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(54) **METHODS FOR FORMING AN OPENING IN THE TRABECULAR MESHWORK OF THE EYE OF A PATIENT**

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USPC 606/107, 161-162, 166-167, 170, 606/184-185; 600/566, 567
See application file for complete search history.

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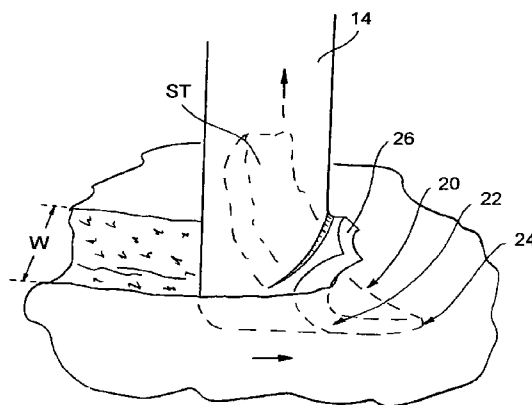
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(57) **ABSTRACT**

Methods and devices for cutting strips of tissue from masses of tissue inside or outside of the bodies of human or animal subjects. The device generally comprises a) an elongate cutting tube that has a distal end and a lumen that opens through an opening in the distal end and b) first and second cutting edges formed on generally opposite edges of the distal end of the cutting tube and separated by a distance D. The device is advanced through tissue to cut a strip of tissue of approximate width W. Width W is approximately equal to distance D.

