claim 9, wherein the controller is further configured to, by processing the signal from the second ultrasonic transducer, derive an indication of a status of the fracture, and wherein the wireless signal includes the indication.

11. The apparatus according to claim 9, further comprising at least one processor configured to:

receive the wireless signal, and

in response to the wireless signal, generate an output that indicates a status of the fracture.

12. The apparatus according to claim 11, further comprising a mobile device, the processor being a processor of the mobile device.

13. The apparatus according to any one of claims 1-7, wherein the band comprises a material selected from the group consisting of: spandex and cotton.

14. The apparatus according to any one of claims 1-7, wherein the one or more ultrasonic transducers comprise at least one array of ultrasonic transducers.

15. The apparatus according to any one of claims 1-7, further comprising a plurality of electrodes coupled to the band, the controller being further configured to cause the electrodes to pass an electric current between the electrodes.

16. A method, comprising:

placing a band on a portion of a body of a subject, one or more ultrasonic transducers being coupled to the band; and

subsequently, causing at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture of a bone that is contained within the portion of the body of the subject.

17. The method according to claim 16, wherein the portion of the body of the subject is a limb of the subject, and wherein placing the band on the limb of the subject comprises wrapping the band around the limb of the subject.

18. The method according to claim 16, wherein the bone is a tibia of the subject.

19. The method according to claim 16, wherein the ultrasonic wave has a frequency of between 800 kHz and 1.5 MHz.

20. The method according to claim 16, wherein the ultrasonic wave has a frequency of between 3 and 5 MHz.

21. The method according to any one of claims 16-20, wherein the at least one of the ultrasonic transducers is a first one of the ultrasonic transducers, and wherein the method further comprises, using a second one of the ultrasonic transducers:

receiving a reflection of the ultrasonic wave; and in response to the reflection, generating a signal.

22. The method according to claim 21, further comprising:

receiving the signal from the second one of the ultrasonic transducers, and

in response to the signal from the second one of the ultrasonic transducers, generating a wireless signal.

23. The method according to claim 22, further comprising, by processing the signal from the second one of the ultrasonic transducers, deriving an indication of a status of the fracture, wherein the wireless signal includes the indication.

24. The method according to claim 22, further comprising:

receiving the wireless signal, and

in response to the wireless signal, generating an output that indicates a status of the fracture.

25. The method according to any one of claims 16-20, further comprising placing a cast over the band.

26. The method according to claim 25, wherein placing the cast over the band comprises placing the cast over the band such that the ultrasonic transducers are embedded in the cast.

27. The method according to any one of claims 16-20, wherein the at least one of the ultrasonic transducers includes an array of ultrasonic transducers, and wherein the method comprises causing the at least one of the ultrasonic transducers to transmit the ultrasonic wave by causing the array of ultrasonic transducers to transmit an ultrasonic beam.

28. The method according to any one of claims 16-20, wherein a plurality of electrodes are coupled to the band, and wherein the method further comprises, while the band is on the portion of the body of the subject, causing the electrodes to pass an electric current between the electrodes.

