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(71) Applicants: **THE REGENTS OF THE UNIVERSITY OF COLORADO, A BODY CORPORATE** [US/US]; 1800 Grant Street, 8th Floor, Denver, CO 80203 (US). **NEW WORLD MEDICAL, INC.** [US/US]; 10763 Edison Court, Rancho Cucamonga, CA 91730 (US).

(72) Inventors: **KAHOOK, Malik, Y.**; 9102 E 34th Avenue, Denver, CO 80238 (US). **MANSOUR, Khalid**; 11450

American River Road, Corona, CA 92880 (US). **ABDUL-LAH, Suhail**; 15178 Holiday Drive, Fontana, CA 92336 (US). **PORTEOUS, Eric**; 1275 Conestoga Circle, Corona, CA 92881 (US).

(74) Agent: **HOWERTON, Thomas C.**; MEDLEN & CARROLL, LLP, 1440 Broadway, Suite 510, Oakland, CA 94612 (US).

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(54) Title: AN OPHTHALMIC KNIFE AND METHODS OF USE

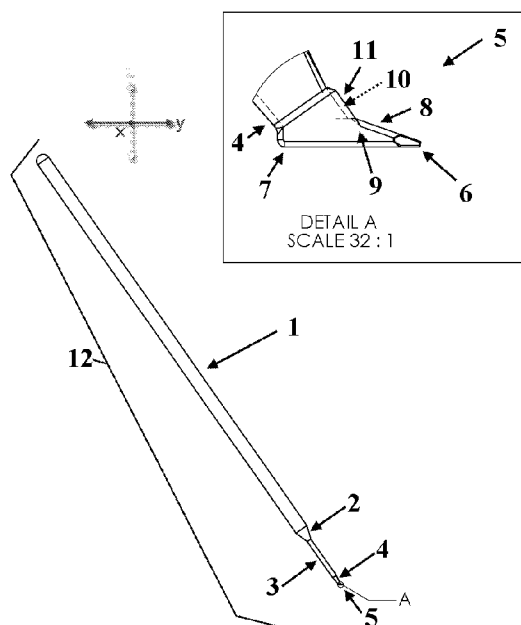


Figure 1

(57) Abstract: The present invention relates to an ophthalmic knife and methods of its use for treatment of various conditions including eye diseases, such as glaucoma, using minimally invasive surgical techniques. The invention relates to a multi-blade device for cutting the tissues within the eye, for example, a trabecular meshwork (TM).



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AN OPHTHALMIC KNIFE AND METHODS OF USE

FIELD OF THE INVENTION

The present invention relates to an ophthalmic knife and methods of its use for treatment
5 of various conditions including eye diseases, such as glaucoma, using minimally invasive
surgical techniques. An ophthalmic knife can be used for cutting the tissues within the eye, for
example, a trabecular meshwork (TM). This invention also relates to surgical medicinal
intervention. For example, the present invention relates to a microsurgical device and methods
of its use for treatment of various medical conditions including but not limited to eye diseases,
10 such as glaucoma, using minimally invasive surgical techniques.

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
15 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, cutting blade or needle) in the
eye, skin, mucous membrane, tumor, organ or other tissue or a human or animal. In addition, 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
20 DNA identification purposes, etc. In addition, 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
25 goniotomy procedure, a device that is operative to cut or ablate a strip of tissue of
approximately 2-10 mm in length or more and about 50-200 μ m 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. At present there remains a need in the art for the development of simple, inexpensive
and accurate instruments useable to perform the procedure of cutting the trabecular meshwork
30 (TM) in the eye and effectively remove a complete full thickness strip of TM without leaving

TM leaflets as well as other procedures where it is desired to remove a strip of tissue from a larger mass of tissue.

5 SUMMARY OF THE INVENTION

The present invention relates to an ophthalmic knife and methods of its use for treatment of various conditions including eye diseases, such as glaucoma, using minimally invasive surgical techniques. An ophthalmic knife can be used for cutting the tissues within the eye, for example, a trabecular meshwork (TM). This invention also relates to surgical medicinal
10 intervention. For example, the present invention relates to a microsurgical device and methods of its use for treatment of various medical conditions including but not limited to eye diseases, such as glaucoma, using minimally invasive surgical techniques.

In one embodiment, the present invention contemplates a dual platform/dual-blade ophthalmic knife comprising a handle connected to a shaft, said shaft connected to a first
15 platform and a second platform, said first platform comprising a first and second blade and a first anterior blade tip and said second platform comprising a third and fourth blade and a second anterior blade tip. In one embodiment, the anterior blade tip is a retractable blade tip. In one embodiment, said first and second anterior blade tips are retractable blade tips. In one embodiment, the anterior blade tip is a wedge blade tip. In one embodiment, the first blade and
20 a second blade are attached to a first lateral side and a second lateral side (respectively) of the first platform. In one embodiment, the third blade and a fourth blade are attached to a third lateral side and a fourth lateral side (respectively) of the second platform. In one embodiment, the first platform and second platform are configured at a 180° angle. In one embodiment, said blade tips comprise right triangles. In one embodiment, said right triangle follows the
25 Pythagoras' theorem formula ($a^2 + b^2 = c^2$) wherein the sides of said tip comprise length a and b and the length of the hypotenuse is c. 8. In one embodiment, said platforms each comprises a ramp. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades that are positioned above the level of the TM. In one
30 embodiment, the first and second platform are offset. In one embodiment, the first platform and

second platform are parallel. In one embodiment, the first platform comprises a first ramp increasing in depth extending from the first anterior blade tip to a first posterior end. In one embodiment, the second platform comprises a second ramp increasing in depth extending from the second anterior blade tip to a second posterior end. In one embodiment, the first and second
5 blades are parallel. In one embodiment, the first and second blade are at an angle. In one embodiment, the platform comprises an annular cutting edge. In one embodiment, the third and fourth blades are parallel. In one embodiment, the third and fourth blades are at an angle. In one embodiment, the first platform comprises an annular cutting edge. In one embodiment, the second platform comprises an annular cutting edge. In one embodiment, the first and second
10 lateral blades are retractable and attached within a first and second platform cavity (respectively). In one embodiment, the third and fourth lateral blades are retractable and attached within a third and fourth platform cavity (respectively). In one embodiment, the handle comprises a lateral blade actuator switch in operable communication with the first, second, third and fourth platform cavities. In one embodiment, the platform further comprises a grasping feature. In one
15 embodiment, said parallel dual platforms can be actuated to come together to grasp tissue. In one embodiment, the grasping feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, parallel dual platforms can be actuated to come together to grasp tissue. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the grasping feature
20 is made of a shape-memory material that is retractable into a lumen of the device. In one embodiment, the platform further comprises a slidable punch that can detach tissue from the multi-bladed device. In one embodiment, the multi-blade device further comprises at least one lumen extending longitudinally within said handle, shaft and platform. In one embodiment, the lumen comprises an exit port in said platform. In one embodiment, the exit port is on the top
25 surface of the platform. In one embodiment, the exit port is on the bottom surface of the platform. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the platform further comprises a through-hole extending from the top surface to the posterior end. In one embodiment, the handle is curved. In one
30 embodiment, the device further comprises a fiber optic visualization system. In one

embodiment, the width of the platform is approximately 150-180 microns. In one embodiment, the platform is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the platform comprises a concave bottom surface. In one embodiment, the shaft comprises an annular ring. In one embodiment, the platform further
5 comprises at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates a quad-blade ophthalmic knife comprising a handle connected to a shaft, said shaft connected to a platform comprising four cutting blades and an anterior blade tip. In one embodiment, the anterior blade tip is a retractable blade tip. In one embodiment, the anterior blade tip is a wedge blade tip. In one embodiment,
10 the platform comprises a first blade and a second blade attached to a first lateral side and a second lateral side (respectively) of the platform. In one embodiment, said blade tip comprises a right triangle. In one embodiment, said right triangle follows the Pythagoras' theorem formula ($a^2 + b^2 = c^2$) wherein the sides of said tip comprise length a and b and the length of the hypotenuse is c. In one embodiment, said platform comprises a ramp. In one embodiment, said
15 distal end of said platform ramps up from the piercing blade towards to parallel blades. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades that are positioned above the level of the TM. In one embodiment, the shaft further comprises a third blade and a fourth blade attached to a first lateral side and a second lateral side (respectively) of the shaft. In one embodiment, the third and fourth blade are slidably
20 engaged with the shaft. In one embodiment, the handle comprises a compressible material that contacts said third and fourth blades. In one embodiment, the shaft is connected to a second quad-blade knife positioned at a 180° angle from the first quad-blade knife. In one embodiment, the shaft is connected to a second quad-blade knife position in parallel to the first quad-blade knife. In one embodiment, the platform comprises a ramp increasing in depth extending from
25 the anterior blade tip to the posterior end. In one embodiment, the first and second blades are parallel. In one embodiment, the first and second blade are at an angle. In one embodiment, the platform comprises an annular cutting edge. In one embodiment, the first and second lateral blades are retractable and attached within a first and second platform cavity (respectively). In one embodiment, the handle comprises a lateral blade actuator switch in operable
30 communication with the first and second platform cavities. In one embodiment, the platform

further comprises a grasping feature. In one embodiment, the grasping feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the platform further comprises a slidable punch that can detach
5 tissue from the multi-blade device. In one embodiment, the multi-blade device further comprises at least one lumen extending longitudinally within said handle, shaft and platform. In one embodiment, the lumen comprises an exit port in said platform. In one embodiment, the exit port is on the top surface of the platform. In one embodiment, the exit port is on the bottom surface of the platform. In one embodiment, the lumen comprises an entry port in said handle. In one
10 embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the platform further comprises a through-hole extending from the top surface to the posterior end. In one embodiment, the handle is curved. In one embodiment, the device further comprises a fiber optic visualization system. In one embodiment, the width of the platform is approximately 150-180 microns. In one embodiment,
15 the platform is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the platform comprises a concave bottom surface. In one embodiment, the shaft comprises an annular ring. In one embodiment, the platform further comprises at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates an ultrasonic ophthalmic knife
20 comprises a handle, shaft, an anterior blade tip, and platform wherein the platform comprises an ultrasonic emitter and a footplate protecting surrounding tissue from the ultrasonic blades. In one embodiment, the ultrasonic emitter anterior blade tip vibrates in a fixed frequency when the device is actuated. In one embodiment, both longitudinal and lateral motions are possible for the tip. In one embodiment, said ultrasonic emitter has adjustable power settings. In one
25 embodiment, said power settings are optimized to minimize the application of heat during use. The ultrasonic knife allows for tissue cutting while reducing the need to pre-stretch or tension tissue. The knife tip vibrates in a fixed frequency when the device is actuated. Both longitudinal and lateral motions are possible for the tip. Power settings are optimized to minimize the application of heat to the tissue. In one embodiment, the anterior blade tip is a wedge blade tip.
30 In one embodiment, the anterior blade tip is a retractable blade tip. In one embodiment, said

blade tip comprises a right triangle. In one embodiment, said right triangle follows the Pythagoras' theorem formula ($a^2 + b^2 = c^2$) wherein the sides of said tip comprise length a and b and the length of the hypotenuse is c. In one embodiment, said platform comprises a ramp. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades that are positioned above the level of the TM. In one embodiment, the platform further comprises a grasping feature. In one embodiment, the grasping feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the platform further comprises a slidable punch that can detach tissue from the ultrasonic knife. In one embodiment, the ultrasonic device further comprises at least one lumen extending longitudinally within said handle, shaft and platform. In one embodiment, the lumen comprises an exit port in said platform. In one embodiment, the exit port is on the top surface of the platform. In one embodiment, the exit port is on the bottom surface of the platform. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the platform further comprises a through-hole extending from the top surface to the posterior end. In one embodiment, the handle is curved. In one embodiment, the ultrasonic device further comprises a fiber optic visualization system. In one embodiment, the width of the platform is approximately 150-180 microns. In one embodiment, the platform is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the platform comprises a concave bottom surface. In one embodiment, the shaft comprises an annular ring. In one embodiment, the platform further comprises at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates a pincer ophthalmic knife comprising a handle connected to a shaft, said shaft connected to a lower platform and an upper platform. In one embodiment, the lower platform comprises an anterior blade tip. In one embodiment, the anterior blade tip is a wedge blade tip. In one embodiment, the shaft and the upper platform are connected by a hinge. In one embodiment, the lower platform comprises a

first lateral side attached to a first blade and a second lateral side attached to a second blade. In one embodiment, the upper platform comprises a first slot and a second slot, wherein the first and second slots are positioned above said first and second blades. In one embodiment, the lower platform further comprises an anterior blade tip. In one embodiment, said blade tip
5 comprises a right triangle. In one embodiment, said right triangle follows the Pythagoras' theorem formula ($a^2 + b^2 = c^2$) wherein the sides of said tip comprise length a and b and the length of the hypotenuse is c. In one embodiment, said platform comprises a ramp. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades. In one embodiment, said distal end of said platform ramps up from the piercing
10 blade towards to parallel blades that are positioned above the level of the TM. In one embodiment, the lower platform is at least 8 mm in length. In one embodiment, the platform further comprises a grasping feature. In one embodiment, the grasping feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator
15 switch. In one embodiment, the platform further comprises a slidable punch that can detach tissue from the pincer ophthalmic knife. In one embodiment, the pincer ophthalmic knife device further comprises at least one lumen extending longitudinally within said handle, shaft and platform. In one embodiment, the lumen comprises an exit port in said platform. In one embodiment, the exit port is on the top surface of the platform. In one embodiment, the exit port
20 is on the bottom surface of the platform. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the platform further comprises a through-hole extending from the top surface to the posterior end. In one embodiment, the handle is curved. In one embodiment, the pincer ophthalmic knife device
25 further comprises a fiber optic visualization system. In one embodiment, the width of the platform is approximately 150-180 microns. In one embodiment, the platform is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the platform comprises a concave bottom surface. In one embodiment, the shaft comprises an annular ring. In one embodiment, the platform further comprises at least one
30 heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates a gripping ophthalmic knife comprising a handle connected to a shaft, said shaft comprises an first lateral alligator clip and a second lateral alligator clip, a platform connected to the shaft, said platform comprising a first lateral blade and a second lateral blade, and an anterior blade tip. In one embodiment, the anterior blade tip is a wedge blade tip. In one embodiment, the anterior blade tip is a retractable blade tip. In one embodiment, said blade tip comprises a right triangle. In one embodiment, said right triangle follows the Pythagoras' theorem formula ($a^2 + b^2 = c^2$) wherein the sides of said tip comprise length a and b and the length of the hypotenuse is c. In one embodiment, said platform comprises a ramp. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades that are positioned above the level of the TM. In one embodiment, the first lateral blade and the second lateral blade are attached to a first lateral side and a second lateral side (respectively) of the platform. In one embodiment, the first lateral alligator clip comprises a first serrated jaw and a second serrated jaw. In one embodiment, the second lateral alligator clip comprises a first serrated jaw and a second serrated jaw. In one embodiment, the first and second serrated jaws of the first lateral alligator clip are hinged. In one embodiment, the first and second serrated jaws of the second lateral alligator clip are hinged. In one embodiment, the handle comprises a compressible material that contacts said first and second alligator clips. In one embodiment, the platform further comprises a grasping feature. In one embodiment, the grasping feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the platform further comprises a slidable punch that can detach tissue from the multi-blade device. In one embodiment, the multi-blade device further comprises at least one lumen extending longitudinally within said handle, shaft and platform. In one embodiment, the lumen comprises an exit port in said platform. In one embodiment, the exit port is on the top surface of the platform. In one embodiment, the exit port is on the bottom surface of the platform. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the platform further comprises a through-hole extending