10 Claims, 3 Drawing Sheets



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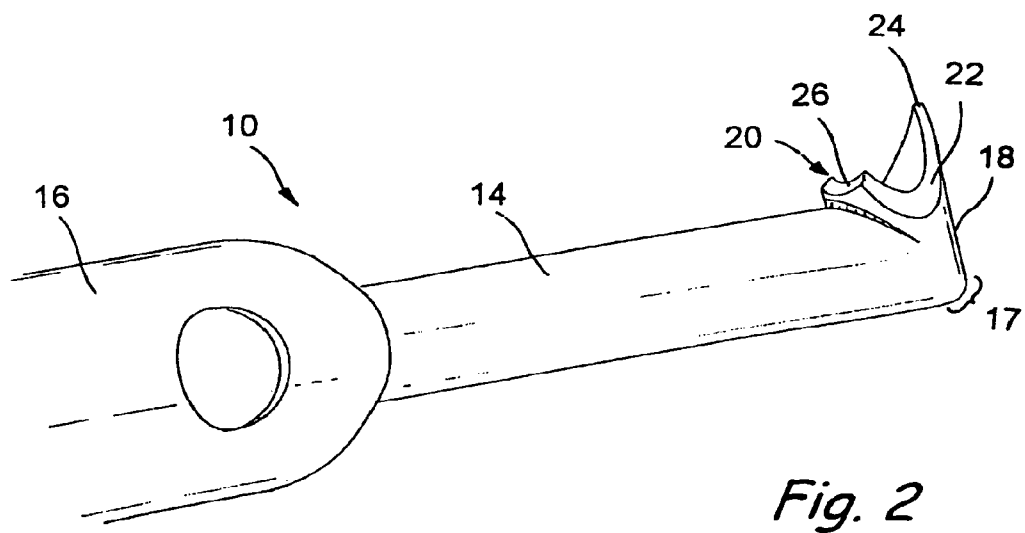
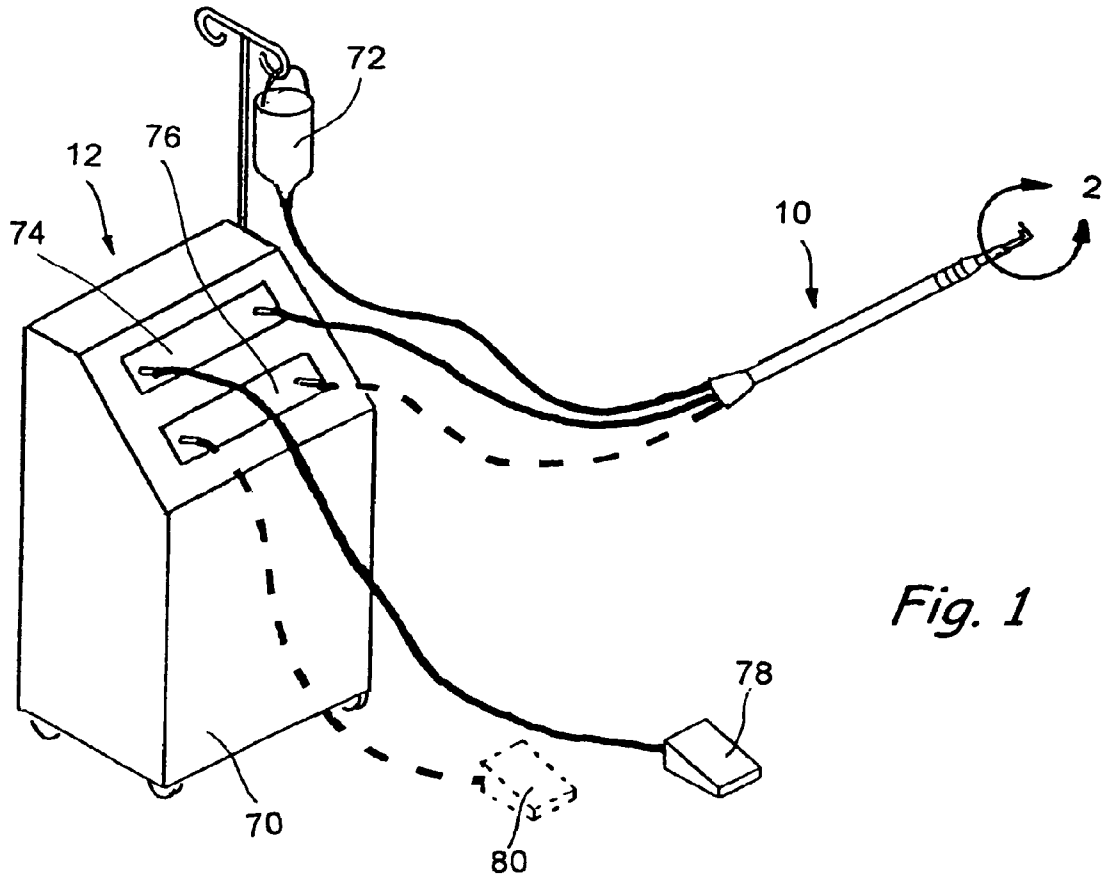
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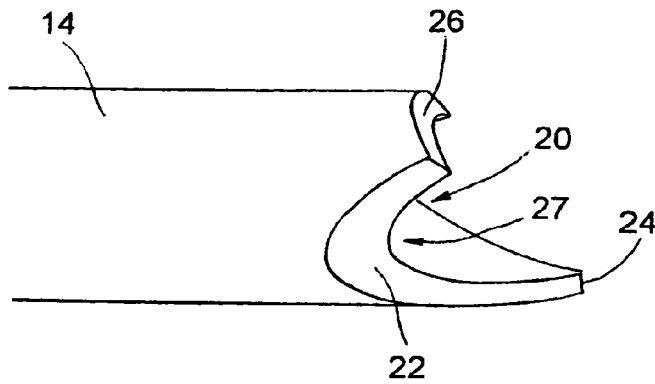


