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(54) **ULTRASOUND LIQUID BLADE SCALPEL METHOD**

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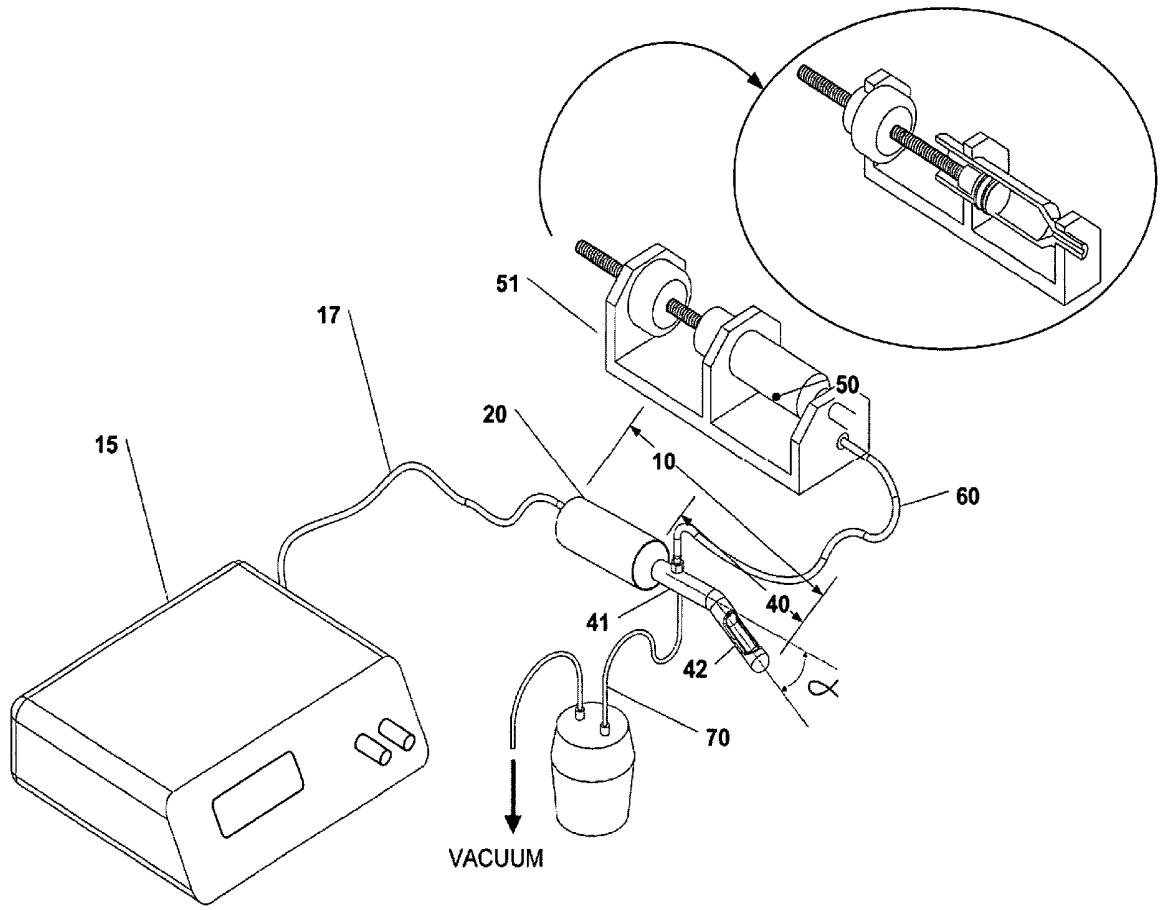
(57) **ABSTRACT**

An ultrasound assisted liquid blade cutting device such as a scalpel that may be used for routine surgical operations is disclosed in this invention. The ultrasound scalpel comprises an ultrasound generator, ultrasound transducer, transducer tip, a cavity on the transducer tip using a liquid spray shaped to form a cutting surface. The spray serves as a carrier medium for the applied ultrasound energy which enhances the features and performance of the scalpel. Ultrasonic energy transmitted from the transducer tip assists the transport of the liquid to a liquid blade formed outside of the cavity. The ultrasound energy focuses and activates the liquid to allow cutting of tissue with the liquid blade. This device may be utilized for cutting through skin and/other soft tissues during surgical operations, thereby enhancing cutting efficacy, decreasing and/or eliminating necrosis formation.



