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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A61B 17/22, B06B 3/00 — A1

(11) International Publication Number: WO 99/44514

(43) International Publication Date: 10 September 1999 (10.09.99)

(21) International Application Number: PCT/US99/04468

(22) International Filing Date: 2 March 1999 (02.03.99)

(30) Priority Data:
09/032,982 2 March 1998 (02.03.98) US

(81) Designated States: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

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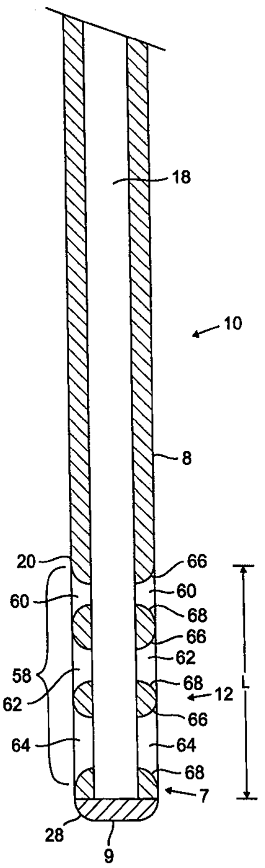
(54) Title: ULTRASONIC LIPOSUCTION PROBE

(57) Abstract

A probe for ultrasonic tissue treatment includes a longitudinally extending body for transmitting ultrasonic vibrations. A surface of the body includes a plurality of openings configured and arranged to decrease the mass of the body in a distal direction to provide velocity amplification of the ultrasonic vibrations. The openings increase in size in a distal direction by varying in shape from round to oval. The openings can be arranged equally spaced, offset, or in a spiral.



ULTRASONIC LIPOSUCTION PROBE

Background of the Invention

This invention relates to a probe for generating ultrasonic vibrations to treat tissue, for example, liposuction of adipose tissue.

Ultrasonic assisted liposuction is typically conducted using an ultrasonically vibrating probe extending through a portal to a surgical site. The surgeon carefully manipulates the ultrasonically vibrating probe to treat tissue to be removed while avoiding other body tissue such as muscles, body organs and blood vessels. As described in Parisi et al., U.S. Patent No. 4,886,491, titled LIPOSUCTION PROCEDURE WITH ULTRASONIC PROBE, incorporated by reference herein, the ultrasonically vibrating probe acts to liquify or melt the adipose tissue. The liquified tissue is then aspirated from the body to produce a slimmer profile.

It is known to step down or taper distally the outer diameter of an ultrasonic probe to provide for amplification of the ultrasonic vibrations.

Summary of the Invention

According to the invention, to provide for amplification of the ultrasonic vibrations of an ultrasonic probe, the mass of the probe is reduced by relieving the wall of the probe with a series of openings in the wall rather than tapering or stepping down the outer diameter of the probe.

In one aspect of the invention, a probe for ultrasonic tissue treatment includes a longitudinally extending body for transmitting ultrasonic vibrations. A surface of the body includes a plurality of openings configured and arranged to decrease the mass of the body in a distal direction to provide velocity amplification of the ultrasonic vibrations.

Embodiments of this aspect of the invention may include one or more of the following features.

The openings increase in size in a distal direction. The openings are defined by sloped surfaces. The openings are equally spaced about an outer circumference of the body. Alternatively, a first set of the plurality of openings is located on a first side of the body and a second set of the plurality of openings is located on a second side of the body opposite the first side. The first set and the second set being relatively offset in a longitudinal direction. Alternatively, the openings are arranged in a spiral.

In particular embodiments, the body defines an interior lumen and the plurality of openings are a plurality of holes in fluid communication with the lumen. Alternatively, the body is a solid shaft.

The openings are shaped to provide cavitation surfaces oriented transverse to the longitudinal extent of the body. Additionally or alternatively, the openings are shaped to provide cavitation surfaces oriented parallel to the longitudinal extent of the body. An outer diameter of the body is constant along a distal region of the body, and an inner diameter of the body is constant along the distal region of the body. The probe is configured to treat adipose tissue.

In another aspect of the invention, a method of amplifying the amplitude of ultrasonic vibrations includes applying ultrasonic vibrations to a proximal end of an ultrasonic probe, and amplifying the ultrasonic vibrations in the probe by providing a plurality of openings in a surface of the probe. The openings are configured and arranged to decrease the mass of the probe in a distal direction to provide velocity amplification of the ultrasonic vibrations.

According to another aspect of the invention, a method of amplifying the amplitude of ultrasonic vibrations in a probe includes decreasing the mass of the probe in a distal direction. The decrease in mass is provided while maintaining constant inner and outer diameters of the probe.