Fig. 3A

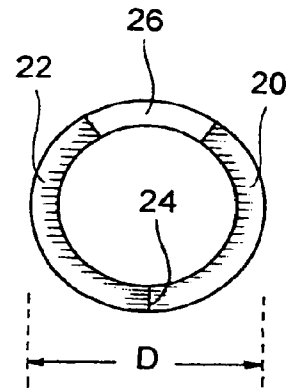


Fig. 3B

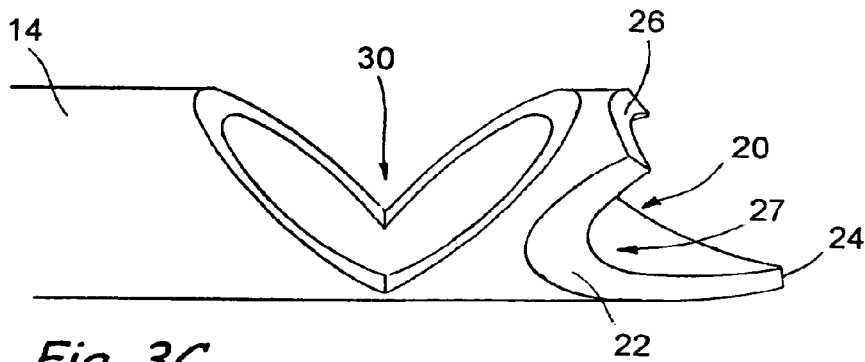


Fig. 3C

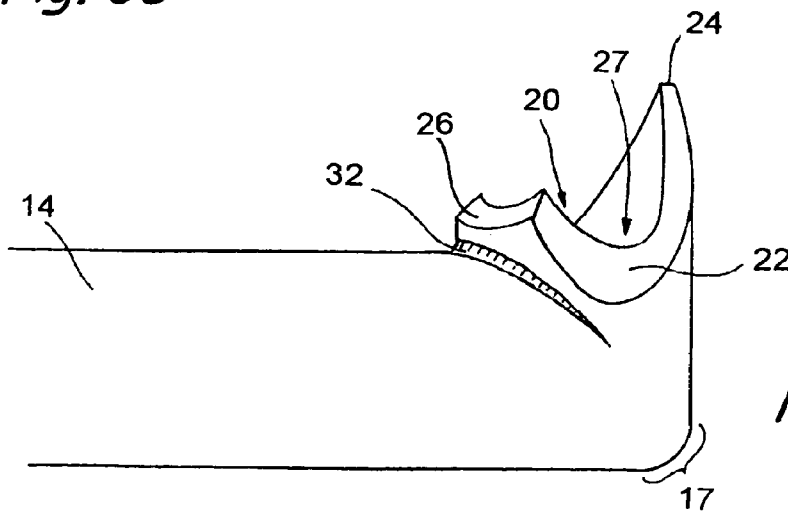


Fig. 3D

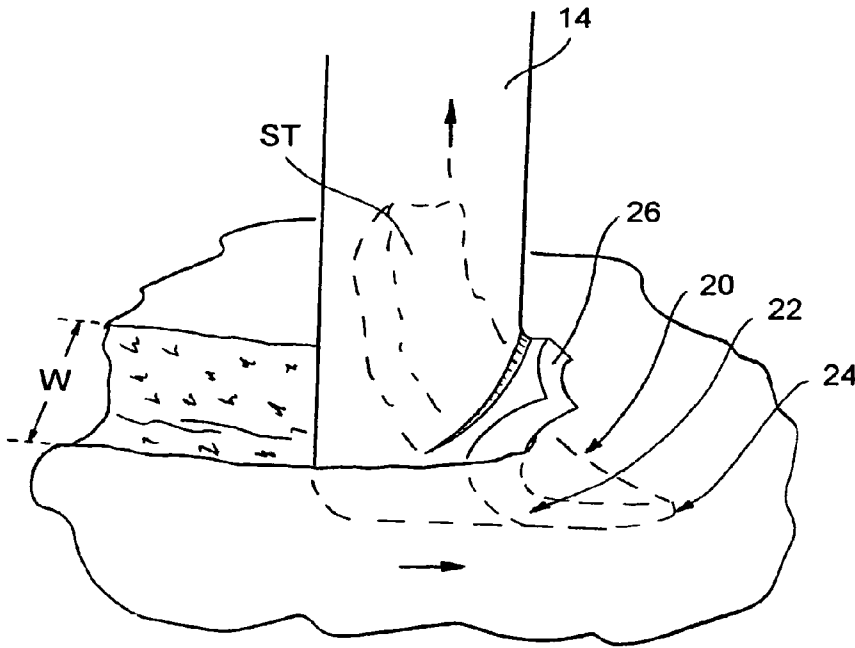


Fig. 4

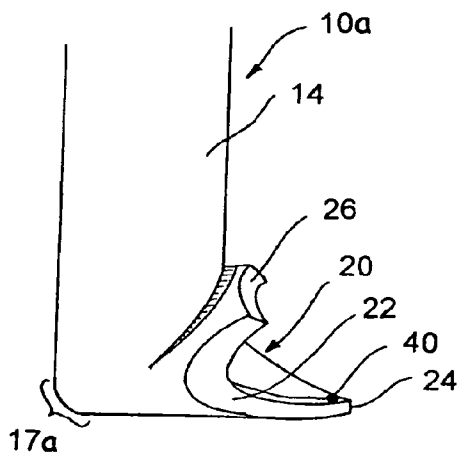


Fig. 5

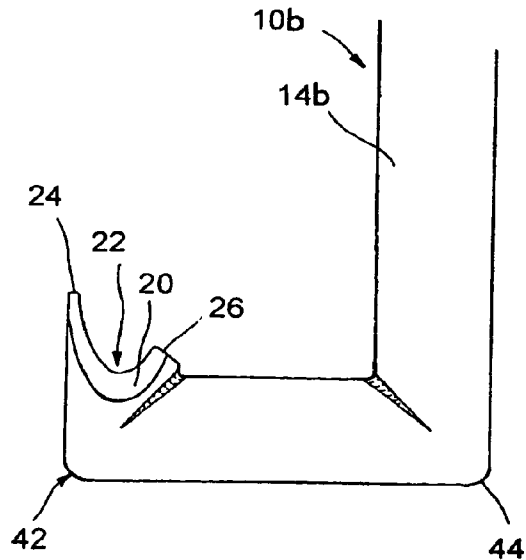


Fig. 6

**METHODS FOR FORMING AN OPENING IN
THE TRABECULAR MESHWORK OF THE
EYE OF A PATIENT**

RELATED APPLICATIONS

This application is a division of U.S. patent application Ser. No. 13/159,356 filed Jun. 13, 2011 currently abandoned which is a division of U.S. patent application Ser. No. 10/560,267 filed May 11, 2006 and issued as U.S. Pat. No. 7,959,641 on Jun. 14, 2011, which is a 35 U.S.C. §371 national stage of PCT International Patent Application No. PCT/US2004/018488 filed Jun. 10, 2004, which claims priority to U.S. Provisional Patent Application No. 60/477,258 timed on Jun. 10, 2003, the entire disclosure of each such prior patent and application being expressly incorporated herein by reference.

BACKGROUND OF THE INVENTION

There are numerous medical and surgical procedures in which it is desirable to cut and remove a strip of tissue of controlled width from the body of a human or veterinary patient. For example, it may sometimes be desirable to form an incision of a controlled width (e.g., an incision that is wider than an incision made by a typical scalpel or cutting blade) in the skin, mucous membrane, tumor, organ or other tissue or a human or animal. Also, it may sometimes be desirable to remove a strip or quantity of tissue from the body of a human or animal for use as a biopsy specimen, for chemical/biological analysis, for retention or archival of DNA identification purposes, etc. Also, some surgical procedures require removal of a strip of tissue of a known width from an anatomical location within the body of a patient.