from the top surface to the posterior end. In one embodiment, the handle is curved. In one embodiment, the device further comprises a fiber optic visualization system. In one embodiment, the width of the platform is approximately 150-180 microns. In one embodiment, the platform is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the platform comprises a concave bottom surface. In one embodiment, the shaft comprises an annular ring. In one embodiment, the platform further comprises at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present embodiment contemplates a lancet ophthalmic knife comprising a handle connected to a shaft, said shaft connected to a wire element. In one embodiment, the wire element comprises a geometric shape including, but not limited to, a triangle, square, a rectangular, an octagon, a circle, an ellipse or an oval. In one embodiment, the wire element comprises a first wire end and second wire end. In one embodiment, the first wire end is connected to the shaft at a first position. In one embodiment, the second wire end is connected to the shaft at a second position. In one embodiment, the shaft further comprises a grasping feature. In one embodiment, the grasping feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the shaft further comprises a slidable punch that can detach tissue from the wire element. In one embodiment, the lancet knife further comprises at least one lumen extending longitudinally within said handle and shaft. In one embodiment, the lumen comprises an exit port in said shaft. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the handle is curved. In one embodiment, the device further comprises a fiber optic visualization system. In one embodiment, the wire element is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the shaft comprises an annular ring. In one embodiment, the wire element further comprises at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates an axial blade ophthalmic knife comprising a handle connected to a shaft, said shaft connected to a first and second blade. In one

embodiment, the first and second blade extend axially from the shaft. In one embodiment, a shaft overhang is positioned between the first and second blades and the lateral edges of the shaft. The overhang is positioned so as to limit the depth of cut made by the blades. In one embodiment, the shaft further comprises a grasping feature. In one embodiment, the grasping
5 feature includes but is not limited to, a tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the shaft further comprises a slidable punch that can detach tissue from the shaft. In one embodiment, the ophthalmic knife further comprises at least one lumen extending longitudinally within said handle and shaft. In one embodiment, the lumen
10 comprises an exit port in said shaft. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the handle is curved. In one embodiment, the device further comprises a fiber optic visualization system. In one embodiment, the shaft is a color including, but not limited to, blue, white, black, orange and
15 yellow or any combination thereof. In one embodiment, the shaft comprises an annular ring. In one embodiment, the first and second blades further comprise at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates a V-blade ophthalmic knife comprising a handle connected to a shaft comprising a first blade, said shaft connected to a
20 platform, wherein the first blade overhangs said platform such that the first blade and said platform are connected at an angle. In one embodiment, the platform further comprises an anterior blade tip. In one embodiment, the anterior blade tip is a retractable blade tip. In one embodiment, the anterior blade tip is a wedge blade tip. In one embodiment, said blade tip comprises a right triangle. In one embodiment, said right triangle follows the Pythagoras'
25 theorem formula ($a^2 + b^2 = c^2$) wherein the sides of said tip comprise length a and b and the length of the hypotenuse is c. In one embodiment, said platform comprises a ramp. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades. In one embodiment, said distal end of said platform ramps up from the piercing blade towards to parallel blades that are positioned above the level of the TM. In one
30 embodiment, the platform comprises a ramp increasing in depth extending from the anterior

blade tip to the posterior end. In one embodiment, the platform comprises a ramp increasing in depth extending from the anterior blade tip to the posterior end. In one embodiment, the platform comprises an annular cutting edge. In one embodiment, the shaft further comprises a grasping feature. In one embodiment, the grasping feature includes but is not limited to, a
5 tweezer element or a forcep element. In one embodiment, the grasping feature comprises a sleeve extending over the shaft, wherein the handle comprises a sleeve actuator switch. In one embodiment, the shaft further comprises a slidable punch that can detach tissue from the shaft. In one embodiment, the ophthalmic knife further comprises at least one lumen extending longitudinally within said handle and shaft. In one embodiment, the lumen comprises an exit
10 port in said shaft. In one embodiment, the lumen comprises an entry port in said handle. In one embodiment, the lumen comprises a viscoelastic fluid. In one embodiment, the lumen comprises an aspiration fluid. In one embodiment, the handle is curved. In one embodiment, the device further comprises a fiber optic visualization system. In one embodiment, the shaft is a color including, but not limited to, blue, white, black, orange and yellow or any combination thereof. In one embodiment, the shaft comprises an annular ring. In one embodiment, the first and
15 second blades further comprise at least one heating element. In one embodiment, the shaft is a telescoping shaft.

In one embodiment, the present invention contemplates, a method for using an ophthalmic knife, comprising: a) providing an ophthalmic knife selected from the group
20 consisting of a dual platform/dual blade ophthalmic knife, a quad-blade ophthalmic knife, an ultrasonic ophthalmic knife, a pincer ophthalmic knife, a gripping ophthalmic knife, a lancet ophthalmic knife, an axial blade ophthalmic knife and a V-blade ophthalmic knife; b) advancing said ophthalmic knife through an incision to a tissue target site; and c) cutting a strip of tissue from said target site. In one embodiment, the knife is integrated into an endoscope. In one
25 embodiment, the method further comprises visualizing said cutting with a fiber optic visualization system. In one embodiment, the tissue target site is located within the body of a patient. In one embodiment, the method further comprises the step of removing said strip of tissue from said tissue target site. In one embodiment, the method further comprises the step of treating said patient for glaucoma. In one embodiment, the treating comprises draining aqueous
30 humor from the eye of said subject. In one embodiment, said advancing further comprises; i)

inserting said knife into an ocular anterior chamber; and ii) positioning said knife adjacent to, or within, a trabecular meshwork of the eye. In one embodiment, said incision is in an anatomical location selected from the group consisting of an eyeball, skin, mucous membrane, an organ, and a tumor.

5

DEFINITIONS

To facilitate the understanding of this invention, a number of terms are defined below. Terms defined herein have meanings as commonly understood by a person of ordinary skill in the areas relevant to the present invention. Terms such as “a”, “an” and “the” are not intended to

10 refer to only a singular entity, but include the general class of which a specific example may be used for illustration. The terminology herein is used to describe specific embodiments of the invention, but their usage does not delimit the invention, except as outlined in the claims.

As used herein, the term “patient” or “subject” refers to a living mammalian organism, such as a human, monkey, cow, sheep, goat, dog, cat, mouse, rat, guinea pig, or transgenic species thereof.

15 In certain embodiments, the patient or subject is a primate. Non-limiting examples of human subjects are adults, juveniles, infants and fetuses.

The inventive subject matter disclosed herein is not to be restricted except in the spirit of the disclosure. Moreover, in interpreting the disclosure, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and

20 "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.

“Prevention” or “preventing” includes: (1) inhibiting the onset of a disease in a subject or

25 patient which may be at risk and/or predisposed to the disease but does not yet experience or display any or all of the pathology or symptomatology of the disease, and/or (2) slowing the onset of the pathology or symptomatology of a disease in a subject or patient which may be at risk and/or predisposed to the disease but does not yet experience or display any or all of the pathology or symptomatology of the disease.

The term “therapeutically effective amounts” or “pharmaceutically effective amounts”, as used herein means that amount which, when administered to a subject or patient for treating a disease, is sufficient to effect such treatment for the disease or to ameliorate one or more symptoms of a disease or condition (e.g. ameliorate pain).

5 As used herein, the terms "treat" and "treating" are not limited to the case where the subject (e.g. patient) is cured and the disease is eradicated. Rather, the present invention also contemplates treatment that merely reduces symptoms, improves (to some degree) and/or delays disease progression. It is not intended that the present invention be limited to instances wherein a disease or affliction is cured. It is sufficient that symptoms are reduced.

10 As used herein “goniotomy” refers to a surgical procedure primarily used to treat congenital glaucoma or other types of glaucoma.

 As used herein “trabecular meshwork” refers to area of tissue in the eye located around the base of the cornea, near the ciliary body, (between the scleral spur and schwalbe’s line) and is responsible for draining the aqueous humor from the eye via the anterior chamber (the
15 chamber on the front of the eye covered by the cornea). The tissue is spongy and lined by trabeculocytes; it allows fluid to drain into a set of tubes called Schlemm’s canal and eventually flowing into the blood system.

 As used herein “Schlemm’s canal” refers to a circular channel in the eye that collects aqueous humor from the anterior chamber and delivers it into the bloodstream via the collector
20 channels and anterior ciliary veins.

 As used herein “eye diseases” refers to various conditions of the eye including, but not limited to Glaucoma — optic neuropathy, Glaucoma suspect — ocular hypertension, Primary open-angle glaucoma, Primary angle-closure glaucoma, primary open angle glaucoma, normal or low tension glaucoma, pseudoexfoliation glaucoma, pigment dispersion glaucoma, angle closure
25 glaucoma (acute, subacute, chronic), neovascular or inflammatory glaucoma, ocular hypertension, and other types of glaucoma that are related to dysregulation of intraocular pressure

 As used herein “hypotony” refers to reduced intraocular pressure. The statistical definition of hypotony is intraocular pressure (IOP) less than 6.5mmHg, which is more than 3
30 standard deviations below the mean IOP. The clinical definition of hypotony is IOP low enough

to result in pathology (vision loss). The vision loss from low IOP may be caused by corneal edema, astigmatism, cystoid macular edema, maculopathy, or other condition. Hypotony maculopathy is characterized by a low IOP associated with fundus abnormalities, including chorioretinal folds, optic nerve head edema in the acute setting, and vascular tortuosity.

5 As used herein “Schwalbe's line” refers to the anatomical line found on the interior surface of the eye's cornea, and delineates the outer limit of the corneal endothelium layer. Specifically, it represents the termination of Descemet's membrane.

 As used herein “descemet's membrane” refers to the basement membrane that lies between the corneal proper substance, also called stroma, and the endothelial layer of the cornea.

10 As used herein “scleral spur” refers to an annular structure composed of collagen in the human eye, a protrusion of the sclera into the anterior chamber. It is the origin of the longitudinal fibres of the ciliary muscle and is attached anteriorly to the trabecular meshwork. Open-angle glaucoma (OAG) and closed-angle glaucoma (CAG) may be treated by muscarinic receptor agonists (e.g., pilocarpine), which cause rapid miosis and contraction of the ciliary muscles, this
15 pulls the scleral spur and results in the trabecular meshwork being stretched and separated. This opens the fluid pathways and facilitates drainage of the aqueous humour into the canal of Schlemm and ultimately decreasing intraocular pressure.

 As used herein “Trabectome®” refers to a minimally invasive glaucoma surgical tool for the surgical management of adult, juvenile and infantile glaucoma. Unlike a trabeculectomy, the
20 surgery with a Trabectome® should not create an external filtering bleb or require leaving a permanent hole in the eye. Instead, the Trabectome® electro-surgical handpiece opens access to the eyes natural drainage system. This procedure is performed through a small incision similar to that of cataract surgery and allows the patient to go home on the same day.

25 **BRIEF DESCRIPTION OF THE FIGURES**

 The accompanying figures, which are incorporated into and form a part of the specification, illustrate several embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The figures are only for the purpose of illustrating a preferred embodiment of the invention and are not to be construed as limiting the
30 invention.

Figure 1 shows an angled, side view of one embodiment of the device with an enlarged detailed view of the operative end of the device with the beveled platform.

Figure 2 shows an angled, side view of one embodiment of the device with an enlarged detailed view of the operative end of the device with the beveled platform 5. The shaded aspect
5 provided a view of the dimensions of the beveled platform. The angle of tool shaft 3 attachment and of first and second blade attachment relative to the beveled platform 5 are indicated.

Figure 3 shows a front face view of one embodiment of the device with an enlarged detailed view of the operative end of the device with the beveled platform 5. Shown are examples of the different angles of attachment of the handle 1 to the beveled platform 5
10 clockwise 0, 15, and 30 degrees relative to the Z-axis and X-axis. The increased platform thickness is also indicated as the platform extends from the insertion tip 6 towards the back of the platform 7 and from the first side (on the right) to the second side (on the left).

Figure 4A, B, &C present exemplary embodiments of a dual platform/dual blade ophthalmic knife. Figure 4A depicts bi-directional configuration 35 of two platforms configured
15 at a 180° angle. Figure 4B depicts a parallel configuration of two platforms. Figure 4C depicts an offset configuration of the first and second platforms.

Figure 5 presents an exemplary embodiment of quad-blade ophthalmic knife comprising two platform blades (10 and 11) and two shaft blades (30 and 31). In one embodiment, the two upper (shaft) blades positioned above the lower (platform) blades, the upper and lower blades
20 being able to move up and down to cut TM between the upper and lower blades (like scissors on either side of the ramp). In one embodiment, the upper blades may be moved by triggering a mechanism, such as squeezing the handle (like MST forceps).

Figure 6 depicts one embodiment of the ultrasonic ophthalmic knife.

Figure 7 presents an exemplary embodiment of a pincer ophthalmic knife comprising a
25 lower platform comprising at least two blades and a hinged upper platform having a complementary surface to the lower platform. . In one embodiment, said first platform is guided into the canal whilst the second platform is inside said handle, tool shaft, or barrel. In one embodiment, said first platform is advanced into TM and subsequently said second platform is then pushed down towards said first platform to capture TM between said first platform and
30 second platform. In one embodiment, said platforms further comprise blades or recesses on both

said first platforms and said second platform. In one embodiment, said platforms have curved surfaces. In one embodiment, said platforms have complementary surfaces. In one embodiment, said complementary surfaces articulate at a surface of articulation. In one embodiment, said surface of articulation is the edge of said blades. In one embodiment, said platforms marry to each other and amputate the strip of TM in one 8 mm strip.

Figure 8 presents an exemplary embodiment of a gripping ophthalmic knife comprises a shaft connected to one pair of serrated jaws (e.g., alligator clips).

Figure 9 presents an exemplary embodiment of a lancet ophthalmic knife comprising a wire element connected to a shaft.

Figure 10 presents an exemplary embodiment of an axial ophthalmic knife comprising at least two blades connected to a shaft.

Figure 11 presents an exemplary embodiment of a V-blade ophthalmic knife.

Figure 12 presents an exemplary embodiment of an ophthalmic knife having a platform comprising a through-hole.

Figure 13 presents an exemplary embodiment of an ophthalmic knife comprises at least one internal lumen.

Figure 14 presents an exemplary embodiment of an ophthalmic knife comprising a platform that lacks a ramp (or bevel).

Figure 15 presents an exemplary embodiment of an ophthalmic knife comprising a platform attached to two blades, wherein the blades extend from the posterior end to the distal anterior blade tip.

LIST OF REFERENCE NUMERALS

- 1 handle
- 2 first interface
- 3 tool shaft
- 4 second interface
- 5 platform
- 6 insertion tip
- 7 second end/ back of the beveled platform

	8	first side
	9	second side
	10	first blade
	11	second blade
5	12	device
	13	second platform
	14	third blade
	15	fourth blade
	16	barrel of the device
10	17	alligator clip
	18	first alligator clip blade
	19	second alligator clip blade
	20	wire element
	21	axial extension
15	22	internal lumen/collector channel
	23	through-hole
	24	fiber optic
	25	ultrasonic emitter
	26	grasping feature
20	27	sleeve or cap
	28	sleeve or cap actuator switch
	29	curved platform
	30	first upper blade
	31	second upper blade
25	32	handle trigger
	33	blade heating element
	34	lancet type/hollow/wire
	35	double sided/bi-directional device
	36	overhang
30	37	no beveled platform, angled blades

38 wedge

39 slidable punch

5 DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to an ophthalmic knife and methods of its use for treatment of various conditions including eye diseases, such as glaucoma, using minimally invasive surgical techniques. An ophthalmic knife can be used for cutting the tissues within the eye, for example, a trabecular meshwork (TM). This invention also relates to surgical medicinal
10 intervention. For example, the present invention relates to a microsurgical device and methods of its use for treatment of various medical conditions including but not limited to eye diseases, such as glaucoma, using minimally invasive surgical techniques.