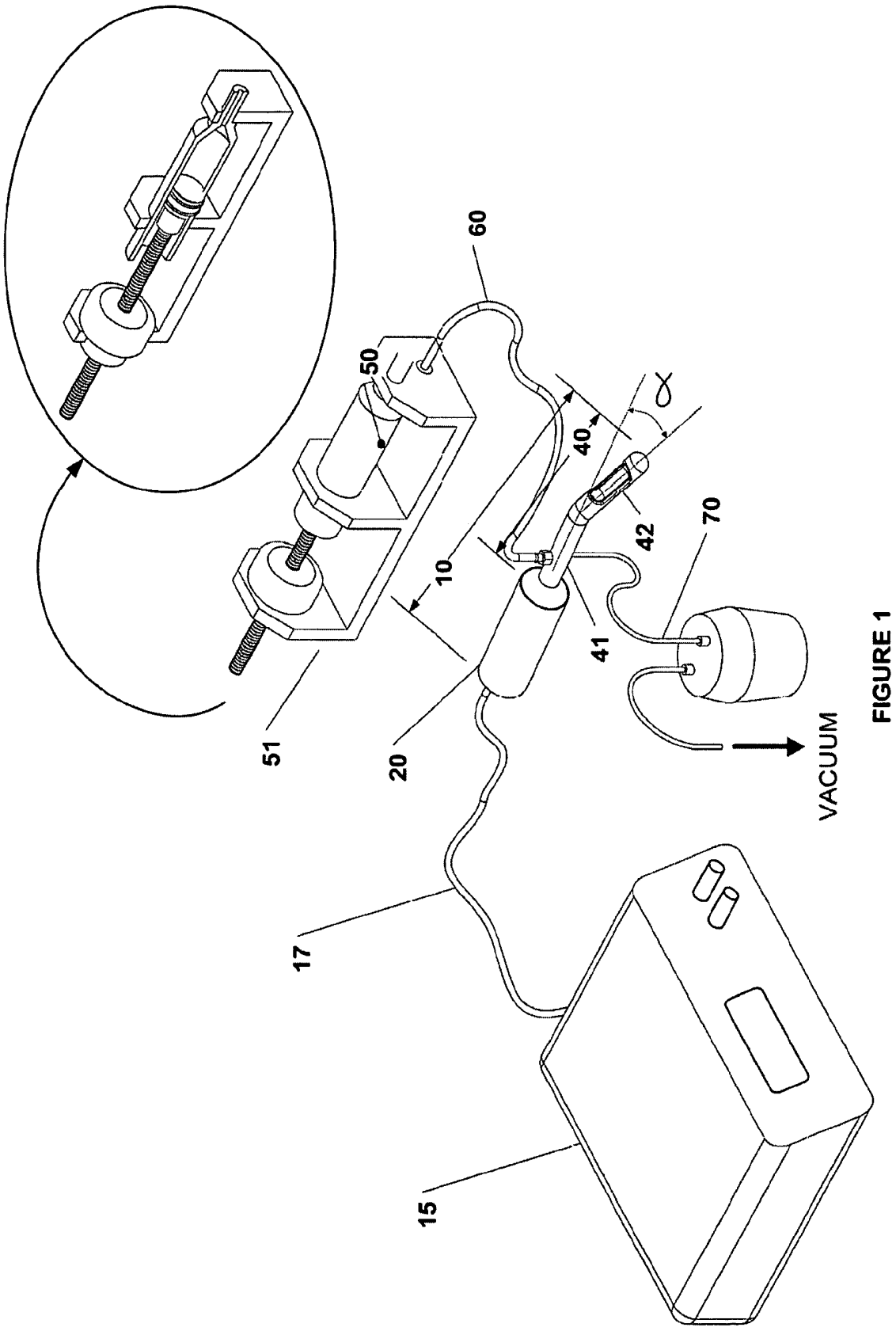


FIGURE 1

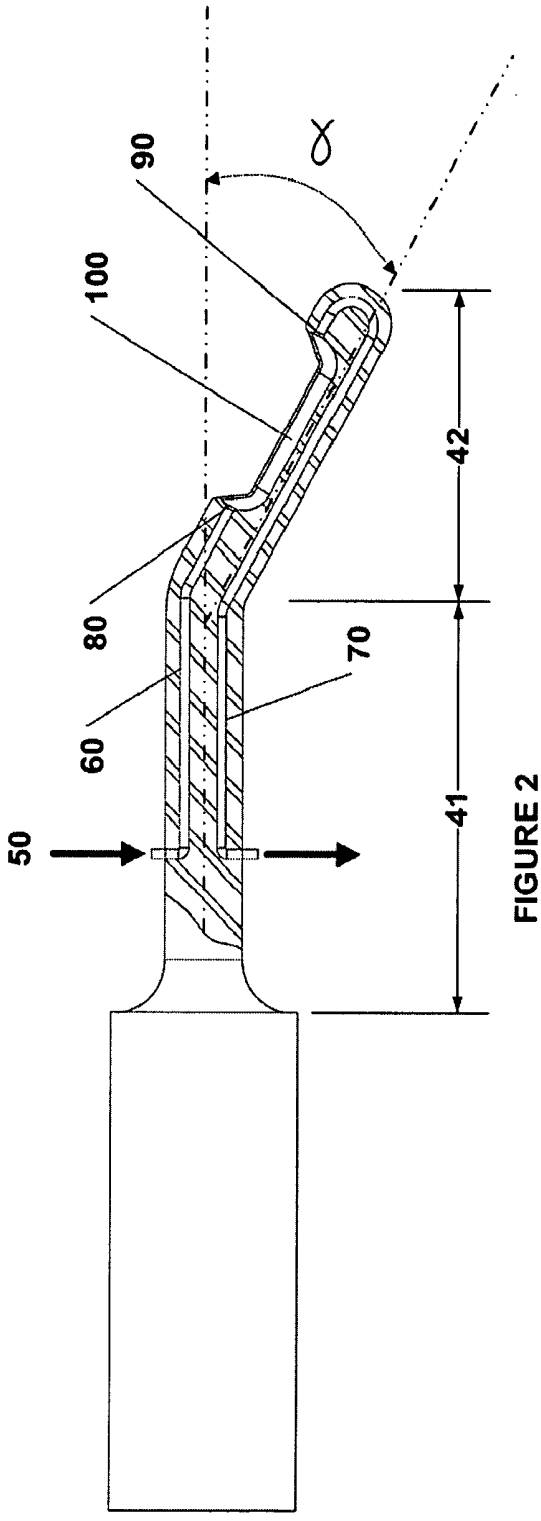


FIGURE 2

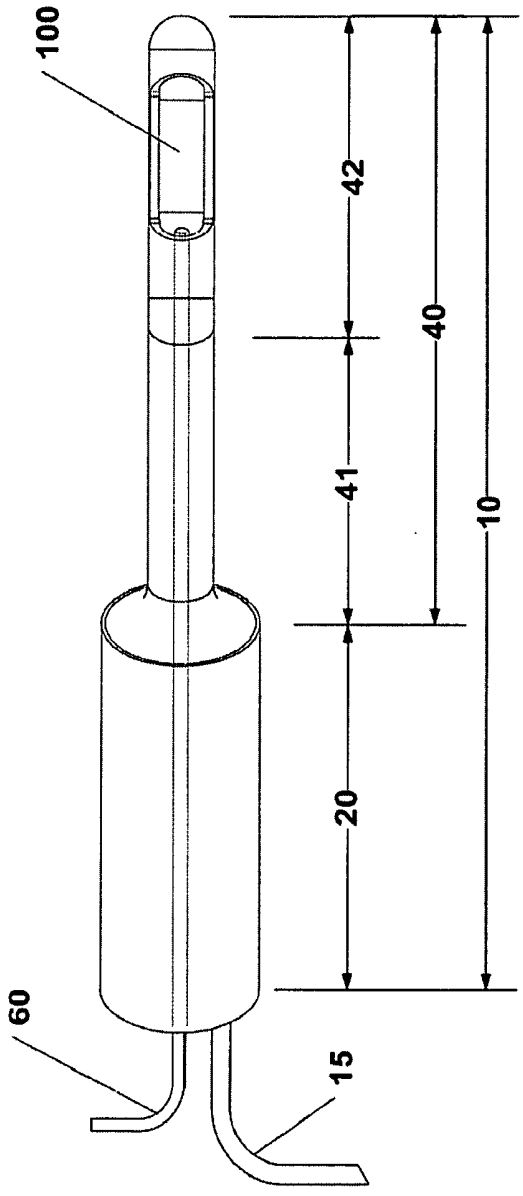


FIGURE 3

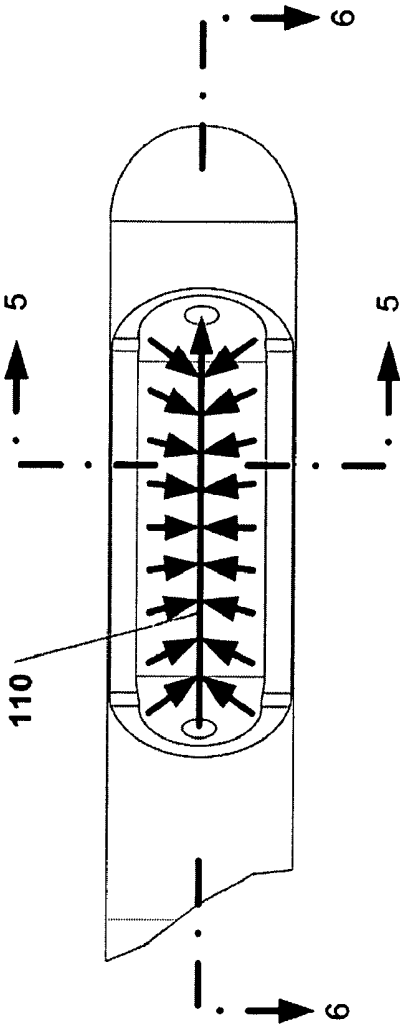


FIGURE 4

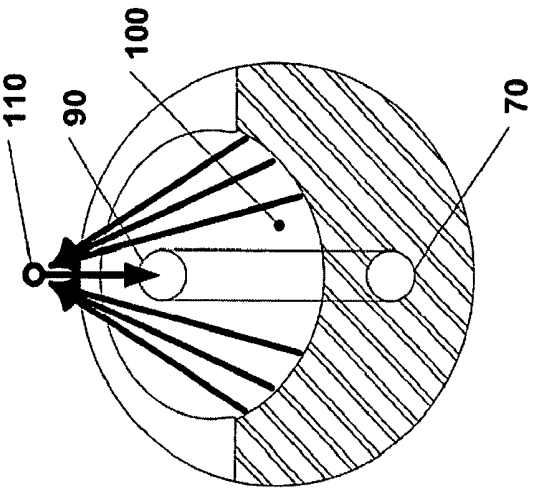


FIGURE 5

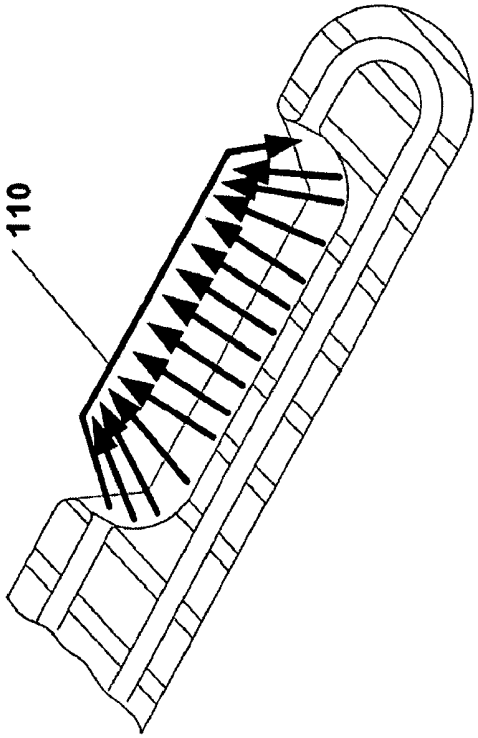


FIGURE 6

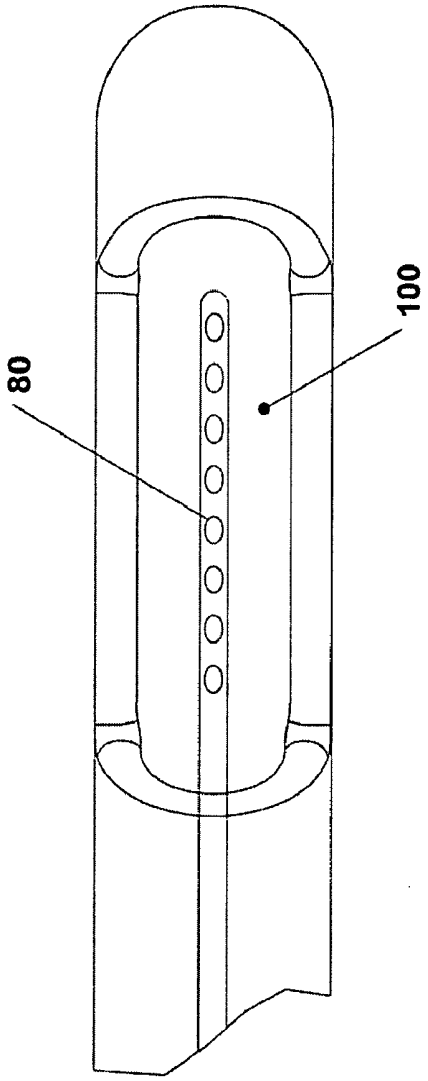


FIGURE 7

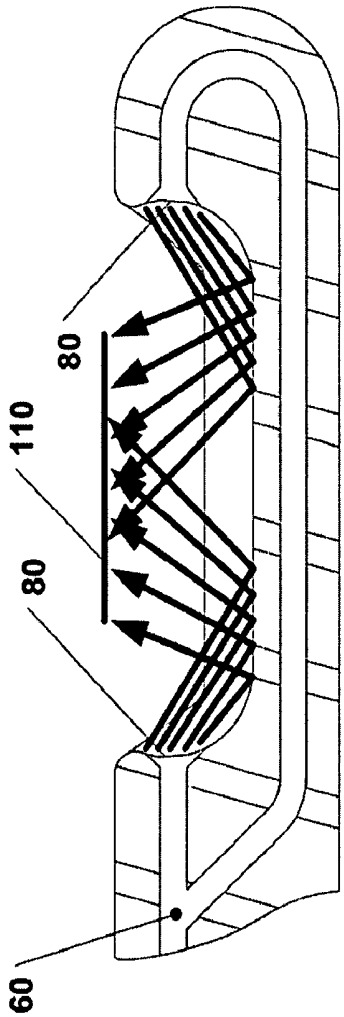


FIGURE 8

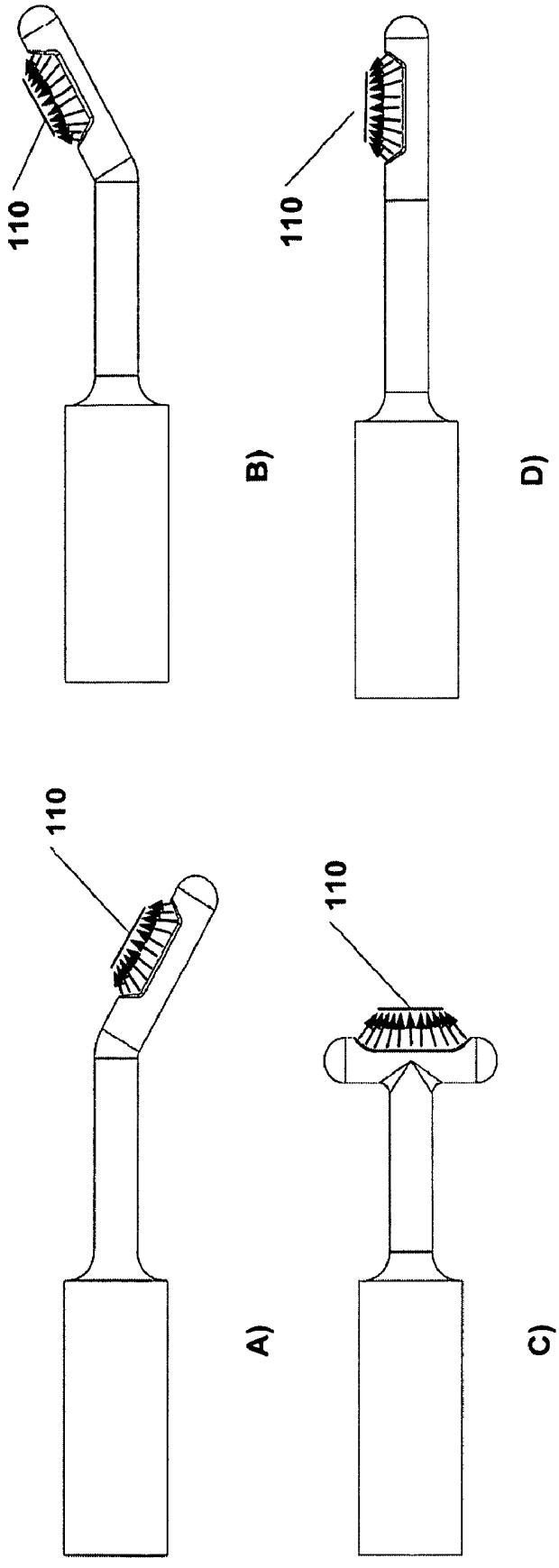


FIGURE 9

ULTRASOUND LIQUID BLADE SCALPEL METHOD

BACKGROUND OF THE INVENTION

[0001] This present invention relates generally to a surgical instrument that can use ultrasound to influence and energize a liquid such as water to form the blade of a knife or scalpel with improved cutting abilities. More particularly the invention relates to an ultrasound liquid scalpel having improved properties for use during surgical operations involving cutting through skin tissues, organ tissues and other tissues.

[0002] Generally, a scalpel is a tool for cutting through skin and/or other soft tissues during surgeries. U.S. Pat. No. 2,650,426 to Montelius, U.S. Pat. No. 5,055,106 to Lundgren and U.S. Pat. No. 5,078,724 to Takase describe examples of scalpels known in the prior art. These surgical scalpels comprise basically a cutting edge, such as a blade attached to a handle. In addition to use in surgery, scalpels generally, as well as the present invention in particular, may be used in a variety of cutting application in the arts, crafts and other precision cutting processes for cutting wood, paper, plastics, foams and other natural and man-made materials. The size and shape of the blade and handle vary depending on the particular application of use.

