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(54) **END EFFECTOR WITH A CLAMP ARM ASSEMBLY AND BLADE**

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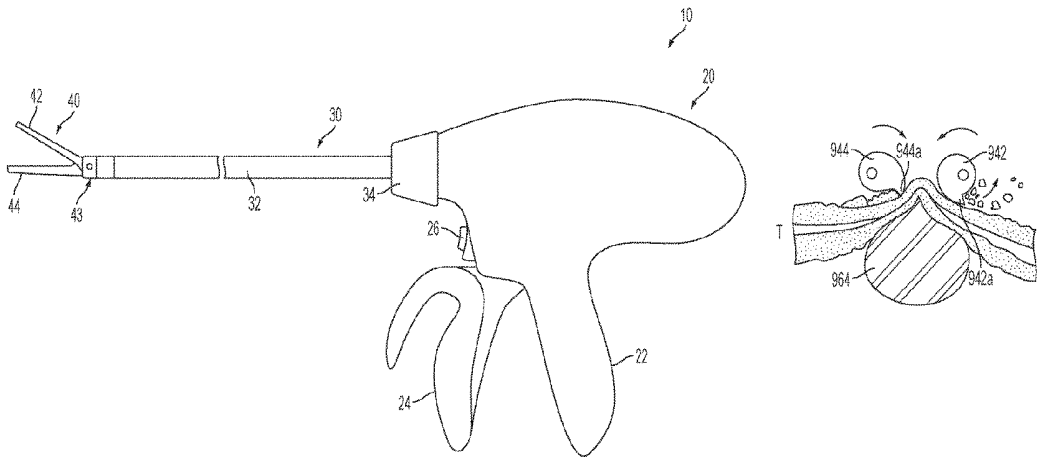
(57) **ABSTRACT**

An end effector of a surgical instrument may generally comprise a blade, and a clamp arm assembly comprising a clamp arm movable between an open position and a closed position relative to the blade, and at least one camming member rotationally attached to the clamp arm, wherein the at least one camming member is configured to rotate relative to the blade as the clamp arm moves from the open position to the closed position.

21 Claims, 42 Drawing Sheets



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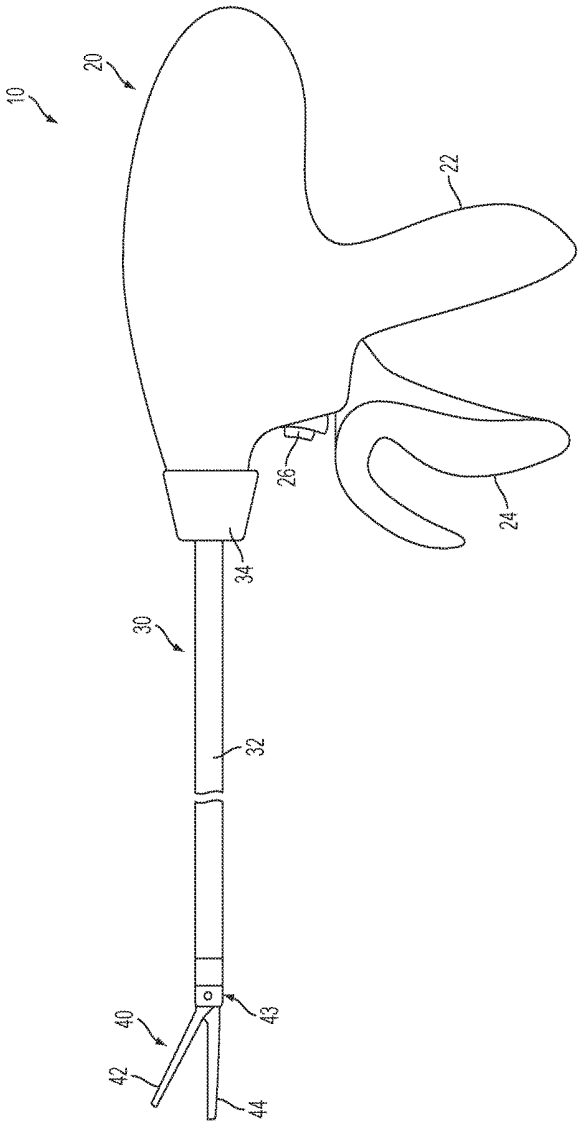
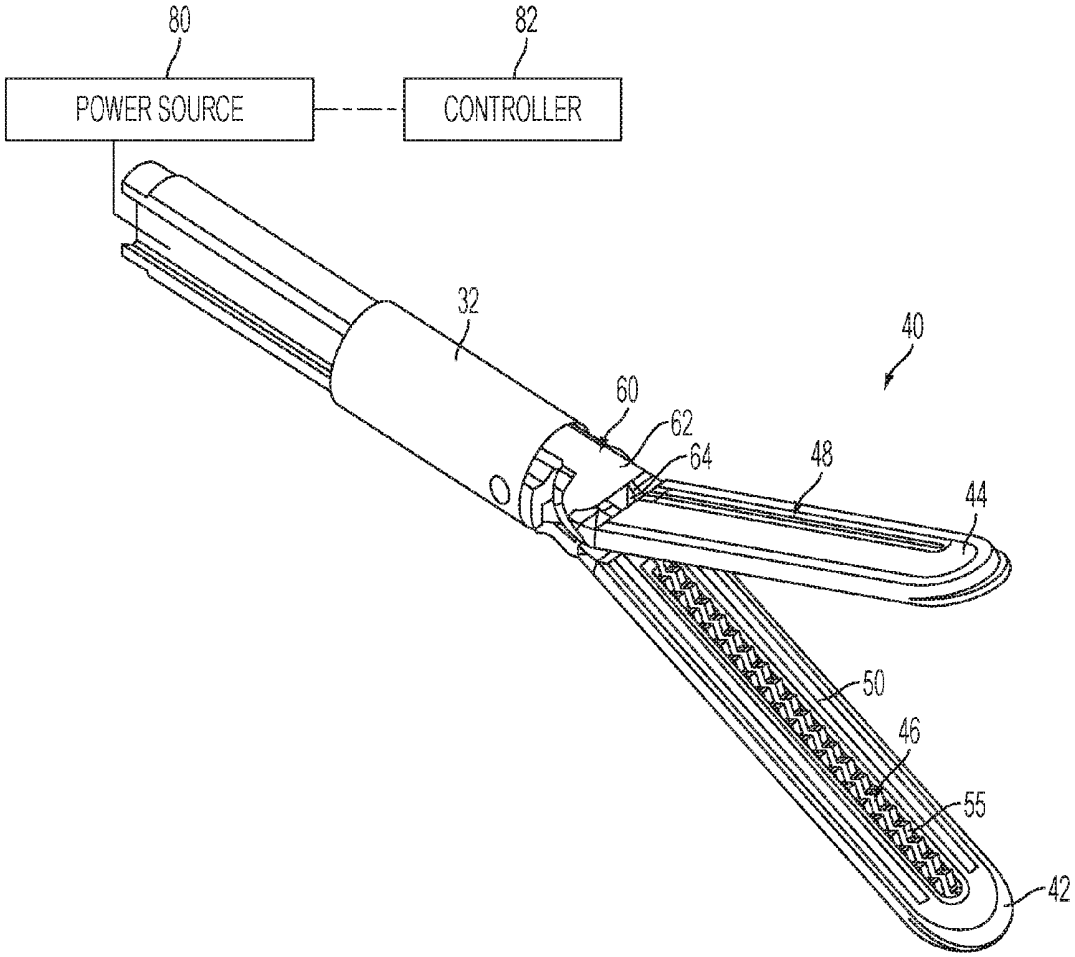


FIG. 1



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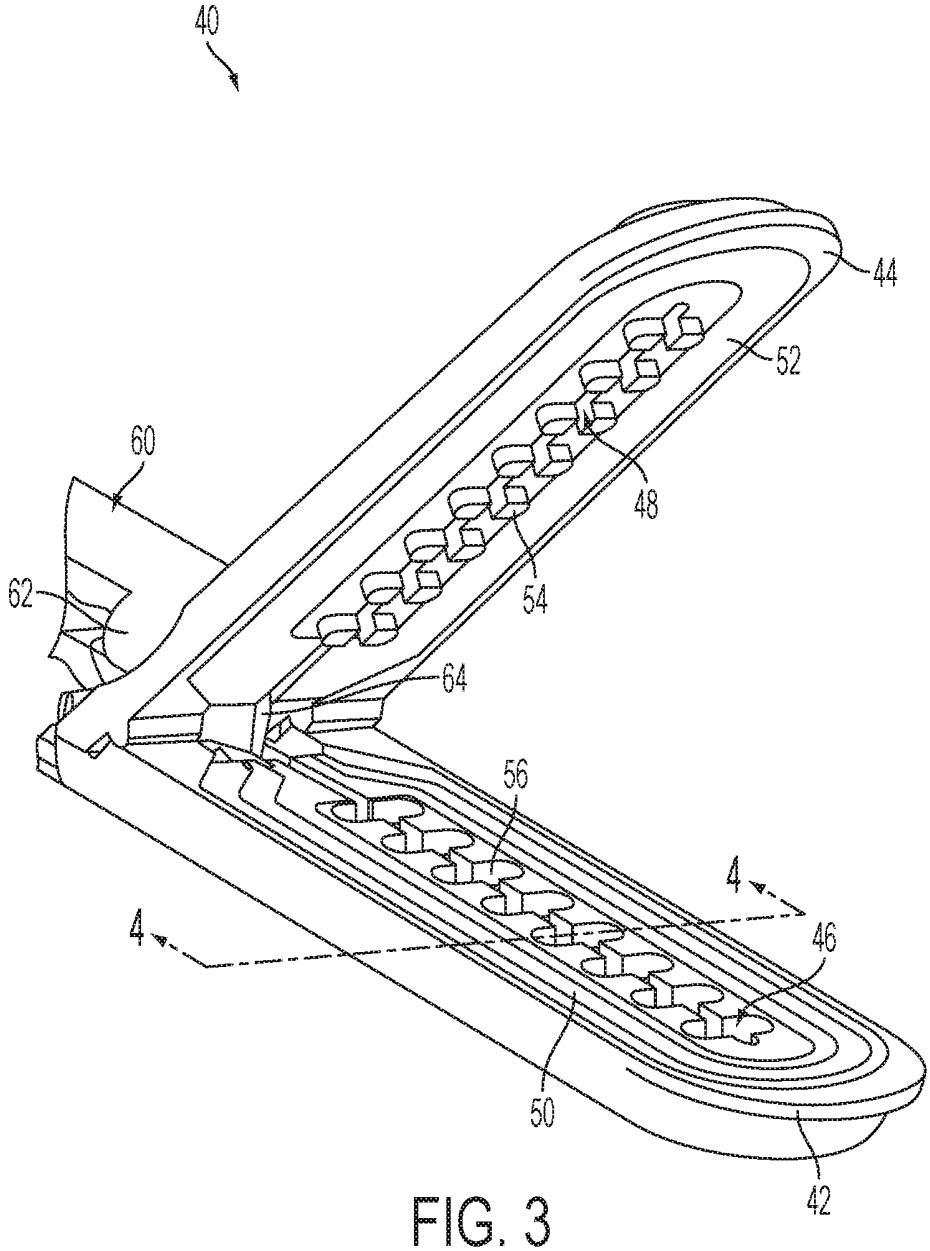