I. Conventional Treatments For Ocular Diseases

15 A. Glaucoma

Glaucoma is believed to be one of the leading causes of blindness worldwide [1]. It has been reported that a modifiable disease risk factor is intraocular pressure (IOP). Conventional treatment has centered on lowering IOP pharmaceutically with hypotensive medications or surgically through the use of lasers or incisional procedures. The main area of obstruction to
20 aqueous outflow, with subsequent dysregulation of IOP, is thought to be located at the juxtacanalicular trabecular meshwork (TM) and distal outflow structures [2-4]. Performing a goniotomy or trabeculotomy in adults with glaucoma has not been associated with great success in lowering IOP [5, 6]. In contrast, these procedures have been reported to be more successful in congenital glaucoma, where a membrane covering the TM is thought to be a major factor in
25 impedance of aqueous outflow [7]. More recently, there have been attempts to use novel ab interno trabeculectomy procedures to remove TM in adult patients and results have been mixed [8-10].

One reason for poor long-term outcomes with this approach in adults might be related to incomplete removal of TM and membrane formation across the remaining TM leaflets with
30 subsequent elevation in IOP [11]. It is unclear how a more complete removal of TM tissue might

compare to procedures that simply incise TM, such as an MVR blade goniotomy, or procedures that cauterize TM with tissue removal, such as Trabectome® (Neomedix, Tustin, California, USA). The dual-blade device is specifically designed to conform to the drainage angle anatomy of the human eye. While not limiting the current invention, the device is meant to perform an ab

5 interno trabeculectomy by engaging TM and cutting the target tissue while minimizing leaflets left in place and damage to adjacent tissues. The device was designed and manufactured at the University of Colorado Eye Center (United States Provisional Patent Application Number 61/637611) [12]. Tissue effects from the novel device are compared to those from a goniotomy using a microvitrectomy (MVR) blade (BD, Franklin Lakes, New Jersey, USA) and cautery of

10 TM with the Trabectome® device. Human eye perfusion studies were also completed to assess the IOP-lowering efficacy of each approach.

Recently, there has been a growing trend toward innovations in minimally invasive glaucoma surgery (MIGS). The risks and imperfections of guarded filtration surgery and tube shunt procedures have driven this paradigm shift despite the proven long-term efficacy of these

15 incisional procedures. Drawbacks of traditional incisional procedures include unpredictable IOP-lowering results, prolonged visual recovery, long-term risk of infection and vision loss, frequency of follow-up visits, and long-term failure rate [13]. Procedures such as endoscopic cyclophotocoagulation, ab interno trabeculectomy with Trabectome®, and canaloplasty with the iScience illuminated catheter (iScience, Menlo Park, California, USA) were all introduced to

20 address limitations of full-thickness surgery, most notably to eliminate the presence of a filtering bleb. However, a major drawback of all of these procedures is the additional equipment cost required and, in some cases, a steep learning curve. The added equipment cost in particular presents a significant hurdle to providers, hospitals, and surgery centers that may require several procedures to recoup the initial investment. Providers and patients may also face opposition from

25 insurance companies regarding coverage of a novel procedure lacking longterm efficacy data. The requirement for additional equipment also limits patient access to these procedures in underserved areas of the world.

B. Goniotomy

A goniotomy is generally referred to as a surgical procedure primarily used to treat

30 congenital glaucoma. It can be caused by a developmental arrest of some of the structures within

the anterior (front) segment of the eye. These structures include the iris and the ciliary body, which produces the aqueous fluid needed to maintain the integrity of the eye. These structures do not develop normally in the eyes of patients with isolated congenital glaucoma. Instead, they overlap and block the trabecular meshwork, which is the primary drainage system for the aqueous fluid. Because of this blockage, the trabecular meshwork itself becomes thicker and the drainage holes within the meshwork are narrowed. These changes lead to an excess of fluid in the eye, which can cause pressure that can damage the internal structures of the eye and cause glaucoma.

In general, congenital glaucoma is caused by a decrease in or even a complete obstruction of the outflow of intraocular fluid. The ocular syndromes and anomalies that predispose a child to congenital glaucoma include the following: Reiger's anomaly; Peter's anomaly; Axenfeld's syndrome; and Axenfeld-Rieger's syndrome. Systemic disorders that affect the eyes in ways that may lead to glaucoma include Marfan's syndrome; rubella (German measles); and the phacomatoses, which include neurofibromatosis and Sturge-Weber syndrome. Since these disorders affect the entire body as well as the eyes, the child's pediatrician or family doctor will help to diagnose and treat these diseases.

One purpose of a goniotomy is to clear the obstruction to aqueous outflow from the eye, which in turn lowers the intraocular pressure (IOP). Although it is not necessary to understand the mechanism of an invention, it is believed that lowering the IOP helps to stabilize the enlargement of the cornea and the distension and stretching of the eye that often occur in congenital glaucoma. The size of the eye, however, may not return to normal. Most importantly, once the aqueous outflow improves, damage to the optic nerve is halted or reversed. The patient's visual acuity may improve after surgery.

Before the surgeon begins the procedure, the patient may be given miotics, which are drugs that cause the pupil to contract. The partial closure may improve the surgeon's view of and access to the trabecular meshwork; it may also protect the lens of the eye from trauma during surgery. Other drugs may be administered to lower the intraocular pressure. Goniotomy procedures may be done without use of miotics. In one embodiment, the current invention may be used in the setting of a dilated (non-miotic) pupil, as can devices described as prior art.

Once the necessary drugs have been given and the patient is anesthetized, the surgeon may use forceps or sutures to stabilize the eye in the correct position. The patient's head may be rotated away from the surgeon so that the interior structures of the eye are more easily seen. Next, with either a knife-needle or a goniotomy knife, the surgeon punctures the cornea while
5 looking at the interior of the eye through a microscope or a loupe. An assistant may use a syringe to introduce fluid into the eye's anterior chamber through a viscoelastic tube as the surgeon performs the goniotomy.

A gonioscopy lens may be then placed on the eye. As the eye is rotated by an assistant, the surgeon sweeps the knife blade or needle through 90–120 degrees of arc in the eye, making
10 incisions in the anterior trabecular meshwork, avoiding the posterior part of the trabecular meshwork in order to decrease the risk of damage to the iris and lens. Endoscopic visualization may also be used to guide cutting. In one embodiment, the device of the current invention may be placed at the end of an endoscope, precluding the need for a gonio lens during treatment. Once the knife and tubing are removed, saline solution may be introduced through the hole to
15 maintain the integrity of the eye and the hole is closed with sutures. The surgeon then applies antibiotics and corticosteroids to the eye to prevent infection and reduce inflammation. The head may be then rotated away from the incision site so that blood cannot accumulate. The second eye may be operated on at the same time. If the procedure needs to be repeated, another area of the eye may be treated.

Previous devices have been described in Sorensen et al., “Tubular Cutter Device and
20 Methods For Cutting and Removing Strips of Tissue from the Body of a Patient,” United States Patent No. 7,959,641 (Issued June 14, 2011; [14]) Also see International Publication No. WO 2004/110501 [15] and United States Publication No. US 2007/0276420 related parts [16]). This reference discloses a device for cutting a strip of tissue with a width of about 50-200 μm from
25 the trabecular meshwork. The device has a first and second cutting edge formed on the distal end of the cutting tube. The tip can be blunt and in some applications is configured and used to facilitate the insertion of the device into its intended location i.e. Schlemm's canal. Further, one or more bends or curves may be optionally formed to facilitate its use. The tip of the device may be advanced through the trabecular meshwork and into the Schlemm's canal thereby causing the
30 cutting edges to cut a strip of the trabecular meshwork, thereby creating an opening for drainage

of aqueous humor. While this reference teaches a cutting blade with dual cutting sides and a tip for placement into Schlemm's canal for removal of trabecular meshwork with optional bends/curvatures it does not specifically mention use of a 0.3 mm blade width.

Another device is described in Huculak, "Small Gauge Mechanical Tissue
5 Cutter/Aspirator Probe for Glaucoma Surgery," United States Patent Publication No. US 2009/0287233 [17]. This reference discloses use of a small gauge mechanical tissue cutter/aspirator probe to remove trabecular meshwork. The probe can be guided into Schlemm's canal and moved in a forward motion following the curvature of the trabecular meshwork. The motion causes the trabecular meshwork to be fed into the cutting port of the cutter, thereby
10 cutting and removing the trabecular meshwork that blocks the outflow of aqueous humor. Due to the size of Schlemm's canal, it is preferable to have the distal end of the outer cannula measure about 0.25 to 0.36 mm diameter. The cannula can be tapered so its distal end measures about 0.25 to 0.36 mm (Schlemm's canal is about 0.3 mm). Further, the leading edge can be curved to enhance its ability to pierce the trabecular meshwork. While the reference teaches use of a small
15 gauge cutter with a diameter of about 0.25 to 0.36 mm with a sharp or blunt leading edge for piercing the trabecular meshwork and entry into Schlemm's canal with a cutting port to cut the trabecular meshwork it does not per se teach a dual sharp edge cutting blade.

Another device is described in Baerveldt et al., "Minimally Invasive Glaucoma Surgical Instrument and Method," United States Patent Publication No. US 2011/0077626 [18] (Also see
20 United States Patent No. 7,785,321 [19] and 6,979,328[20]; and United States Patent Publication No. US 2006/0106370 [21] and US 2002/0111608 [22] selected parts). This reference discloses use of a cutting probe to cut and remove trabecular meshwork. The probe comprises a tip that is approximately 25 gauge (about 0.5mm). The tip further comprises a footplate that serves as a guide into Schlemm's canal. The sharpened end of the footplate is used to pierce the trabecular
25 meshwork. The trabecular meshwork is cut using a rotatable blade or cut in a guillotine fashion. While the reference discloses use of a cutting probe with a tip approximately 25 gauge including a footplate for piercing the trabecular meshwork and targeting Schlemm's canal it does not per se mention use of a dual sharp edge cutting blade sized for navigating Schlemm's canal (0.3 mm). Another device is described in Huculak, "Small Gauge Mechanical Tissue Cutter/Aspirator
30 Probe for Glaucoma Surgery," International Publication No. WO 2009/140185 [23] (Also see

European Patent No. EP 2303203 [24] selected parts). This reference discloses use of a small gauge mechanical tissue cutter/aspirator probe to remove trabecular meshwork. The probe consists of an outer cannula and an inner cannula. The inner cannula's distal end is configured to cut tissue when it enters port 310. The inner cannula is moved up and down to cut tissue. The
5 outer cannula includes a retractable pick that has a sharp end for piercing the trabecular meshwork. Due to the size of Schlemm's canal, it is preferable to have the distal end of the outer cannula measure about 0.25 to 0.36 mm in diameter. The cannula can be tapered so its distal end measures about 0.25 to 0.36 mm (Schlemm's canal is about 0.3 mm). While the reference discloses use of a probe sized between 0.25 and 0.36 mm for piercing the trabecular meshwork
10 and placement into the Schlemm's canal, it does not mention use of a dual sharp edge cutting blade with a curvature for navigating Schlemm's canal.

Another device is described in Bergheim, O. B. and Gharib, M. "Apparatus and Method for Treating Glaucoma," WIPO Patent WO/2001/078631 Application PCT/US2001/007398, filed March 8, 2001. (Published October 25, 2001) [25]. This reference discloses use of a cutting
15 member positioned at the distal end of a tube consisting of a knife, a pointed guide member, and a sharpened distal end of said tube. The cutting member is configured to form an opening in the trabecular meshwork for placement of a seton into Schlemm's canal. The knife includes a microknife sized within the range of 20 to 40 gauge preferably 30 (0.3 mm) gauge. While the reference discloses use of a cutting member sized from 20 to 40 gauge for cutting the trabecular
20 meshwork and delivery of a seton to Schlemm's canal it does not mention use of a dual sharp edge cutting blade with a curvature for navigating Schlemm's canal.

Another device is described in Skjaerpe, Finn, "Microsurgical Instrument," United States Patent No. 4,501,274 [26] (Issued Feb. 26, 1985; also see European Patent No. EP 0073803 [27] selected parts). This reference discloses a microsurgical probe with a cutting member comprised
25 of two knife blades protruding in different directions from the probe each with at least one sharp cutting edge. The cutting member has a double-cutting knife, where the two cutting edges are angularly separated such that they create a V-form adapted to the local anatomical features of the eye at the Schlemm's canal and the trabecular meshwork. The probe diameter is approximately 0.25 mm and the width of the knives is 0.3 to 0.5 mm. The knife blades also include a cutting
30 edge on both sides so the probe can be pulled in both directions through the Canal of Schlemm.

While the reference discloses a dual-knife with at least one sharp cutting edge for cutting the trabecular meshwork and the inner wall of Schlemm's canal it does not per se mention a curvature for navigating Schlemm's canal.

Another device is described in Conston et al., "Ophthalmic Microsurgical System,"
5 United States Patent Publication No. US 2006/0149194 [28] (Also see International Publication
No. WO 2003/045290 [29], European Patent No. EP 1455698 [30] and Korean Patent No. KR
1020040058309 [31] selected parts). This reference discloses a microsurgical system with an
outer microcannula sheath that includes an inner member that is sized to adapt to the Schlemm's
canal that is about 50 to 200 microns in diameter. The inner member is in the range of 50-240
10 microns in outer diameter in order to fit within the outer cannula, which is 50-250 microns in
inner diameter. The outer microcannula and inner member each are adaptable to the curvature of
Schlemm's canal and the inner member optionally includes a cutting tool at the distal end with a
diamond or sapphire tip or blade or similar element. While the reference discloses a micro sized
probe for cutting trabecular meshwork and targeting Schlemm's canal it does not per se mention
15 use of a dual sharp edge cutting blade for piercing the trabecular meshwork and targeting
Schlemm's canal.

Another device is described in Conston et al., "Ophthalmic Microsurgical Instruments,"
United States Patent Publication No. US 2007/0073275 [32] (Also see International Publication
No. WO 2004/093761 [33] and European Patent No. EP 1615604 [34] selected parts). This
20 reference discloses a microsurgical instrument that can be directly inserted into Schlemm's canal
to allow controlled treatment or removal of adjacent tissues such as TM. The instruments
comprise an outer sheath microcannula and an inner member where the distal end of the
instruments can be curved to approximate the curvature of Schlemm's canal. The instruments
include a cutting means to excise targeted tissue. The microcannula is sized to accommodate the
25 Schlemm's canal (approximately 200 microns in diameter) approximately ranging from 100 to
350 microns outer diameter. The distal tip of an inner member can be beveled or sharpened to
provide a cutting action. While the reference discloses a micro sized probe for cutting trabecular
meshwork and targeting Schlemm's canal it does not per se mention use of a dual sharp edge
cutting blade for piercing the trabecular meshwork and targeting Schlemm's canal.