One surgical procedure wherein a strip of tissue of a known width is removed from an anatomical location within the body of a patient is an ophthalmological procedure used to treat glaucoma. This ophthalmological procedure is sometimes referred to as a goniotomy. In a goniotomy procedure, a device that is operative to cut or ablate a strip of tissue of approximately 2-10 mm in length and about 50-200 μm in width is inserted into the anterior chamber of the eye and used to remove a full thickness strip of tissue from the trabecular meshwork. The trabecular meshwork is a loosely organized, porous network of tissue that overlies a collecting canal known as Schlemm's canal. A fluid, known as aqueous humor, is continually produced in the anterior chamber of the eye. In normal individuals, aqueous humor flows through the trabecular meshwork, into Schlemm's Canal and out of the eye through a series of ducts. In patients who suffer from glaucoma, the drainage of aqueous humor from the eye may be impaired by elevated flow resistance through the trabecular meshwork, thereby resulting in an increase in intraocular pressure. The goniotomy procedure can restore normal drainage of aqueous humor from the eye by removing a full thickness segment of the trabecular meshwork, thus allowing the aqueous humor to drain through the open area from which the strip of trabecular meshwork has been removed. The goniotomy procedure and certain prior art instruments useable to perform such procedure are described in U.S. patent application Ser. No. 10/052,473 published as No. 2002/011608A1 (Baerveldt), the entirety of which is expressly incorporated herein by reference.

At present there remains a need in the art for the development of simple, inexpensive and accurate instruments useable

to perform the goniotomy procedure as well as other procedures where it is desired to remove a strip of tissue from a larger mass of tissue.