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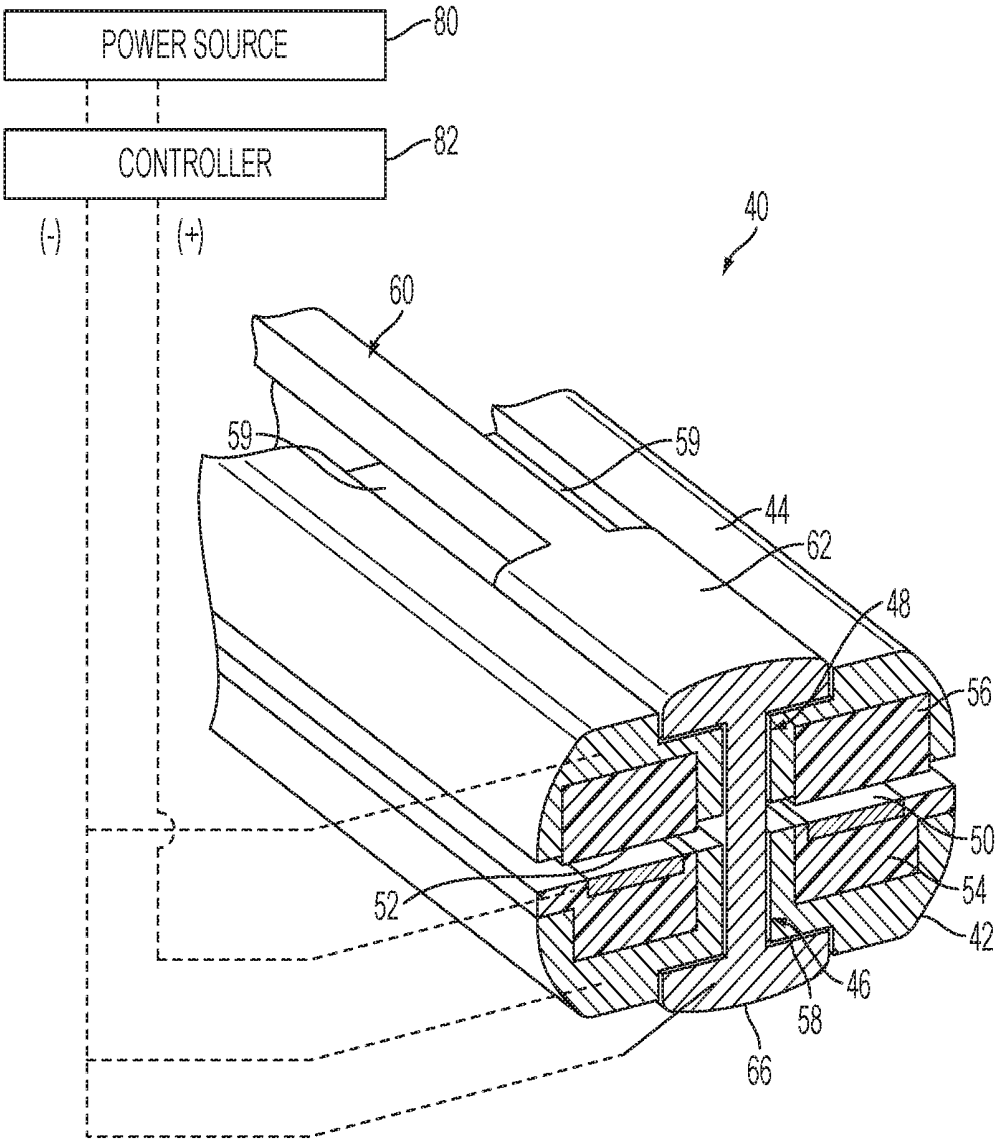
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FIG. 4

