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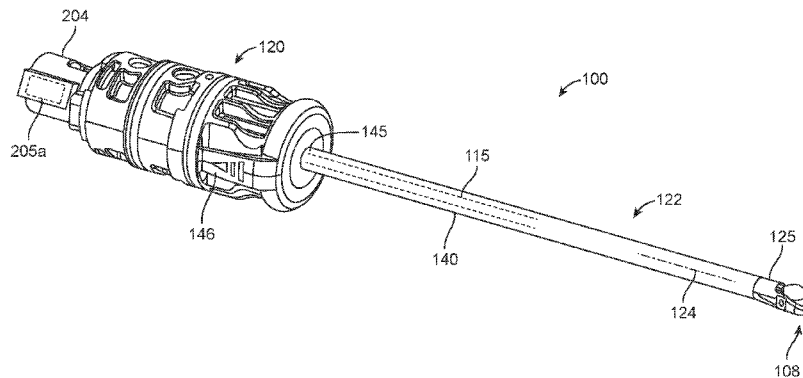


FIG. 1

(57) Abstract: Arthroscopic cutters are used for resecting tissues, such as meniscal tissues, in meniscectomies or other arthroscopic procedures. The arthroscopic cutters have a shaft assembly with openable-closeable jaws at a working end of the shaft. A handpiece having a motor drive may be detachably coupled to a hub on a hub end of the handpiece. When the shaft is coupled to the handpiece, the motor drive will couple to the jaw structure to open and close the jaw structure to cut meniscal and other tissues.

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ARTHROSCOPIC DEVICES AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Patent Application No. 15/483,940 (Attorney Docket No. 41879-721.201), filed April 10, 2017, which claims the benefit of provisional application no. 62/321,114 (Attorney Docket No. 41879-721.101), filed on April 11, 2016, provisional application no. 62/325,224 (Attorney Docket No. 41879-721.102), filed on April 20, 2016, and provisional application no. 62/325,326 (Attorney Docket No. 41879-724.101), filed on April 20, 2016, the full disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention. This invention relates to arthroscopic tissue cutting and removal devices by which anatomical tissues may be cut and removed from a joint or other site. More specifically, this invention relates to instruments with a motor driven openable-closeable jaw that cuts tissue.

[0003] 2. Description of the Background Art. In several surgical procedures including a meniscectomy, anterior cruciate ligament reconstruction involving notchplasty, and arthroscopic resection of the acromioclavicular joint, there is a need for cutting and removal of bone and soft tissue. Currently, surgeons use arthroscopic shavers and burrs having rotational cutting surfaces to remove hard tissue in such procedures.

[0004] The need exists for arthroscopic cutters that remove soft tissue rapidly.

SUMMARY OF THE INVENTION

[0005] In a first aspect, the present invention provides an arthroscopic cutter comprising a handpiece having a motor drive. A shaft assembly includes an openable-closable jaw structure at a working end of the shaft and a hub at a hub end of the shaft. The hub is configured for detachable coupling to the handpiece, and the motor drive is configured to couple to the jaw structure when the hub is coupled to the handpiece. In particular, when coupled to the jaw structure, the motor drive can continuously, intermittently, or otherwise selectively open and close individual jaws of the jaw structure to cut tissue, typically in a series of sequential resections or “bites” as the shaft assembly is advanced to engage the jaw structure against target tissue.

[0006] In a specific aspect of the arthroscopic cutter, the jaw structure may include sharp edge portions configured for cutting tissue, typically formed on at least one jaw of the jaw structure. The hub structure may also include a gear mechanism configured to amplify an output torque of the motor drive to increase a closing force of the jaw structure to enhance its ability to resect, cut, or otherwise remove tissue. Typically, the gear mechanism will increase an “effective” torque delivered by the jaw structure to the tissue by a factor of at least 10 when compared to the torque delivered by a spindle or other rotational drive element of the motor drive, often by a factor of at least 20, frequently by a factor of at least 40, and in some instances by a factor of at least 60, or more. That is, the torque applied by the jaws of the jaw structure as they pivot about a pivot point will have a torque which is greater than the torque provided by the motor drive by the factors recited above. In this way, the gear mechanism can increase the motor output torque to apply a jaw structure torque of at least 10 in-lbs, often at least 40 in-lbs, frequently at least 60 in-lbs, and sometimes at least 80 in-lbs, or greater. Exemplary gear mechanisms will include a planetary gear set.

[0007] The arthroscopic cutters of the present invention will usually include a mechanism for converting a rotational motion of the motor drive to a linear motion to reciprocate an actuator member for opening and closing the jaws of the jaw structure. In such cases, the gear mechanism is typically operatively coupled to the mechanism for converting the rotational motion into linear motion.

[0008] In still further exemplary embodiments, the motor drive is configured to open and close the jaw structure at a rate of at least 1 CPS (cycle(s) per second), often at a rate in the range of between 1 CPS and 100 CPS, frequently at a rate in the range between 1 CPS and 10 CPS, and the like.

[0009] Other exemplary arthroscopic cutters of the present invention may include a passageway extending through the shaft assembly to the working end of the shaft. The passageway is typically configured for connection to a negative pressure source which can provide for continuous or periodic aspiration or suction of resected tissue from the operative site.

[0010] In additional exemplary embodiments, the arthroscopic cutters of the present invention may further comprise a processor configured to control the motor drive, e.g., to stop and/or start movement of a first jaw in the jaw structure relative to a second jaw of the jaw structure. Typically, the movement may be stopped in a variety of positions, such as one or more default positions. For example, a default position may be with the jaws open. In other cases, a default position may be with the jaws closed or in any other relative position between

open and closed. Typically, a sensor in the handpiece will be connected to the controller and configured to sense jaw position, e.g., using a magnet coupled to the jaw structure (in one instance carried by a separate moving member coupled to the jaw structure) to indicate default and non-default positions, thus allowing motion to be stopped at a desired position.

[0011] In still further exemplary embodiments, the arthroscopic cutters of the present invention may include an actuator for actuating the motor drive to open and close the jaw structure, for example at a rate of at least 1 CPS. Such actuators may also be configured to move the jaw structure to a jaw-open position, to a jaw-closed position as well as for other purposes, such as for actuating a negative pressure source, for actuating both the motor drive and a negative pressure source, for modulating the negative pressure source in response to actuation in the motor drive, and the like. In other instances, the processor may be configured to modulate the negative pressure source relative to a fully open position, a partially open position, or a closed position of the jaw structure.

[0012] The arthroscopic cutters of the present invention, in still other embodiments, may include radio frequency (RF) electrode edge portions configured for cutting or otherwise resecting tissue. Alternative, the jaw structures may have first and second jaws including honed, or other scissor-like edge portions for shearing tissue. In still other embodiments, the jaw structure may have at least one cup-shaped jaw adapted for cutting and capturing tissue. In yet other embodiments, the jaw of the jaw structure may have a metal cutting edge, a ceramic cutting edge, or may simply comprise a ceramic material.

[0013] In a second aspect, the present invention provides methods for performing a meniscectomy. Such methods comprise providing a handpiece with a motor drive. The probe is coupled to the handpiece, where the probe has a working end with openable-closeable jaws configured to resect tissue. The motor drive is configured to open and close the jaws when the handpiece is coupled to the probe. The working end may then be advanced into a patient's joint to engage the jaws against meniscal tissue. The meniscal tissue may then be resected by actuating the motor drive to open and close the jaws.

[0014] In specific embodiments, the methods for performing meniscectomy may further comprise controlling the motor drive with a controller to actuate the jaws to resect the meniscal tissue in a single bite, or in multiple bites. For example, the motor drive may be controlled to open and close the jaws at a rate of at least 1 CPS, often at a rate of between 1 CPS and 100 CPS. At the actuating step may further comprise activating a negative pressure source in communication with an interior passageway of the probe to suction resected meniscal tissue from the working end.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Various embodiments of the present invention will now be discussed with reference to the appended drawings. It should be appreciated that the drawings depict only typical embodiments of the invention and are therefore not to be considered limiting in scope.

[0016] FIG. 1 is a perspective view of a disposable arthroscopic cutter or probe with a working end comprising a jaw structure having cutting edges.

[0017] FIG. 2 is a perspective view of a handpiece with a motor drive to which the cutter of FIG. 1 can be coupled, with the handle body including an LCD screen for displaying operating parameters of device during use together with a joystick and mode control actuators on the handle.

[0018] FIG. 3 is a detailed view of a working end of a probe constructed in accordance with the principles of the present invention.

[0019] FIG. 4A is an enlarged side view of the working end of the probe of FIG. 1 in a jaw-open position.

[0020] FIG. 4B is a side view of the working end of FIG. 4A in a jaw-closed position.