SUMMARY OF THE INVENTION

The present invention provides a device for cutting a strip of tissue of approximate width W from a mass of tissue. The device generally comprises a) an elongate cutting tube that has a distal end and a lumen that opens through an opening in the distal end and b) first and second cutting edges formed on generally opposite edges of the distal end of the cutting tube and separated by a distance D . The cutting tube is advanceable through tissue such that the first and second cutting edges will cut a strip of tissue having approximate width W , wherein the approximate width W is approximately equal to the distance between the first and second cutting edges. In some embodiments, the strip of tissue may be aspirated or otherwise removed through the lumen of the cutter tube. In some embodiments, the device may include apparatus useable to sever (e.g., transversely cut or transect) the strip of tissue when the strip of tissue has reached a desired length.

Further in accordance with the invention there is provided a method for cutting a strip of tissue of width W from a tissue mass. This method generally comprises the steps of a) providing a device that comprises i) an elongate cutting tube that has a distal end and a lumen that opens through an opening in the distal end and ii) first and second cutting edges formed on generally opposite edges of the distal end of the cutting tube and separated by a distance D that is approximately equal to the width W of the strip of tissue to be cut; and b) advancing the distal end of the cutting tube through the mass of tissue such that the first and second cutting edges cut a strip of tissue of approximate width W . Further aspects and elements of the invention will be understood by those of skill in the art upon reading the detailed description of specific examples set forth herebelow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a system incorporating a needle cutting device of the present invention.

FIG. 2 is an enlarged perspective view of section 2 of FIG. 1.

FIGS. 3A-3D show various steps in a method for manufacturing a needle cutter of the present invention.

FIG. 4 is a side view of a distal portion of a needle cutter device of the present invention being used to cut a strip of tissue of approximate width W .

FIG. 5 is a perspective view of the distal portion of a needle cutter device of the present invention incorporating apparatus for severing a strip of tissue cut by the needle cutter device after the strip of tissue has reached a desired length.

FIG. 6 is a side view of the distal portion of another embodiment of a needle cutter device of the present invention having a plurality of curves or bends formed in the cutting tube.

DETAILED DESCRIPTION

The following detailed description, and the drawings to which it refers, are provided for the purpose of describing and illustrating certain preferred embodiments or examples of the invention only, and no attempt has been made to exhaustively describe all possible embodiments or examples of the invention. Thus, the following detailed description and the accompanying drawings should not be construed to limit, in any way,

3

the scope of the claims recited in this patent application and any patent(s) issuing therefrom.

One example of a needle cutter device **10** of the present invention is shown in FIGS. 1-4. This needle cutter device **10** generally comprises an elongate cutting tube **14** that has a distal end and a lumen **27** that opens through an opening in the distal end. First and second cutting edges **20, 22** are formed on generally opposite edges of the distal end of the cutting tube **14**. These first and second cutting edges **20, 22** are separated by a distance **D**, as shown in the distal end view of FIG. 3B. In the particular example shown in the drawings, the first and second cutting edges **20, 22** are located on opposite lateral sides of the distal end of the cutting tube **14** and a blunt, protruding tip **24** is located on the bottom of the distal end of the cutting tube. Also, a blunt edge **26** is located at the top of the distal end of the cutting tube **14**. Thus, only the lateral cutting edges **20, 22** are sharp and intended to cut tissue. The blunt, protruding tip **24** can, in some applications, be configured and used to facilitate insertion of the device **10** to its intended location and/or the blunt protruding tip **24** may be placed in an anatomical or man made groove or channel (e.g., Schlemm's Canal of the eye) such that it will then advance through the channel or groove and guide the advancement and positioning of the remainder of the device **10**.

One or more bends or curves may optionally be formed in the cutting tube **14** to facilitate its use for its intended purpose. For example, in the embodiment of the device **10** shown in FIG. 2, a single bend **17** of approximately 90 degrees is formed near the distal end of the cutting tube **14**. In the embodiment of the device **10b** shown in FIG. 6, two separate bends of approximately 90 degrees each are formed at spaced apart locations on the cutting tube **14**, thereby giving the cutting tube **14** a generally U shaped configuration. It will be appreciated that any number of bends or curves, in any direction and of any severity may be formed in the cutting tube **14** to facilitate its use in specific procedures or to enable it to be inserted through tortuous anatomical channels of the body. In most cases, the degree of curvature in embodiments where a single bend or curve is formed will be between approximately 30 and approximately 90 degrees and in embodiments where more than one bend or curve are formed in the cutting tube **14** each such bend or curve will typically be between approximately 15 to approximately 90 degrees.