Another device is described in Huculak, “Pulsed Electric Field Probe for Glaucoma Surgery,” United States Patent Publication No. US 2011/0230877 [35]. This reference discloses use of a small gauge pulsed electric field probe for removal of trabecular meshwork. The distal end of the probe includes a pick adapted to fit into Schlemm’s canal so the electric pulsed field
5 can be used to dissociate and remove the trabecular meshwork. The pick has a sharp end so it can pierce the trabecular meshwork and so the pick can be placed into the Schlemm’s canal. The pick is retractable. The probe has a diameter between 0.25 and 0.36 mm. While the reference discloses use of a probe sized between 0.25 and 0.36 mm for piercing the trabecular meshwork and placement into the Schlemm’s canal, it does not mention use of a dual sharp edge cutting
10 blade with a curvature for navigating Schlemm’s canal.

Another device is described in Pantcheva, M. B. and Kahook, M. Y. (2010) Ab Interno Trabeculectomy, Middle East Afr. J. Ophthalmol. 17(4), 287-289 [10]. This reference is a review of the Trabectome® device that is used in this general field.

Another device known in the art that has been used for ab interno trabeculectomy is
15 known as the “gonioscraper,” as described by Jacobi and associates [36]. This device consisted of a handle and curette tip and was used to remove TM by scraping the curette within the Schlemm’s canal. The curette tip is in line with the handle and does not conform to the geometry of the drainage angle and adjacent structures. After promising preclinical experiments, a nonrandomized clinical trial of 25 eyes was completed [37]. Preoperative IOP was 34.7 ± 7.1
20 mm Hg on 2.2 ± 0.56 medications and mean follow-up time was 32 months. Based on the success criteria of postoperative IOP of 19 mm Hg or less with 1 pressure-reducing agent, 15 eyes (60%) were successful. Nonetheless, complications developed in some patients including localized Descemet membrane detachments and/or anterior chamber bleeding. Histologic analysis of banked human eyes treated with the curettage showed successful removal of TM
25 tissue, but with damage to the septa and endothelium of the external and posterior wall of the Schlemm’s canal [36]. In the data presented herein, similar damage to adjacent sclera was also observed when using the MVR blade, but was notably absent with use of one embodiment of a dual-blade device as contemplated by the present invention.

There have been reports of both success and failure with the Trabectome® device over
30 the past few years [8-11, 38]. In a recent retrospective study of Trabectome® versus ab externo

trabeculectomy, Jea and associates found poor success rates in eyes treated with Trabectome® at 2 years [8]. Of the 115 eyes treated with Trabectome®, only 22.4% achieved success with failure defined as IOP >21 mm Hg or <20% reduction in IOP. It is conceivable that, after initial opening of the canal with TM removal, the residual leaflets occlude the Schlemm's canal and/or the more distal collector channels, leading to failure of the intervention. This mechanism of failure after Trabectome® treatment would be overcome by the dual-blade device, as a more complete removal of TM tissue is produced without residual leaflets.

A modified dual blade device geometry was designed to minimize any impact to adjacent tissues such as Descemet membrane by leveraging specific angles between the handle and the distal blade as well as use of specific angles between the cutting blade and the adjacent cutting tip. Kahook M., WO 2013/163034 [39] (herein incorporated by reference). Several practical advantages of a dual blade device for use in ab interno trabeculectomy were reported. First, a dual blade device may be reusable and can be added to a standard cataract surgical tray. Second, the lack of moving parts or the need for coupled irrigation or a separate power source allows for inexpensive manufacturing and rapid acquisition of surgical expertise. This would permit easy, economical access to a new technique, especially in underserved locations around the world. For comparison, a conventional Trabectome® device requires a substantial initial investment for the irrigation/aspiration unit and generator in addition to the cost of one-time-use items such as the hand piece and tubing. The simple design and material requirements of dual-blade device embodiments would be more economical. Finally, in contrast to other techniques for TM removal, embodiments of dual-blade device designs conform to the Schlemm's canal anatomy, minimizes damage to adjacent tissues, and provides excellent control over excised tissue. . In conclusion, the conventional dual-blade device may perform ab interno trabeculectomy with or without concomitant cataract extraction.

II. Ophthalmic Knives

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 shall not be construed to limit, in any way, the scope of the claims recited in this patent application and any patent(s) issuing there from.

In one embodiment, the present invention contemplates an ophthalmic knife for cutting ocular tissue (e.g., for example, trabecular meshwork (TM)). In particular, the knife may have a device tip providing entry into the Schlemm's canal via its size (i.e., for example, between approximately 0.3-.2 mm width) and a configuration where the entry blade tip curves up providing a ramp-like action for cutting tissue (e.g., for example, trabecular meshwork tissue).

Specific advantages of some embodiments described herein as compared to other conventional devices include but are not limited to:

1. No mechanically moving parts
2. No cautery or burning of tissue
3. A multi-blade configuration can be in place on the sides of the device that cut the TM in a precise fashion leaving little TM behind (current devices leave considerable residual TM leaflets behind that then scars over)
4. The entry into Schlemm's canal is done with use of the blade tip. Other similar devices use a non-blade footplate to enter Schlemm's canal.
5. The dimensions of these devices allow for a complete cutting and fit in Schlemm's canal with precision.
6. A tip of the blade may ramp up to the multiple side blades forming a surface that presents the TM to the blades, which then allows for more precise cutting.
7. A device distal end is a right triangle that follows the $a^2 + b^2 = C^2$.
8. The distal end ramps up from the piercing blade towards to parallel blades that are positioned above the level of the TM.
9. The ramp causes the TM to elevate away from canal of schlemm as the device is advanced thus lifting the TM above the usual position of the inner wall of the canal of Schlemm.
10. Once the TM is elevated and the device is advanced, the TM presents to the parallel blades resulting in a clean cut of the tissue.
11. The stretch of the tissue away from the natural position of the inner wall of the canal of schlemm is a key step for success.

12. The piercing tip blade is not continuous with the blades on the top of the ramp (ie, there is no sharp part that is continuous from the tip all the way to the blades that cut the TM). The area of the ramp is generally devoid of a cutting edge.

13. In one embodiment, the device has a flat bottom which results in the bulk of the bottom of the device not touching the outer wall of Schlemm's canal once the device is placed flush with heel down (the curve of canal of Schlemm results in this (so the bottom of the footplate is cupped by canal of schlemm). This means less contact and friction with the footplate of the current invention as it is advanced.

14. All cutting of tissue (except for the initial piercing with the blade tip) is done away from (elevated towards the anterior chamber) canal of Schlemm.

A. An Ophthalmic Knife Platform

In some embodiments, the present invention contemplates an ophthalmic knife comprising a platform. In some embodiments, the platform comprises a ramp, thereby forming a beveled, or wedge shape **38**. In some embodiments, the platform is attached to lateral blades, preferably on the lateral sides of the platform, see Figure 1.

In one embodiment, a first lateral blade **10** and a second lateral blade **11** are in a perpendicular alignment to the bottom of the beveled platform **5**. In one embodiment, the invention relates to a device **12** comprising a handle **1** and a beveled platform **5**, wherein said platform **5** is set at a specific angle and orientation relative to said handle **1**. In one embodiment, the invention relates to a device **12** comprising a handle **1** and a beveled platform **5**, wherein said platform **5** freely rotates in at least two dimensions. In one embodiment, said handle **1** and beveled platform **5** are operably attached at an angle ranging between 90 and 120 degrees in the Y-Z axis. In one embodiment, said handle **1** and beveled platform **5** are operably attached at an angle ranging between 90 and 180 degrees in the X-Z axis. In one embodiment, said platform **5** freely rotates in an X-Y dimension relative to said handle **1**. In one embodiment, said platform **5** remains at a fixed angle in the X-Y, X-Z, and Y-Z dimensions relative to said handle **1**. In one embodiment, said platform **5** freely rotates in a positive Z dimension relative to said handle **1**. In

one embodiment, said beveled platform 5 comprises a first end/ beveled platform tip/ insertion blade tip 6 and a second end/ back of the beveled platform 7, wherein said second end/ back of the beveled platform 7 is between two and thirty times greater in thickness relative to said first end/ beveled platform tip/ insertion blade tip 6. In one embodiment, the dimensions of the

5 beveled platform 5 are dictated by the formula $A^2 + B^2 = C^2$, wherein A is the length of said beveled platform 5 from said insertion blade tip 6 to the back of the beveled platform 7, B is the height of the beveled platform 5 and C is the length of the ramp. In one embodiment, the height of said beveled platform 5 is not to exceed 0.5 millimeters. In one embodiment, the length of said beveled platform 5 from said insertion blade tip 6 to the back of the beveled platform 7, is

10 not to exceed 1.0 millimeters. In one embodiment, said first end/ beveled platform tip/ insertion blade tip 6 comprises a fine surgical lancet. In one embodiment, said first end/ beveled platform tip/ insertion blade tip 6 comprises an angle of between 20 and 90 degrees. In one embodiment, said beveled platform 5 increases in thickness from a fine blade tip towards the second end/ back of the beveled platform 7 in the direction of the Y-axis. In one embodiment, said first end/

15 beveled platform tip/ insertion blade tip 6 comprises a pointed tip with fine edges of surgical sharpness. In one embodiment, said first end/ beveled platform tip/ insertion blade tip 6 comprises a lancet. In one embodiment, said beveled platform 5 further comprises a first blade **10** and a second blade **11**. In one embodiment, said first blade **10** is attached to a first side 8 of said second end/ back of the beveled platform 7. In one embodiment, said first blade **10** and

20 beveled platform 5 are operably attached at an angle ranging between 90 and 180 degrees in the Y-Z axis. In one embodiment, said angle is preferably between 90 and 120 degrees in the Y-Z axis. In one embodiment, said second blade **11** and beveled platform 5 are operably attached at an angle ranging between 90 and 120 degrees in the Y-Z axis. In one embodiment, said first blade **10** and handle 1 are operably positioned at an angle ranging between 90 and 120 degrees in

25 the Y-Z axis. In one embodiment, said second blade **11** and handle 1 are operably positioned at an angle ranging between 90 and 120 degrees in the Y-Z axis. In one embodiment, said second blade **11** is attached to a second side 9 of said second end/ back of the beveled platform 7.

Figure 2. In one embodiment, wherein said anterior blade tip is a retractable blade tip.

In one embodiment, said beveled platform 5 increases in thickness from said second side 9 towards the first side 8 in the direction of the X-axis. Figure 3. In one embodiment, said beveled platform 5 increases in thickness from said second side 9 towards the first side 8 in the direction of the X-axis and said beveled platform 5 increases in thickness from a fine blade tip of the first end 6 towards the second end/ back of the beveled platform 7 in the direction of the Y-axis.

In one embodiment, said beveled platform 5 increases in thickness from said first side 8 towards the second side 9 in the direction of the X-axis. In one embodiment, said beveled platform 5 increases in thickness from said first side 8 towards the second side 9 in the direction of the X-axis and said beveled platform 5 increases in thickness from a fine blade tip of the first end 6 towards the second end/ back of the beveled platform 7 in the direction of the Y-axis . In one embodiment, said first blade **10** and said second blade **11** extend above the top surface of said second end/ back of the beveled platform 7. In one embodiment, said first blade **10** and said second blade **11** are positioned at an angle between approximately 100 to 140 degrees relative to the top surface of said second end/ back of the beveled platform 7. In one embodiment, said beveled platform 5 is approximately 0.3 millimeters wide. In one embodiment, said beveled platform 5 is approximately 0.2 millimeters wide. In a preferred embodiment, said beveled platform 5 is approximately 0.25 millimeters wide. In one embodiment, said beveled platform 5 is approximately 1.0 millimeters long. In one embodiment, said beveled platform 5 is approximately 0.4 millimeters high. In one embodiment, said highest point on the beveled platform 5 is the first and second blades. The device **12**, may be provided as a pre-sterilized, single-use disposable probe or tip that is attachable to a standard surgical handpiece. In one embodiment, the device further comprises a fiber optic visualization system **24**. In one embodiment, said shaft 3 further comprises a grasping feature **26**. In one embodiment, said grasping feature **26** is selected from the group consisting of a tweezer element and a forcep element. In one embodiment, said grasping feature **26** comprises a sleeve **27** extending over said shaft, wherein said handle comprises a sleeve actuator switch.

B. A Dual Platform/Dual-Blade Ophthalmic Knife

In one embodiment, the present invention contemplates a dual platform/dual-blade ophthalmic knife comprising a handle 1 connected to a shaft 3, said shaft connected to a first platform and a second platform, said first platform comprising a first and second blade and a first anterior blade and said second platform comprising a third **14** and fourth **15** blade and a second anterior blade tip. In one embodiment, depicted in Figure 4A, said device comprises two oppositely faced platforms with each platform each having at least two lateral blades and each having a blade tip. In another embodiment, depicted in Figure 4B, the device comprises two roughly parallel platforms with each platform each having at least two lateral blades and each having a blade tip. In one embodiment, said first and second anterior blade tips are retractable blade tips. In another embodiment, the device comprises at least two offset platforms. In another embodiment, the device comprises at least two offset platforms each having at least two lateral blades and each having a blade tip

C. A Quad-Blade Ophthalmic Knife

In one embodiment, the present invention contemplates a quad-blade ophthalmic knife comprising a handle 1 connected to a shaft 3, said shaft connected to a platform comprising four cutting blades and an anterior blade tip, see Figure 5. In one embodiment, the two upper (shaft) blades (**30** and **31**) positioned above the lower (platform) blades (**10** and **11**), the upper and lower blades being able to move up and down to cut TM between the upper and lower blades (like scissors on either side of the ramp). In one embodiment, the upper blades may be moved by triggering a mechanism **32**, such as squeezing the handle 1 (like MST forceps).

D. An Ultrasonic Ophthalmic Knife

In one embodiment, the present invention contemplates an ultrasonic ophthalmic knife comprises a handle 1, shaft 3, an anterior blade tip, and platform wherein the platform comprises an ultrasonic emitter **25**. In one embodiment, said ultrasonic ophthalmic knife is shown in Figure 6.

E. A Pincer Ophthalmic Knife

In one embodiment, the present invention contemplates a pincer ophthalmic knife comprising a handle 1 connected to a shaft 3, said shaft connected to a lower platform and an upper platform. In one embodiment, said platforms are curved. In one embodiment, said first platform is guided into the canal whilst the second platform is inside said handle 1, tool shaft 3, or barrel 16. In one embodiment, said first platform is advanced into TM and subsequently said second platform is then pushed down towards said first platform to capture TM between said first platform and second platform. In one embodiment, said platforms further comprise blades or recesses on both said first platforms and said second platform. In one embodiment, said platforms have complementary surfaces. In one embodiment, said complementary surfaces articulate at a surface of articulation. In one embodiment, said surface of articulation is the edge of said blades. In one embodiment, said platforms marry to each other and amputate the strip of TM in one 8 mm strip. In one embodiment, said device is depicted in Figure 7.

F. A Gripping Ophthalmic Knife

In one embodiment, the present invention contemplates a gripping ophthalmic knife comprising a handle 1 connected to a shaft 3, said shaft comprises a lateral alligator clip 17, a platform connected to the shaft 3, said platform 5 comprising a first lateral blade 10 a, and an anterior blade tip 6. In one embodiment, said alligator clip 17 comprises a first 18 and second 19 alligator clip blades. In one embodiment, said alligator clip 17 comprises a clip with a spring that closes the articulating jaws. In one embodiment, said alligator clip comprises a clip with a spring that closes the serrated jaws. An example of an alligator clip (17) is shown in Figure 8. In one embodiment, only the top jaw of said alligator clip moves up and down. In one embodiment, the bottom jaw of said alligator clip stays in the Schlemm's canal. In one embodiment, the elliptical motion of the top jaw of said alligator clip draws in the TM, cuts it, and then pushes it out from the back side.