[0003] Due to problems associated with such surgical scalpels such as, but not limited to, the application of too much pressure on the cutting area, trauma, and scaring, ultrasonic scalpels using metal blades were developed. Ultrasonic scalpels are well known in the art and used widely for surgical operations. An ultrasonic scalpel can reduce bleeding and reduce the amount of pressure needed during cutting. As such, ultrasonic scalpels using metal blades may eliminate some of the trauma associated with pressure applied to the cut and with the surgery in general.

[0004] Using metal bladed ultrasonic scalpels can reduce the scarring and bleeding associated with surgical operations compared to ordinary scalpels lacking ultrasound energy. Examples of related devices are disclosed in U.S. Pat. No. 5,167,725 to Clark et al, and U.S. Pat. No. 6,514,267 to Jewett. The cauterization effect of ultrasound is also utilized in related devices such as U.S. Pat. No. 5,263,957 to Davison and U.S. Pat. No. 5,324,299 to Davison et al.

[0005] Despite their advantages, the prior art ultrasonic scalpels fail to effectively cut through skin and/or soft tissue without inflecting collateral damage on the skin and/or soft tissue being cut. The infliction of collateral damage occurs because most prior art ultrasonic scalpels are designed to be used with longitudinal motions which either result in excessive bleeding from the incision, require the application of excessive pressure on tissue, or are insufficient for cutting without damaging the surrounding skin and/or soft tissue. Such trauma to