As shown in FIG. 4, when the cutting tube **14** is advanced through tissue, distal end first, the first and second cutting edges **20, 22** will cut a strip **ST** of tissue having approximate width **W**, such approximate width **W** being approximately equal to the distance **D** between the first and second cutting edges **20, 22**. The severed strip **ST** of tissue will enter the lumen **27** of the cutting tube **14** as the device advances. Negative pressure may be applied to lumen **27** to aspirate the strip **ST** of tissue and/or fluid and/or other matter through lumen **27**.

The device **10** may optionally include a second lumen. Such second lumen may be used for infusion of fluid through the device **10** or for other purposes. In the embodiment shown in FIGS. 1 and 2, the device **10** comprises an outer tube **16** in addition to the cutting tube **14**. The cutting tube **14** is of smaller diameter than the outer tube **16** and the cutting tube **14** may extend through the lumen **19** of the outer tube **16** such that a distal portion of the cutting tube **14** extends out of and beyond the distal end of the outer tube **16**, as may be seen in FIG. 2. The distal end of the outer tube **16** is tapered and in close approximation with the outer surface of the cutting tube **14**. Fluid may be infused through the lumen **19** of the outer tube **16**, through the space between the outer surface of the cutting tube **14** and the inner surface of the outer tube **16**.

4

Fluid that is infused through the lumen **19** of the outer tube **16** may flow out of one or more apertures **11** formed near the distal end of the outer tube.

In some embodiments, the device **10** may be equipped with severing apparatus for severing (e.g., transversely cutting or transecting) the strip **ST** of tissue to fully excise or detach the strip **ST** of tissue from the remaining tissue mass and/or from the body of a human or animal subject. Such severing apparatus may comprise any suitable type of tissue cutter such as a blade, scissor, guillotine, electrode(s), laser, energy emitting tissue cutter, mechanical tissue cutter, etc. FIG. 5 shows an example of an embodiment of the device **10a** wherein monopolar or bipolar electrode(s) **40** are located on the distal end of the cutting tube **14**. When it is desired to sever the strip **ST** of tissue, the electrode(s) is/are energized with sufficient energy to sever the strip **ST**, thereby disconnecting the strip **ST** from the remaining tissue mass and/or the body of the human or animal subject.

In some embodiments of the device **10**, the cutting edges **20, 22** may be heated such that they will cauterize as the cut. As those of skill in the art will appreciate, such heating of the cutting edges **20, 22** may be accomplished by placement of electrode(s) near the cutting edges **20, 22** such that, when the electrode(s) is/are energized, the cutting edges **20, 22** will become heated to a temperature suitable for the desired cauterization function.

The needle cutter device **10** of the present invention may optionally be used as part of a system **12**, as shown in FIG. 1. The basic components of the system **12** comprise an aspiration pump module **74** and a source of irrigation fluid **72**, mounted on a surgical roller cart **70**. Control of the console functions during procedures may be accomplished by an aspiration foot pedal **78** which controls an aspiration pump **74** and variation in the height of the source of infusion fluid **72** to change the gravity fed pressure or flow rate of infusion fluid through the device. A pinch valve, or other means, may also be incorporated in the console to control flow of the irrigation fluid to the needle cutter device **10**. In embodiments that include apparatus (e.g., electrode(s)) for heating the cutting edges **20, 22** and/or for severing the strip **ST** of tissue (FIG. 5), the system **11** may additionally comprise an electrical current source, such as an electrosurgical generator **76** and electrosurgical foot pedal **80** which controls the electrosurgical generator to deliver desired amount(s) of energy to the electrode(s) or other electrical elements (e.g., resistance heater(s), etc.) on the device **10**. As an option, all of the basic control functions of system **12** may be integrated into a single footpedal to facilitate use.