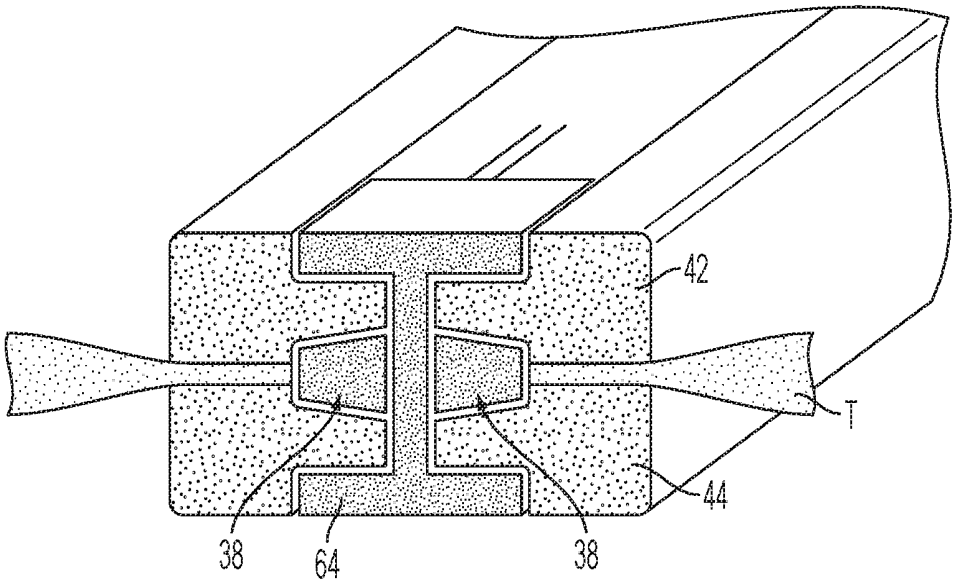

FIG. 4A

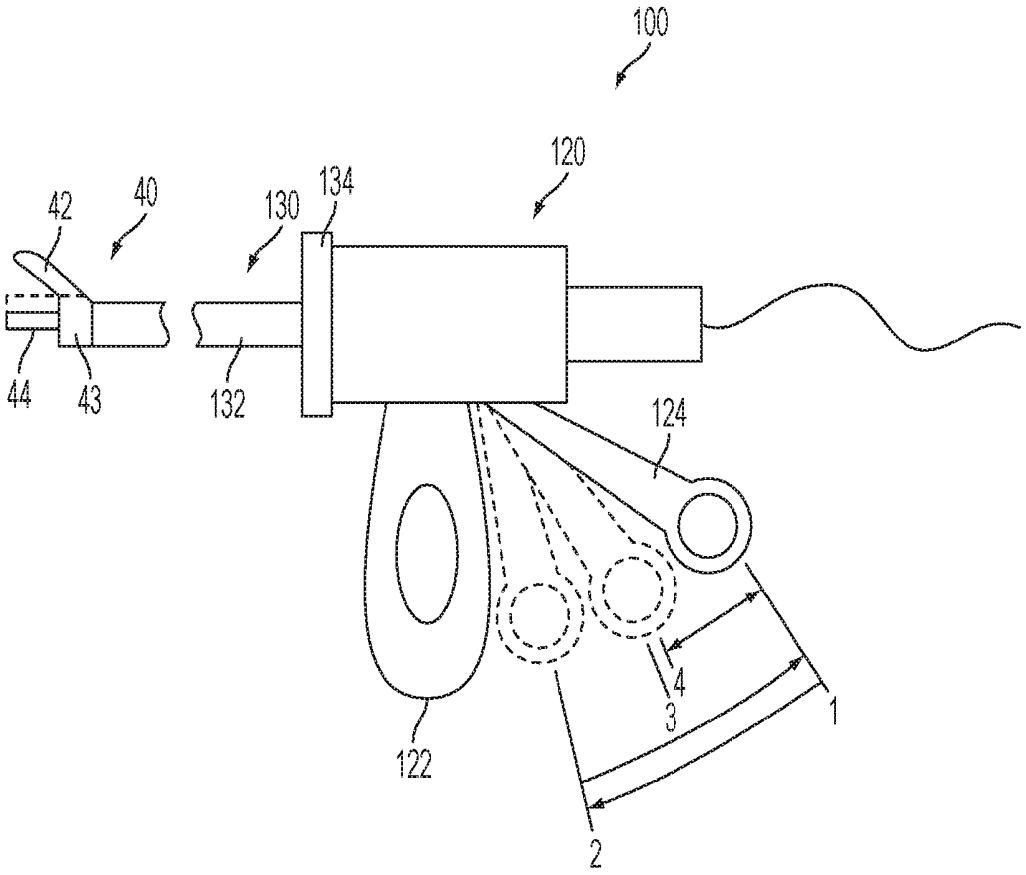

FIG. 5

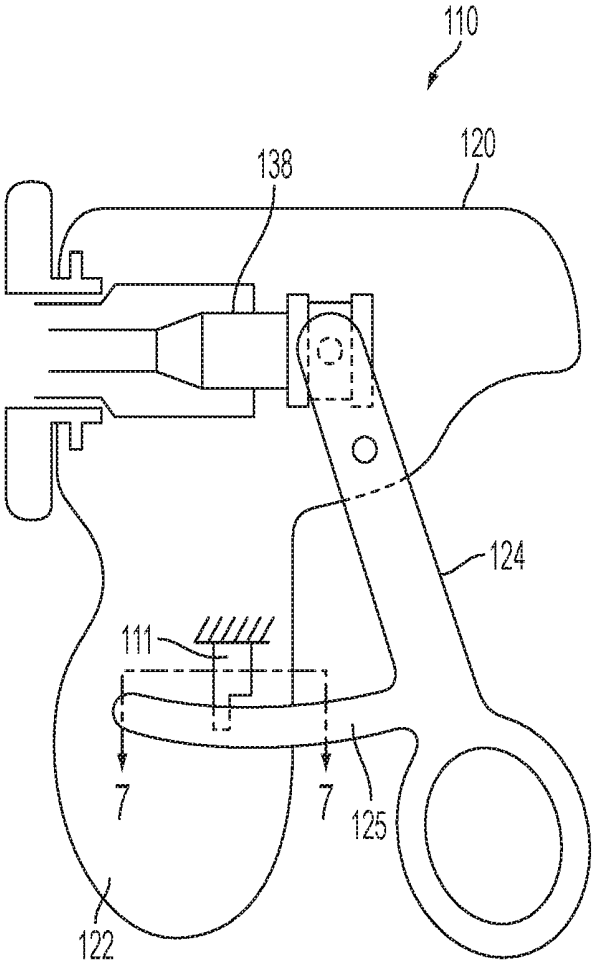

FIG. 6

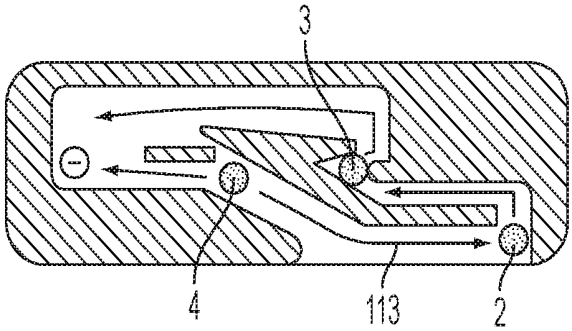

FIG. 7

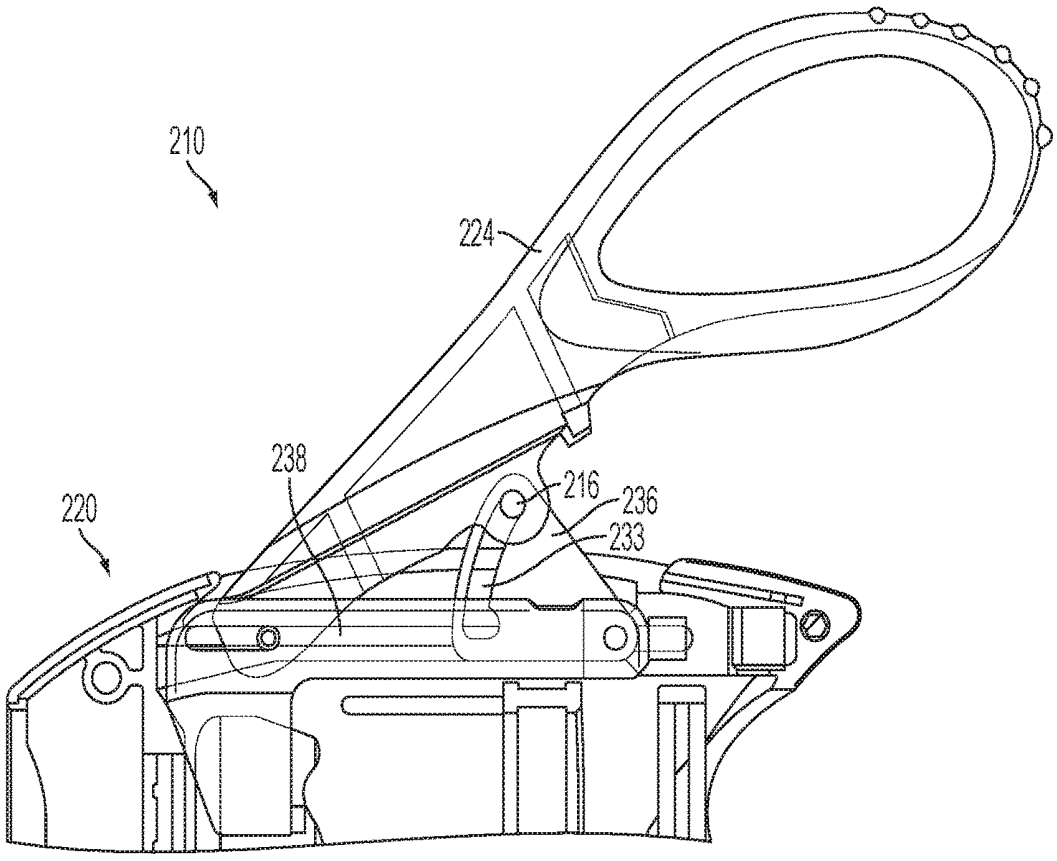

FIG. 8A

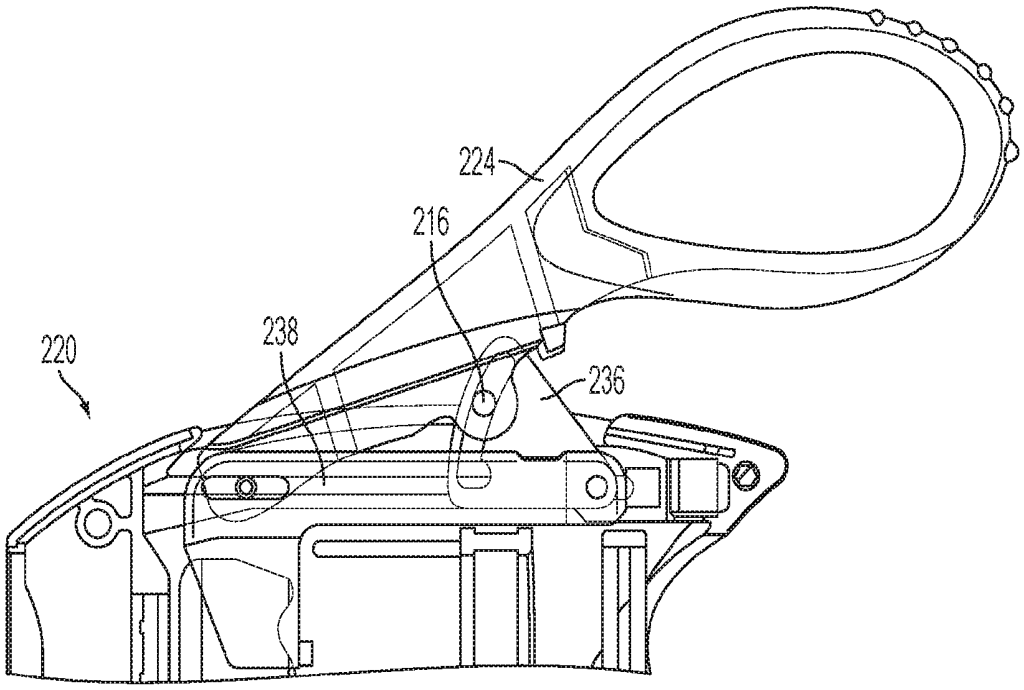

FIG. 8B

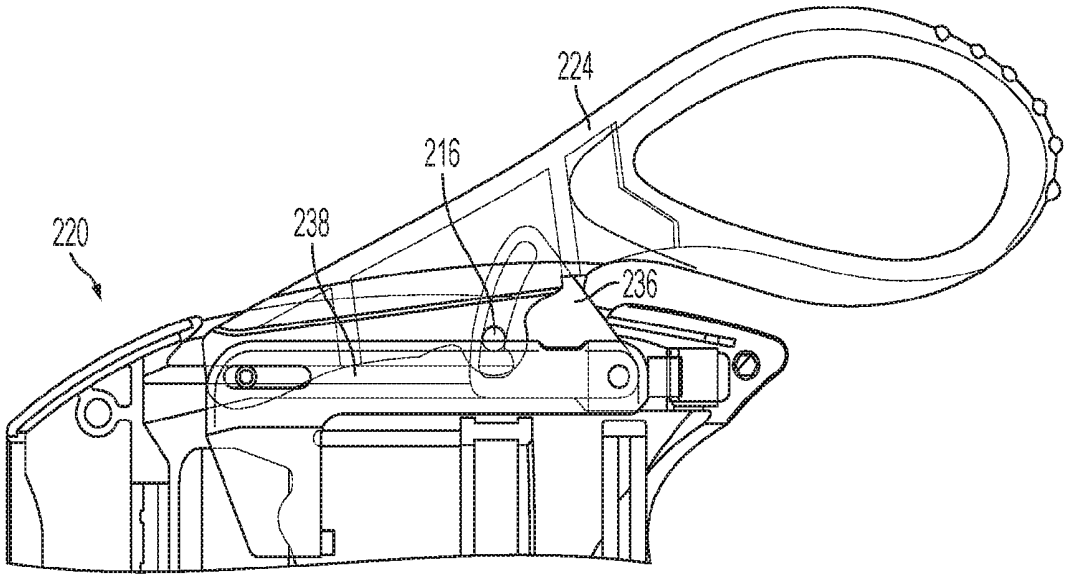

FIG. 8C

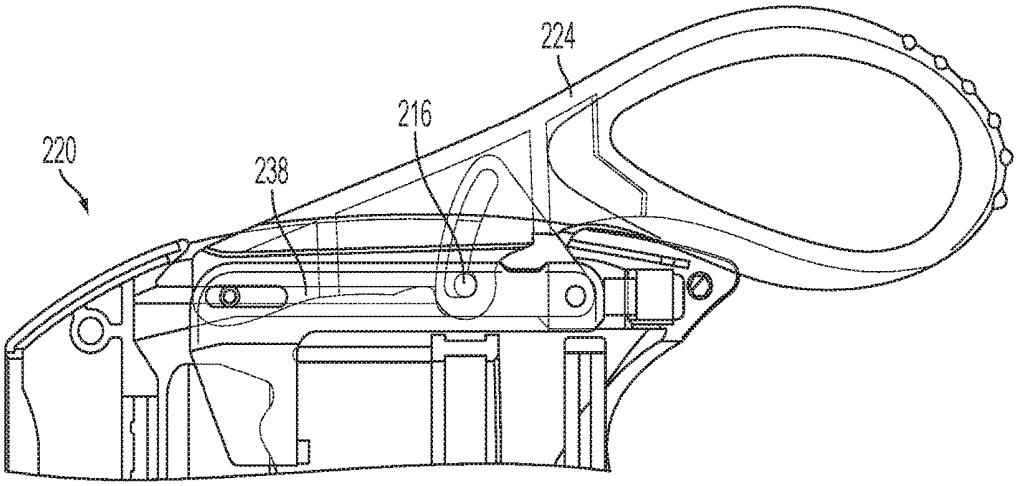

FIG. 8D