[0021] FIG. 5A is a longitudinal sectional view of the working end of FIG. 4A in the jaw-open position showing a portion of the jaw actuation mechanism.

[0022] FIG. 5B is a sectional view of the working end of FIG. 4B in the jaw-closed position.

[0023] FIG. 6 is a longitudinal sectional view of the hub of the probe of FIG. 1 taken along line 6-6 of FIG. 1 showing a gear mechanism and a mechanism for converting rotational motion to linear motion to actuate the jaw structure at a selected CPS rate (cycles per second).

[0024] FIG. 7A is a perspective view of the planetary or epicyclic gear mechanism of the probe hub of FIG. 6 and the rotation-to-linear motion mechanism.

[0025] FIG. 7B is an exploded view of the components of the epicyclic gear mechanism of FIG. 7A.

[0026] FIG. 8 is a schematic view of a method of using the probe of FIGS. 1-6 in a meniscectomy procedure.

[0027] FIG. 9A is a perspective view of a working end of a probe with an electrosurgical jaw structure with the jaws in an open position.

[0028] FIG. 9B is a view of the working end of the electrosurgical jaw structure of FIG. 9A with the jaws in a closed position.

DETAILED DESCRIPTION OF THE INVENTION

[0029] The present invention relates to tissue cutting and removal devices and related methods of use. Variations of the invention will now be described to provide an overall understanding of the principles of the form, function and methods of use of the devices disclosed herein. In general, the present invention provides an arthroscopic cutter or punch for cutting tissue that is disposable and is configured for detachable coupling to a non-disposable handle and motor drive component. This description of the general principles of this invention is not meant to limit the inventive concepts in the appended claims.

[0030] FIGS. 1-5B illustrates a tissue cutting probe 100 with a jaw structure 108 that is motor driven to close and open the jaws in a single actuation that applies high cutting forces, or alternatively, the motor drive can be actuated to close and open the jaws sequentially at 1 CPS to 100 CPS (cycle per second) to progressively nibble or cut tissue. The probe can be used in arthroscopy and other fields, for example, ENT, gynecology and urology.

[0031] FIG. 1 shows the disposable cutting probe 100 that is adapted for detachable coupling to a handpiece 104 and motor drive unit 105 therein as shown in FIG. 2. In the variation shown in FIGS. 1 and 3, the upper jaw 110 and lower jaw 112 are configured as cup-shaped jaws to assist in capturing and extracting tissue chips through an interior passageway 115 as will be described below (see FIGS. 5A-5B).

[0032] Referring to FIG. 1, it can be seen that cutting probe 100 has a proximal hub 120 that can be detachably coupled to the handle or handpiece 104 of FIG. 2. In the variation of FIG. 1, the probe 100 has a shaft 122 that extends about longitudinal axis 124 to a working end 125 that comprises the openable-closeable jaw structure 108 that is coupled to the motor drive 105. The shaft 122 comprises an outer sleeve 140 and an inner actuation member 142 that is adapted to reciprocate in bore 144 of the outer sleeve 140. The proximal end 145 of outer sleeve 140 is coupled in a fixed manner to the hub 120 which can be an injection molded plastic, for example, with the outer sleeve 140 insert molded therein. The outer sleeve 140 typically can be a thin wall stainless steel tube, but other materials can be used such as ceramics, metals, plastics or combinations thereof. In this variation, the reciprocation of actuation member 142 is adapted to close and open to jaw structure 108 as can be understood from FIGS. 5A-5B. Referring to FIGS. 1 and 2, the hub 120 is configured with snap-fit features 146, or other suitable features, for detachably locking the hub 120 into the handpiece 104.

[0033] In FIG. 2, it can be seen that the handpiece 104 is operatively coupled by electrical cable 148 to a controller-processor 150 which controls the motor drive unit 105. The cable

148 also couples power from electrical power source 155 to the motor drive 105. Any of the actuator buttons 156a-156d on the handpiece 104 can be used to select operating modes, such as a single open-close actuation of the jaws, or a continuous sequence of opening and closing the jaws. Further, an actuator button can be used to modulate the CPS of opening and closing the jaws. The various modes can be displayed on the LCD 158. FIG. 2 further shows that negative pressure source 160 is coupled to aspiration tubing 162 which communicates with a flow channel 165 in the handpiece 104 and passageway 115 in actuating member 142 which extends to the working end 125.

[0034] As can be seen in FIGS. 1, 3 and 4A-5B, the second or lower jaw 112 and lower jaw housing 170 is immobile and fixed to outer sleeve 140. The upper jaw 110 pivots around pivot point 172 in the lower jaw housing 170. The actuation member 142 can comprise a sleeve with passageway 115 therein and a distal end 174 coupled to an actuation rod 175 with a transverse bore 176 in a collar portion 177 that surrounds a transverse shaft 180 in the upper jaw 110. Thus, it can be seen how reciprocation of the actuating member 142 can move the first or upper jaw 110 relative to the second or fixed lower jaw 112. It should be appreciated that both the upper and lower jaw members of the jaw structure can be moveable as is known in biopsy punches and similar end effectors on medical cutting probes. In FIG. 3, the upper jaw 110 is fabricated of a high-strength metal, but it should be appreciated that such a jaw also can be fabricated out of a ceramic, such as the ceramics with a high fracture toughness as described in co-authored U.S. Patents 9,585,675 and 9,603,656, which are incorporated herein by this reference. The lower jaw 112 likewise can be fabricated from a metal or a suitable ceramic with a sharp cutting edge.

[0035] Referring to FIGS. 3, 4A-4B and 5A-5B, it can be seen that upper jaw 110 is cup-shaped as is known in biopsy punches or meniscal punches for resecting tissue. The upper jaw 110 has a gripping and/or cutting edge 185 that extends in a U-shape around interior cavity 188 of the jaw. The lower jaw 112 has a cooperating U-shaped sharp cutting edge 190. It can be understood from FIGS. 4A-5B, the closing of jaw structure 108 shears tissue between cutting edges 185 and 190 to thus capture a tissue chip 192 (FIG. 5B) in the jaw's interior cavity 188. In the closed position of FIGS. 4B and 5B, it can be seen that the U-shaped edge 185 of the upper jaw 110 passes into U-shaped slot 194 in baseplate portion 195 of the lower jaw housing 170. Thereafter, the tissue chip 192 can be aspirated through interior passageway 115 by the negative pressure source 160 and be collected in a collection reservoir 196 (see FIG. 8).

[0036] Now turning to FIGS. 6 and 7A-7B, the mechanism that converts the rotation of the rotating shaft 202 of motor drive 105 to linear motion of actuation member 142 can be described. In one aspect of the invention, when cutting somewhat hard tissue such as meniscus, what is needed is an amplification of force that can be applied by the cutting edges of the jaw structure 108 against the targeted tissue. In FIGS. 6 and 7A, it can be seen rotatable drive coupling 204 is adapted for engaging the motor shaft 202 as is known in the art. The drive coupling 204 carries magnets 205a in 205b that cooperate with a Hall sensor 206 in the handpiece (FIGS. 2 and 6) to acquire signals relating to the rotational orientation of drive coupling 204. The controller and processor 150 then can determine the open and closed positions of the jaw structure 108 depending on the rotational orientation of the coupling 204. It can be seen that the proximal end 208 of the actuator member 142 extends through the drive coupling 204 to the opening 212 in the side of drive coupling 204 to allow tissue chips (e.g., tissue chip 195 in FIG. 5B) to be extracted through the hub 120. The actuation member 242 is fixed in a collar 220 having a cam surface 222 that rotates in interior chamber 215 of the hub 120 (FIG. 6).

[0037] In one aspect of the invention, the drive coupling 204 engages the gear reduction mechanism comprising an epicyclic gear train assembly 250 which also may be called a planetary gear mechanism. FIG. 7A shows the epicyclic gear train assembly 250 removed from the hub 120 of FIG. 6. FIG. 7B depicts the gear train 250 of FIG. 7A in an exploded view showing the sun gear 252, the planet gears 255a and 255b, carrier ring 258, stationary output ring gear 260, output ring gear 262 and output ring gear transfer plate 265 as is known in the art. FIGS. 7A-7B also show a projecting element or stud 270 that interfaces with the angled cam surface 222 on rotating collar 220 that is adapted to convert rotational motion to linear motion. Thus, rotation of rotating motor shaft 202 rotates the sun gear 252 and planet gears 255a and 255b to provide gear reduction and ultimately rotate the output ring gear transfer plate 265 and rounded-end stud 270 to actuate the non-rotatable cam surface 222, which in turn reciprocates the actuator member 242. A spring 276 is provided to urge the rotating collar 220 carrying the cam surface 222 toward a proximal or retracted position in the interior chamber 215 of the hub 120. The stroke of reciprocation R is shown in FIG. 6 which is required to open and close the jaw structure 108.