The device **10** may be provided as a pre-sterilized, single-use disposable probe or tip that is attachable to a standard surgical irrigation/aspiration handpiece such as that commercially available as The Rhein I/A Tip System from Rhein Medical, Inc., Tampa, Fla. After the device **10** has been attached to the handpiece, it may be connected to any or all of the electrosurgical generator module **76**, aspiration pump module **74** and the source of irrigation fluid **72**, as shown. Thus, the device **10** may be fully equipped for irrigation, aspiration, and electrosurgical capabilities, as described herein.

FIGS. 3A-3D show an example of a method for manufacturing the cutting tube **14** from standard tubing (e.g., stainless steel hypodermic tubing). Initially, the distal end of a tube is cut to form the lateral cutting edges **20, 22**, the protruding tip **24** and the blunt top edge **26**. Thereafter, if it is desired to have one or more bends or curves in the cutting tube **14**, angular cut out(s) **30** may be formed in the tube **14**, as shown in FIG. 3C.

5

Thereafter, the tube **14** is bent to bring the edges of each angular cut out **30** into apposition and weld, adhesive or other joining techniques are used to weld or join the apposed edges of the cut outs together, thereby forming the desired bend(s) or curve(s) in the cutting tube **14**. Likewise, if it is desired to have one or more bends or curves in the cutting tube **14**, the tube **14** may be directly bent to form said curves or bends without the use of angular cut outs(s) **30**. It may be appreciated that the use of angular cut-out(s) **30** allow a tube **10** of a given diameter to incorporate a curve or angle in a more compact form than is possible by bending tubing **10** of a given diameter to said curve or angle without kinking or damaging tube **10**.

The device **10** and system **12** are useable to perform a variety of procedures wherein it is desired to form an incision or opening of a desired width or to remove, from a mass of tissue, a strip ST of tissue of a desired width.

One particular procedure that may be performed to treat glaucoma, using the device **10** and system **12** of the present invention, is a goniotomy. As explained herein a goniotomy procedure is an ab interno surgical procedure wherein a sector of the trabecular meshwork is removed from the eye of the patient to facilitate drainage of aqueous humor from the anterior chamber of the eye through Schlemm's Canal and the associated collector channels, thereby relieving elevated intraocular pressure.

To perform a goniotomy procedure using the device **10**, first a small incision is made in the cornea at about 3 o'clock in the left eye, or at about 9 o'clock in the right eye. A 1.5 mm slit knife may be used to make this incision.

The device **10** is attached to the source of irrigation fluid **72** (e.g. basic balanced salt solution) such that irrigation fluid will flow through lumen **19** of the outer tube **16** and out of outflow aperture **11**. The device **10** is then inserted through the incision and into the anterior chamber of the eye (with irrigation flowing). In some cases, during the insertion of the device **10**, the source of irrigation fluid **72** may initially be connected to the device such that the irrigation fluid will flow through the lumen **27** of the cutter tube **14**. In this manner, irrigation fluid will begin to infuse into the anterior chamber of the eye as soon as the distal end of the cutter tube **14** has entered the anterior chamber, rather than being delayed until the larger outer tube **16** and aperture **11** have been advanced through the incision and into the anterior chamber. By this alternative approach, irrigation fluid may be caused to flow out of the distal end of the cutter tube **14** as the device **10** is being inserted, thereby spreading or opening the incision by hydraulic force while in addition increasing the fluid pressure in the anterior chamber. Such spreading or opening of the incision may facilitate advancement of the larger diameter outer tube **16** through the incision. Pressurizing the fluid in the anterior chamber causes the anterior chamber to deepen and may facilitate maneuvering of device **10** within the anterior chamber. In cases where this alternative approach is used, the source of infusion fluid **72** may be disconnected from lumen **27** of the cutter tube **14** after the device **10** has been inserted into the anterior chamber and, thereafter, the infusion fluid source **72** may be reconnected to lumen **19** of outer tube **16** such that infusion fluid will flow out of aperture **11**. Negative pressure (e.g., via aspiration pump module **74**) may then be applied to lumen **27** of the cutter tube **14** so as to aspirate fluid and debris through lumen **27** as shown in FIG. **4**. The vertical height of the infusion fluid source **72** may be adjusted to provide sufficient gravity feed of infusion fluid to make up for the volume of fluid or matter being aspirated from the

6

anterior chamber through lumen **27**, thereby maintaining the desired pressure of fluid within the anterior chamber during the procedure.