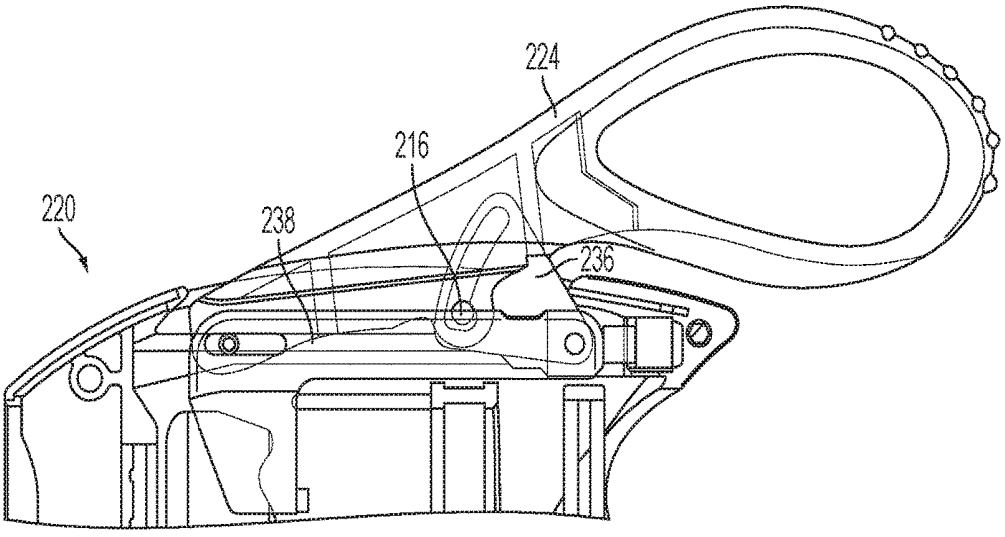

FIG. 8E

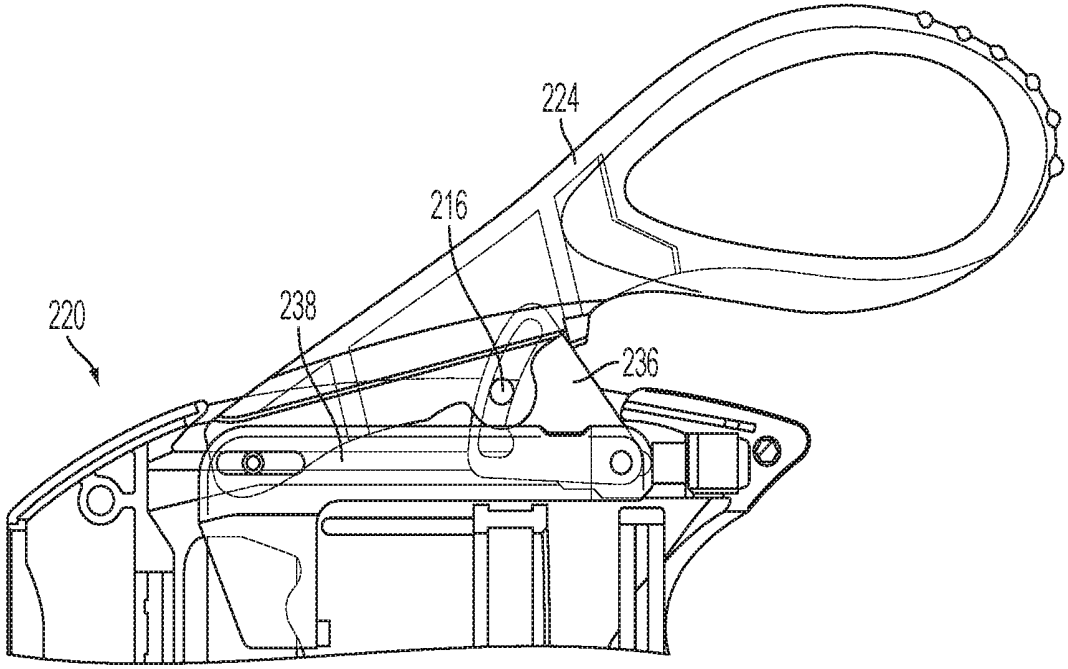

FIG. 8F

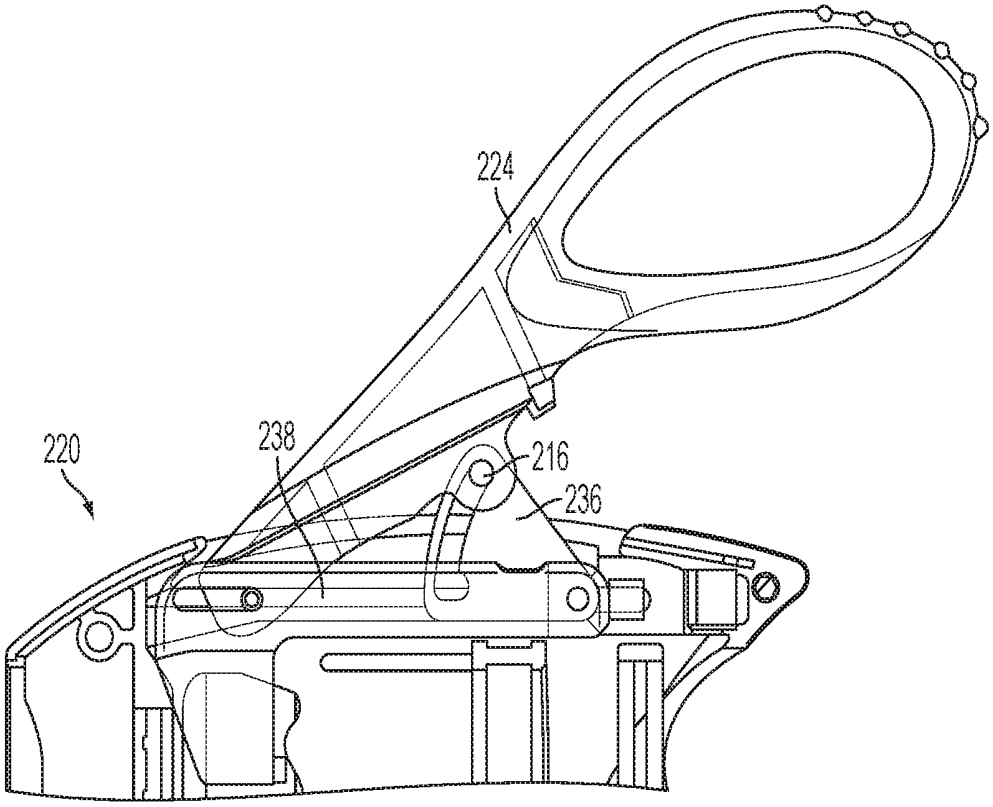

FIG. 8G

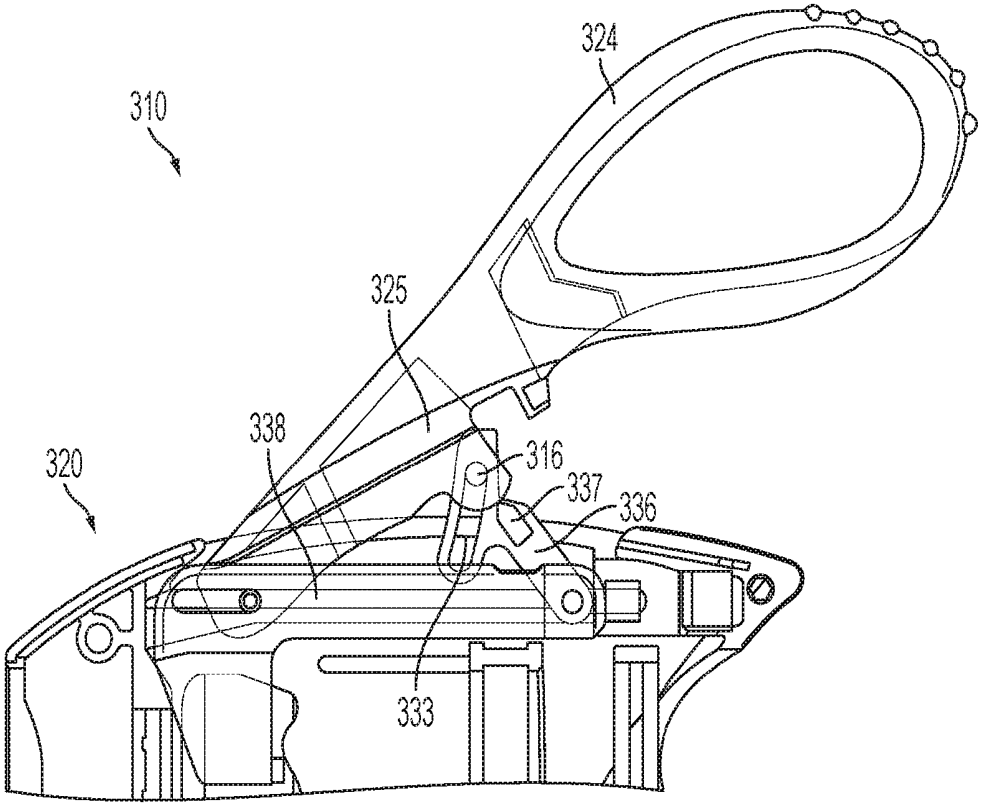

FIG. 9A

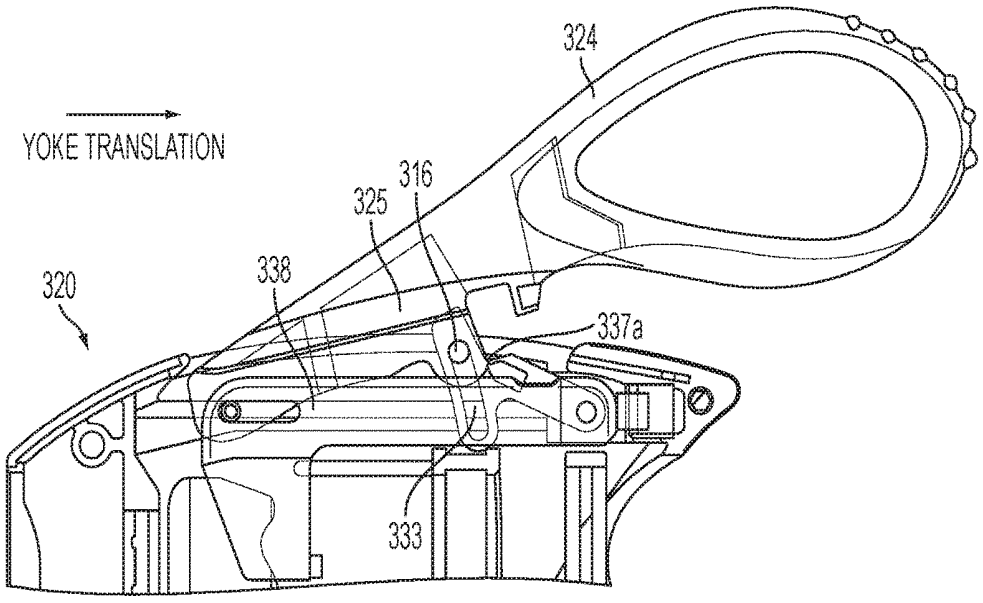
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FIG. 9B

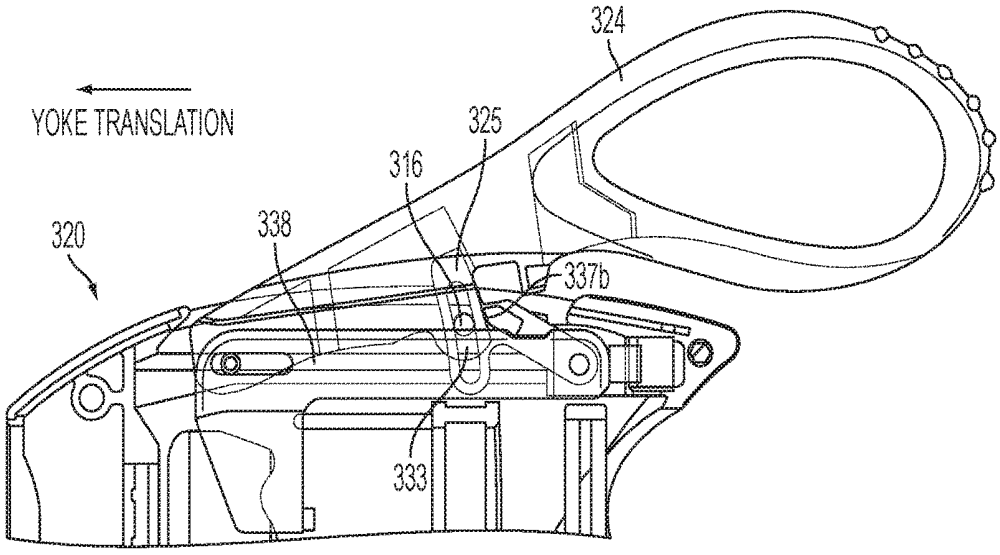
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FIG. 9C