viable tissue can impede the healing potential. Necrosis (i.e., death of cells and living tissue) may also result from the trauma. Necrosis is caused by the continuous friction created from the blade's cutting edge and/or surface being in continuous contact with the skin and/or tissue as it is cut, leading to acoustic burns. Such continuous contact is the outcome of the blade's repeated longitudinal motion during cutting. The resulting damage to the surrounding skin and/or tissue is often irreversible.

[0006] Cutting devices using water as a blade material such as; U.S. Pat. No. 5,944,686 to Patterson et al., U.S. Pat. No. 6,511,493 to Moutafis et al and U.S. Pat. No. 7,122,017 to Moutafis et al provide a very highly pressurized stream of water that may be used for cutting tissue. As a result of the high discharge pressures, relatively large volumes of water are discharged from the cutting devices. To facilitate collecting this water, the devices generally have a return orifice opposite the supply orifice within a cavity, thereby confining the water cutting surface entirely within the cavity. Although this configuration is effective at returning the water for collection, it effectively shrouds the cutting blade making it very difficult to access on the body to be cut. Accessing body tissue often requires pressing the device into the surrounding tissue so that the water cutting surface may make contact with the tissue being cut. This pressure may be necessary to access the tissue, but may also result in extensive pain to the patient during the procedure, especially when cutting tissue in injured or sensitive areas of the patients body.