Among other advantages, the ultrasonic probe of the present invention provides both amplification of ultrasonic vibrations and an increase in the number of cavitation surfaces for emulsifying adipose tissue. The cavitation surfaces oriented both perpendicular and parallel to the longitudinal extent of the probe provide increased emulsification capabilities. Additionally, amplification of ultrasonic vibrations is achieved in a distal region of the probe while maintaining the inner and outer diameters of the probe constant over the length of the distal region.

Other features and advantages of the invention will become apparent from the following detailed description and from the claims.

Brief Description of the Drawings

FIG. 1 is an illustration of an ultrasonic probe according to the invention.

FIG. 2 is a cross-sectional side view of a distal region of the probe of FIG. 1.

FIG. 3A is a side view of the distal region of FIG. 1; and FIG. 3B is a cross-sectional end view of the ultrasonic probe of FIG. 3 taken along line 3B-3B.

FIG. 4A is a cross-sectional end view of an alternative embodiment of a distal region of an ultrasonic probe; and FIG. 4B is a cross-sectional end view of another alternative embodiment of a distal region of an ultrasonic probe.

FIG. 5 is a side view of a distal region of another alternative embodiment of an ultrasonic probe.

FIG. 6A is a side view of a distal region of another alternative embodiment of an ultrasonic probe;

and FIG. 6B shows the probe of FIG. 6A rotated 90° with respect to FIG. 6A.

FIG. 7 is a cross-sectional side view of a distal region of another alternative embodiment of an ultrasonic probe.

FIG. 8 illustrates a system for torsionally vibrating an ultrasonic probe.

FIG. 9 illustrates an alterative embodiment of the system of FIG. 8.

Detailed Description of the Preferred Embodiments

Referring to FIG. 1, an ultrasonic probe 10 for removing adipose tissue from a human or other animal body includes a distal region 12, a mid region 16, and a proximal end 14. Proximal end 14 is configured to releasably engage with a handpiece 50 of an ultrasonic liposuction system 52 for generating ultrasonic vibrational energy. An ultrasonic liposuction system is described, for example, in Podany et al., U.S. Serial No. 08/965,799, titled ULTRASONIC ASSISTED LIPOSUCTION SYSTEM, filed November 7, 1997, incorporated by reference herein. Pressure waves produced by ultrasonic vibrations received by proximal end 14 are transmitted from distal region 12 to a surgical site. A step down 40 between proximal end 14 and mid region 16 acts to amplify the ultrasonic vibrations received by proximal end 14.

Referring to FIGS. 2 and 3A, a portion 20 of distal region 12 of probe 10 further acts to amplify the amplitude of the ultrasonic vibrations. A probe wall 8 includes a series of openings, e.g., holes 58 extending through wall 8 and in fluid communication with a probe lumen 18. Holes 58 increase in size and vary in shape from, e.g., a pair of opposed proximal-most round holes 60, to a pair of opposed mid-location oval holes 62, to a pair of opposed distal-most oval holes 64. The holes increase in size from the proximal-most holes to the distal-most holes thus decreasing the mass of portion 20 in a distal direction. The holes can be of various shapes which result in the mass of portion 20 decreasing in a distal direction. The decrease in mass causes amplification of the amplitude of the ultrasonic vibrations in ultrasonic probe 10 while creating a substantially constant stress in distal region 12. Portion 20 serves as a Gaussian-type resonator, which is described generally in Wuchinich et al., U.S. Patent 4,922,902, titled METHOD FOR REMOVING CELLULAR MATERIAL WITH ENDOSCOPIC ULTRASONIC ASPIRATOR, incorporated by reference herein.

Each of holes 60, 62, 64 define a pair of opposed cavitation surfaces 66, 68 oriented transverse to the longitudinal extent of probe 10. Surfaces 66, 68 are sloped to provide increased surface contact area with adipose tissue to increase the emulsification capability of ultrasonic probe 10. Surfaces 66, 68 are also rounded to preserve tissue selectivity, that is, the surgeon is able to treat adipose tissue while avoiding cutting blood vessels.

Referring particularly to FIG. 3A, each of holes 60, 62, 64 also includes pair of opposed cavitation surfaces 70, 72 arranged substantially parallel to the longitudinal extent of ultrasonic probe 10. As discussed above with reference to surfaces 66, 68, surfaces 70, 72 are sloped to provide increased surface contact area with adipose tissue, and are rounded to preserve tissue selectivity.