[0038] In one aspect of the invention, the epicyclic gear mechanism of FIGS. 6-7B is configured for amplifying the output torque of the motor drive to increase closing forces of the jaw structure. In one variation, the gear mechanism increases the motor output torque by a factor of at least 10 or by a factor of at least 20. In some variations, the gear mechanism

increases the motor output torque by at a factor of at least 40, and often by a factor of at least 60. In another aspect, the gear mechanism increases the motor output torque to at least 10 in-lbs, at least 40 in-lbs, at least 60 in-lbs, or at least 80 in-lbs.

[0039] In another aspect of the invention, the processor 150 is adapted to operate the motor drive 105 to move the jaw structure between open and closed positions at a rate of at least 1 CPS (cycles per second). Typically, the motor drive is configured to move the jaw structure between open and closed positions at a rate between 1 CPS and 100 CPS, and often at a rate between 1 CPS and 10 CPS. The processor also can be configured to control the motor drive 105 to stop movement of a first jaw relative to a second jaw in a selected default position, which typically is a closed position but also can be an open position. It can be understood that the jaw must be in a closed position for introduction into a patient's body, therefore a closed position is the typical default position. However, when the physician has positioned the working end 125 in a treatment site, the jaw structure 108 preferably would be in an open position. Therefore, a button (156a-156d) on the handpiece 104 can be adapted to move the jaws from the default closed position to the open position.

[0040] In use, an actuator button (156a-156d) can be used to close and open to jaw structure 108 in a single bite, or the actuator button can sequentially close and open the jaws at a selected rate. In one variation, an actuator button such as a joystick can increase the closing opening rate from a lower rate to a higher rate. Typically, an actuator button on the handpiece 104 actuates the motor drive 105 to move the jaw structure 108 between the jaw-open and jaw-closed positions at a rate of at least 1 CPS (cycles per second). More often, the rate of actuation is between 2 CPS and 10 CPS, although the rate could be higher, for example up to 100 CPS.

[0041] In another aspect of the invention, the processor 150 can be configured to modulate the negative pressure source 160 in response to actuation of the motor drive 105, so the negative pressure is actuated contemporaneously with closing and opening jaws. In another variation, the processor 150 can be configured to modulate the negative pressure source relative to a fully open jaw position, a partially open jaw position or a closed jaw position.

[0042] Now referring to FIGS. 1, 2 and 8, a method of using probe 100 of FIG. 1 is shown schematically in a meniscectomy procedure. First, the physician inserts the probe 100 of FIG. 1 into the handpiece 104 of FIG. 2. Magnets 280 and 282 in the probe hub 120 (FIG. 6) are oriented relative to relative to a Hall sensor 284 in the handpiece (FIG. 2) such that the controller-processor 150 identifies the type of probe coupled to the handpiece 104 and the up or down orientation of the probe. The use of a Hall sensors and magnets in a probe hub for (i)

device identification and (ii) positioning of working end components of arthroscopic tools is further described in co-pending U.S. Patent Application No. 15/454,432 filed March 9, 2017 (Atty. Docket No. 41879-715.201) which is incorporated herein by this reference. Based on such a device identification, the controller then selects the appropriate processor algorithms for operating the probe 100. The handpiece 104 is adapted to receive and operate multiple different tools including rotating mechanical shavers, reciprocating electrosurgical shavers, hook shaped electrosurgical devices and articulating radiofrequency devices. Therefore, device identification is necessary because each different type of probe requires different processor algorithms to control the motor drive 105, the negative pressure source 160 and potentially the RF source 285, as will be described below.

[0043] Returning to FIG. 8, the cut-away view of the patient's knee shows the meniscus 290 with a "bucket handle" tear indicated at 292. The physician introduces a cannula 295 into the joint space and then advances an endoscope 298 through the cannula to view the treatment site. A fluid source 300 is coupled to the cannula 255 to introduce a distention fluid, such as saline, into the treatment site. Thereafter, the physician introduces the shaft 122 and working end of the probe 100 into the treatment site with the jaw structure 108 in the default closed position. Thereafter as shown in FIG. 8, the physician uses an actuator button (156a-156d) on the handpiece 104 (FIG. 2) to move the jaw structure 108 to the jaw-open position. Next, the physician manipulates working end to position the open jaw structure 108 over the meniscus tissue of the tear 292 targeted for resection. Thereafter, the physician uses an actuator button (156a-156d) to close the jaw structure with high closing forces in a single bite, or sequentially in repeated bites. The physician can then move the jaw structure 108 about the treatment site to remove targeted tissue. The resected tissue chips are then aspirated through the interior channel 115 of the probe 100 and flow channel 165 of handpiece 104 to be collected in collection reservoir 196.

[0044] FIGS. 9A-9B illustrate another working end 400 of a probe with a jaw structure 408 with first or upper jaw 410 and lower jaw 412. In this variation, the upper jaws 410 again has a cup shape and carries an active electrode 415 that extends in a U-shape around the perimeter of the upper jaw 410. The upper jaw 410 is formed of a dielectric material such as a ceramic with the electrode 415 secured thereto. The electrode is operatively coupled to an RF source 285 as shown in FIG. 2. The upper jaw 410 rotates around pivot pin 418 and can be actuated as the previous embodiment above. As can be seen in FIG. 9A, the electrode 415 can be set back from the outermost edge 422 of the jaw face 424 by a dimension D which can be from 0.05 mm to 2 mm, so that the lower jaw 412 can function as a return electrode 425.

Alternatively, the lower jaw can comprise a ceramic material and the elongate outer sleeve 428 can function as a return electrode indicated at 425'. It can be understood from FIGS 9A-9B that the cavity 440 in the jaws when closed allows the electrode 415 with a cutting current from RF source 285 to shear tissue chips from targeted tissue as the electrode 415 passes the edge 445 of the lower jaw 412. The targeted tissue is submerged in saline as is known in arthroscopic surgeries. The targeted tissue typically comprises at least one of cartilage, meniscus, connective tissue, tendons, and ligaments as in any arthroscopic procedure.

[0045] An electrosurgical probe as shown in FIGS. 9A-9B can connect RF current from RF source 285 through the handpiece 104 (FIG. 2) to the probe hub and jaw structure 408 as further described in co-pending U.S. Patent Applications Nos. 15/454,390 filed March 9, 2017 (Atty. Docket No. 41879-716.201) and 15/454,432 filed March 9, 2017 (Atty. Docket No. 41879-715.201) which are incorporated herein by this reference.

[0046] In the variation of FIGS. 9A-9B, the upper jaw 410 rotates on a pivot pin 418, but it should be appreciated that flex hinges or living hinges are also possible. In another variation, it should be appreciated that another electrode 455 (see FIG. 9B) can be disposed on an outer surface of the lower jaw 412, or either jaw surface, which can be configured for ablation or coagulation as is known in the art.

[0047] In another variation, a probe with a jaw opening and closing mechanism similar to that described above can operate a working end comprising a mechanical scissors or shears for cutting tissue.

[0048] Although particular embodiments of the present invention have been described above in detail, it will be understood that this description is merely for purposes of illustration and the above description of the invention is not exhaustive. Specific features of the invention are shown in some drawings and not in others, and this is for convenience only and any feature may be combined with another in accordance with the invention. A number of variations and alternatives will be apparent to one having ordinary skills in the art. Such alternatives and variations are intended to be included within the scope of the claims. Particular features that are presented in dependent claims can be combined and fall within the scope of the invention. The invention also encompasses embodiments as if dependent claims were alternatively written in a multiple dependent claim format with reference to other independent claims.

[0049] Other variations are within the spirit of the present invention. Thus, while the invention is susceptible to various modifications and alternative constructions, certain illustrated embodiments thereof are shown in the drawings and have been described above in

detail. It should be understood, however, that there is no intention to limit the invention to the specific form or forms disclosed, but on the contrary, the intention is to cover all modifications, alternative constructions, and equivalents falling within the spirit and scope of the invention, as defined in the appended claims.