[0007] Cutting devices using water and ultrasound for debridement have been developed. Examples within the prior art include, U.S. Pat. No. 7,025,737 to Soring et al., U.S. Pat. No. 6,569,099 to Babaev and U.S. App. No. 20070287934 to Babaev. These devices may be used for debridement, but do not disclose a scalpel using a liquid influenced by ultrasound energy to form a knife blade that is useable for routine surgical applications.

SUMMARY OF THE INVENTION

[0008] An ultrasound assisted liquid blade cutting device and associated methods of use enabling relatively pain-free incision is provided. As described herein, the invention is used for procedures in somewhat the same manner other scalpels and cutting devices are used. Example uses include surgical cutting on skin, organs and other tissues of a patient. Non-surgical uses of the invention are also possible. The invention may be useful for cutting wood, plastics, foam or other materials for purposes of art, crafts, hobbies and manufacturing applications were precise hand manipulated cutting is required.

[0009] The device comprises an ultrasound generator driving an ultrasound transducer connected to an ultrasound transducer tip containing a cavity. The transducer tip preferably contains a supply tube to transport a liquid to the cavity. The cavity is a hollowed out area within the transducer tip, preferably of a parabolic shape defined by walls within the transducer tip. When driven or otherwise activated by the ultrasound generator, the ultrasonic transducer induces ultrasonic vibrations within the tip, causing ultrasonic waves carrying ultrasonic energy to be released from the various surfaces of the tip, including the walls defining the cavity. Within the cavity, the liquid may be transformed into a spray by ultrasound waves emanating from the walls defining the cavity. In the alternative or in combination, the ultrasound waves may push the liquid stream within the cavity towards the focal point of the cavity. The cavity generally has a focal point towards which the ultrasound waves and liquid are directed. The ultrasound waves and liquid directed towards the focal point creates a cutting focus forming a liquid blade, preferably outside of the opening of the cavity. The cutting focus may overlap or diverge from the focal point of the cavity.

[0010] Configuring the walls of the cavity as to form a parabola in at least two dimensions may focus the ultrasonic energy emanating from the walls of the cavity towards the focal point of the parabola. In a preferred embodiment, the focal point of the parabola lies outside the cavity, so that the ultrasonic energy emitted from the cavity may be concentrated towards a point outside of the perimeter of the cavity.

[0011] When the transducer tip is ultrasonically vibrated, cavitations may form within the liquid. Cavitations formed in the liquid may have benefits such as, but not limited to, further nebulizing the liquid, producing ozone, deactivating microorganisms, reducing patient pain levels and improving debridement.

[0012] Known ultrasonic cutting devices have orthogonal dimensions to the lateral axis at their distal end and proximal end. Generally the distal end orthogonal dimension is greater than the proximal end orthogonal dimension, making use of the device cumbersome. An advantage of the present invention, is that the transducer tip's distal end orthogonal dimension does not need to be greater than the transducer tip's proximal end orthogonal dimension making use of the invention much more convenient, particularly where maneuverability is an issue such as for internal cutting.

[0013] One of the major advantages of the present invention is improved and more effective cutting of skin and/or soft tissue. The use of ultrasonic energy to form a liquid blade, and then use the liquid blade in cooperation with the ultrasonic energy produces a number of substantial benefits over the prior art.

[0014] Another aspect of the device of the present invention may be to provide an ultrasonic liquid blade cutting device that does not require the use of metal blades.

[0015] Another aspect of the device of the present invention may be to provide an ultrasonic liquid blade cutting device that may effectively cut through skin and/or soft tissue easier and/or inflicting less trauma than conventional scalpels.

[0016] Another aspect of the device of the present invention may be to provide an ultrasonic liquid blade cutting device that will minimize blood loss through cauterization, protein denaturization, coagulation and/or sealing both interoperatively and postoperatively.

[0017] Another aspect of the device of the present invention may be to provide an ultrasonic liquid blade cutting device that will allow tissue differentially dissected during its use.

[0018] Another aspect of the device of the present invention may be to provide an ultrasonic liquid blade cutting device that may be used without generating sharps for disposal.

[0019] Another aspect of the device of the present invention may be to prevent, reduce and/or eliminate necrosis of tissues.

[0020] These and other aspects of the invention will become more apparent from the written description and figures below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The present invention will be shown and described with reference to the drawings of preferred embodiments and will be clearly understood in details. Like elements of the various embodiments within the figures are equivalently numbered.

[0022] FIG. **1** depicts the ultrasonic liquid blade cutting device of the present invention.

[0023] FIG. **2** depicts a cross-sectional view of a portion of the transducer tip of the present invention.

[0024] FIG. **3** depicts a planar view of hand piece portion of the ultrasonic scalpel.

[0025] FIG. **4** depicts a planar view of the transducer tip.

[0026] FIG. **5** depicts a cross-sectional end view of one possible embodiment of the transducer tip.

[0027] FIG. **6** depicts a cross-sectional side view of an alternative embodiment of the transducer tip.

[0028] FIG. **7** depicts a planar view of an alternative embodiment of the transducer tip.

[0029] FIG. **8** depicts a cross-sectional view of an alternative embodiment of the transducer tip.

[0030] FIGS. **9**A-D depicts alternative embodiments of the transducer tip portion of the hand piece.

DETAILED DESCRIPTION OF THE INVENTION

[0031] The present invention is an ultrasonic liquid blade cutting device that may be used for various surgical operations including cutting through skin tissue, organ tissue and/or other soft tissues. FIG. **1** depicts one possible embodiment of the ultrasonic liquid blade cutting device of the present invention. The depicted embodiment of the present invention comprises an ultrasound generator **15** with an electrical cord supplying the ultrasound generator **15** power, such as standard AC or battery power from a power source. The ultrasound generator **15** is in electrical communication with an ultrasound transducer **20** through a signal connector **17**. A hand piece **10** contains the ultrasound transducer **20** driven by the ultrasound generator **15**, a housing surrounding the ultrasound transducer **20** that provides a gripping surface and an transducer tip **40** or horn connected to the distal end of the ultrasound transducer **20**.

[0032] The transducer tip **40** may be connected to transducer **20** either directly or through a mechanical interface such as by threading, welding and/or other means readily recognizable by people of ordinary skill in the art. The transducer tip **40**, or portions of the transducer tip **40** may be removable from the hand piece **10** for cleaning, sterilization and/or replacement as would be understood by those skilled in the art upon review of this disclosure. The transducer tip **40** may be fabricated from metals such as, but not limited to, alloys of titanium, aluminum and/or steel.