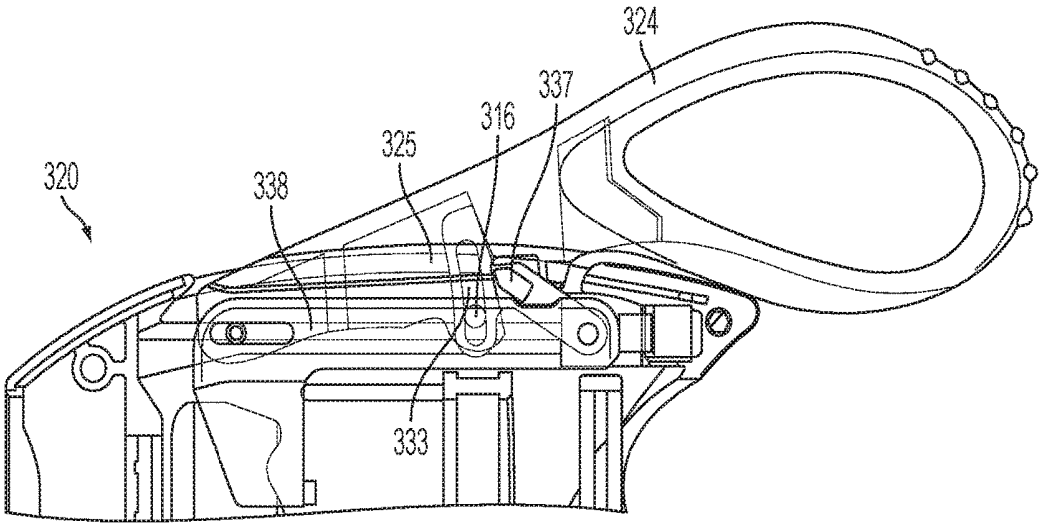

FIG. 9D

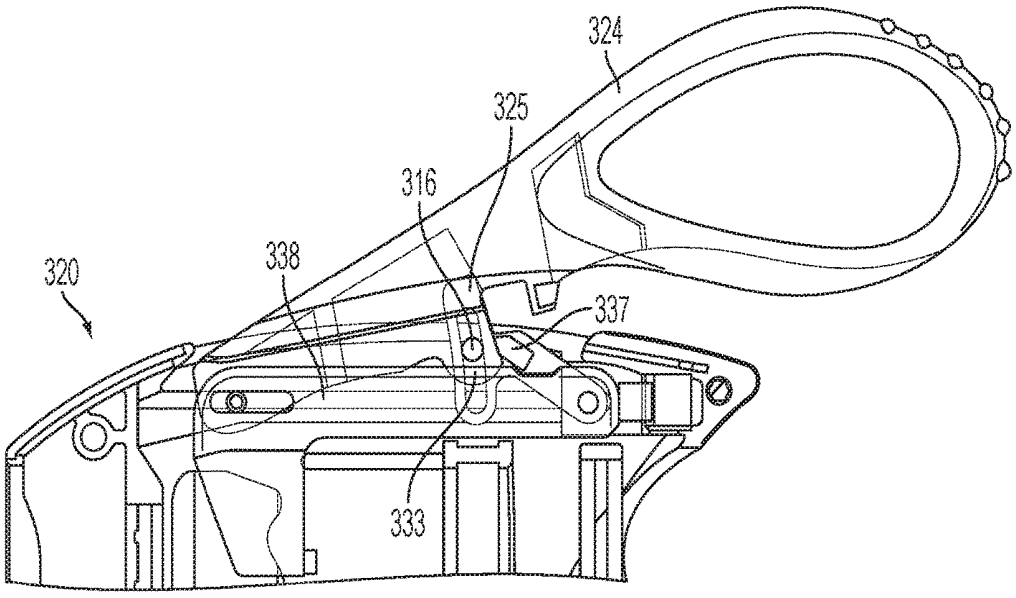

FIG. 9E

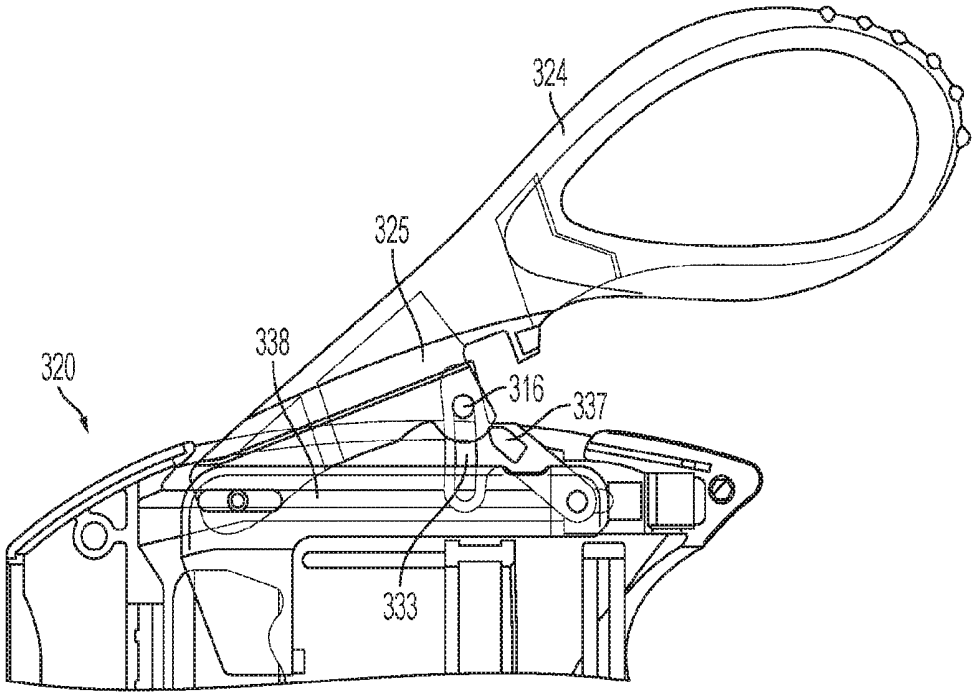

FIG. 9F

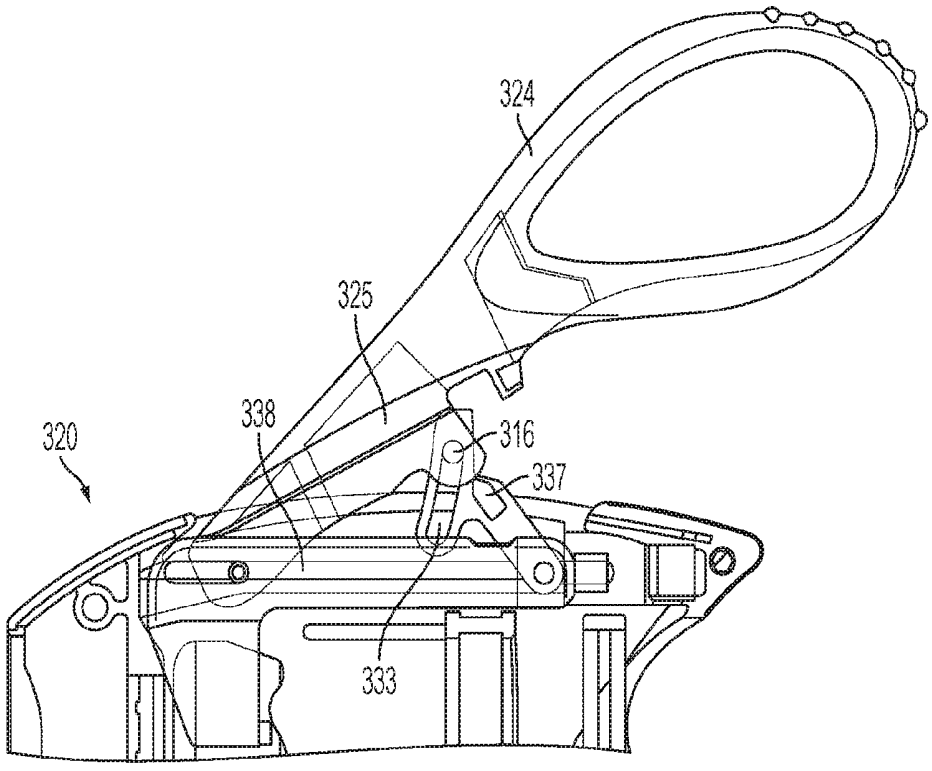

FIG. 9G

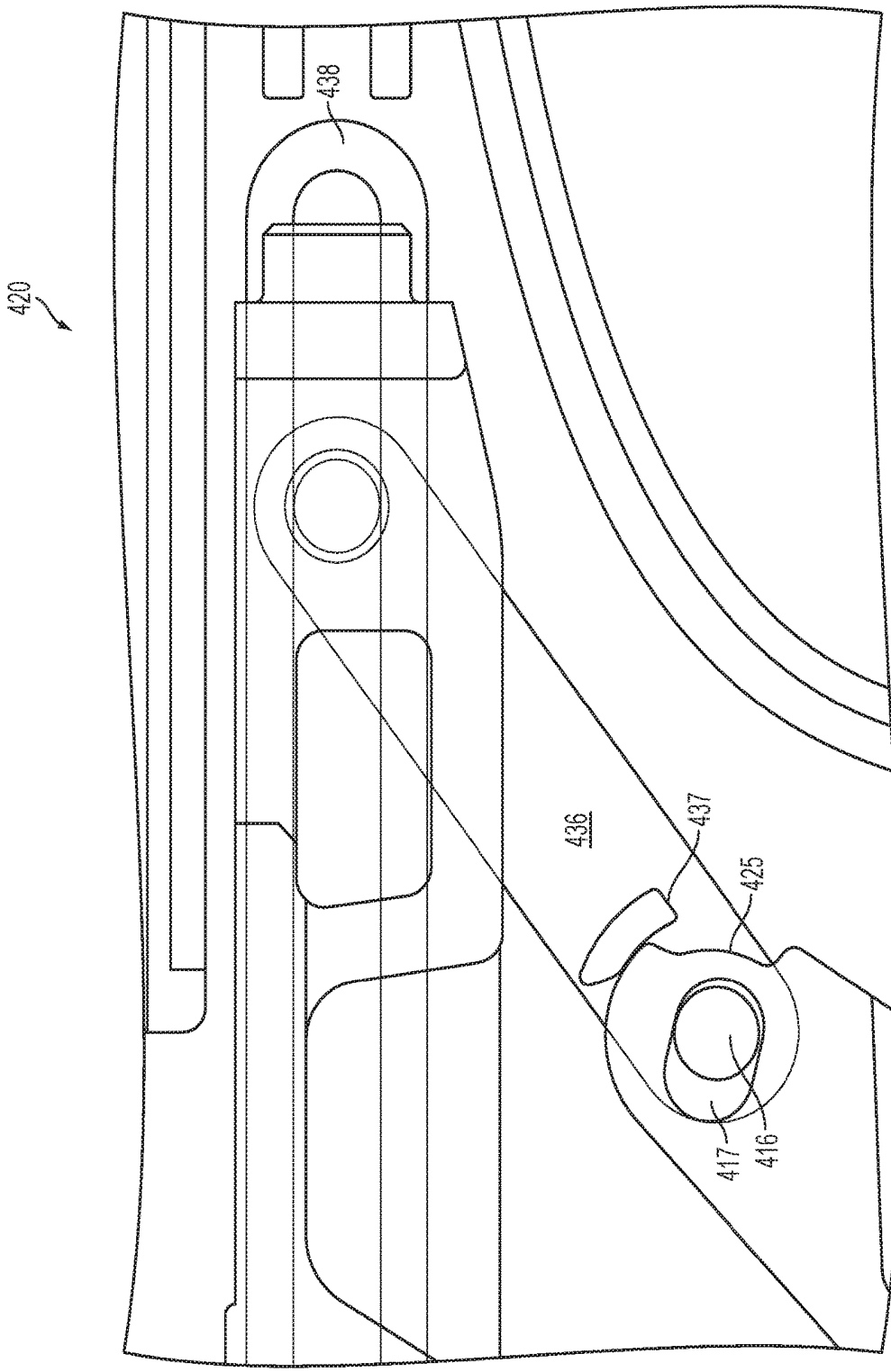