G. A Lancet Ophthalmic Knife

In one embodiment, the present embodiment contemplates a lancet ophthalmic knife comprising a handle 1 connected to a shaft 3, said shaft connected to a wire element **20**. In one embodiment, the shape of said wire element may retract into said shaft 3. In one embodiment, said wire element is rigid. In one embodiment, the shape of said wire element may be various, from having a tip to as simple as a square wire. In one embodiment, said wire element **20** has at least one sharp edge. In one embodiment, said wire element **20** has at least one dull edge. In one embodiment, said wire element **20** has a square shape, as depicted in Figure 9. In one embodiment, said wire element **20** can be a triangle, square, rectangle, or an ellipse. In one embodiment, said wire element **20** is pushed into the TM. In doing so said wire element **20** stretches open the Schlemm's canal a bit. The wire element **20** is then advanced through the canal so that the sharp wire cuts the TM leaving a long trailing strip of TM

H. An Axial Blade Ophthalmic Knife

In one embodiment, the present invention contemplates an axial blade ophthalmic knife comprising a handle 1 connected to a shaft **3**, said shaft connected to a first and second blade. In one embodiment, said axial blade comprises an axial extension **21** comprising at least one distal blade. In one embodiment, said distal blade is affixed to said axial extension wherein the distance between said blade and the edge of said axial extension distal tip comprises an overhang **36**. In one embodiment, said overhang **36** limits the depth of the cut. In one embodiment, depicted in Figure 10, said device comprises two parallel blades (**10** and **11**) attached to said axial extension **21**, wherein the space between the blades and the edge of said axial extension **21** comprises an overhang **36**.

I. A V-Blade Ophthalmic Knife

In one embodiment, the present invention contemplates a V-blade ophthalmic knife comprising a handle 1 connected to a shaft 3 comprising a first blade, said shaft connected to a platform, wherein the first blade overhangs said platform such that the first blade and said

platform are connected at an angle. In one embodiment, the angle of attachment and overhand of said shaft 3 to said platform provides a surface for shearing tissue. In one embodiment, said knife further comprises a pass through window for cut tissue. Figure 11 provides a side view of one embodiment of this device, wherein the dashed lines indicates one embodiment of the internal through-hole 23.

III. Construction Materials

It is not intended that embodiments of the invention be limited to any particular construction material; however, it is believed that preferred materials include titanium, stainless steel, polyether ether ketone (PEEK), ceramics, rigid plastics, shape memory alloy such as nitinol, and shape memory polymers. In some embodiments, the platform is made of silicon or another polymer or a hydrogel.

In some embodiments, the knives as contemplated herein may be made of a material that is transparent to optical coherence tomography (OCT) wavelengths (e.g., typically 800-1600nm). In one embodiment, an OCT transparent material includes, but is not limited to glycol modified poly(ethylene terephthalate), polyvinyl chloride, poly(methyl methacrylate), or polyphenylsulfone. Although it is not necessary to understand the mechanism of an invention, it is believed that these materials allow the performance of intraoperative OCT during intraocular surgery without any visual interference by the ophthalmic knife.

In one embodiment, the present device is made from metal alloy materials described by Furst, J. G. et al. "Metal Alloys for Medical Devices," United States Patent 7,648,591 [40], Richter, K. "Amorphous Metal Alloy Medical Devices," United States Patent 7,955,387 [41], all herein incorporated by reference. In one embodiment, the present device is made from a shape memory polymer materials described by Reimink, M. S. and Ogle, M. F. "Medical Devices with Polymer/Inorganic Substrate Composites," United States Patent 7,604,663 [42], Langer, R. S. and Lendlein, A. "Shape Memory Polymers," United States Patent 6,388,043 [43], Langer, R. S. and Lendlein, A. "Shape Memory Polymers," United States Patent 6,720,402 [44], Tong, T. H. "Shape Memory Styrene Copolymer," United States Patent 6,759,481 [45], Stalker, K. C. B. et al. "Variable Stiffness Medical Devices," United States Patent 7,632,303 [46], Anthamatten, M.

L. and Li, J. "Shape Memory Polymers," United States Patent 7,935,131 [47], and Berger, E. J. et al. "Methods of Forming a Part Using Shape Memory Polymers," United States Patent 8,038,923 [48], all herein incorporated by reference. In some embodiments, the device of the current invention is rigid at room temperature, but is more flexible at body temperature. In some
5 embodiments, the portions of the device of the current invention are rigid at room temperature, but are more flexible at body temperature. In some embodiments, portions of the device are made from different materials. In some embodiments, portions of the device are made from materials of various rigidity. In one embodiment, said shaft is flexible. In some embodiments, said shaft is made from a lower density material.

10 It is not intended that embodiments of the invention be limited to any particular construction material; however, it is believed that preferred materials include titanium, stainless steel, polyether ether ketone (PEEK), shape memory alloy, and shape memory polymers. In some embodiments, the device of the current invention is rigid at room temperature, but is more flexible at body temperature. In some embodiments, the portions of the device of the current
15 invention are rigid at room temperature, but are more flexible at body temperature. In some embodiments, portions of the device are made from different materials. In some embodiments, portions of the device are made from materials of various rigidity. In one embodiment, said tool shaft 3 is flexible. In some embodiments, said shaft is made from a lower density material.

20 C. Methods Of Using The Multi-Blade Ophthalmic Knives

In one embodiment, the present invention contemplates, a method for using an ophthalmic knife, comprising: a) providing an ophthalmic knife selected from the group consisting of a dual platform/dual blade ophthalmic knife, a quad-blade ophthalmic knife, an
25 ultrasonic ophthalmic knife, a pincer ophthalmic knife, a gripping ophthalmic knife, a lancet ophthalmic knife, an axial blade ophthalmic knife and a V-blade ophthalmic knife; b) advancing said ophthalmic knife through an incision to a tissue target site; and c) cutting a strip of tissue from said target site.

Detailed Differences Between the Devices

It is not intended that embodiments of the invention be limited to any particular method, medical target, or device confirmation; however, it is believed that the device may be optimally designed to remove trabecular meshwork of the eye, unroofing small vessels (such as veins,
5 arteries, lymphatic vessels, or other vessel with a lumen), and for creating a hole or opening in the tympanic membrane of the ear. It is not intended that embodiments of the invention be limited to any particular mechanism; however, it is believed that creating an opening in the tympanic membrane of the ear may help aid in treating ear disease.

It is not intended that embodiments of the invention be limited to any particular
10 endoscope, it is believed that the device may be optimally designed for an ophthalmic endoscopy system endoscope. One such system is commercially called "Endo Optiks."

Thus, specific compositions and configurations of multiple blade cutting systems have been disclosed. It should be apparent, however, to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive
15 concepts herein.

All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited. The
20 publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates, which may need to be independently confirmed.

EXPERIMENTAL

Approval for a preclinical study [49] was obtained from the Colorado Multiple
Institutional Review Board for the use of human material prior to initiation of the study and the tenets of the Declaration of Helsinki were followed. Informed consent was obtained from donors
30 or relatives for use in research by the eye bank from which human globes were obtained.

Example I

Histological Analysis

Six (6) corneal rim specimens were obtained from the Rocky Mountain Lions Eye Bank (Aurora, Colorado, USA) and the San Diego Eye Bank (San Diego, California, USA). Tissue samples were removed from the storage medium and mounted on a platform with the TM side facing up and secured in place using tissue pins. A total of 2 samples were used for each of the 3 treatment methods studied. An MVR blade was used to incise the central TM under microscopic visualization along the length of 2 corneal rims. For the Trabectome® device, the foot plate of the device tip was inserted into the Schlemm's canal under microscopic visualization. Once in place, the foot pedal was used to apply continuous ablation while advancing the tip slowly across the extent of the TM sample. A standard power setting of 0.8 W was used during treatment. A dual-blade device was used to incise the TM of 2 samples. The blade tip was used to incise TM in a manner similar to that used for goniotomy and the blade was then advanced in a clockwise fashion along the extent of the TM. At the distal end, the blade tip was tilted upwards to incise a complete ribbon of TM and the process was repeated in a counterclockwise fashion to incise the remaining TM tissue.

All tissue samples were then immediately preserved in 4% paraformaldehyde/ phosphate-buffered saline overnight at 4 °C and then radially cut into quadrants. Rim sections were processed for histology and embedded into paraffin so that the cut edge of the tissue was facing the front of the block. Tissue sections (6 mm thick) were cut and stained with Mayer's hematoxylin-eosin Y (Richard-Allan Scientific, Kalamazoo, Michigan, USA). Bright-field imaging was performed using a Nikon Eclipse 80i microscope (Nikon, Melville, New York, USA) equipped with a Nikon D5-Fi1 color camera and a Nikon CFI 103/Plan Fluor objective lens.

Example II

Human Eye Perfusion

A total of 12 human globes from pseudophakic donors with no history of glaucoma were obtained from various eye banks around the country for perfusion studies on each device. The

perfusion system used a standard programmable syringe pump (Pump 11 Plus; Harvard Apparatus, Holliston, Massachusetts, USA). Pressure was monitored via an in-line real-time pressure transducer (Research Grade Pressure Transducer; Harvard Apparatus) connected to a single-channel chart recorder (Pharmacia REC-481; Pharmacia/Pfizer New York, New York, USA). Polyethylene tubing with a 1.14 mm inner diameter (PE-160; Warner Instruments, Hamden, Connecticut, USA) was used for all connections.

In each case, the human globe was first prepared by injecting Dulbecco's modified Eagle medium (DMEM; Invitrogen/ Life Technologies, Carlsbad, California, USA) through the optic nerve with a 26-gauge needle until the globe had returned to a spherical shape. The perfusion line (terminating in another 26-gauge needle) was inserted diagonally through the anterior chamber of the eye, passing through the cornea and pupil and ending with the tip beneath the iris. The globe was surrounded by damp gauze and the perfusion pump (filled with DMEM) was set to an initial inflow rate of 7 mL/min. IOP was allowed to increase until it reached 30 mm Hg. The infusion rate was then reduced to 2-5 mL/min to maintain a steady-state IOP for at least 60 minutes prior to TM incision. A preoperative IOP was measured immediately prior to incision in each case. A 1.7 mm stainless steel keratome blade (BD) was used create a tri-beveled clear corneal incision near the limbus, and the anterior chamber was filled with enough viscoelastic (HealonGV; Abbott Medical Optics, Abbott Park, Illinois, USA) to maintain the anterior chamber and provide adequate visualization during the procedure in each case. Each technique was performed under gonioscopic view using a standard direct gonioscope with microscope assistance. The surgical procedure used for each device is described above. In each case, approximately 100-180 degrees of TM was treated. For each device, treatment was started 180 degrees away from the corneal wound and extended along the angle in a clockwise direction. The device was then extended in a counterclockwise direction from the same starting point. Every effort was made to treat the maximum amount of degrees possible with each device.

In the case of a conventional modified dual-blade device and a Trabectome[®], the instrument was rotated 180 degrees after the initial pass to direct the device tip in the direction of treatment. IOP was allowed to reach a steady state before measuring the postprocedure IOP. Each of the 3 studied surgical techniques was performed on a total of 4 eyes.

Two corneal rim sections were analyzed for each device. Six-micron-thick histologic sections were taken from various clock hours treated with each device and stained with Mayer's hematoxylin-eosin Y (Richard-Allan Scientific). Findings were consistent across all sections from each device tested. Cuts with the MVR blade exhibited complete incision through the entire thickness of TM tissue. However, there was minimal removal of TM with large leaflets of tissue remaining over the Schlemm's canal. The incision extended deeply through the Schlemm's canal with obvious injury to the adjacent deep sclera in the majority of sections (Figure 1). The Trabectome® also achieved an opening through the entirety of TM tissue into the Schlemm's canal. Although the device also removed a large portion of the central TM, significant leaflets of residual tissue still remained. The residual TM demonstrated extensive charring from thermal injury. Tissue debris was also noted to be occluding distal collector channels (Figure 2). Tissue incised with the dual-blade device demonstrated a more complete removal of TM without collateral damage (Figure 3).

Data from human eye perfusion studies are included in Table 1. The extent of TM treatment varied between devices and between eyes from 100 to 180 degrees. All 3 treatment modalities achieved a significant reduction in measured IOP 30 minutes after treatment. Treatment with the dual-blade device and Trabectome® resulted in a mean IOP reduction of 40% each, whereas the MVR blade achieved a 31% reduction. Although the percentage of IOP decrease was greater for Trabectome® and the dual-blade device, there was no statistically significant difference in the IOP lowering between devices (dualblade/ MVR $P = .13$; dual-blade/Trabectome® $P = .96$; Trabectome®/MVR $P = .12$). There was no correlation between the number of degrees of TM treated and the percentage IOP change for any device ($r^2 = 0.077-0.271$).

Table 1. Human Eye Perfusion Studies After Treatment of Trabecular Meshwork by Various Conventional Devices

	Eye	Degree of	Preprocedure IOP	Postprocedure IOP	Absolute IOP	Percent IOP	P Value
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		Angle Treated			Change	Change	
Modified Dual-blade device	1	140	17	10	-7	-41	
	2	180	19	11	-8	-42	
	3	130	15	9	-6	-40	
	4	180	22	14	-8	-36	
	Mean	157.5 ± 26.3	18.3 ± 3.0	11.0 ± 2.2	-7.3	-40	0.00063
MVR blade	1	180	20	14	-6	-30	
	2	180	20	15	-5	-25	
	3	150	18	12	-6	-33	
	4	170	16	10	-6	-38	
	Mean	170.0 ± 14.1	18.5 ± 1.9	12.8 ± 2.2	-5.8	-31	0.00018
Trabectome®	1	120	18	12	-6	-33	
	2	130	21	12	-9	-43	
	3	100	17	11	-6	-35	
	4	120	19	10	-9	-47	
	Mean	117.5 ± 12.6	18.8 ± 1.7	11.3 ± 1.0	-7.5	-40	0.00324

IOP = intraocular pressure; MVR = microvitrectomy.

In the study, the initial preclinical evaluation of an embodiment of the present invention, a dual-blade device for the treatment of glaucoma, is presented [49]. Histologic analysis of human cadaver eye tissue treated with the dual-blade device achieved more complete removal of TM tissue while avoiding any discernible damage to surrounding tissue. Treatment with other methods of TM removal such as MVR blade goniotomy and ab interno trabeculectomy with the Trabectome® device failed to attain equivalent histologic results to the novel dual-blade device. While histology data were obtained from ex vivo-treated corneal rims, similar findings were noted when treatment was performed using the ab interno approach on perfused eyes. The near-absence of TM leaflets with the dual-blade device may be beneficial in reducing the chances of future physical obstruction, and the lack of tissue damage may also reduce the inflammatory response or subsequent fibrosis at the surgical site.

In addition to potentially favorable histologic outcomes, the dual-blade device resulted in significant IOP lowering in a human eye perfusion model. Although all 3 devices yielded similar immediate reduction in IOP after use in a perfusion model, it is unclear how a more complete removal of TM tissue and decreased collateral damage with the dual-blade device of the present invention will translate into long term surgical outcomes when used to treat glaucoma. No correlation was found between degrees of TM treated and IOP reduction. It is plausible that IOP reduction may depend more on the number of downstream collector channels exposed rather than the absolute amount of TM removal alone.