As probe 10 vibrates longitudinally, pressure waves generated from transverse cavitation surfaces 66, 68 of each hole 60, 62, 64 and from distal transverse surface 9 act to emulsify adipose tissue. Additionally or alternatively, probe 10 may be vibrated torsionally, as described further below, such that pressure waves are generated from opposed surfaces 70, 72 of each hole to emulsify adipose tissue.

Referring to FIG. 3B, each pair of holes 60, 62, 64 is circumferentially spaced apart by 180° (distal-most holes 64 being shown in FIG. 3B). By equally spacing the holes about the circumference of portion 20, the proper mass balance of portion 20 is maintained.

Referring again to FIG. 2, a cap 28 abuts distal region 12 of ultrasonic probe 10 to close off a distal end 7 of lumen 18. Cap 28 is secured to head portion 12 by, for example, welding, brazing, gluing, or press fitting, or with a machine thread. Probe 10 can be made from, for example, titanium, aluminum, or stainless steel. Holes 60, 62, 64 are typically machined into portion 20 by, for example, milling or electro-discharge machining.

Probe 10 is of a selected length having nodes and anti-nodes along its length. As an example of one implementation, for a 27 KHz ultrasonic probe, the length of probe 10 from step down 40 to distal end 7 is about 13.5 inches. Holes 60, 62 and 64 are located between the last node and the distal end of the probe, which is an anti-node where maximum vibration occurs, and are spaced along distal region 12 having a length, L, of about 1.5 inches. Distal region 12 and mid region 16 have a constant outer diameter of, for example about 0.2 inch. The thickness of wall 8 is about 0.05 inch. The inner diameter of wall 8, extending from step down 40 to distal end 7, is constant at about 0.10 inch. The dimensions and shape of probe 10 can be varied according to the application requirements and needs.

In operation, the surgeon inserts probe 10 near the surgical site. Ultrasonic vibrations generated in handpiece 50 are delivered to proximal end 14 of probe 10. The ultrasonic vibrations in probe 10 are transmitted to tissue to emulsify the tissue by distal region 12 of probe 10. Holes 60, 62, 64 act to increase the amplitude of the ultrasonic vibrations in the distal region. The tissue is treated by the ultrasonic vibrations, and suction is applied to remove treated tissue through holes 60, 62, 64 and lumen 18 by, for example, an aspirator connected to a proximal opening 30 of lumen 18.

Other embodiments are within the scope of the following claims.

For example, one, two or more of each of holes 60, 62, 64 may be arranged in portion 20 of distal region 12. For example, referring to FIG. 4A, a portion 120 of a distal region 112 of an ultrasonic probe includes three equally spaced distal-most oval holes 164 extending through a wall 108 and in fluid communication with a lumen 118. Portion 120 also includes three mid-location oval holes (not shown) and three proximal-most round holes (not shown). Alternatively, referring to FIG. 4B, a portion 220 of a distal region 212 of an ultrasonic probe includes four equally spaced distal-most oval holes 264 extending through a wall 208 and in fluid communication with a lumen 218. In addition, portion 220 includes four mid-location oval holes (not shown) and four proximal-most round holes (not shown).

To decrease the mass of the distal region in a distal direction, rather than increasing in size, the number of distal-most holes can be greater than the number of mid-location holes, which in turn are greater than the number of proximal-most holes.

Referring to FIG. 5, a portion 320 of a distal region 312 of an ultrasonic probe includes a series of holes 350 in a spiral configuration. Holes 350 are circumferentially spaced apart from each other by 120°, and include one proximal round hole 360, one mid-location oval hole 362, and one distal-most oval hole 364.

Holes 350 are arranged such that a distal end 370 of round hole 360 aligns longitudinally with a proximal end 372 of mid-location oval hole 362, and a end portion

374 of mid-location oval hole 362 aligns longitudinally with a proximal end 376 of distal most oval hole 374. Holes 350 increase in size distally towards a distal end 307 of portion 320 such that the mass of portion 320 of distal region 312 decreases in the distal direction towards distal end 307. Portion 320 of distal region 312 serves as a Gaussian-type resonator as described above with reference to FIG. 2. By not providing spacing longitudinally between holes 360, 362, 364, the spiral configuration provides a constant increase in amplification over the length of portion 320 of distal region 312. More than three holes may be arranged in a spiral configuration in portion 320.

Referring to FIGS. 6A and 6B, an ultrasonic probe 380 has six rectangular holes 382a-382f. Holes 382a-382c are located on a first side 184 of probe 380 and holes 382d-382f are located on a second side 186 of probe 380. Holes 382a-382c alternate with holes 382d-382f such that the holes on one side are offset with respect to the holes on the opposite side along the longitudinal axis, X, of the probe. The holes progressively decrease the mass of probe 380 in a distal direction to provide vibrational amplification.