[0050] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. The term “connected” is to be construed as partly or wholly contained within, attached to, or joined together, even if there is something intervening. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate embodiments of the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0051] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

[0052] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually

and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

WHAT IS CLAIMED IS:

1. An arthroscopic cutter, comprising:
a handpiece having a motor drive; and
a shaft assembly having an openable-closeable jaw structure at a working end and a hub at a hub end;
wherein the hub configured for detachable coupling to the handpiece; and
wherein the motor drive is configured to couple to the jaw structure to open and close the jaw structure to cut tissue when the hub is coupled to the handpiece.
2. The arthroscopic cutter of claim 1 wherein the jaw structure includes sharp edge portions configured for cutting tissue.
3. The arthroscopic cutter of claim 1 wherein the hub includes a gear mechanism configured to amplify an output torque of the motor drive to increase a closing force of the jaw structure.
4. The arthroscopic cutter of claim 3 wherein the gear mechanism increases the motor output torque by at least a factor of 10.
5. The arthroscopic cutter of claim 3 wherein the gear mechanism increases the motor output torque by at least a factor of 20.
6. The arthroscopic cutter of claim 3 wherein the gear mechanism increases the motor output torque by at least a factor of 40.
7. The arthroscopic cutter of claim 3 wherein the gear mechanism increases the motor output torque by at least a factor of 60.
8. The arthroscopic cutter of claim 3 wherein the gear mechanism increases the motor output torque to at least 10 in-lbs, 40 in-lbs, 60 in-lbs, or 80 in-lbs.
9. The arthroscopic cutter of claim 3 wherein the gear mechanism includes a planetary gear set.
10. The arthroscopic cutter of claim 3 further comprising a mechanism for converting a rotational motion of the motor drive to a linear motion to reciprocate an actuator member for opening and closing the jaw structure, wherein the gear mechanism is operatively coupled to the mechanism for converting the rotational motion.
11. The arthroscopic cutter of claim 1 wherein the motor drive is configured to open and close the jaw structure at a rate of at least 1 CPS (cycles per second).
12. The arthroscopic cutter of claim 1 wherein the motor drive is configured to open and close the jaw structure at a rate between 1 CPS and 100 CPS.

13. The arthroscopic cutter of claim 1 wherein the motor drive is configured to open and close the jaw structure at a rate between 1 CPS and 10 CPS.
14. The arthroscopic cutter of claim 1 further comprising a passageway extending through the shaft assembly to the working end, wherein said passageway is configured for connection to a negative pressure source.
15. The arthroscopic cutter of claim 1 further comprising a processor configured to control the motor drive to stop movement of a first jaw relative to a second jaw of the jaw structure in a selected default position.
16. The arthroscopic cutter of claim 15 further comprising a sensor in the handpiece configured to sense a magnet carried by a moving member coupled to the jaw structure to indicate the default position and non-default position.
17. The arthroscopic cutter of claim 16 wherein the default position in the jaw-open position.
18. The arthroscopic cutter of claim 16 wherein the default position is the jaw-closed position.
19. The arthroscopic cutter of claim 1 wherein the handpiece includes an actuator for actuating the motor drive to open and close the jaw structure at a rate of at least 1 CPS (cycles per second).
20. The arthroscopic cutter of claim 1 wherein the handpiece includes an actuator for actuating the motor drive to move the jaw structure to a jaw-open position.
21. The arthroscopic cutter of claim 1 wherein the handpiece includes an actuator for actuating the motor drive to move the jaw structure to a jaw-closed position.
22. The arthroscopic cutter of claim 14 wherein the handpiece includes an actuator for actuating the negative pressure source.
23. The arthroscopic cutter of claim 14 wherein the handpiece includes an actuator for actuating the motor drive and negative pressure source.
24. The arthroscopic cutter of claim 14 further comprising a processor configured to modulate the negative pressure source in response to actuation of the motor drive.
25. The arthroscopic cutter of claim 14 further comprising a processor configured to modulate the negative pressure source relative to a fully open position, partially open position or a closed position of the jaw structure.
26. The arthroscopic cutter of claim 1 wherein the jaw structure includes RF electrode edge portions configured for cutting tissue.

27. The arthroscopic cutter of claim 1 wherein the jaw structure has first and second jaws including scissor-like edge portions for shearing tissue.
28. The arthroscopic cutter of claim 1 wherein the jaw structure has at least one cup-shaped jaw adapted for cutting and capturing tissue.
29. The arthroscopic cutter of claim 1 wherein a jaw of the jaw structure has a metal cutting edge.
30. The arthroscopic cutter of claim 1 wherein a jaw of the jaw structure includes a ceramic material.
31. The arthroscopic cutter of claim 1 wherein a jaw of the jaw structure has a ceramic cutting edge.
32. A method of performing a meniscectomy, comprising:
 - providing a handpiece with a motor drive;
 - coupling a probe to the handpiece, wherein the probe has a working end with openable-closeable jaws configured to resect tissue, and wherein the motor drive is configured to open and close the jaws when the handpiece is coupled to the probe;
 - advancing the working end into a patient's joint to engage the jaws against meniscal tissue; and
 - actuating the motor drive to open and close the jaws to resect the meniscal tissue.
33. The method of performing a meniscectomy of claim 32 further comprising controlling the motor drive with a controller to actuate the jaws to resect meniscal tissue in a single bite.
34. The method of performing a meniscectomy of claim 33 wherein the motor drive is controlled to open and close the jaws at a rate of at least 1 CPS.
35. The method of performing a meniscectomy of claim 33 wherein the motor drive is controlled to open and close the jaws at a rate between 1 CPS and 100 CPS.
36. The method of performing a meniscectomy of claim 33 wherein the actuating step further comprises activating a negative pressure source in communication with an interior of the probe to suction resected meniscal tissue from the working end.