[0033] Ultrasound generators and ultrasound transducers are well known in the art and will not be described in detail herein. However, the ultrasound generator **15** should be capable of producing an electrical signal of a sufficient alternating voltage to drive the ultrasound transducer **20**. The ultrasound transducer **20** converts the alternating voltage into mechanical motion as to induce the transducer tip **40** to vibrate. Preferably transducer tip **40** is induced to vibrate approximately in resonance. The amplitude of the vibrations produced may be any in the ultrasound spectrum, but are typically between approximately 1 micron and approximately 300 microns. The preferred amplitude range is approximately 60 microns-100 microns. The recommended amplitude value is approximately 80 microns.

[0034] The electrical signal produced by ultrasound generator **15** should also be sufficient to drive the ultrasound transducer **20** to induce transducer tip **40** to vibrate approximately in resonance at any frequency within the ultrasound spectrum, such as, but not limited to, between approximately 15 kHz and approximately 3 MHz. The preferred frequency range for the transducer tip **40** is 15 kHz to 50 kHz with a recommenced frequency of approximately 30 kHz.

[0035] Ultrasound transducer **20** may be driven with a continuous wave or pulsed frequency signal supplied by ultrasound generator **15**. Driving transducer **20** with a continuous wave tends to induce the release of standing waves from the various surfaces of tip **20**, while a pulsed frequency reduces or avoids the release of standing waves. The pulsed frequency signal generates less heat and may increase the longitudinal force of the induced vibrations as a result of the on/off cycle

changes. The electrical signal may be changed depending on the desired features of the released ultrasound waves for the particular application. For example, inducing the release of standing waves may be helpful to produce or increase cavitation effects.

[0036] The wave form of the electrical signal may be sinusoidal, rectangular, trapezoidal and/or triangular. In addition, the electrical signal from the ultrasound generator **15** may be fixed or modulated. Ultrasound generator **15** may include feedback control to adjust the signal.

[0037] A housing serving as a handle for the ultrasonic liquid blade cutting device may isolate the ultrasound transducer **20** from the device operator. Surgeons and/or users of the ultrasonic liquid blade cutting device could hold the housing during surgical operations to manipulate the device. The housing provides a surface appropriate for hand manipulation by the surgeon and/or user while allowing the user to avoid direct contact with vibrations within the device. The housing may extend over the entire ultrasound transducer **20** and/or may partially enclose portions of the transducer tip **40**.

[0038] The transducer tip **40** receives a liquid **50**, typically through a supply tube **60**. Supply tube **60** may enter the transducer tip **40** longitudinally through the ultrasound transducer **20** and/or handle. The liquid **50** may also be delivered radially through means external to the device. Various liquids such as, but not limited to, tap water, distilled water, saline, and/or other therapeutic agents such as, but not limited to, anti-inflammatories and/or antibiotics may be used with the device. The liquid **50** is preferably provided by a pump **51** to the supply tube **60**. Various pumps may be utilized to provide liquid **50** to supply tube **60**. For example, pump **51** may be a syringe pump or other positive displacement pump. Depending on the desired operating characteristics and use of the device, liquid **50** may be provided at a relatively low pressure of approximately 1 to 100 psi, or at higher pressures of up to approximately 20,000 psi using available prior art devices. The pump and supply tube provided must be compatible with the pressure ranges actually used. If the transducer tip **40** requires additional cooling beyond that provided by the flow and/or atomization of liquid **50**, transducer tip **40** may be equipped with additional cooling capabilities. A possible means of equipping tip **40** with cooling capabilities is to provide internal lumen within tip **40** for circulating a cryogenic fluid such as but not limited to liquid nitrogen. Other means of equipping tip **40** with cooling capabilities, readily recognizable by those of ordinary skill in the art, are equally possible.

[0039] The transducer tip **40** may also include a return tube **70** in some embodiments. The return tube **70** may remove liquid **50**, tissue and other materials and fluids in the incision site and/or the cavity **100**. The return tube **70** preferably connects between the transducer tip distal end **42** and a vacuum source. Although the use of a vacuum source is preferred, with proper alignment of the orifice **80** and return orifice **90** the kinetic energy of the liquid can be used to collect some of the excess fluid in the return tube **70** and then through the tube for removal.

[0040] An aspirator may be used to remove fluids and other materials from the surgical area. The aspirator may be integrated with the transducer tip **40**. Alternatively or in combination, the aspirator may be a device independent and separate from the transducer tip **40**.

[0041] FIG. **2** depicts a partial view of the transducer tip **40**. The longitudinal axis of the transducer tip distal end **42** may be positioned to create an angle α with the longitudinal axis of the transducer tip proximal end **41**. In the preferred embodiment a may vary from approximately 0 to 45 degrees.

[0042] The transducer tip distal end **42** includes a cavity **100** that receives the liquid **50** from an orifice **80** via the supply tube **60**. The orifice **80** may be of any geometric shape, but is typically circular, oval or slot shaped. A circular shape is preferred for the orifice **80**. The return tube **70** originates at a return orifice **90** on the transducer tip distal end **42**. The cavity is generally of an open parabolic shape preferably elongated along the transducer tip's longitudinal axis. The cavity may be defined by at least one wall with an open perimeter edge. Preferably the cavity is defined by a distal end wall, a proximal end wall and two side walls all terminating at an open perimeter edge.

[0043] Even though the transducer tip distal end **42** includes the cavity **100**, as FIG. **2** shows, at its largest dimension, the transducer tip's distal end **42** orthogonal dimension does not need to be greater than the transducer tip's proximal end largest orthogonal dimension. This allows the device to provide improved maneuverability and convenience, particularly where tight space may be an issue such as for internal cutting in hard to reach locations.

[0044] FIG. **3** depicts a plan view of the hand piece portion of the ultrasound liquid cutting device. The supply tube **60** may enter the hand piece and run along the longitudinal axis through the ultrasound transducer **20** and the transducer tip **40** to reach the transducer tip proximal end **41**.