Hole 382a is, for example, about 0.068 inch wide and 0.149 inch long, hole 382b is, for example, about 0.094 inch wide and 0.199 inch long, hole 382c is, for example, about 0.116 inch wide and 0.249 inch long, hole 382d is, for example, about 0.091 inch wide and 0.160 inch long, hole 382e is, for example, about 0.102 inch wide and 0.249 inch long, and hole 382f is, for example, about 0.135 inch wide and 0.299 inch long.

Probe 10 can be constructed without a cap 28 to provide an open-ended lumen. Probe 10 can include an enlarged distal head such as described in Podany et al., ULTRASONIC ASSISTED LIPOSUCTION SYSTEM, supra.

Probe 10 can be used in conjunction with a sheath to provide infiltration/irrigation capabilities to the ultrasonic liposuction procedure. In such a combination, the sheath is disposed about probe 10, thereby defining a channel between probe 10 and the sheath through which the infiltration/irrigation fluid flows.

Referring to FIG. 7, an ultrasonic probe 400 has a solid shaft 402 with two, three or four each of proximal-most round openings 404, mid-location oval openings 406, and distal-most oval openings 408, corresponding in shape and size to holes 58 of Fig. 1. The openings progressively decrease the mass of probe 400 in a distal direction to provide vibrational amplification. The openings in solid shaft 402 can be arranged in a spiral configuration as described above with reference to FIG. 5.

The axially oriented surfaces of the openings can provide additional cavitation surfaces when the ultrasonic probe is vibrated torsionally. Referring to FIG. 8, a horn 502 of an ultrasonic generator 500 is vibrated torsionally using piezoelectric crystals 504. A crystal 504 is located on either side 506, 508 of a wing section 510 of horn 502, between the horn and a base 512. The crystals alternately expand and contract with crystals on either side of a wing section being driven out-of phase to vibrate the horn radially back and forth (arrow 514) about its central axis 516. Amplitude generated by horn 512 is amplified by a probe 518 attached to the horn.

While four wing sections 510 and eight crystal 504 are shown, one, two or more wing sections are contemplated. In addition, instead of a crystal being located on either side of a wing section, one of the crystals can be replaced with a return spring 520 (FIG. 9).

The openings may be provided at other locations along the probe rather than only at the distal region to provide velocity amplification. If the probe includes a lumen, these openings would preferably not be in communication with the lumen such that aspiration could still be provided to the distal region of the probe. Instead of discrete openings, the opening can be in the shape of a channel that increases in width and/or depth in the distal direction.

The ultrasonic probe may be configured to treat tissue other than adipose tissue.

What is claimed is:

1. A probe for ultrasonic tissue treatment, comprising:

a longitudinally extending body for transmitting ultrasonic vibrations, the probe including a plurality of openings in a surface of the body, the plurality of openings configured and arranged to decrease the mass of the body in a distal direction to provide velocity amplification of the ultrasonic vibrations.

2. The probe of claim 1 wherein the plurality of openings increase in size in a distal direction.

3. The probe of claim 1 wherein the plurality of openings are equally spaced about an outer circumference of the body.

4. The probe of claim 1 wherein a first set of the plurality of openings is located on a first side of the body and a second set of the plurality of openings is located on a second side of the body opposite the first side, the first set and the second set being relatively offset in a longitudinal direction.

5. The probe of claim 1 wherein the plurality of openings are arranged in a spiral.

6. The probe of claim 1 wherein the plurality of openings are defined by sloped surfaces.

7. The probe of claim 1 wherein the body defines an interior lumen and the plurality of openings comprise a plurality of holes in fluid communication with the lumen.

8. The probe of claim 1 wherein the body comprises a solid shaft.

9. The probe of claim 1 wherein the plurality of openings are shaped to provide cavitation surfaces oriented transverse to the longitudinal extent of the body.

10. The probe of claim 1 wherein the plurality of openings are shaped to provide cavitation surfaces oriented parallel to the longitudinal extent of the body.

11. The probe of claim 1 wherein an outer diameter of the body is constant along a distal region of the body, and an inner diameter of the body is constant along the distal region of the body.

12. The probe of claim 1, wherein said probe is configured to treat adipose tissue.

13. A probe for ultrasonic tissue treatment, comprising:

a longitudinally extending body for transmitting ultrasonic vibrations, the body including a wall defining a lumen, the body defining a plurality of holes extending through the wall, the plurality of holes increasing in size in a distal direction to decrease a mass of the body in the distal direction to provide velocity amplification of the ultrasonic vibrations.