FIG. 10A

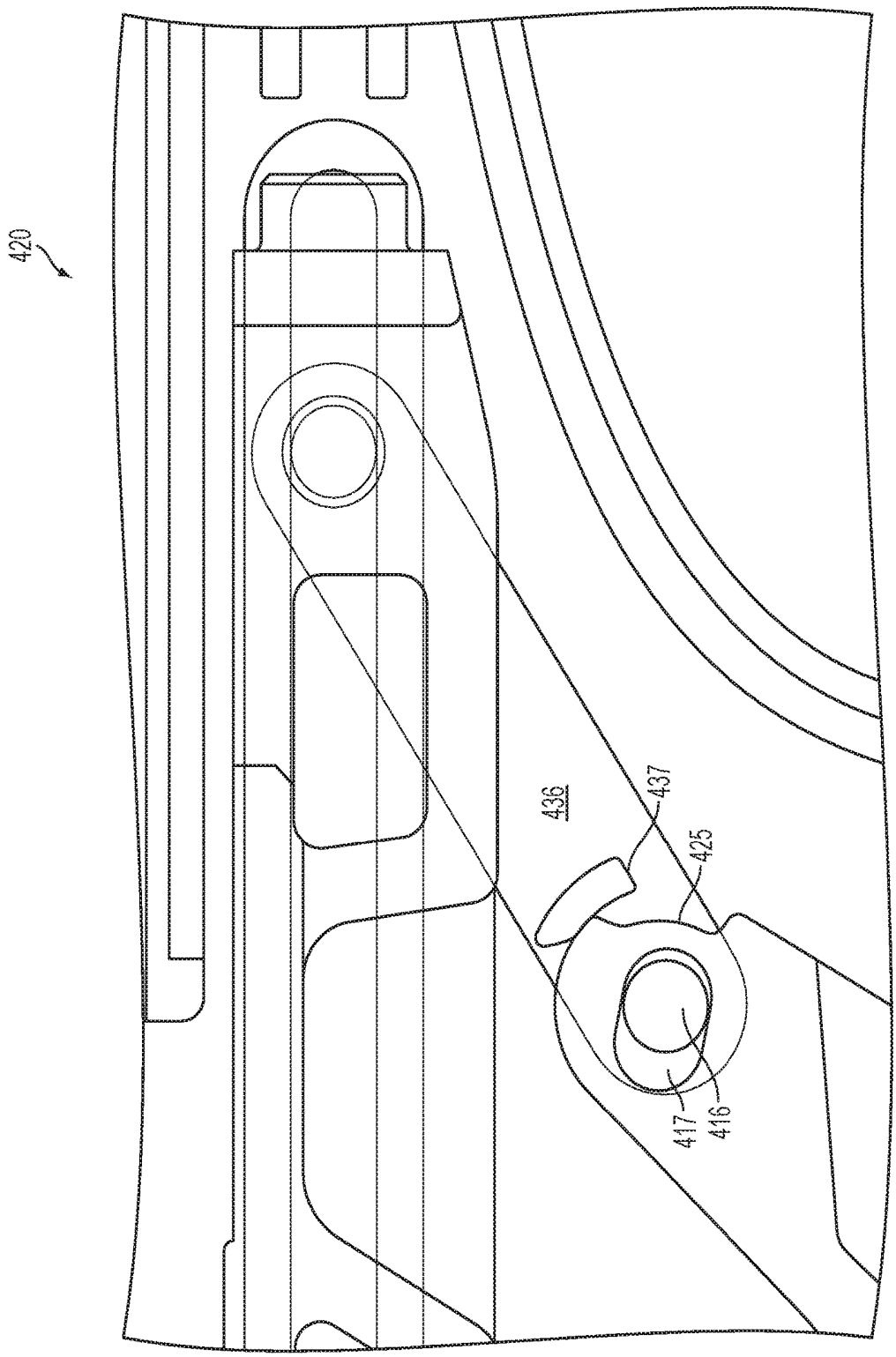

FIG. 10B

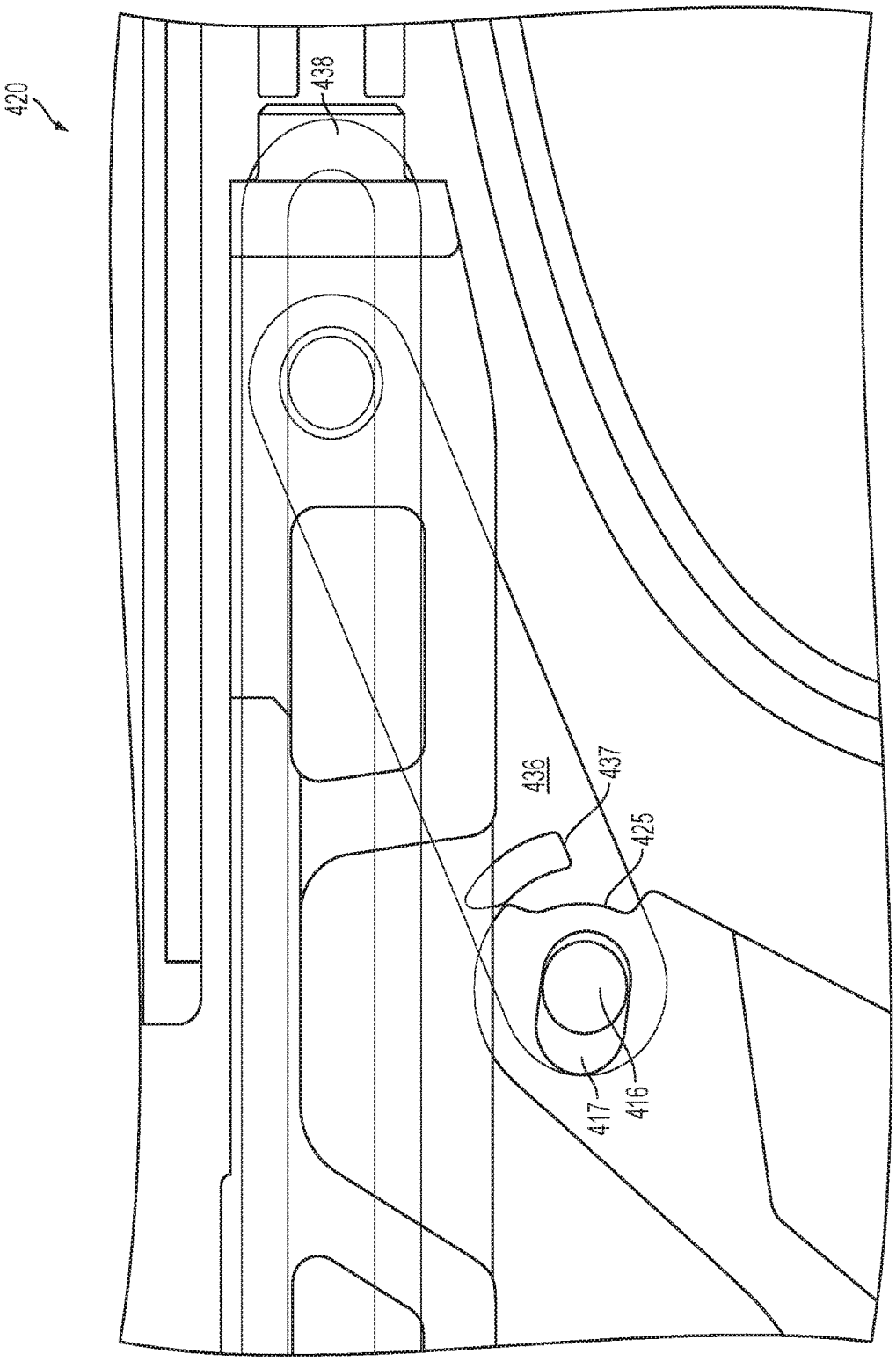

FIG. 10C

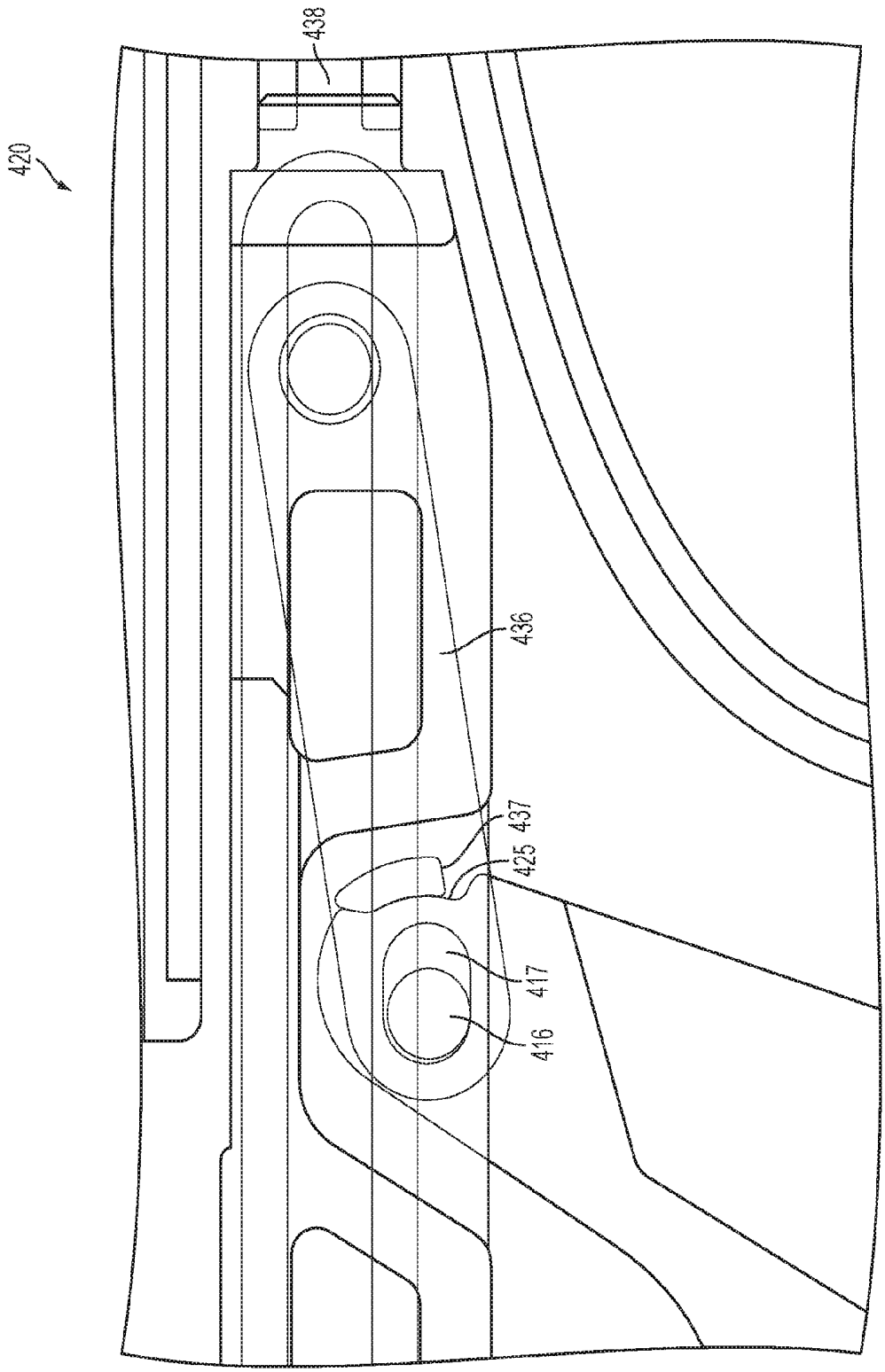

FIG. 10D

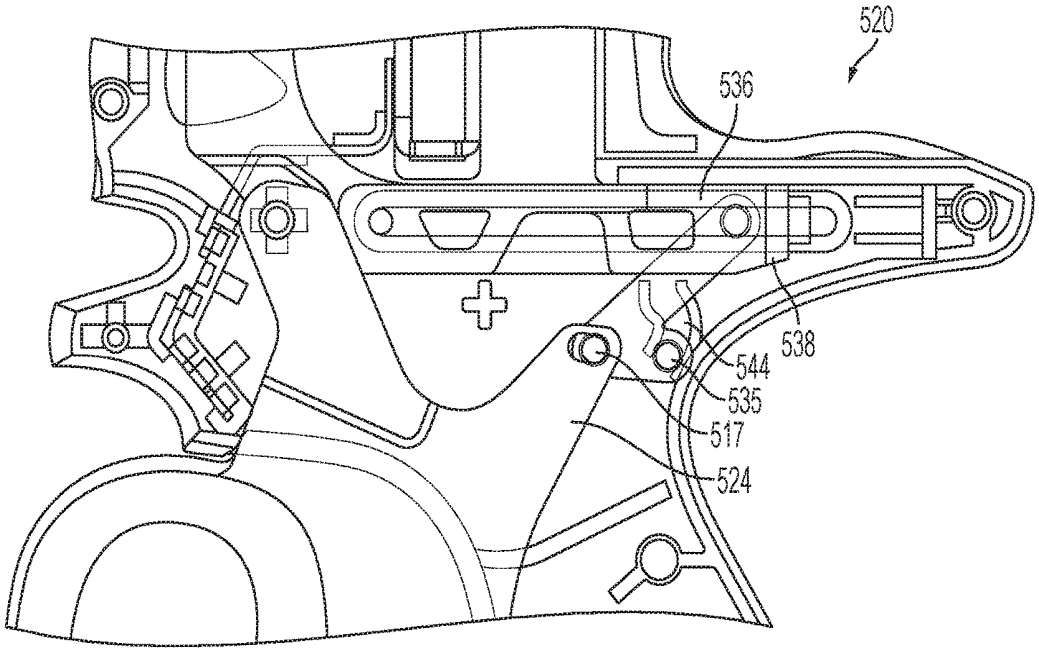

FIG. 11A

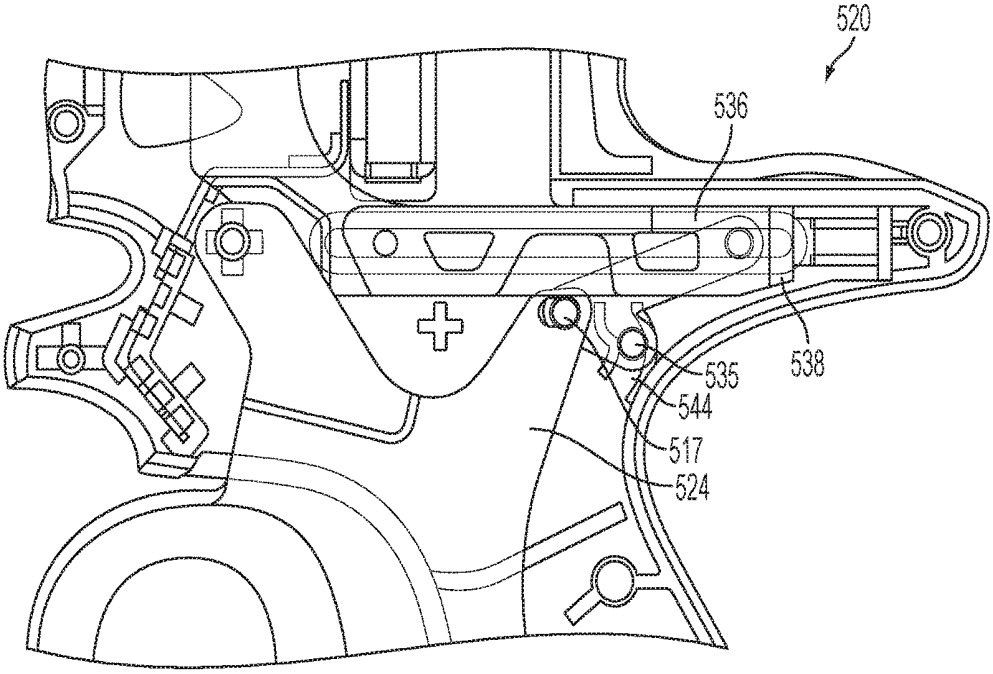