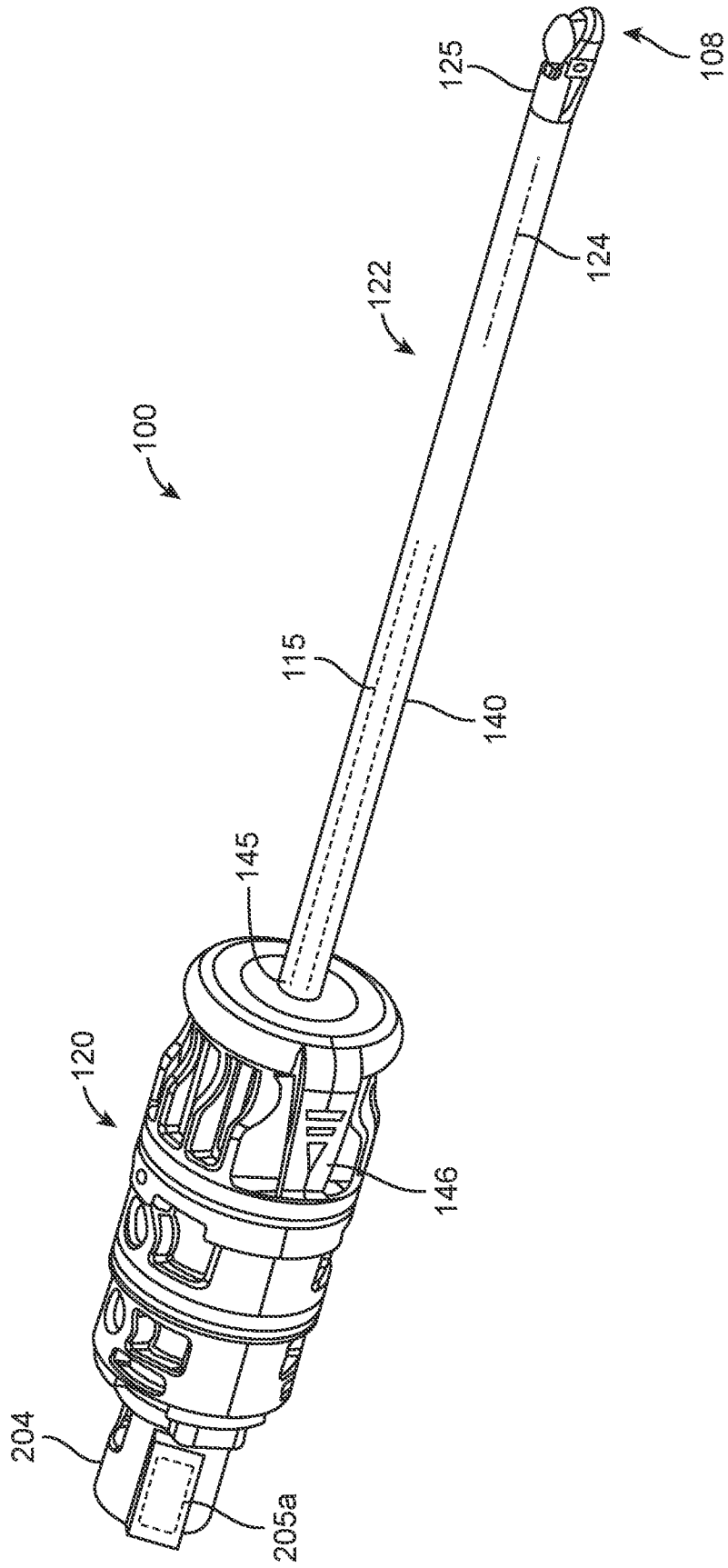


FIG. 1

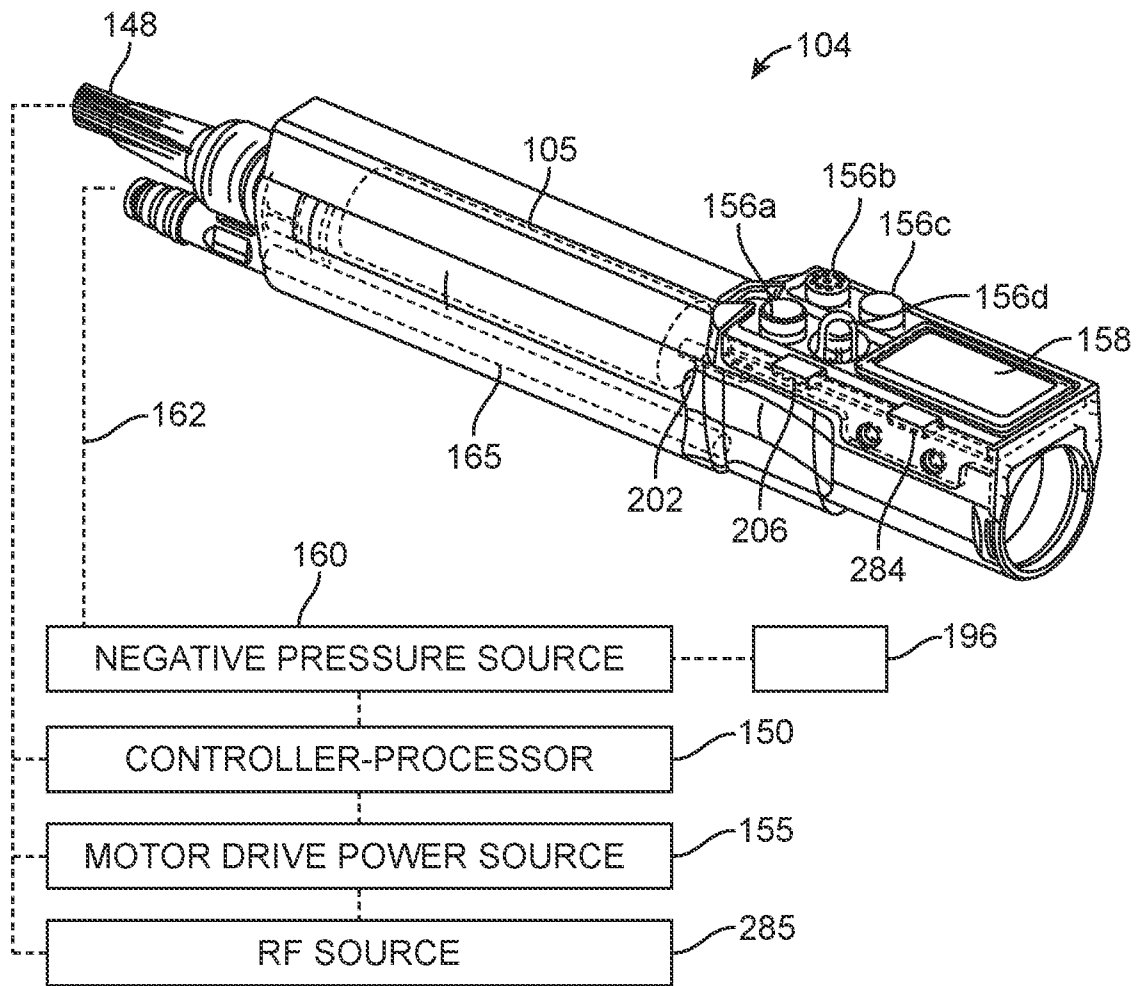


FIG. 2

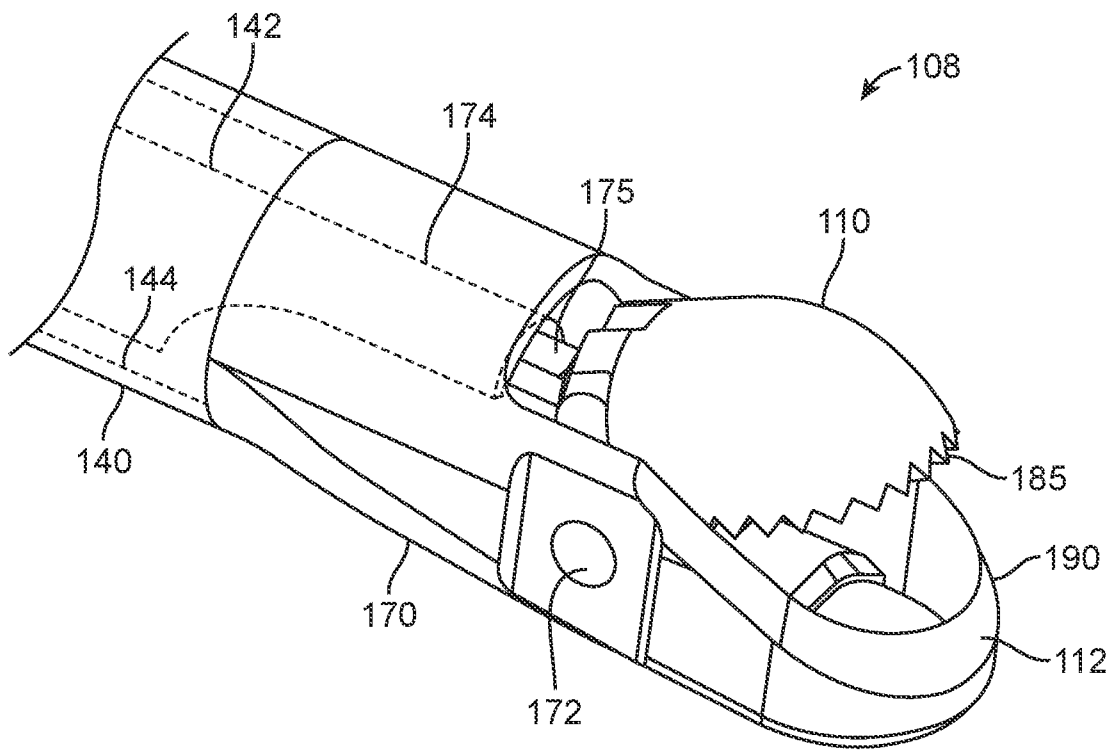


FIG. 3

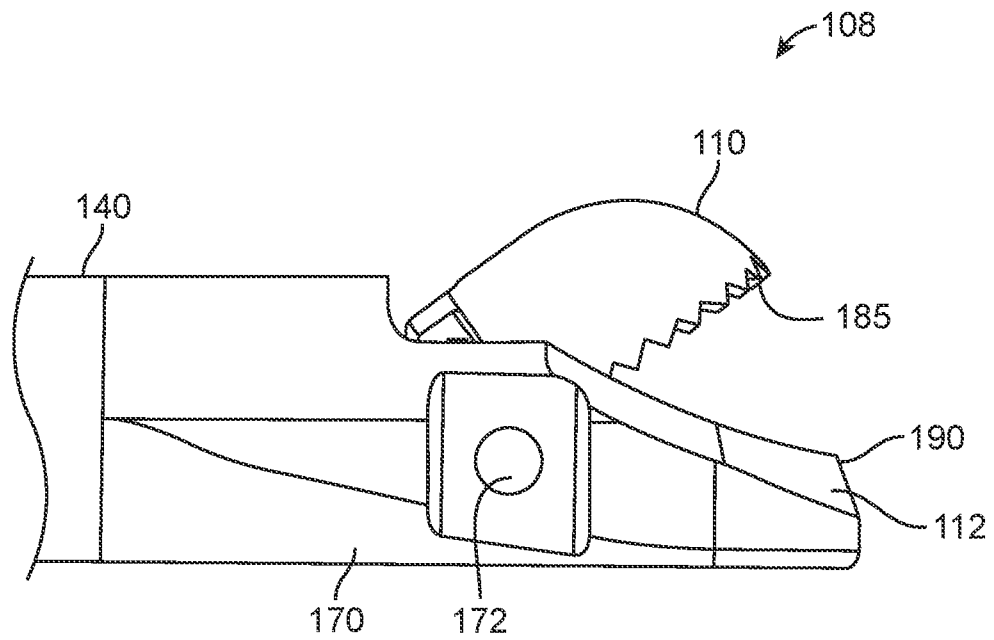


FIG. 4A

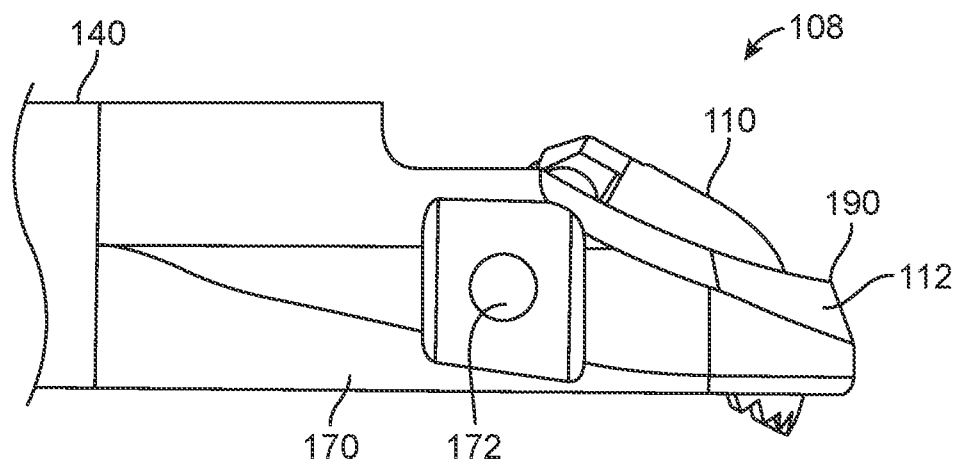


FIG. 4B

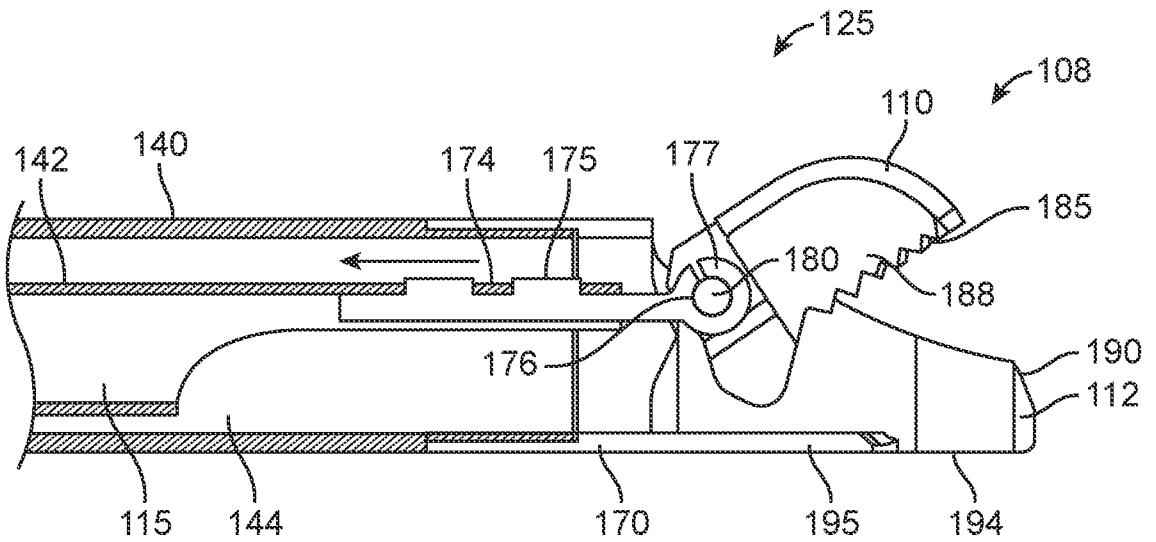


FIG. 5A

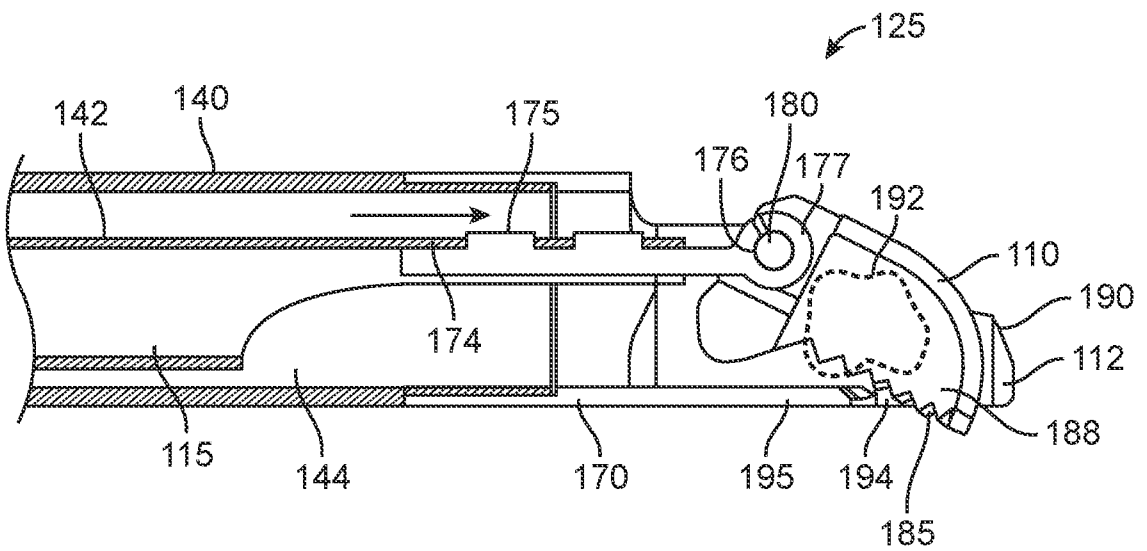


FIG. 5B

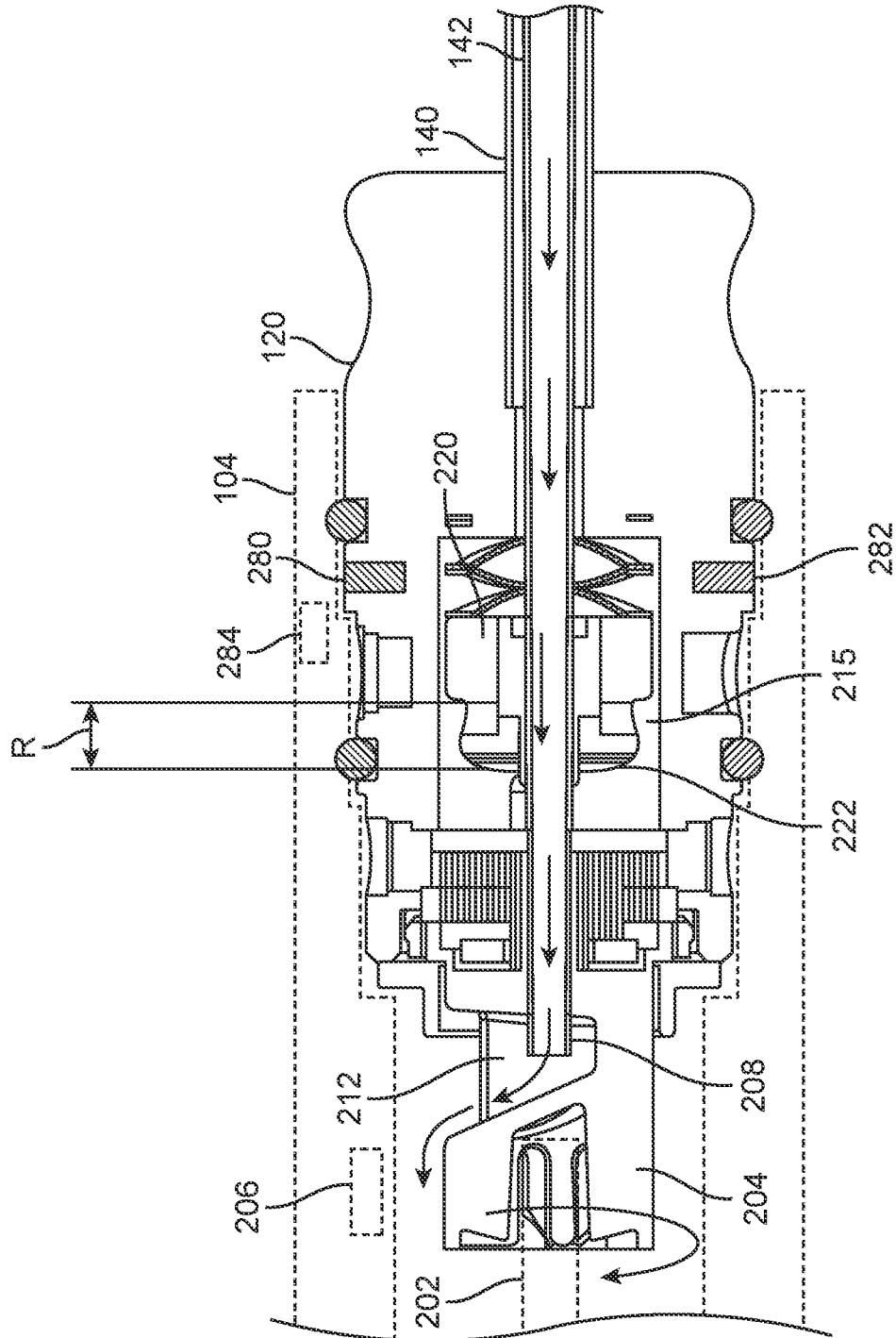


FIG. 6

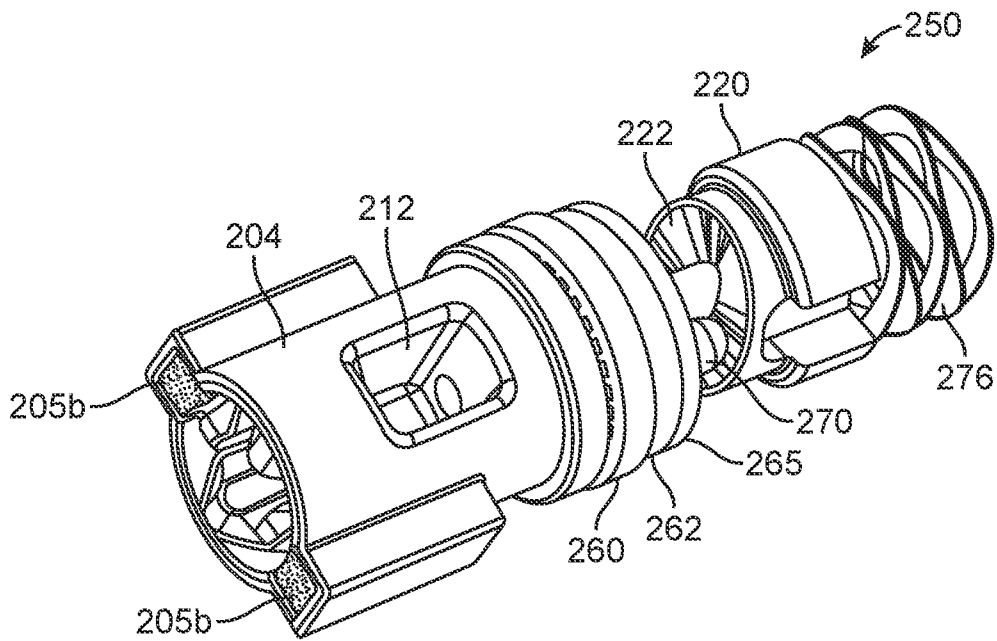


FIG. 7A

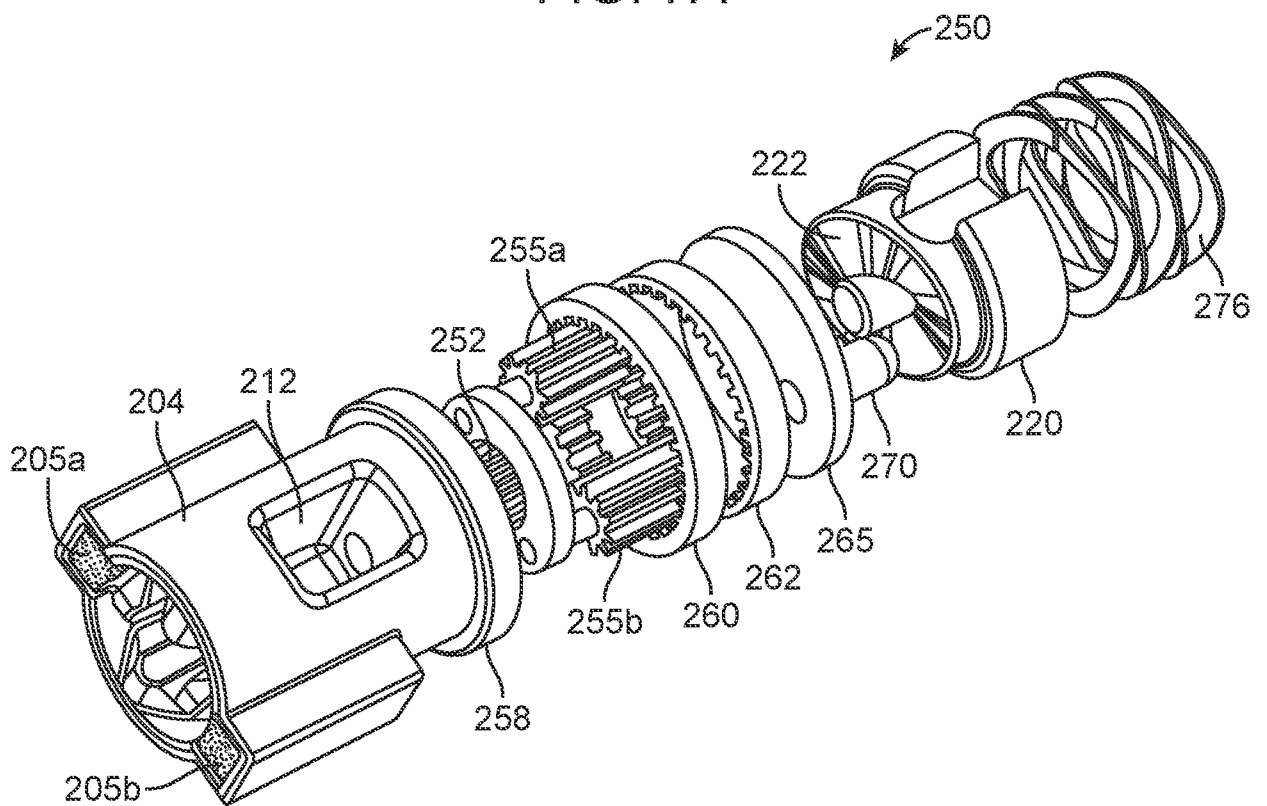


FIG. 7B

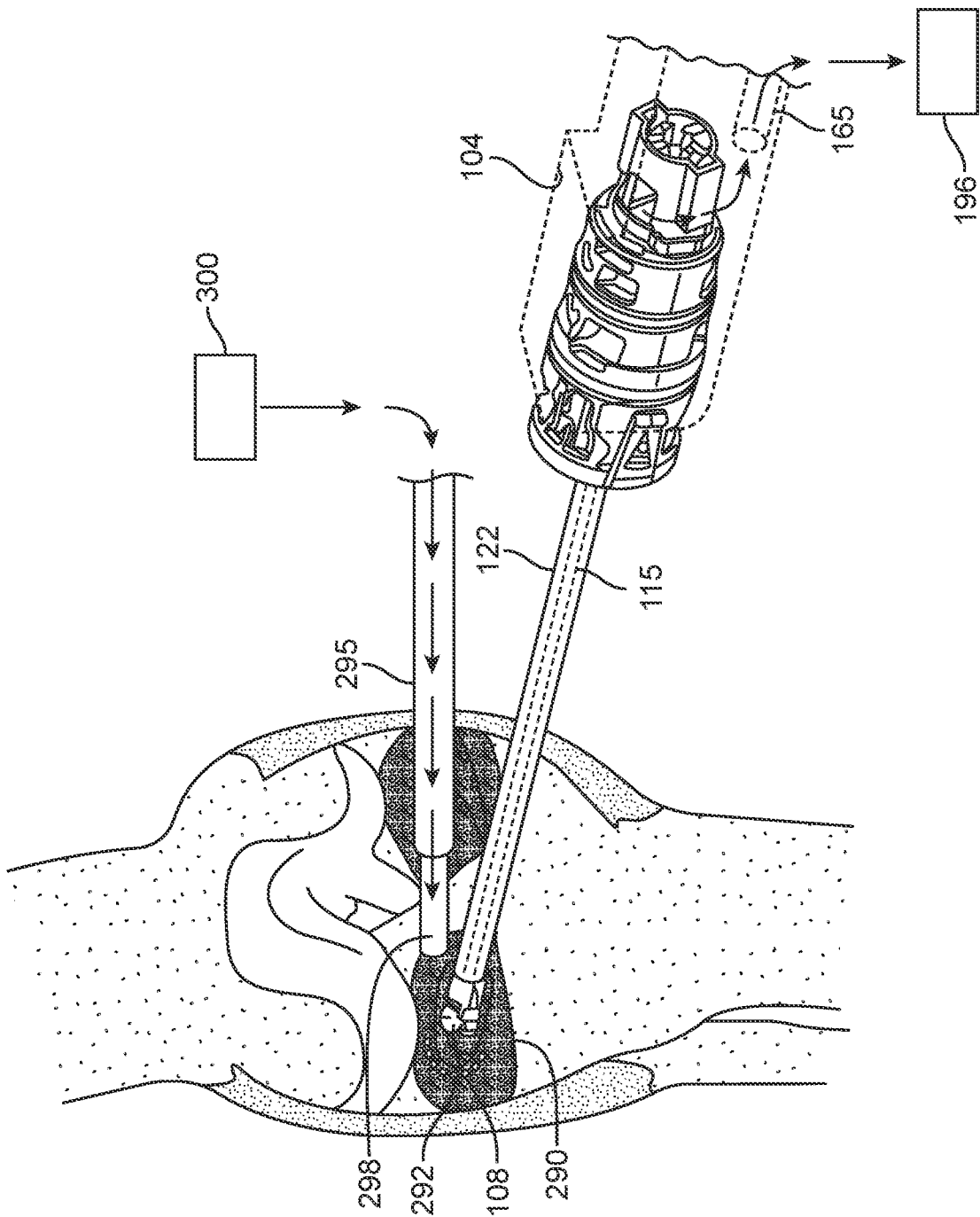


FIG. 8

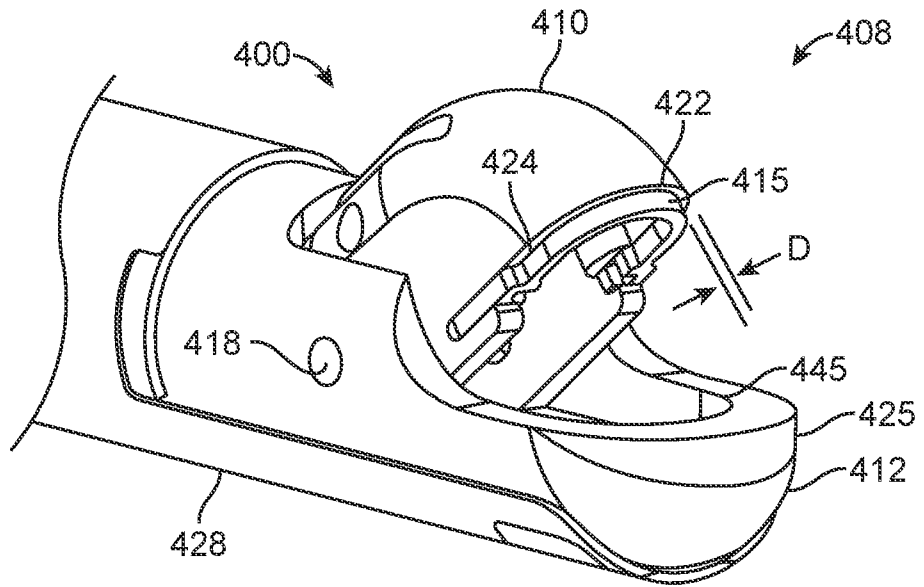


FIG. 9A

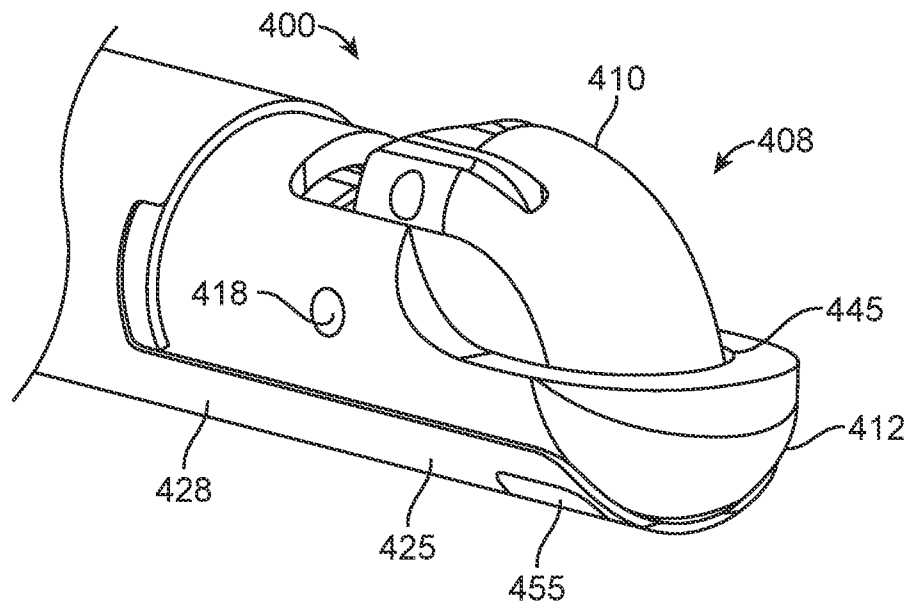


FIG. 9B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/27053

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61B 17/32 (2017.01)
CPC - A61B 17/320016, A61B 2017/0046, A61B 2017/00464, A61B 2017/00469, A61B 17/285, A61B 17/295, A61B 2017/00477, A61B 17/00234

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
See Search History Document

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 2014/0025046 A1 (WILLIAMS et al.) 23 January 2014 (23.01.2014) Entire document, especially Abstract, para[0009], [0018], [0088], [0093]-[0094], [0104] and FIGS. 1-4.	1, 3, 8-10 ----- 4-7, 26