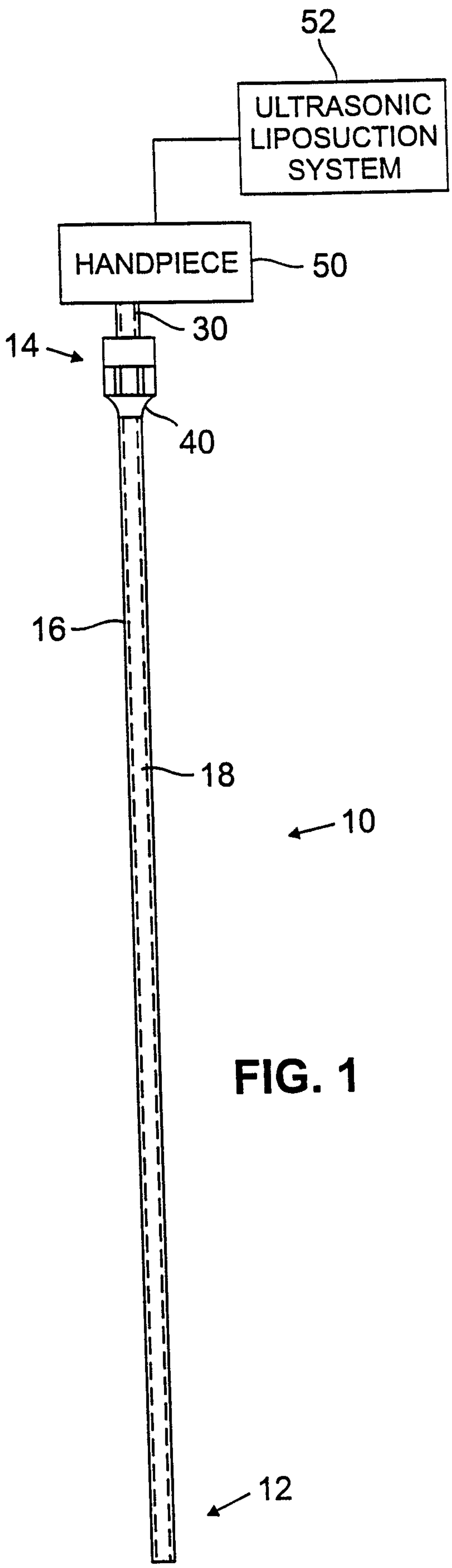
14. A method of amplifying the amplitude of ultrasonic vibrations, comprising:

applying ultrasonic vibrations to a proximal end of an ultrasonic probe, and

amplifying the ultrasonic vibrations in the probe by providing the probe with a plurality of openings in a surface of the probe, the openings configured and arranged to decrease a mass of the probe in a distal direction to provide velocity amplification of the ultrasonic vibrations.

15. A method of amplifying the amplitude of ultrasonic vibrations in a probe, comprising:

decreasing a mass of the probe in a distal direction, the decrease in mass being provided while maintaining a constant outer diameter of the probe and while maintaining a constant inner diameter of the probe.


52
ULTRASONIC LIPOSUCTION SYSTEM
HANDPIECE
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18
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12