FIG. 11B

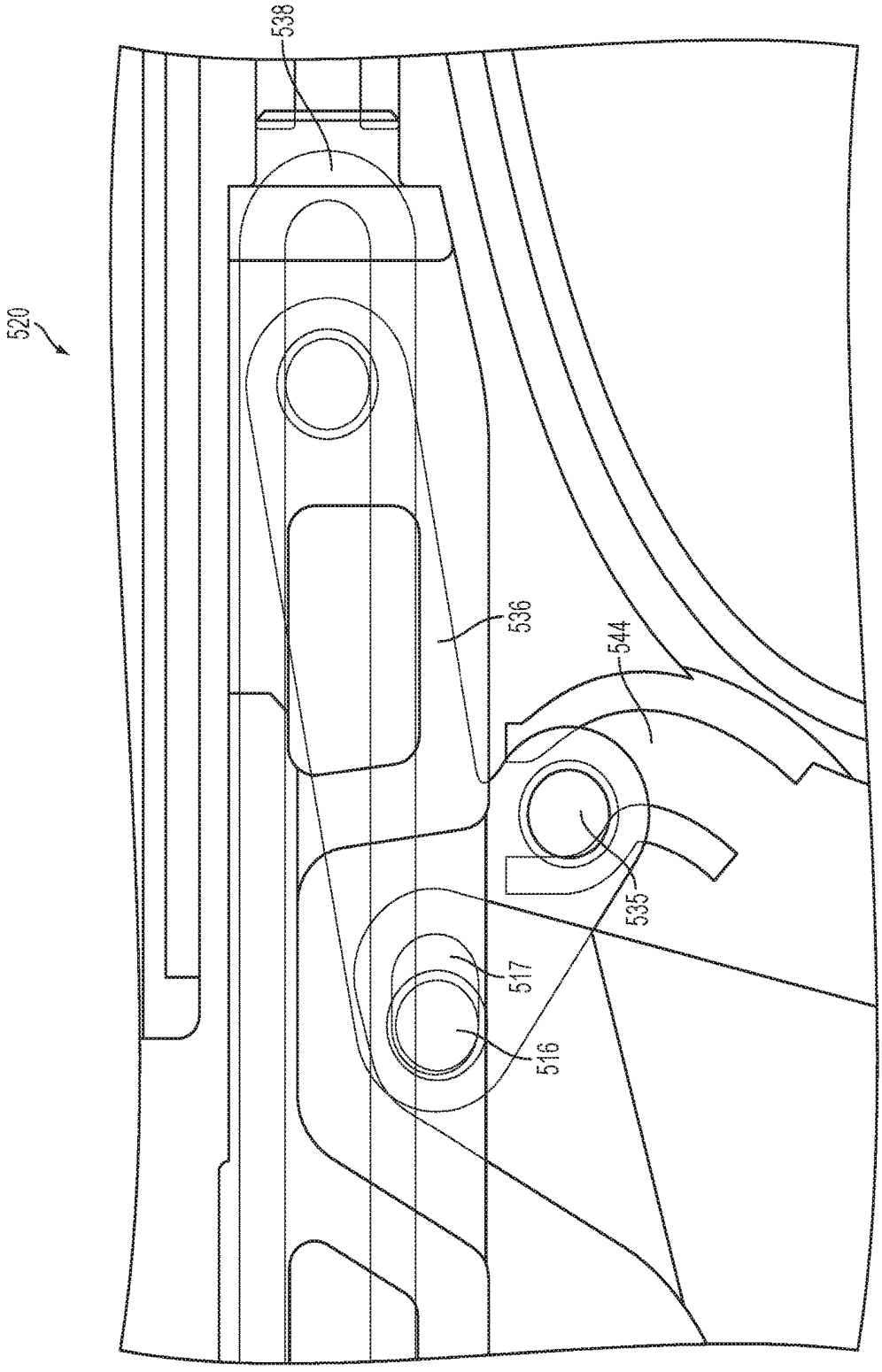

FIG. 11C

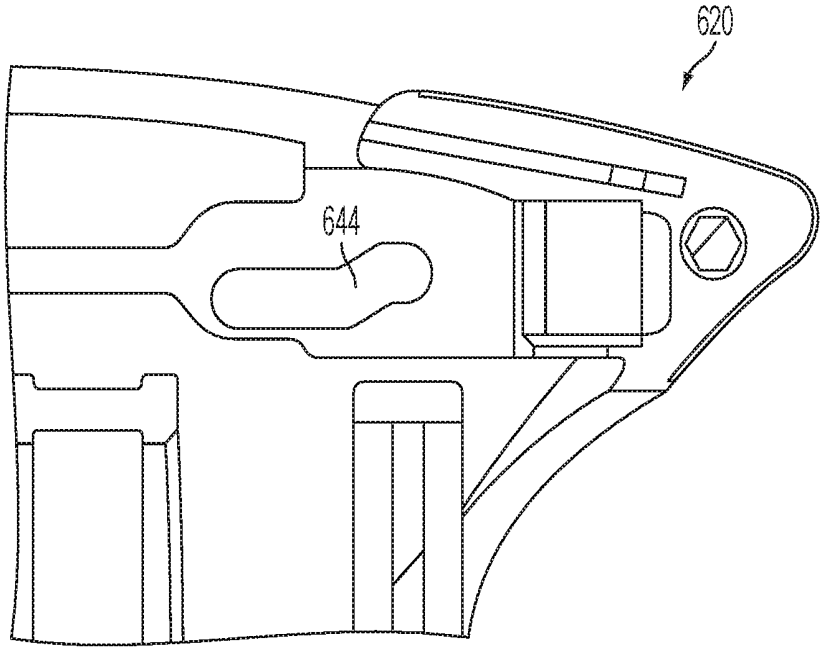

FIG. 12

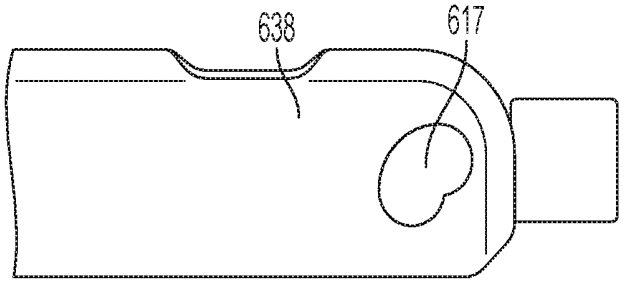

FIG. 13

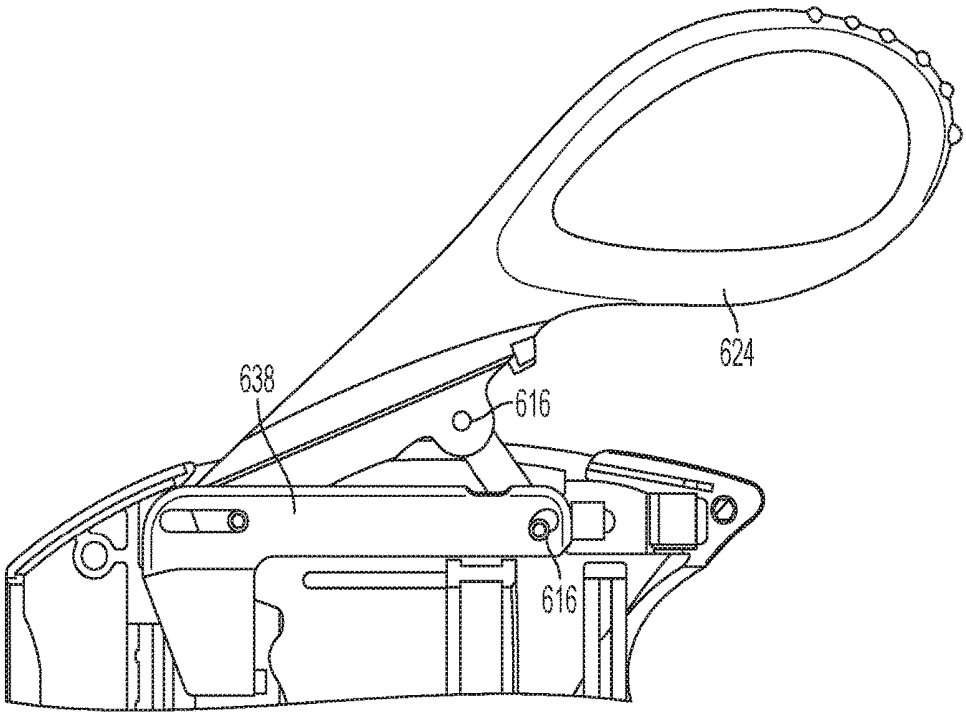

FIG. 14A