A lens device (e.g., Ocular Swan-Jacob Autoclavable Gonioprism, Model OSJAG, Ocular Instruments Inc., Bellevue, Wash.) may be positioned on the anterior aspect of the eye to enable the physician to clearly visualize the angle of the eye where the segment of trabecular meshwork is to be removed. Under direct visualization, the device **10** is advanced until the distal tip of the cutter tube **14** is positioned adjacent to the trabecular meshwork at the location where the strip ST is to be removed. Thereafter, the protruding tip **24** is advanced through the trabecular meshwork and into Schlemm's Canal.

The device **10** is then advanced along Schlemm's Canal, thereby causing the cutting edges **20**, **22** to cut a strip of the trabecular meshwork, thereby creating an opening through which aqueous humor may drain from the anterior chamber of the eye.

After a strip of tissue of the desired length (e.g., about 2-10 mm) has been cut by the lateral cutting edges **20**, **22**, any optional tissue severing apparatus (e.g., electrode(s) **40**) may be used (if present) to transect or sever the strip ST of tissue thereby disconnecting it from the patient's body and allowing it to be aspirated or drawn into or through lumen **27**.

Thereafter, the aspiration is stopped, the device **10** is removed from the eye, and the infusion is stopped.

Following completion of the surgery, aqueous humor will drain from the anterior chamber through the opening that was created by removal of the strip of tissue from the trabecular meshwork TM.

Although the invention has been described above with respect to certain embodiments and examples, it is to be appreciated that such embodiments and examples are non-limiting and are not purported to define all embodiments and examples of the invention. Indeed, those of skill in the art will recognize that various modifications may be made to the above-described embodiments and examples without departing from the intended spirit and scope of the invention and it is intended that all such modifications be included within the scope of the following claims.

What is claimed is:

1. An ab interno method for forming an opening in trabecular meshwork of a patient's eye, said method comprising the steps of:

obtaining a dual blade device which comprises a) an elongate proximal portion sized to be grasped by a hand of a human operator and b) an elongate probe extending from the proximal portion, wherein the elongate probe comprises i) a shaft, ii) a distal protruding tip that extends from a distal end of the shaft to form a bend or curve having an angle of at least 30 degrees, said distal protruding tip being sized to be inserted in Schlemm's Canal and iii) first and second cutting edges located at a junction of the shaft and the distal protruding tip, said first and second cutting edges being formed at spaced-apart locations on the distal end of the shaft, said first and second cutting edges being separated by a distance D; forming an opening into an anterior chamber of the eye; inserting the elongate probe through the opening and into the anterior chamber; advancing the elongate probe through the anterior chamber, while the anterior chamber is filled with fluid, to an operative position where the distal protruding tip is positioned within Schlemm's Canal and the first and second cutting edges are contacting the trabecular meshwork; and, thereafter

7

causing the distal protruding tip to advance through a sector of Schlemm's Canal with the first and second cutting edges concurrently cutting, from the trabecular meshwork, a strip of tissue having approximate width W, said approximate width W being approximately equal to the distance D between the first and second cutting edges.

2. A method according to claim 1 further comprising the step of infusing fluid into the anterior chamber under controlled pressure to keep the anterior chamber filled with fluid during performance of the method.

3. A method according to claim 1 wherein the strip of tissue cut from the trabecular meshwork has a length of about 2 to 10 millimeters.

4. A method according to claim 1 further comprising the step of:

removing the strip of tissue from the patient's eye.

5. A method according to claim 4 wherein, after the first and second cutting edges have cut the strip of tissue from the

8

trabecular meshwork, the strip of tissue remains connected to the trabecular meshwork and wherein the method further comprises the step of:

disconnecting the strip of tissue such that it may be removed from the eye.

6. A method according to claim 5 wherein the disconnecting step comprises using a tissue severing apparatus to transect or sever the strip of tissue so as to disconnect it from the patient's body.

7. A method according to claim 1 wherein the step of forming an opening into the anterior chamber of the eye comprises forming an incision through a cornea of the eye.

8. A method according to claim 1 wherein the method is performed under direct visualization through a lens device positioned on an anterior aspect of the eye.

9. A method according to claim 1 wherein the angle is less than approximately 90 degrees.

10. A method according to claim 9 wherein the angle is approximately 90 degrees.

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