[0045] Liquid **50** may flow along the surface of the cavity wall. Alternatively, liquid **50** may leave the orifice **80** and travel through the interior of the cavity **100** as a stream without contacting the cavity wall. Furthermore, the liquid **50** may be reflected off the cavity wall and dispersed within the cavity **100**. It is possible that liquid **50** may be directed to the return orifice **90** so that at least a portion is removed from the cavity **100**. In any of the above alternatives, as shown in FIG. **4** the liquid **50** is being directed towards the focal point(s) of the cavity **100**. In addition to directing liquid **50** towards the focal point of cavity **100**, liquid **50** may be transformed into a spray by the ultrasound energy being emitted from the interior of the cavity **100**. The ultrasound waves released from the interior of the cavity **100** tend to push the spray in the direction the ultrasound waves are traveling. This direction is generally orthogonal to the surface of the cavity wall which is primarily transverse to the longitudinal axis of the transducer tip distal end **42**. As such, the spray is directed by the ultrasound waves to the focal point of cavity **100**. Directing liquid **50** towards the focal points of cavity **100** forms a series of cutting focuses connecting to form a liquid blade **110**. Liquid blade **110** is preferably along a line, parallel to the longitudinal axis of the transducer tip distal end **42** but located outside the outer edge of the cavity **100**. The location of the liquid blade **110** is primarily defined by the parabolic shape of the cavity **100** directing the ultrasound waves, the characteristics of the ultrasound waves and the characteristics of the fluid stream.

[0046] In FIG. **5** a cross sectional end view of the transducer tip distal end **42** is depicted. In this embodiment, the return tube **70** extends to a return orifice **90** located near the edge of the distal wall of the cavity **100**. The ultrasonic energy and the spray formed from the liquid **50** are directed to the focal line of the cavity **100**, forming liquid blade **110**. The location of the liquid blade **110** is determined by the shape of the cavity

100, the characteristics of the ultrasound energy and the physical, chemical and energy characteristics of the fluid stream.

[0047] The use of liquid **50** and ultrasound energy to form the ultrasonic liquid blade used with this cutting device has the substantial benefit that surgical cutting operations may be performed without generating sharps for disposal. In addition to the avoided expense of obtaining, handling and disposing of sharps, their lack of presence substantially reduces the safety risks associated with surgical cutting operations, particularly with regards to the transmission of blood born pathogens.

[0048] In FIG. **6** a cross sectional view along the longitudinal axis of the transducer tip distal end **42** is shown depicting the liquid blade **110** in its preferable location above the perimeter of cavity **100**. Delivery of the ultrasound energy to the focal line of cavity **100** overlapping the liquid blade **110** is enhanced by the presence of the liquid **50** in the form of a spray, since the liquid **50** serves as a fluid coupling medium, greatly enhancing the transmission of ultrasound energy released from the walls of cavity **100**.

[0049] Ultrasound transmission through air is relatively inefficient. Utilizing the liquid **50** forming the ultrasonic liquid blade **100** as a fluid coupling medium greatly improves the transmission of the ultrasound energy released from the cavity **100**. In addition, the liquid blade **110** serves as a structure allowing the ultrasound energy to form cavitations as the ultrasound energy is delivered from the cavity **100** to the liquid blade **110**. When the tip is ultrasonically vibrated, cavitations may form within the liquid **50**. In addition, liquid **50** within cavity **100** may be atomized into a spray. If a piezoelectric transducer is used to induce the transducer tip **40** to vibrate approximately in resonance, then the voltage of the electrical signal driving the transducer will largely control the degree to which liquid **50** is cavitated and/or atomized. At low voltages, liquid **50** within and/or outside the cavity **100** will be cavitated to a small degree. As the voltage increases, the amount of cavitations within liquid **50** is increased. Further increasing the voltage will eventually induce atomization of liquid **50**. Regardless of whether liquid **50** is atomized and/or cavitated, the presence of liquid within and/or beyond the confines of the cavity **100** may couple the transmission of ultrasonic energy released from the walls of the cavity **100** to the wound and/or tissue to be cut.

[0050] The cavitation of liquid **50**, as well as the mechanical energy associated with the focused ultrasound energy can be used to assist the production of ozone from the oxygen associated with the air and/or liquid. The ozone produced may be utilized to assist the ultrasound energy to disrupt cellular materials and inactive pathogens. Thereby, the ozone may provide therapeutic disinfecting properties to help the patient resist operative and post-operative infections.

[0051] In addition to pathogen deactivation, the combination of ultrasound energy and cavitation effects can be utilized to cooperatively minimize blood loss through cauterization, protein denaturization, coagulation and/or sealing both during the surgical procedure and during postoperative healing. The combination of ultrasound energy induced mechanical vibrations and cavitation effects may also be utilized to prevent, reduce and/or eliminate necrosis of tissues.

[0052] The ultrasonic energy transmitted via liquid **50** may be used to irrigate the surgical area. Additionally, the transmitted ultrasonic energy may provide for less painful treatment. The ultrasonic energy and/or the waves carrying it may elicit a change in the membrane permeability of deep cellular structures such as, but not limited to, axons and somas, decreasing the sensation of pain in surgical area. Additionally or in combination, the mechanical energy generated by directing ultrasound waves towards a focal point may interact with nerve cells as to provide an analgesic effect.

[0053] The parabolic shape of the cavity **100** of the disclosed device will tend to direct ultrasound energy, mechanical energy, and liquid **50** towards the focal point or line of cavity **100**. If liquid **50** is introduced through orifice **80** into cavity **100** at high pressures a jet stream spray traveling across cavity **100** and into return orifice **90** may be produced. When transducer tip **40** is induced to vibrate, ultrasound waves released from the wall surfaces of cavity **100** may direct the jet stream towards the focal point and/or focal line of cavity **100**. Liquid **50** may be transported through return tube **70** either with the assistance of a vacuum source, or simply using the liquid's kinetic energy and gravity. Inducing the transducer tip **40** to ultrasonically vibrate may result in atomizing or nebulizing of at least a portion of the liquid **50** in the spray. If liquid **50** is introduced to the cavity **100** at low pressures it may be directly atomized or nebulized by the ultrasonic energy emanating from the cavity's wall surfaces, whether or not the fluid actually reaches the wall surfaces. In any result, an atomized spray may be produced which may then be directed toward the focal point(s) of cavity **100**.

[0054] Adjustment of the characteristics of the ultrasound energy and/or focal point of cavity **100** may allow the user to select operating conditions so that the ultrasonic liquid blade cutting device will allow the operator to differentiate between tissue during use based on tissue properties. For example, the device may be adjusted so that it will cut soft organ tissue, but not other tissues such as nerve tissues, tendons, ligaments or bone tissues. Furthermore, the device may be adjusted so that it will allow cutting with only minimal pressure being exerted by the operator on the tissue being cut, as to minimize pain being generated by instrument pressure. This feature is present with this invention because the mechanical motion of the fluid and ultrasound provided by the device does not depend on mechanical force from the operator alone to create the incision.