FIG. 1

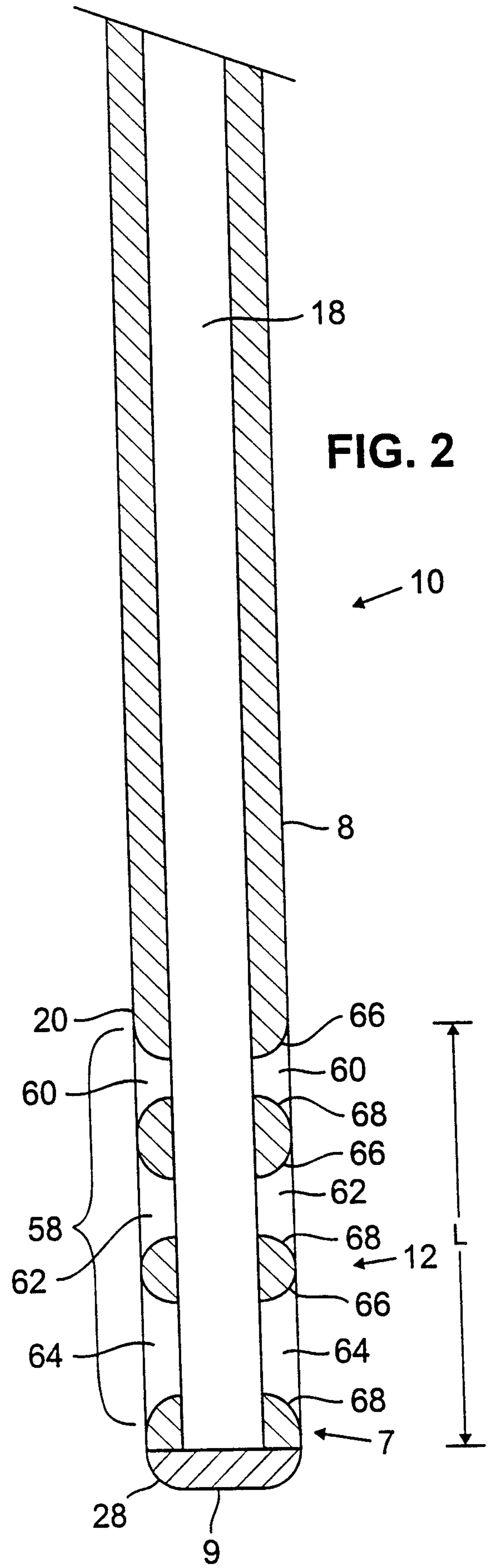
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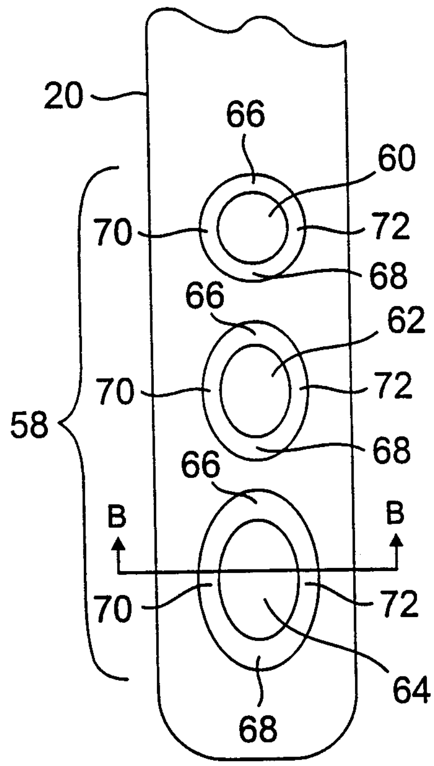
FIG. 2