X	US 3,899,829 A (STORM et al.) 19 August 1975 (19.08.1975) Entire document, especially Abstract, col 3, ln 5-64, col 5, ln 9-33, col 6, ln 50- col 7, ln 2 and FIGS. 1-4.	1-2, 11-13, 19, 27, 29
X -- Y	US 2010/0057078 A1 (ARTS et al.) 04 March 2010 (04.03.2010) Entire document, especially Abstract, para[0020]-[0029], [0032]-[0033] and FIGS. 1-4.	1, 14, 22-23, 28, 30-31 ----- 24-25
X	US 2015/0272569 A1 (LEIMBACH et al.) 01 October 2015 (01.10.2015) Entire document, especially Abstract, para[0118]-[0127] and FIGS. 1-3.	1, 15-18, 20-21
Y	US 5,433,721 A (HOOVEN et al.) 18 July 1995 (18.07.1995) Entire document, especially Abstract, col 8, ln 46-63.	4-7
Y	US 2010/0087816 A1 (ROY) 08 April 2010 (08.04.2010) Entire document, especially Abstract, para[0019]	26
Y	US 5,520,634 A (FOX et al.) 28 May 1996 (28.05.1996) Entire document, especially Abstract, col 2, ln 59- col 4, ln 10 and FIG. 1.	24-25

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	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 01 August 2017	Date of mailing of the international search report 22 AUG 2017
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Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/27053