[0055] In addition to the internal and external liquid delivery methods described previously, as another alternative, depicted in FIG. **7** cavity **100** may have a plurality of orifices **80** arranged in a slot shape. Under this embodiment, the discharge pressure of liquid **50** can be utilized in cooperation with the ultrasound waves released from the wall surface of cavity to direct liquid **50** beyond the outer perimeter of cavity **100** to form the liquid blade **110**.

[0056] Another liquid **50** delivery method, shown in FIG. **8** depicts an embodiment having a supply tube **60** with a plurality of orifices **80** shown in a slot shape. The orifices are positioned to direct liquid **50** away from the perimeter of the cavity **100** so that the liquid **50** is reflected off the wall of the cavity **100** towards the focal point and/or focal line of the cavity **100**. Under this embodiment, the discharge pressure of the liquid **50** is used assist the ultrasound waves in directing liquid **50** beyond the outer perimeter of the cavity **100**, as to form the liquid blade **110**.

[0057] As shown in FIGS. **9**A-D, the transducer tip distal end **42** has a longitudinal axis and transducer tip proximal end **41** also has a longitudinal axis. An angle α may be formed at the intersection of the transducer tip distal end **42** longitudinal axis and the transducer tip proximal end **41** longitudinal axis.

The liquid blade longitudinal axis is preferably parallel with the longitudinal axis of the transducer tip distal end **42**. Various embodiments having varying angles α of the hand piece are possible, which may be preferred for the various uses of the device. FIG. **9**A shows a device with an angle α of less than 90-degrees. FIG. **9**B shows a device with an angle α of greater than 180-degrees. FIG. **9**C shows a device with an angle α equal to 90-degrees. FIG. **9**D shows a device with a horizontal alignment with an angle α equal to approximately 0-degrees.

[0058] Combinations of the above embodiments and other embodiments will be apparent to those having skill in the art upon review of the present disclosure. The scope of the present invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

It should be appreciated that elements described with singular articles such as "a", "an", and/or "the" and/or otherwise described singularly may be used in plurality. It should also be appreciated that elements described in plurality may be used singularly. Although specific embodiments of devices and methods have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, combination, and/or sequence that is calculated to achieve the same purpose may be substituted for the specific embodiments shown. It is to be understood that the above description is intended to be illustrative and not restrictive. Combinations of the above embodiments and other embodiments as wells as combinations and sequences of the above methods and other methods of use will be apparent to individuals possessing skill in the art upon review of the present disclosure. The scope of the claimed apparatus and methods should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

I claim:

1. A method for using an ultrasound assisted liquid cutting device comprising the steps of:

a. generating ultrasound waves with an ultrasound transducer;
b. transmitting the ultrasound waves to an transducer tip connected to the ultrasound transducer;
c. supplying a liquid to a cavity located within the transducer tip;
d. generating a spray within the cavity;
e. using the spray as a coupling medium to transmit the ultrasound waves;
f. focusing the spray and the ultrasound waves; and
g. forming a liquid blade.

2. The method of claim **1** including the additional step of making a tissue incision with the liquid blade.

3. The method of claim **1** wherein at least portions of the transducer tip are detachable.

4. The method of claim **1** wherein the surgical blade is manufactured from a material selected from a group consisting of stainless steel, titanium alloy and aluminum alloy.

5. The method of claim **1** having the additional step of using the liquid to cool the transducer tip.

6. The method of claim **1** wherein the ultrasound waves are generated from a signal form selected from the group including sinusoidal, rectangular, trapezoidal or triangular.

7. The method of claim **1** wherein the liquid is selected from the group including tap water, distilled water, saline, antibiotics, anti-inflammatories or therapeutic agents.

8. The method of claim **2** wherein the ultrasonic energy carries the liquid into the incision.

9. The method of claim **1** having the additional step of deactivating microorganisms with the ultrasonic energy.

10. The method of claim **1** having the additional step of directing the radiation surface by holding a housing.

11. The method of claim **1** wherein the radiation surface emits ultrasound waves at a wavelength between 16 kHz and 20 mHz.

11. The method of claim **1** wherein the radiation surface emits ultrasound waves at a wavelength being approximately 30 kHz.

12. The method of claim **1** wherein the radiation surface emits ultrasound waves at an amplitude between 1 micron and 300 microns.

12. The method of claim **1** wherein the radiation surface emits ultrasound waves at an amplitude of approximately 80 microns.

13. The method of claim **1** having the additional step of providing pain relief with the ultrasonic energy.

14. The method of claim **1** wound comprising tissue selected from the group consisting of heart, lung, liver, brain and stomach.

15. The method according to claim **2** further comprising the step of extracting debris from the incision.

16. The device according to claim **1**, further characterized by said ultrasound generator being capable of generating a continuous or pulsed frequency.

17. The device according to claim **1**, further characterized by said ultrasound generator being capable of generating a fixed or modulated frequency.

18. The device according to claim **1**, further characterized by said ultrasound generator being capable of generating a wave form which is selected from the group consisting of sinusoidal, rectangular, trapezoidal and triangular wave forms.

19. The method according to claim **1** wherein the liquid blade is positioned outside the cavity.

20. The method according to claim **1** wherein the ultrasound generator is capable of producing an electrical signal of a voltage sufficient to induce the substructure formed by the shaft and tip to vibrate approximately in resonance with the amplitude of the vibrations being approximately 100 microns.

21. The method according to claim **1** wherein the ultrasound generator is capable of producing an electrical signal of a voltage sufficient to induce cavitations within the liquid.

22. The method according to claim **1** wherein the ultrasound generator is capable of producing an electrical signal of a voltage sufficient to nebulize the liquid from the cavity.

23. The method according to claim **1** wherein the ultrasound generator is capable of producing standing waves within the liquid.

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摘要(译)

在本发明中公开了一种超声波辅助的液体刀片切割装置，例如可用于常规外科手术的手术刀。超声手术刀包括超声发生器，超声换能器，换能器尖端，换能器尖端上的腔，使用液体喷雾形状以形成切割表面。喷雾用作施加的超声能量的载体介质，其增强了手术刀的特征和性能。从换能器尖端传输的超声能量有助于将液体输送到形成在腔体外部的液体叶片。超声能量聚焦并激活液体以允许用液体刀片切割组织。该装置可用于在外科手术期间切割皮肤和/或其他软组织，从而提高切割效率，减少和/或消除坏死形成。