FIG. 3A



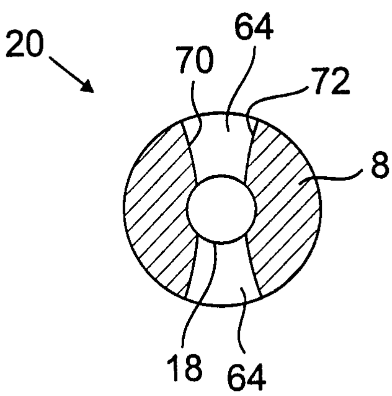


FIG. 3B

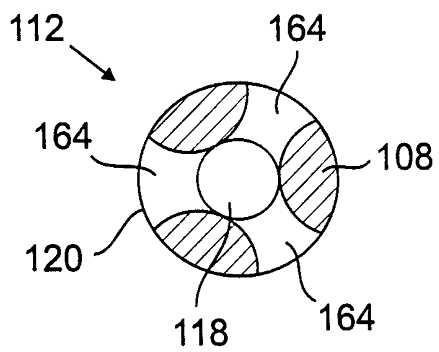


FIG. 4A

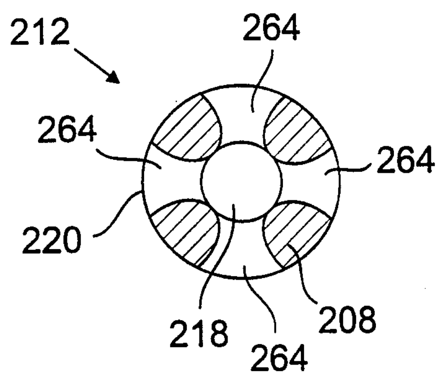


FIG. 4B

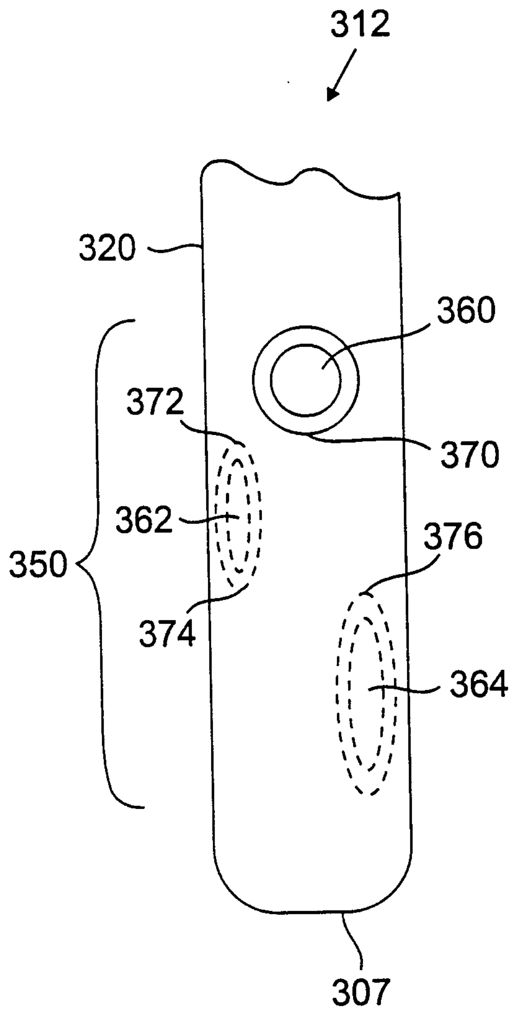


FIG. 5

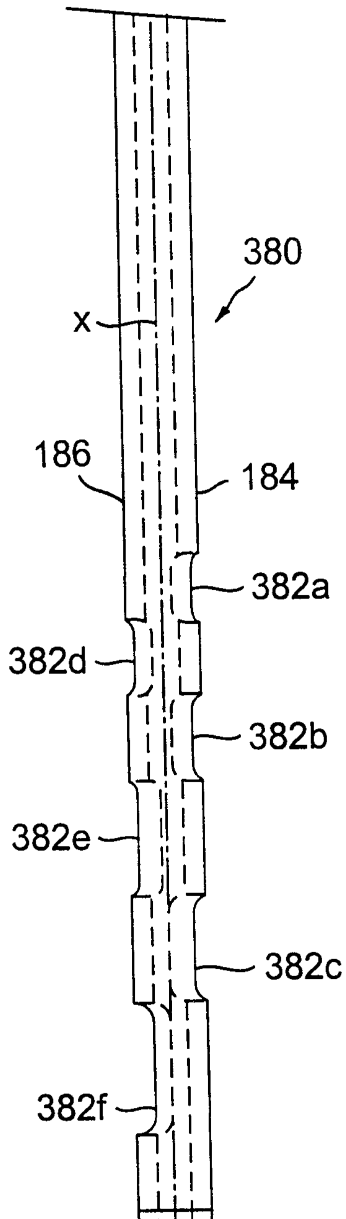

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FIG. 6A

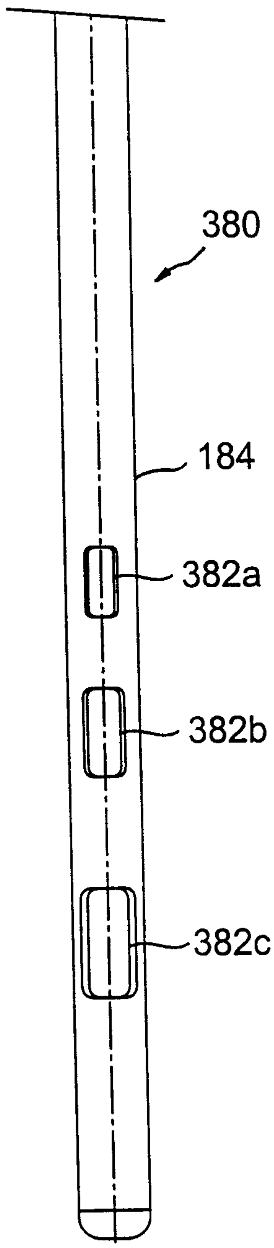
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FIG. 6B