In an effort to provide a low-cost MIGS device that can be widely used by ophthalmic surgeons, one embodiment of the present invention contemplates a novel medical-grade stainless steel dual-blade device that can successfully remove TM with no discernible collateral damage was designed. In one embodiment, the device comprises a unique dual-edge blade design using precise geometries to allow for more complete removal of TM tissue (Figure 4A&B). Although it is not necessary to understand the mechanism of an invention, it is believed that the procedure is performed from an ab interno approach and is viscoelastic to maintain the anterior chamber. For example, the size and tip of the blade can allow for a smooth entry into the Schlemm's canal, similar to techniques used for traditional goniotomy procedures. Once in place, the tip is advanced through the Schlemm's canal and the TM is elevated along a designed ramp that guides tissue toward a set of blades positioned specifically to incise and remove TM. In contrast to the Trabectome® footplate, which is juxtaposed between the outer wall of the Schlemm's canal and the inner wall of the Schlemm's canal to provide protection during cautery, the dual-blade device transects TM and elevates TM off of the outer wall of the Schlemm's canal. Although it is not necessary to understand the mechanism of an invention, it is believed that by elevating the TM along the ramp of the device as it moves forward leads to maximal tissue removal when incised by the superiorly placed and strategically angled dual blades. It is further believed that the angle between the distal cutting edge and the handle is engineered to allow maximal angle treatment through 1 incision while avoiding trauma to the cornea above or the scleral spur below. The excised TM may then be removed from the eye with forceps or aspirated during the irrigation/aspiration phase if combined with cataract extraction. In addition, the device

of the present invention can easily pass through clear corneal incisions as small as 1.2 mm, thus obviating the need for additional incisions when coupled with phacoemulsification.

Example III

Traditional Incisional Goniotomy

This procedure begins with an incision in trabecular meshwork extending into sclera with large segments of trabecular meshwork. For this procedure (considered the gold standard surgery for “cutting” through the trabecular meshwork and traditionally called “goniotomy”) an MVR blade was used to incise the trabecular meshwork to create an opening into Schlemm’s canal. A histological sample was provided from a procedure in which an incision exists through Trabecular meshwork and extends into sclera. There were large leaflets of trabecular meshwork remaining on either side of the incision. These leaflets scar down and close the opening that was created into Schlemm’s canal. This precludes any long-term benefit in intraocular pressure lowering which is the goal of the surgery.

Example IV

Trabectome® Procedures

For this procedure (designed to replace goniotomy and to improve upon that procedure by removing sections of trabecular meshwork), a Trabectome® device was used to engage the trabecular meshwork and cautery was applied to the trabecular meshwork. The circle shows an area where a small segment of trabecular meshwork was removed; however, there are large leaflets of trabecular meshwork remaining and charred tissue on either side of the treatment area. Post Trabectome® treatment showed trabecular meshwork remnants and charring of tissue. Tissue debris is occluding a collector channel this device “burns” tissue and the burning of tissue creates inflammation that leads to more scar formation that leads to failure of the surgically induced opening into Schlemm’s canal. In addition, due to cautery, many bubbles are formed during the procedure that makes visualization difficult during the actual procedure. These issues do not occur with the current invention device, which is a major advantage.

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CLAIMS

We claim:

- 5 1. A dual platform/dual-blade ophthalmic knife, comprising:
- i) a handle connected to a shaft;
- ii) a first platform connected to said shaft, wherein said first platform comprises a
 first and second blade and a first anterior blade tip;
- 10 iii) a second platform connected to said shaft, wherein said second platform
 comprises a third and fourth blade and a second anterior blade tip.
2. The ophthalmic knife of Claim 1, wherein said first and second anterior blade tips are
 retractable blade tips.
- 15 3. The ophthalmic knife of Claim 1, wherein said first and second anterior blade tips are
 wedge blade tips.
4. The ophthalmic knife of Claim 1, wherein said first blade and a second blade are attached
 to a first lateral side and a second lateral side of said first platform.
- 20 5. The ophthalmic knife of Claim 1, wherein said third blade and a fourth blade are attached
 to a third lateral side and a fourth lateral side of said second platform.
6. The ophthalmic knife of Claim 1, wherein said first platform and said second platform
25 are configured at an 180° angle.
7. The ophthalmic knife of Claim 1, wherein said first platform and said second platform
 are configured in parallel.

8. The ophthalmic knife of Claim 1, wherein said first platform comprises a first ramp increasing in depth extending from the first anterior blade tip to a first posterior end.
- 5 9. The ophthalmic knife of Claim 1, wherein said second platform comprises a second ramp increasing in depth extending from the second anterior blade tip to a second posterior end.
- 10 10. The ophthalmic knife of Claim 1, wherein said first and second blades are configured in parallel or at an angle.
11. The ophthalmic knife of Claim 1, wherein said third and fourth blades are configured in parallel or at an angle.
- 15 12. The ophthalmic knife of Claim 1, wherein said first platform further comprises a first annular cutting edge.
13. The ophthalmic knife of Claim 1, wherein said second platform further comprises a second annular cutting edge
- 20 14. The ophthalmic knife of Claim 1, wherein said first and second platforms further comprise a grasping feature selected from the group consisting of a tweezer and a forceps.
- 25 15. The ophthalmic knife of Claim 1, wherein said shaft is a telescoping shaft.
16. A quad-blade ophthalmic knife, comprising:
- i) a handle connected to a shaft, said shaft comprises a first blade and a second blade;
 - ii) a platform connected to said shaft, said platform comprises a third blade, a fourth blade and an anterior blade tip.
- 30

17. The ophthalmic knife of Claim 16, wherein said anterior blade tip is a retractable blade tip.
- 5 18. The ophthalmic knife of Claim 16, wherein said anterior blade tip is a wedge blade tip.
19. The ophthalmic knife of Claim 16, wherein said first blade and said second blade are attached to a first lateral side and a second lateral side of said shaft.
- 10 20. The ophthalmic knife of Claim 16, wherein said third blade and said fourth blade are attached to a first lateral side and a second lateral side of said platform.
21. The ophthalmic knife of Claim 16, wherein said first blade and said second blade are slidably engaged with said shaft.
- 15 22. The ophthalmic knife of Claim 16, wherein said handle further comprises a compressible material that contacts said first and second blades.
23. The ophthalmic knife of Claim 16, wherein said shaft is connected to a second quad-blade knife configured at a 180° angle to said first quad-blade knife.
- 20 24. The ophthalmic knife of Claim 16, wherein said is connected to a second quad-blade knife configured in parallel to said first quad-blade knife.
- 25 25. The ophthalmic knife of Claim 16, wherein said platform comprises a ramp increasing in depth extending from the anterior blade tip to said posterior end.
26. The ophthalmic knife of Claim 16, wherein said first and second blades are configured in parallel or at an angle.

27. The ophthalmic knife of Claim 16, wherein said third and fourth blades are configured in parallel or at an angle.
28. The ophthalmic knife of Claim 16, wherein said third and fourth blades are retractable and attached within a first and second platform cavity.
29. The ophthalmic knife of Claim 16, wherein said platform further comprises a grasping feature selected from the group consisting of a tweezer element and a forcep element.
30. The ophthalmic knife of Claim 29, wherein said grasping feature comprises a sleeve extending over the shaft, wherein said handle comprises a sleeve actuator switch.
31. An ultrasonic ophthalmic knife, comprising:
- i) a handle connected to a shaft;
 - ii) a platform connected to said shaft, said platform comprising an anterior blade tip and an ultrasonic emitter; and
 - iii) a footplate to protect surrounding tissue from the ultrasonic blades.
32. The ophthalmic knife of Claim 31, wherein said ultrasonic emitter anterior blade tip vibrates in a fixed frequency when the device is actuated.
33. The ophthalmic knife of Claim 31, wherein both longitudinal and lateral motions are possible for the tip.
34. The ophthalmic knife of Claim 31, wherein said ultrasonic emitter has adjustable power settings.
35. The ophthalmic knife of Claim 34, wherein said power settings are optimized to minimize the application of heat during use.

36. The ophthalmic knife of Claim 31, wherein said platform further comprises a grasping feature selected from the group consisting of a tweezer element and a forcep element.
- 5 37. The ophthalmic knife of Claim 31, wherein said platform further comprises a slidable punch.
38. The ophthalmic knife of Claim 31, further comprising at least one lumen extending longitudinally within said handle, said shaft and said platform.
- 10 39. The ophthalmic knife of Claim 38, wherein said at least one lumen comprises a fluid selected from the group consisting of a viscoelastic fluid and an aspiration fluid.
40. The ophthalmic knife of Claim 31, wherein said platform further comprises a through-hole extending from a top surface to a posterior end.
- 15 41. The ophthalmic knife of Claim 31, wherein said handle is curved.
42. The ophthalmic knife of Claim 31, wherein said knife further comprises a fiber optic visualization system.
- 20 43. The ophthalmic knife of Claim 31, wherein said shaft further comprises an annular ring.
44. A pincer ophthalmic knife, comprising:
- 25 i) a handle connected to a shaft;
- ii) a lower platform connected to said shaft, said lower platform comprising a first blade attached to a first lateral side and a second blade attached to a second lateral side; and
- iii) an upper platform hinged to said shaft, said upper platform comprising a first slot and a second slot, wherein said first slot and said second slot are respectively
- 30 positioned above said first blade and said second blade.

45. The ophthalmic knife of Claim 44, wherein said lower platform comprises an anterior blade tip.
- 5 46. The ophthalmic knife of Claim 45, wherein said anterior blade tip is a wedge blade tip.
47. The ophthalmic knife of Claim 44, wherein said lower platform is approximately 8 mm in length.
- 10 48. The ophthalmic knife of Claim 44, wherein said platform further comprises a slidable punch.
49. The ophthalmic knife of Claim 44, further comprising at least one lumen extending longitudinally within said handle, said shaft and said platform.
- 15 50. The ophthalmic knife of Claim 49, wherein said at least one lumen comprises an exit port in said platform.
51. The ophthalmic knife of Claim 50, wherein said exit port is on the top surface of the platform.
- 20 52. The ophthalmic knife of Claim 50, wherein said exit port is on the bottom surface of said platform.
- 25 53. The ophthalmic knife of Claim 49, wherein said at least one lumen comprises an entry port in said handle.
54. The ophthalmic knife of Claim 49, wherein said at least one lumen comprises a fluid selected from the group consisting of a viscoelastic fluid and an aspiration fluid.

55. The ophthalmic knife of Claim 44, wherein said platform further comprises a through-hole extending from the top surface to a posterior end.

56. The ophthalmic knife of Claim 44, wherein said handle is curved.

57. The ophthalmic knife of Claim 44, wherein said platform comprises a concave bottom surface.

58. The ophthalmic knife of Claim 44, wherein said platform further comprises at least one heating element.

59. A gripping ophthalmic knife, comprising:

- i) a handle connected to a shaft,
- ii) a lateral alligator clip connected to said shaft;
- iii) a platform connected to said shaft, said platform comprising a first lateral blade, a second lateral blade and an anterior blade tip.

60. The ophthalmic knife of Claim 59, wherein said lateral alligator clip comprises a first serrated jaw and a second serrated jaw.

61. The ophthalmic knife of Claim 60, wherein said first serrated jaw and said second serrated jaw of said lateral alligator clip are hinged.

62. The ophthalmic knife of Claim 59, said handle comprises a compressible material that contacts said first alligator clip and said second alligator clip.

63. The ophthalmic knife of Claim 59, wherein said anterior blade tip is a wedge blade tip.

64. The ophthalmic knife of Claim 59, wherein said anterior blade tip is a retractable blade tip.

65. The ophthalmic knife of Claim 59, wherein said first lateral blade and the second lateral blade are attached to a first lateral side and a second lateral side of said platform.
- 5 66. A lancet ophthalmic knife, comprising:
i) a handle connected to a shaft, and
ii) a wire element connected to said shaft.
- 10 67. The ophthalmic knife of Claim 66, wherein said wire element comprises a geometric shape selected from the group consisting of a triangle, square, a rectangular, an octagon, a circle, an ellipse or an oval.
68. The ophthalmic knife of Claim 66, wherein said wire element comprises a first wire end and a second wire end.
- 15 69. The ophthalmic knife of Claim 68, wherein said first wire end is connected to said shaft at a first position.
- 20 70. The ophthalmic knife of Claim 68, wherein said second wire end is connected to said shaft at a second position.
71. The ophthalmic knife of Claim 66, wherein said shaft further comprises a grasping feature selected from the group consisting of a tweezer element or a forcep element.
- 25 72. The ophthalmic knife of Claim 66, wherein said shaft further comprises a slidable punch.
73. The ophthalmic knife of Claim 66, wherein said wire element further comprises at least one heating element.
- 30 74. The ophthalmic knife of Claim 66, wherein said shaft further comprises an annular ring.

75. The ophthalmic knife of Claim 66, wherein said wire element is a color selected from the group consisting of blue, white, black, orange, yellow and any combination thereof.

5 76. An axial blade ophthalmic knife, comprising:

- i) a handle connected to a shaft, said shaft comprising a distal end;
- ii) a first blade and a second blade extending from said distal end; and
- iii) a shaft overhang positioned between said first blade and a first lateral edge of said shaft.

10 77. The ophthalmic knife of Claim 76, wherein said shaft overhang is further positioned between said second blade and a second lateral edge of said shaft.

15 78. The ophthalmic knife of Claim 76, wherein said first blade and said second blade extend axially from said distal end.

79. The ophthalmic knife of Claim 76, wherein said shaft further comprises a grasping feature.

20 80. The ophthalmic knife of Claim 73, wherein said grasping feature is selected from the group consisting of a tweezer element and a forcep element.

81. The ophthalmic knife of Claim 73, wherein said grasping feature comprises a sleeve extending over said shaft, wherein said handle comprises a sleeve actuator switch.

25 82. The ophthalmic knife of Claim 76, wherein said shaft further comprises a slidable punch.

83. The ophthalmic knife of Claim 76, further comprising at least one lumen extending longitudinally within said handle and said shaft.

84. The ophthalmic knife of Claim 83, wherein said at least one lumen comprises a fluid selected from the group consisting of a viscoelastic fluid and an aspiration fluid.

85. The ophthalmic knife of Claim 76, wherein said handle is curved.

86. The ophthalmic knife of Claim 85, wherein said knife further comprises a fiber optic visualization system.

87. A V-blade ophthalmic knife, comprising:

- i) a handle connected to a shaft, said shaft comprising a blade; and
- ii) a platform connected to said shaft, wherein said blade overhangs at least a portion of said platform, wherein said blade and said platform are connected at an angle.

88. The ophthalmic knife of Claim 87, wherein said platform further comprises an anterior blade tip.

89. The ophthalmic knife of Claim 87, wherein said anterior blade tip is a retractable blade tip.

90. The ophthalmic knife of Claim 87, wherein said anterior blade tip is a wedge blade tip.

91. The ophthalmic knife of Claim 87, wherein said platform comprises a ramp increasing in depth extending from said anterior blade tip to a posterior end.