29. A method of manufacture, comprising:

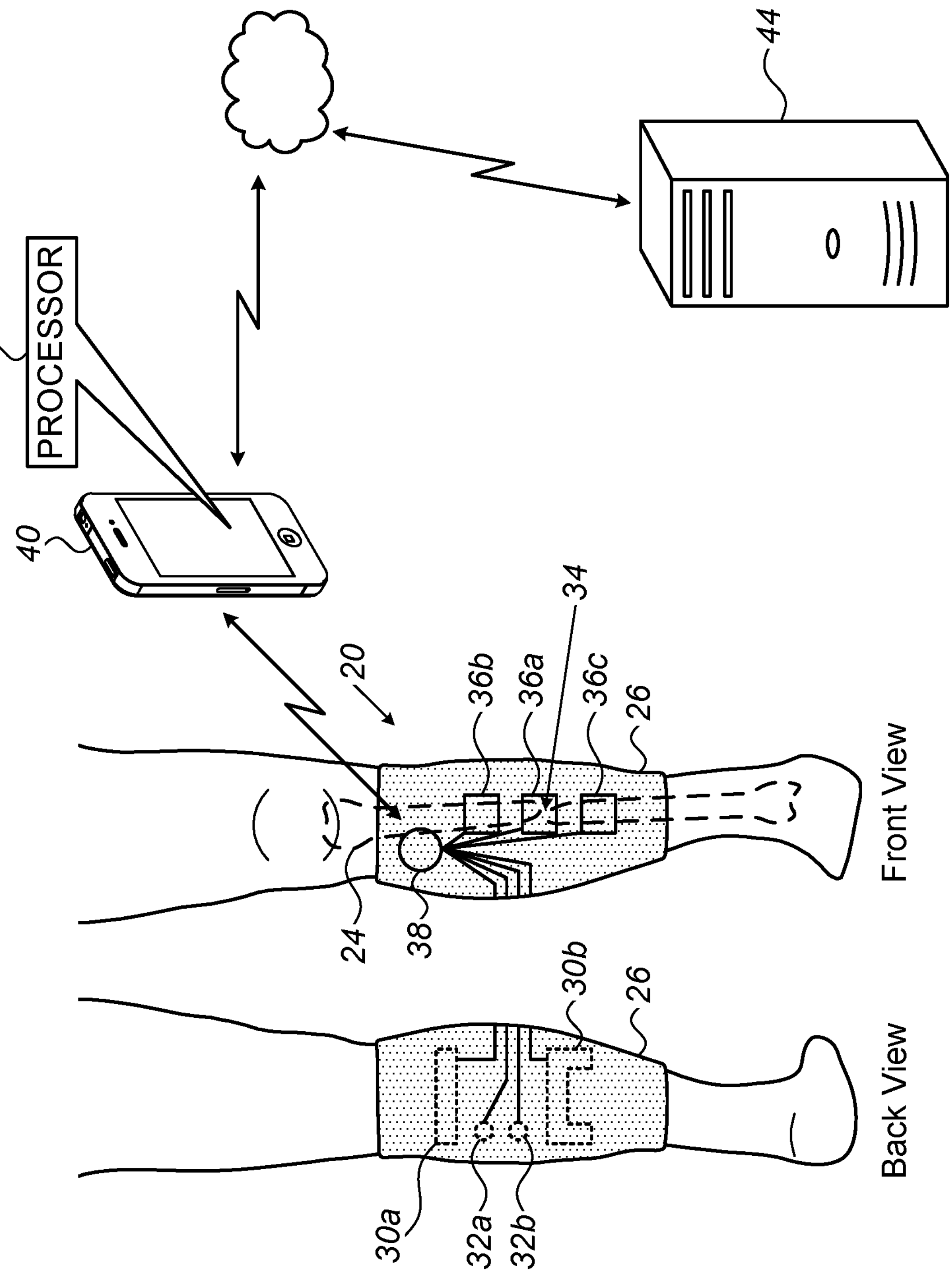
coupling, to a band:

one or more ultrasonic transducers, and

a controller, configured to cause at least one of the ultrasonic transducers to transmit an ultrasonic wave toward a fracture of a bone of a subject; and

connecting the ultrasonic transducers to the controller.

FIG. 1


PROCESSOR
42
40
44
20
34
36b
36a
36c
26
24
38
Front View
30b
26
30a
32a
32b
Back View

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2016/050925

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2016.01) A61N 7/00, A61N 5/00, A61N 1/00

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 (2016.01) A61N 7/00, A61N 5/00, A61N 1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Databases consulted: THOMSON INNOVATION, Esp@cenet, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	(The whole document especially, Figs. 1-4, paragraph 15-17, 27, 31-36, 41-42, 52-54, 57, 64, 70, 71).	2,3,5,8-15,21-28
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance
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"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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 May 2016	31 May 2016
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	Authorized officer NIMER Emad Telephone No. 972-2-5657801

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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