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0012238 A1 (CHEN et al.) 09 January 2014 (09.01.2014) Entire document.	1-31
A	US 2009/0209946 A1 (SWAYZE et al.) 20 August 2009 (20.08.2009) Entire document.	1-31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/27053

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:

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 must be paid.

Group I: Claims 1-31: directed towards a general arthroscopic cutter.

Group II: Claims 32-36: directed towards a method for performing a meniscectomy utilizing a probe.

The inventions listed as Groups I - II 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:

----- see extra sheet -----

- 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.:
1-31

- 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/US 17/27053

----- Continuation of Box III: Observations where unity of invention is lacking (Continuation of item 3 of first sheet) -----

Group II includes the special technical features of method steps including particular use steps (claim 32) performing a meniscectomy, advancing the working end into a patient's joint to engage the jaws against meniscal tissue; and actuating the motor drive to open and close the jaws to resect the meniscal tissue, not required by Group I.

Group I-II are related to an apparatus (Group I) and method(s) of using the apparatus (Group II). These groups therefore share the technical features of the apparatus of claim 1, however, these shared technical features fail to provide a contribution over the prior art of US 5,582,617 A to Klieman et al. (hereinafter: Klieman). Klieman describes an arthroscopic cutter (Abstract, col 1, ln 12-24), comprising: a handpiece (handle 4, FIGS. 29-30) having a motor drive (motors 58/64, FIGS. 29-30; col 18, ln 4-20); and a shaft assembly (barrel 6, FIGS. 28-30) having an openable-closeable jaw structure at a working end (end effector pieces 16/18, FIGS. 27-28; col 15, ln 66- col 16, ln 36) and a hub at a hub end (136, FIGS. 30D, 30A-30D; col 18, ln 21-39); wherein the hub configured for detachable coupling to the handpiece (via 136, FIGS. 30D, 30A-30D; col 18, ln 21-39); and wherein the motor drive is configured to couple to the jaw structure to open and close the jaw structure to cut tissue when the hub is coupled to the handpiece (col 18, ln 4-20; see col 8, ln 44- col 9, ln 9).

Thus, Groups I-II lack unity of invention because they do not share a same or corresponding special technical feature providing a contribution over the prior art.