92. The ophthalmic knife of Claim 87, wherein said platform further comprises an annular cutting edge.

93. The ophthalmic knife of Claim 87, wherein said shaft further comprises a grasping feature.

94. The ophthalmic knife of Claim 93, wherein said grasping feature is selected from the group consisting of a tweezer element and a forcep element.
- 5 95. The ophthalmic knife of Claim 87, wherein said ophthalmic knife further comprises at least one lumen extending longitudinally within said handle and said shaft.
96. The ophthalmic knife of Claim 95, wherein said at least one lumen comprises a fluid selected from the group consisting of a viscoelastic fluid and an aspiration fluid.
- 10 97. A method for using an ophthalmic knife, comprising:
- a) providing an ophthalmic knife selected from the group consisting of a dual platform/dual blade ophthalmic knife, a quad-blade ophthalmic knife, an ultrasonic ophthalmic knife, a pincer ophthalmic knife, a gripping ophthalmic knife, a lancet ophthalmic knife, an axial blade ophthalmic knife and a V-blade
15 ophthalmic knife;
 - b) advancing said ophthalmic knife through an incision to a tissue target site; and
 - c) cutting a strip of tissue from said target site.
98. The method of Claim 97, wherein said knife is integrated into an endoscope.
- 20 99. The method of Claim 97, wherein said method further comprises visualizing said cutting with a fiber optic visualization system.
100. The method of Claim 97, wherein said tissue target site is located within the body of a
25 patient.
101. The method of Claim 97, further comprising the step of removing said strip of tissue from said tissue target site.

102. The method of Claim 100, further comprising the step of treating said patient for glaucoma.

103. The method of Claim 102, wherein said treating comprises draining aqueous humor from the eye of said subject.

104. The method of Claim 97, wherein said advancing further comprises; i) inserting said knife into an ocular anterior chamber; and ii) positioning said knife adjacent to, or within, a trabecular meshwork of the eye.

105. The method of Claim 97, wherein said incision is in an anatomical location selected from the group consisting of an eyeball, skin, mucous membrane, an organ, and a tumor.