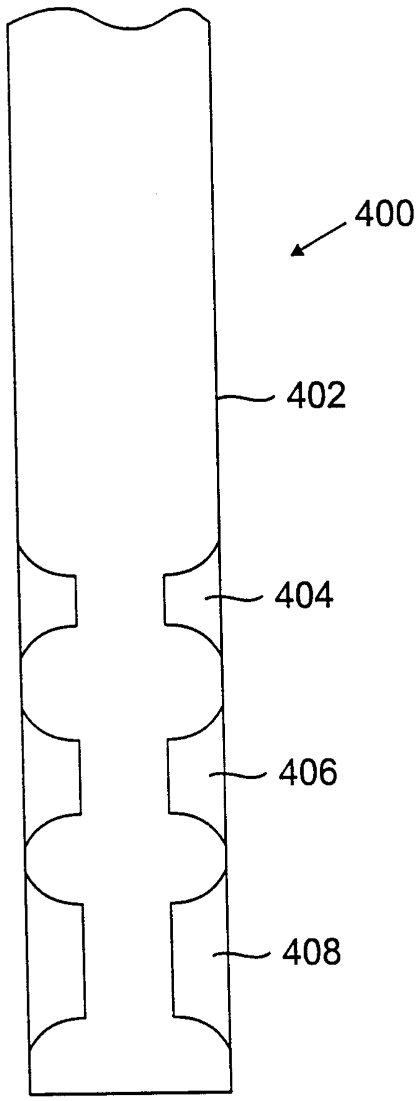

FIG. 7

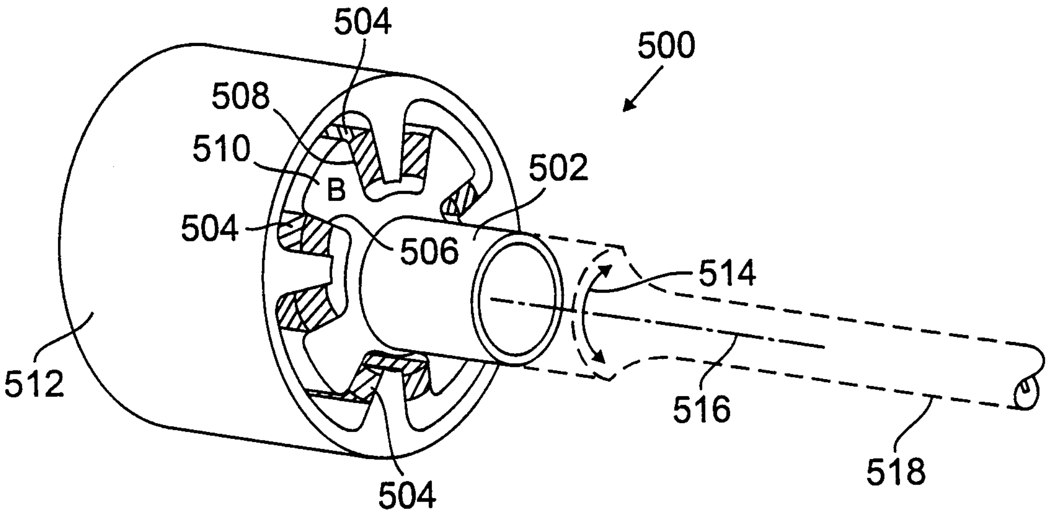
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FIG. 8

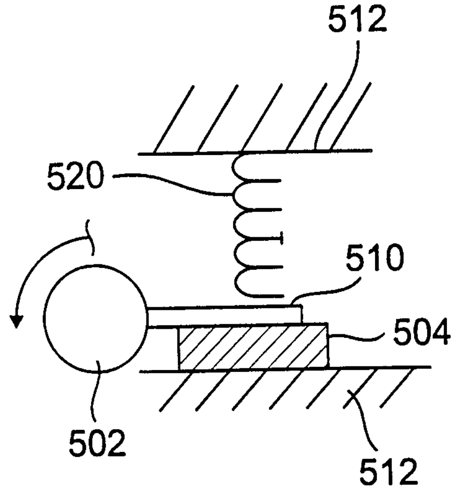
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FIG. 9

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 99/04468

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B17/22 B06B3/00

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 6 A61B B06B

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 163 433 A (KAGAWA HIROAKI ET AL) 17 November 1992 see column 5, line 4 - line 16 see column 11, line 34 - line 53; figures 1,17,18	1-3,7, 11,13-15
X	US 4 886 491 A (PARISI TULIO ET AL) 12 December 1989 cited in the application see column 4, line 29 - line 59; figures 5,6	1
X	US 5 527 273 A (MANNA) 18 June 1996 see abstract; figure 6	1,14
X	US 4 962 330 A (LIERKE ERNST G ET AL) 9 October 1990 see abstract; figure 6	14,15
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"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

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Date of the actual completion of the international search	Date of mailing of the international search report
17 June 1999	24/06/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Moers, R

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/04468

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	DE 297 06 772 U (ENGEL) 19 June 1997 see claim 1; figure 1 ---	1,8
A	EP 0 812 627 A (ETHICON ENDO SURGERY INC) 17 December 1997 see abstract; figure 3 ---	1,13-15
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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