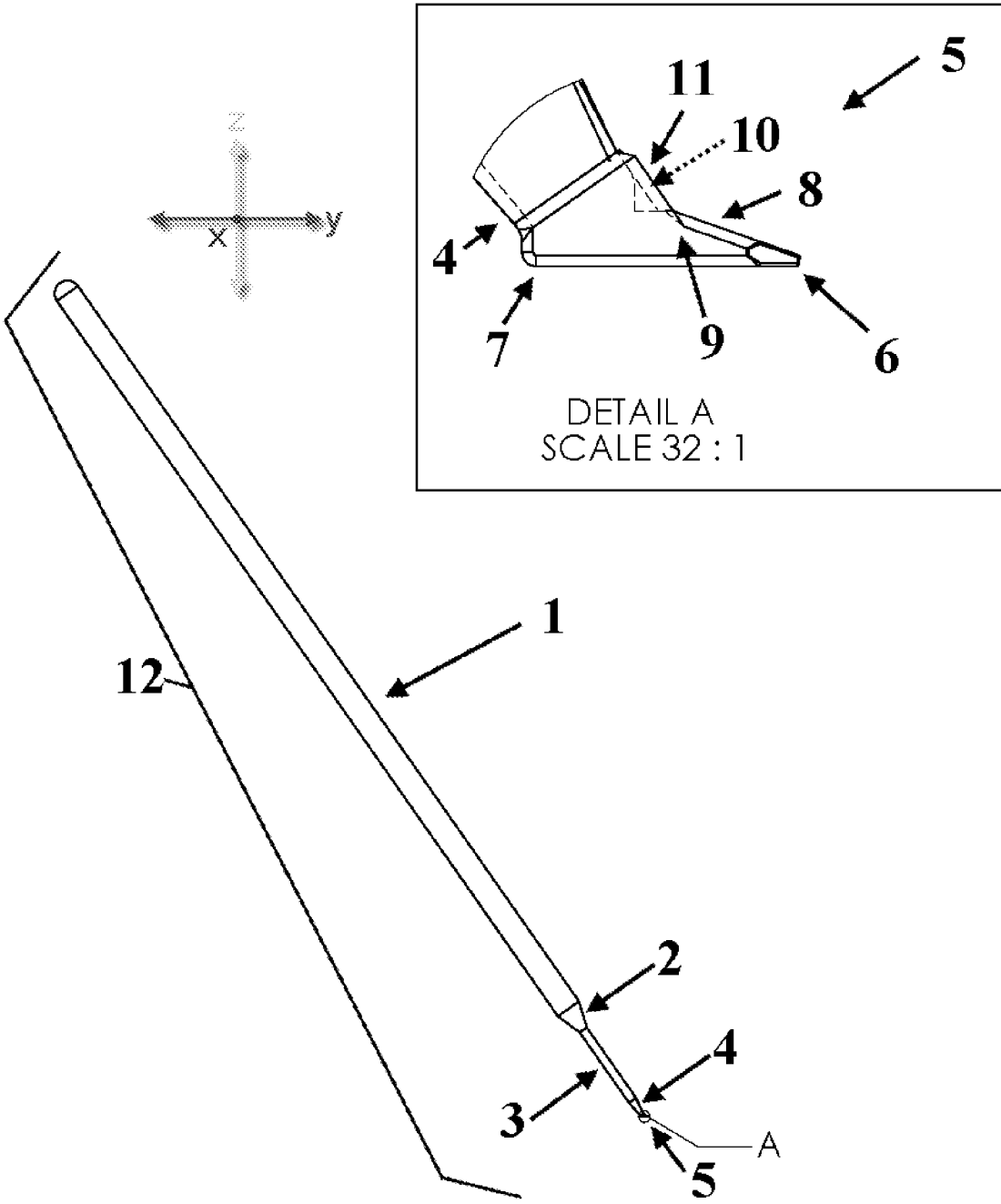


Figure 1

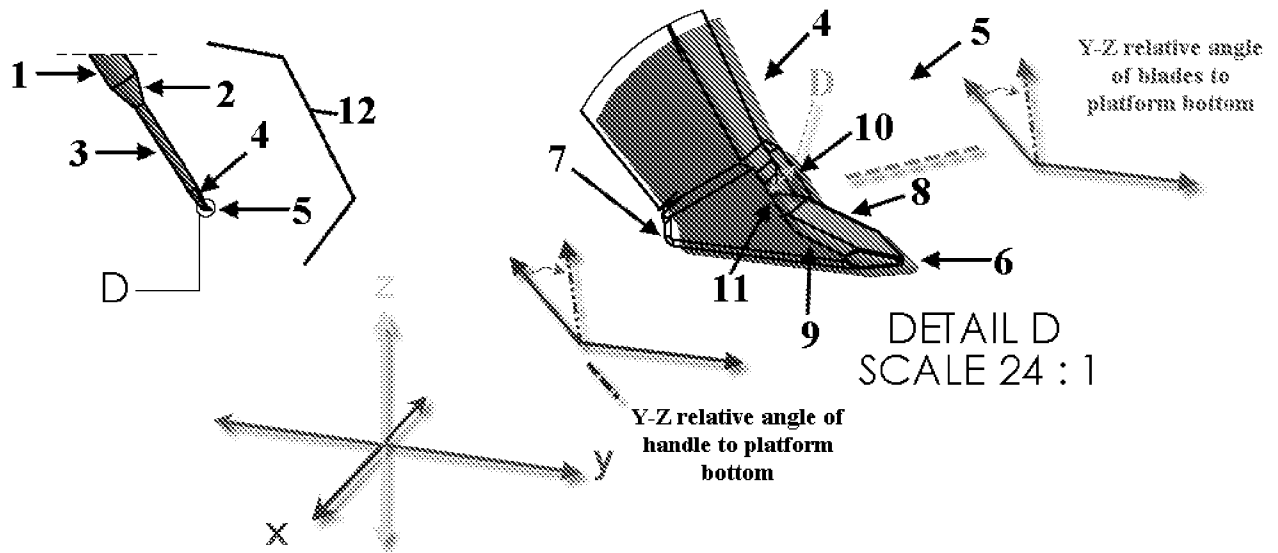


Figure 2

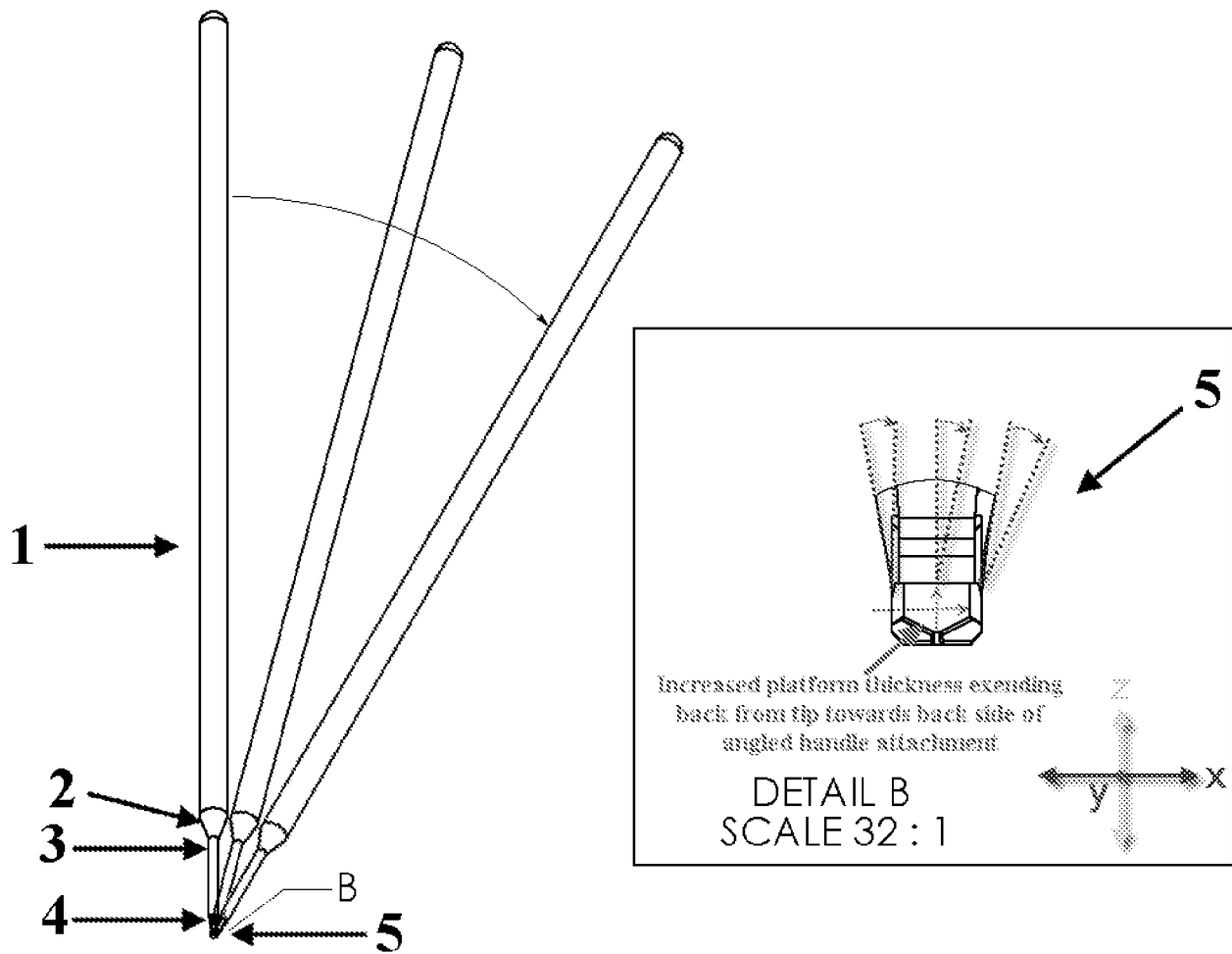


Figure 3

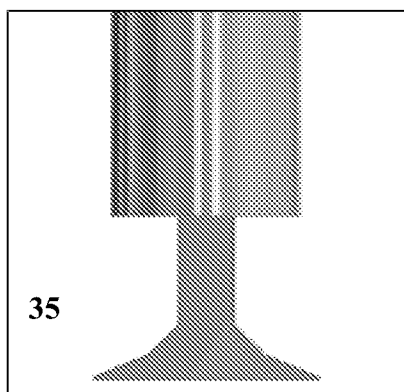


Figure 4A

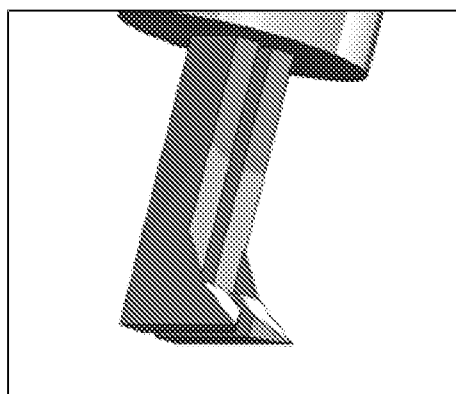


Figure 4B

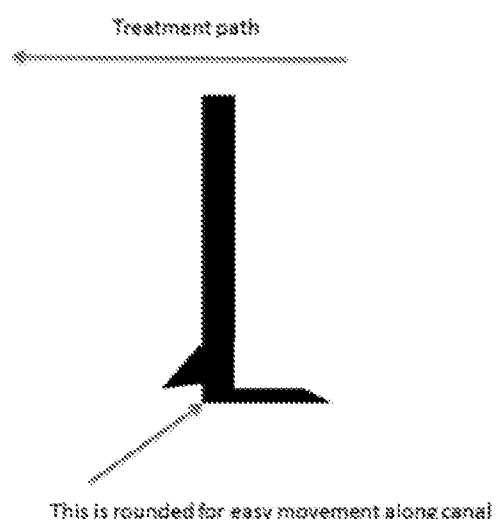


Figure 4C

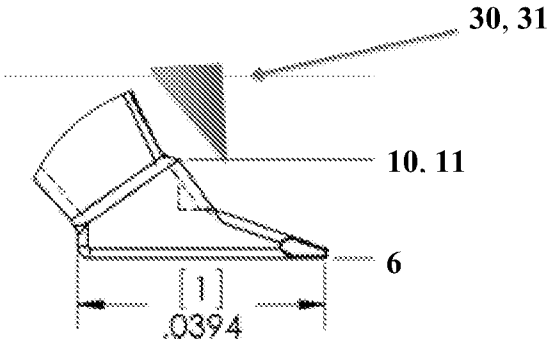


Figure 5

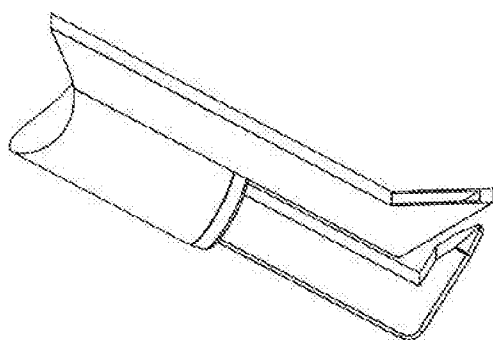


Figure 6

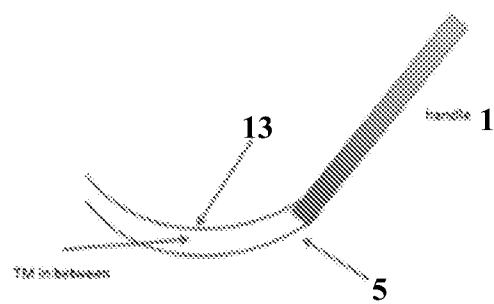


Figure 7

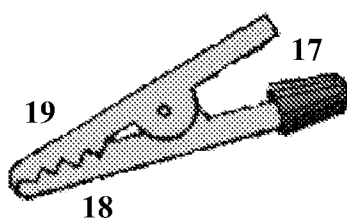


Figure 8

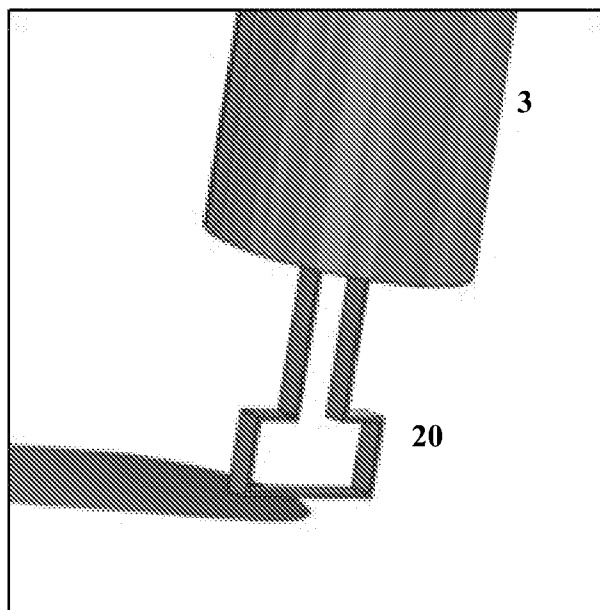


Figure 9

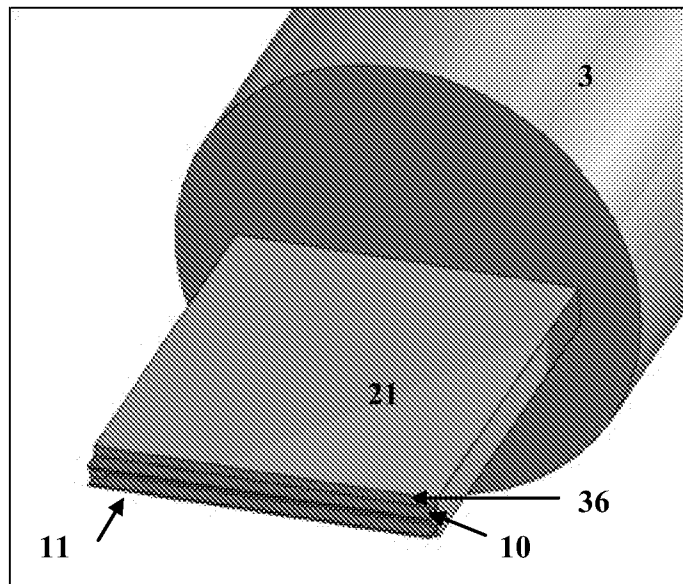


Figure 10

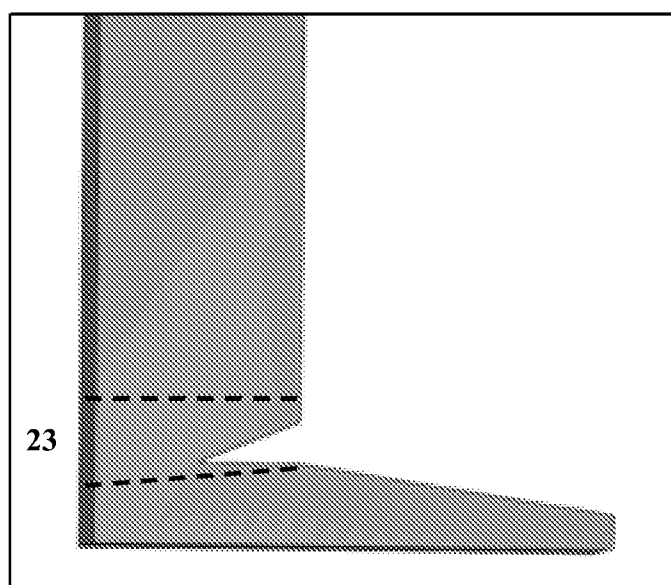


Figure 11

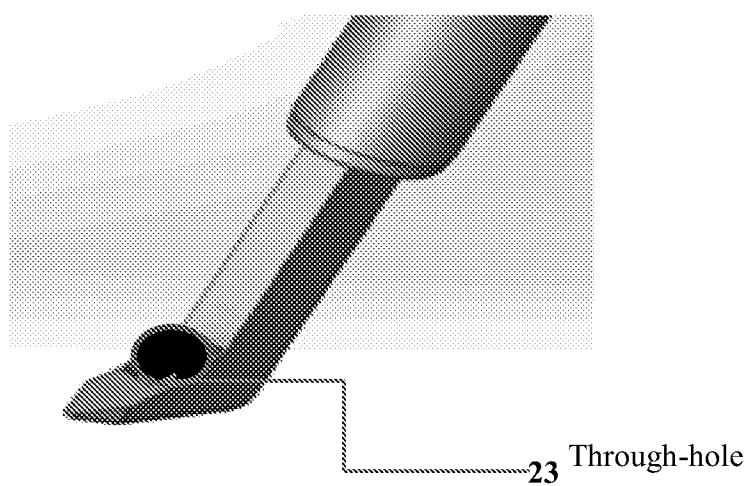


Figure 12

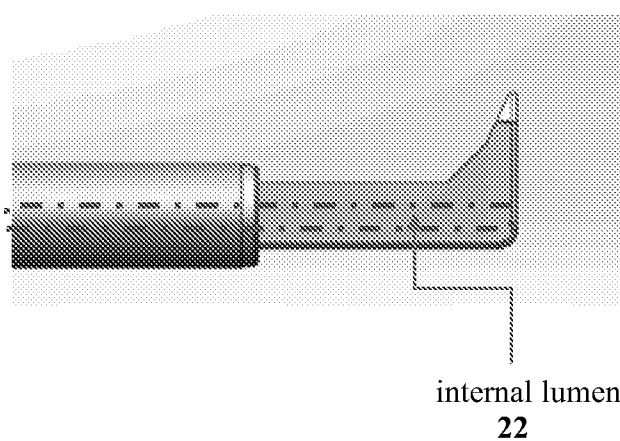


Figure 13

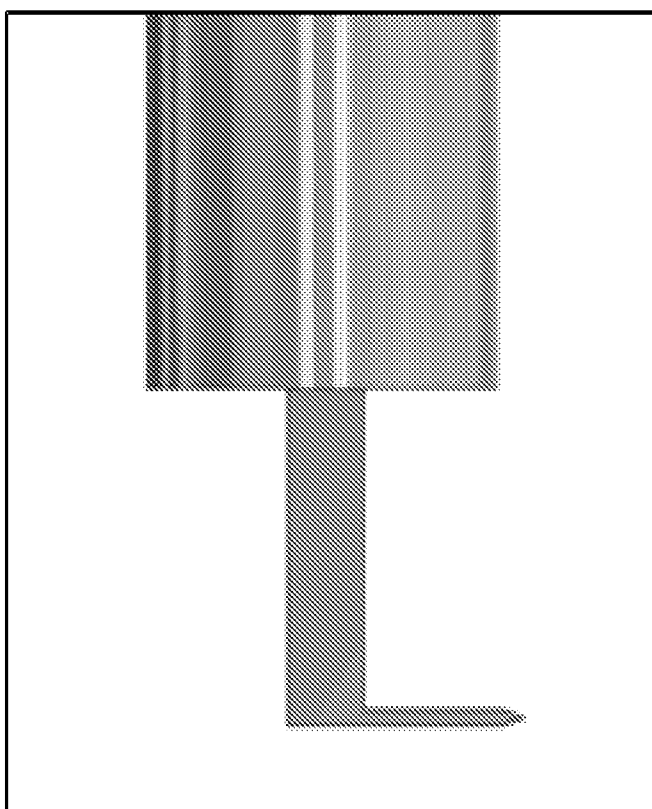


Figure 14

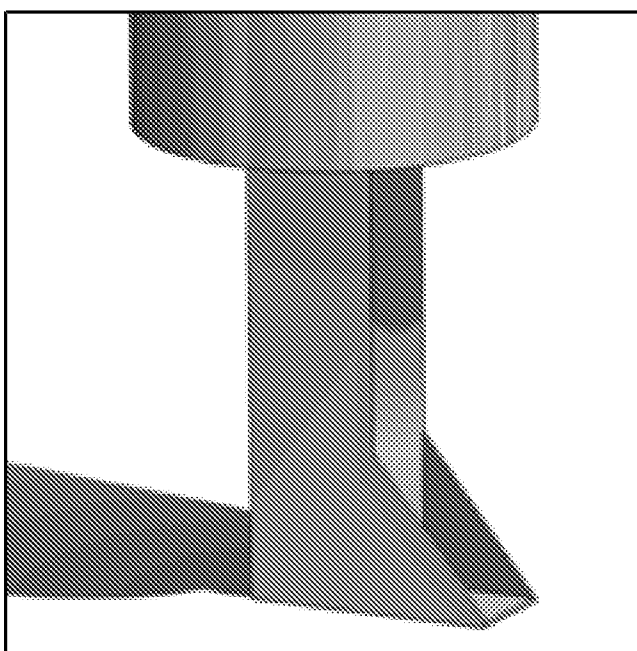


Figure 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/068393

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 17/3211; A61B 1/32; A61B 17/00; A61B 17/28; A61B 17/29; A61B 17/32 (2017.01)

CPC - A61B 17/3211; A61B 17/29; A61B 17/32; A61B 17/320016; A61B 17/3201; A61B 17/32093; A61B 17/3213; A61B 2017/00526; A61B 2017/32113; A61F 9/007; A61F 9/00736; A61F 9/00754; A61F 9/00781; A61F 9/013; A61F 9/0133 (2017.02)

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)

See Search History document

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

USPC - 606/166; 606/107; 606/167; 606/170; 606/174; 606/205; 606/207 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2006/0015128 A1 (FARD) 19 January 2006 (19.01.2006) entire document	1, 3-13 --- 2, 14, 15, 101
X --- Y	US 2005/0113644 A1 (OBENCHAIN et al) 26 May 2005 (26.05.2005) entire document	16, 18-22, 25-27 --- 17, 28-30
X --- Y	US 5,674,233 A (DYBBS) 07 October 1997 (07.10.1997) entire document	31-35, 40-43, 97, 99, 100, 104, 105 --- 36-39, 98, 101-103
X --- Y	US 2006/0271074 A1 (EWERS et al) 30 November 2006 (30.11.2006) entire document	59-61, 63, 65 --- 64, 98
X --- Y	US 6,503,262 B1 (EDENS) 07 January 2003 (07.01.2003) entire document	66-70, 74, 75 --- 71-73
X --- Y	US 2009/0306689 A1 (WELTY et al) 10 December 2009 (10.12.2009) entire document	76-78, 83-85 --- 38, 39, 49, 53, 54, 79, 80, 82, 86, 95, 96



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

30 March 2017

Date of mailing of the international search report

17 APR 2017

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, VA 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/068393

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0216019 A1 (ECKMAN) 29 September 2005 (29.09.2005) entire document	87-92
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Y		2, 17, 28, 64, 93-96
Y	US 2010/0152609 A1 (ZWOLINSKI et al) 17 June 2010 (17.06.2010) entire document	14, 29, 30
Y	US 5,620,453 A (NALLAKRISHNAN) 15 April 1997 (15.04.1997) entire document	15
Y	US 2014/0121697 A1 (KATALYST SURGICAL LLC) 01 May 2014 (01.05.2014) entire document	36, 71, 79, 80, 93, 94
Y	US 2007/0100363 A1 (DOLLAR et al) 03 May 2007 (03.05.2007) entire document	37, 48, 72, 82
Y	US 2014/0330273 A1 (ETHICON ENDO-SURGERY INC) 06 November 2014 (06.11.2014) entire document	44-49, 53-58
Y	US 2012/0239056 A1 (DIJKMAN et al) 20 September 2012 (20.09.2012) entire document	44-49, 53-58
Y	US 2011/0202049 A1 (JIA et al) 18 August 2011 (18.08.2011) entire document	73
Y	US 2006/0149194 A1 (CONSTON et al) 06 July 2006 (06.07.2006) entire document	86, 102, 103
A	US 3,882,872 A (DOUVAS et al) 13 May 1975 (13.05.1975) entire document	1-105
A	US 2006/0241580 A1 (MITTELSTEIN et al) 26 October 2006 (26.10.2006) entire document	1-105
A	US 7,374,566 B1 (SCHOSSAU) 20 May 2008 (20.05.2008) entire document	1-105

INTERNATIONAL SEARCH REPORT

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

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

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

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

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

See Extra Sheet(s)

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/068393

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I, claims 1-30, 59-75, 97-105 are drawn to a knife including four blades.

Group II, claims 31-43, 97-105 are drawn to an ultrasonic knife including an emitter and footplate.

Group III, claims 44-58, 97-105 are drawn to a pincer knife including hinged platforms and slots.

Group IV, claims 76-105 are drawn to blade knives including shaft and blade overhangs.

The inventions listed in Groups I, II, III, or IV do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, wherein said first platform comprises a first and second blade and a first anterior blade tip; a second platform connected to said shaft, wherein said second platform comprises a third and fourth blade and a second anterior blade tip, a lateral alligator clip connected to said shaft, a wire element connected to said shaft, are not present in Groups II, III, or IV; the special technical features of Group II, an ultrasonic emitter; and a footplate to protect surrounding tissue from the ultrasonic blades, are not present in Groups I, III, or IV; the special technical features of Group III, a lower platform connected to said shaft, said lower platform comprising a first blade attached to a first lateral side and a second blade attached to a second lateral side; and an upper platform hinged to said shaft, said upper platform comprising a first slot and a second slot, wherein said first slot and said second slot are respectively positioned above said first blade and said second blade, are not present in Groups I, II, or IV; and the special technical features of Group IV, a shaft overhang positioned between said first blade and a first lateral edge of said shaft, wherein said blade overhangs at least a portion of said platform, wherein said blade and said platform are connected at an angle, are not present in Groups I, II, or III.

Groups I, II, III, and IV share the technical features of a knife comprising a handle connected to a shaft, and a platform connected to the shaft, wherein the platform includes at least one blade. However, these shared technical features do not represent a contribution over the prior art. Specifically, US 2015/0045820 A1 to The Regents of the University of Colorado A Body Corporate teaches of a knife (Fig. 10, device 12 is substantially a knife as it contains cutting blades, para. [0008]) comprising a handle connected to a shaft (Fig. 10, handle 1 is connected to shaft 3, para. [0008]), and a platform connected to the shaft (Fig. 10, platform 5 is coupled to the shaft 3, para. [0008]), wherein the platform includes at least one blade (Fig. 10, wherein the platform 5 includes blades 10 and 11, para. [0008]).

Unity exists between claims 1-30, 59-75, 97-105 (Group I); or claims 31-43, 97-105 (Group II); or claims 44-58, 97-105 (Group III); or claims 76-105 (Group IV). However, unity does not exist between claims 1-30, 59-75 (Group I); or 31-43 (Group II); or 44-58 (Group III); or 76-96 (Group IV); since there exists no common special technical feature between independent claims 1, 16, 59, 66 (Group I); and 31 (Group II); and 44 (Group III); and 76, 87 (Group IV) (see PCT Examination Guidelines Chapter 10 at 10.22 Example 2).

Since none of the special technical features of the Groups I, II, III, and IV inventions are found in more than one of the inventions, unity is lacking.