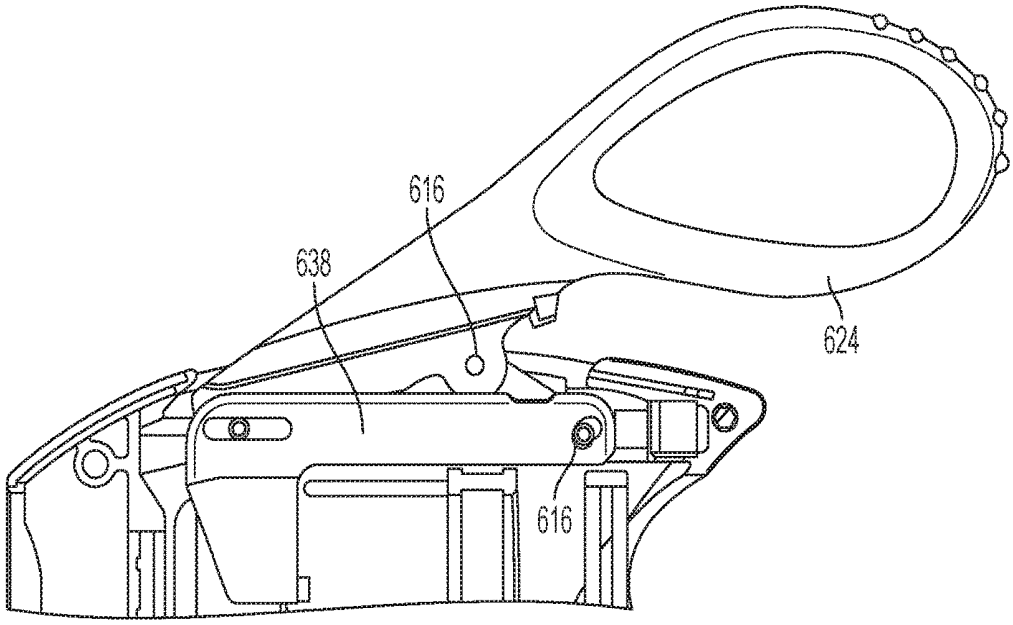

FIG. 14B

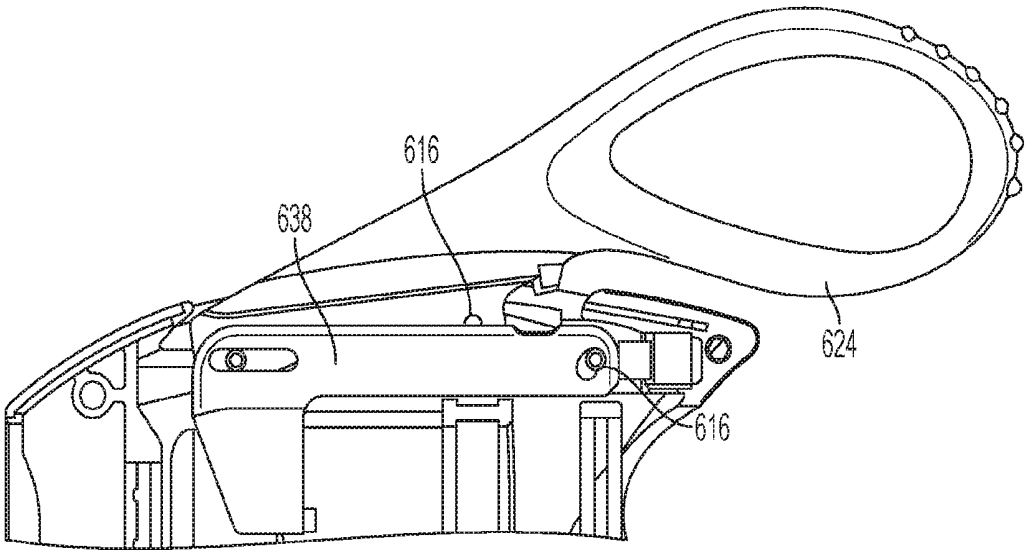

FIG. 14C

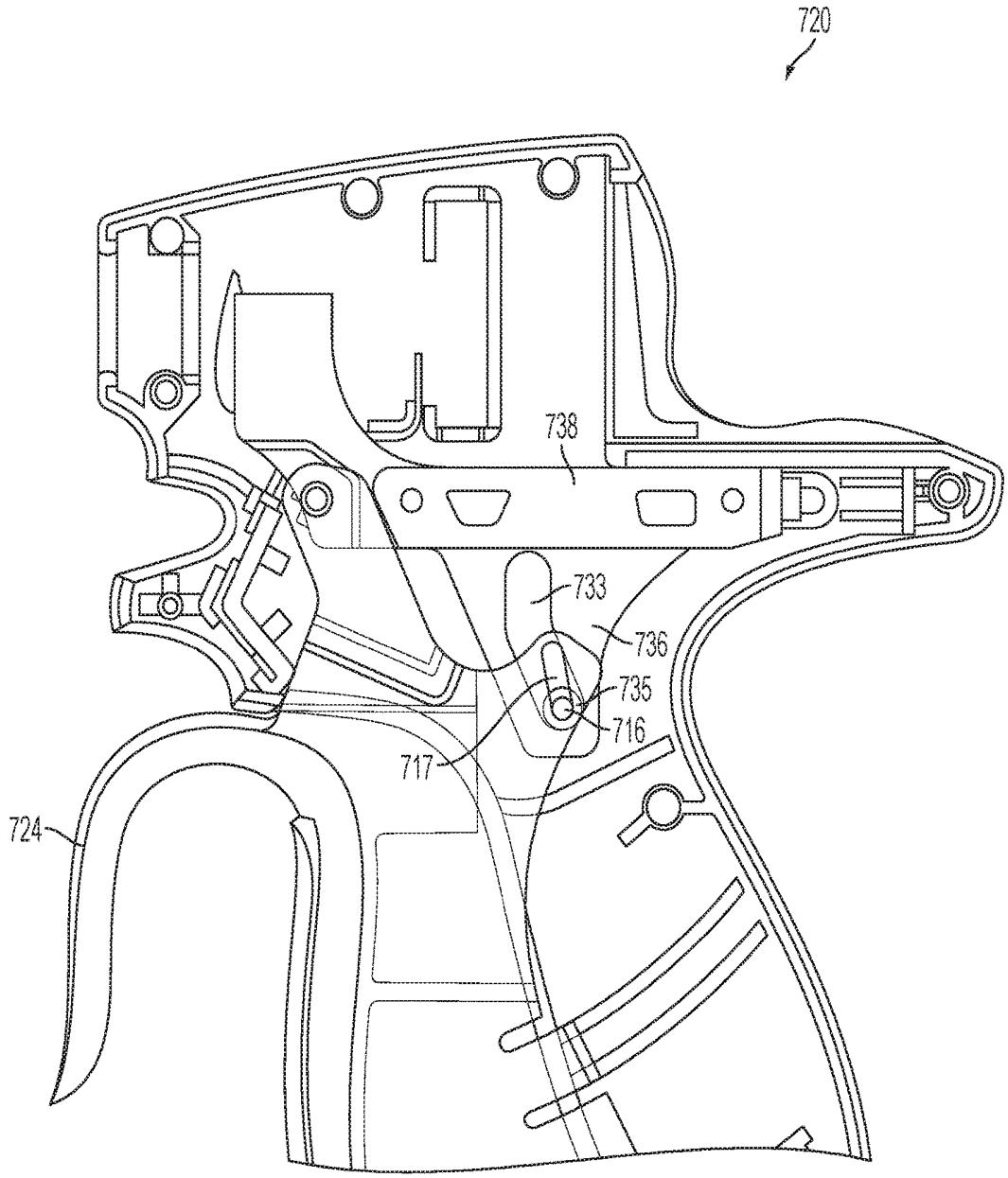

FIG. 15A

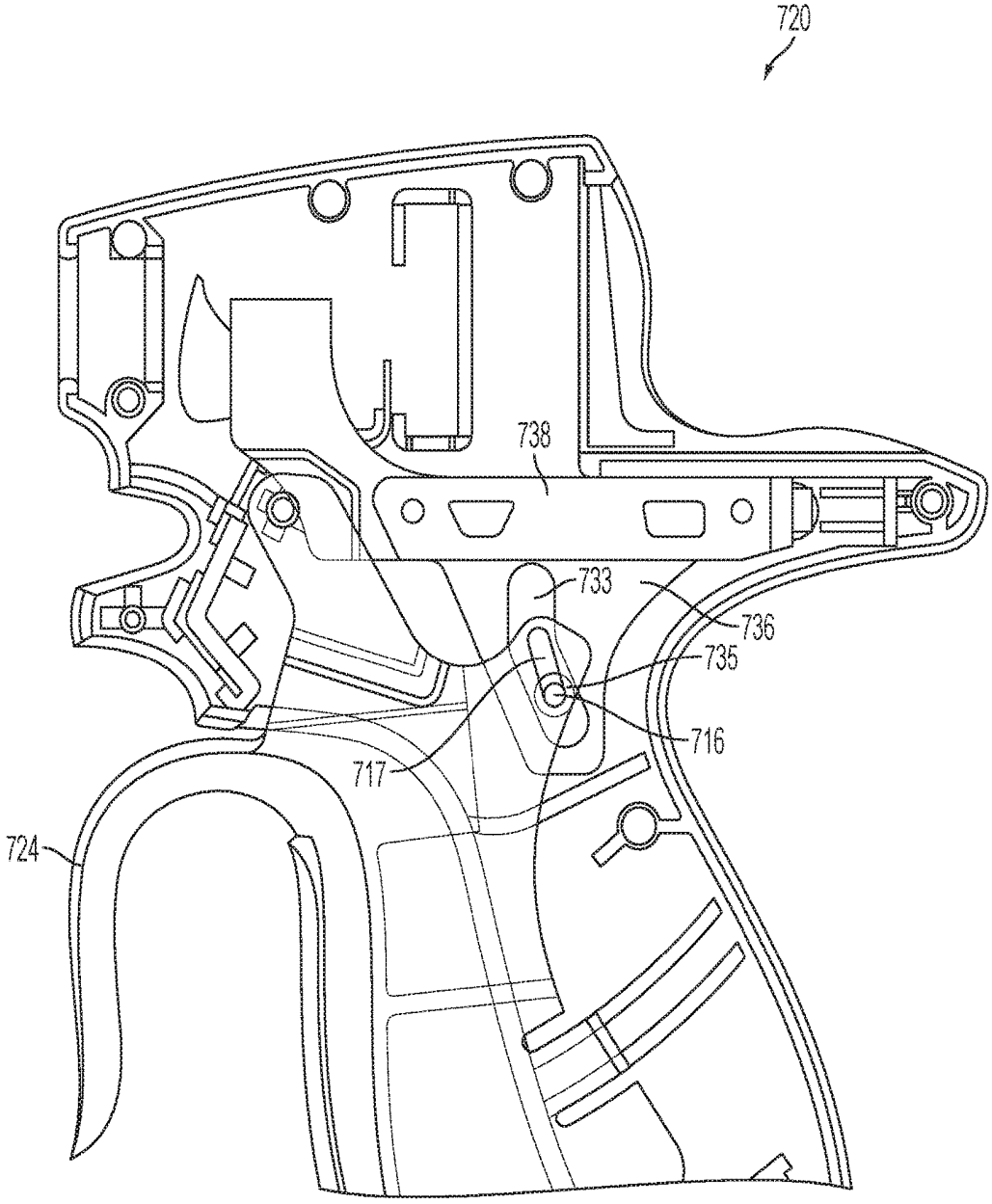

FIG. 15B

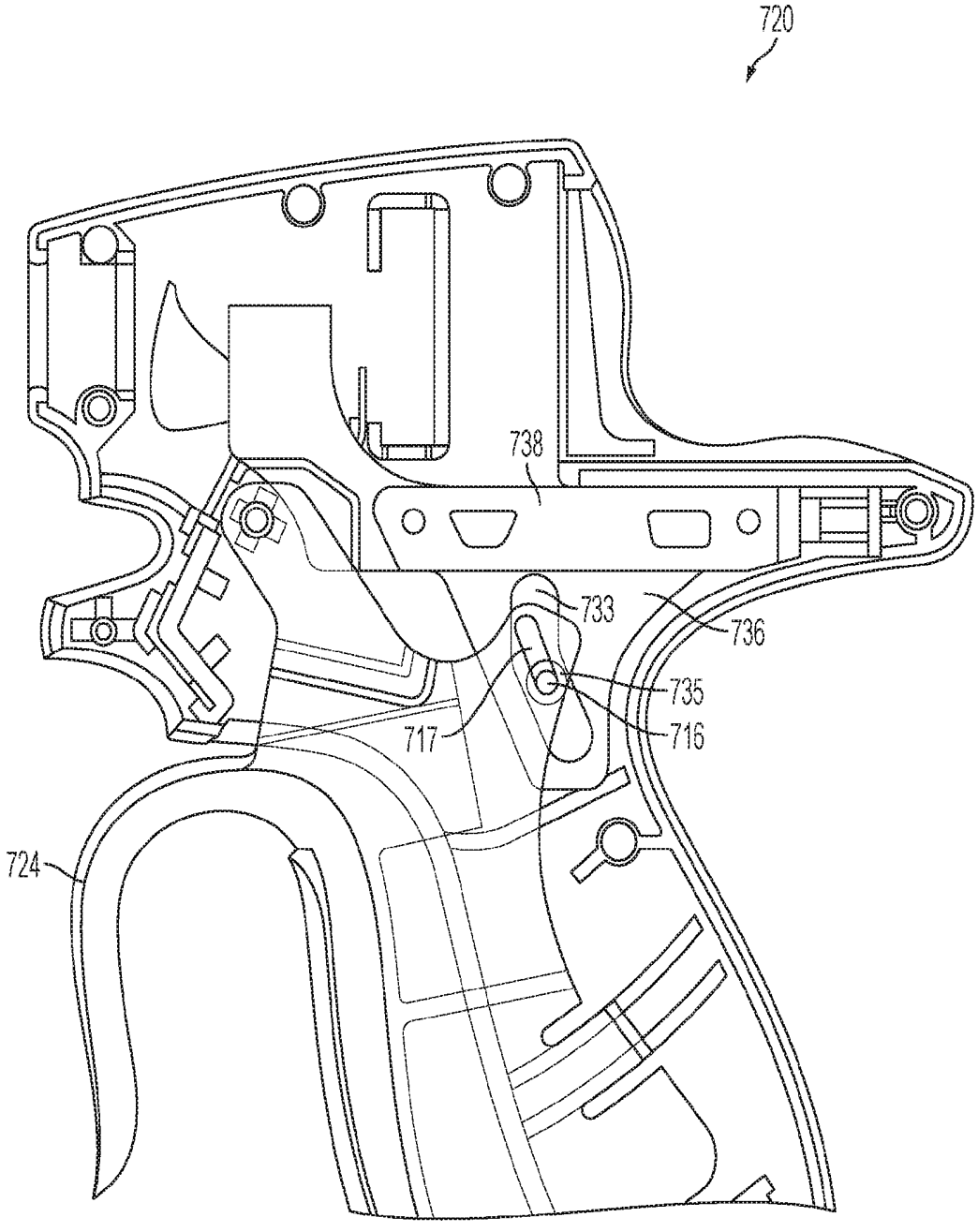

FIG. 15C

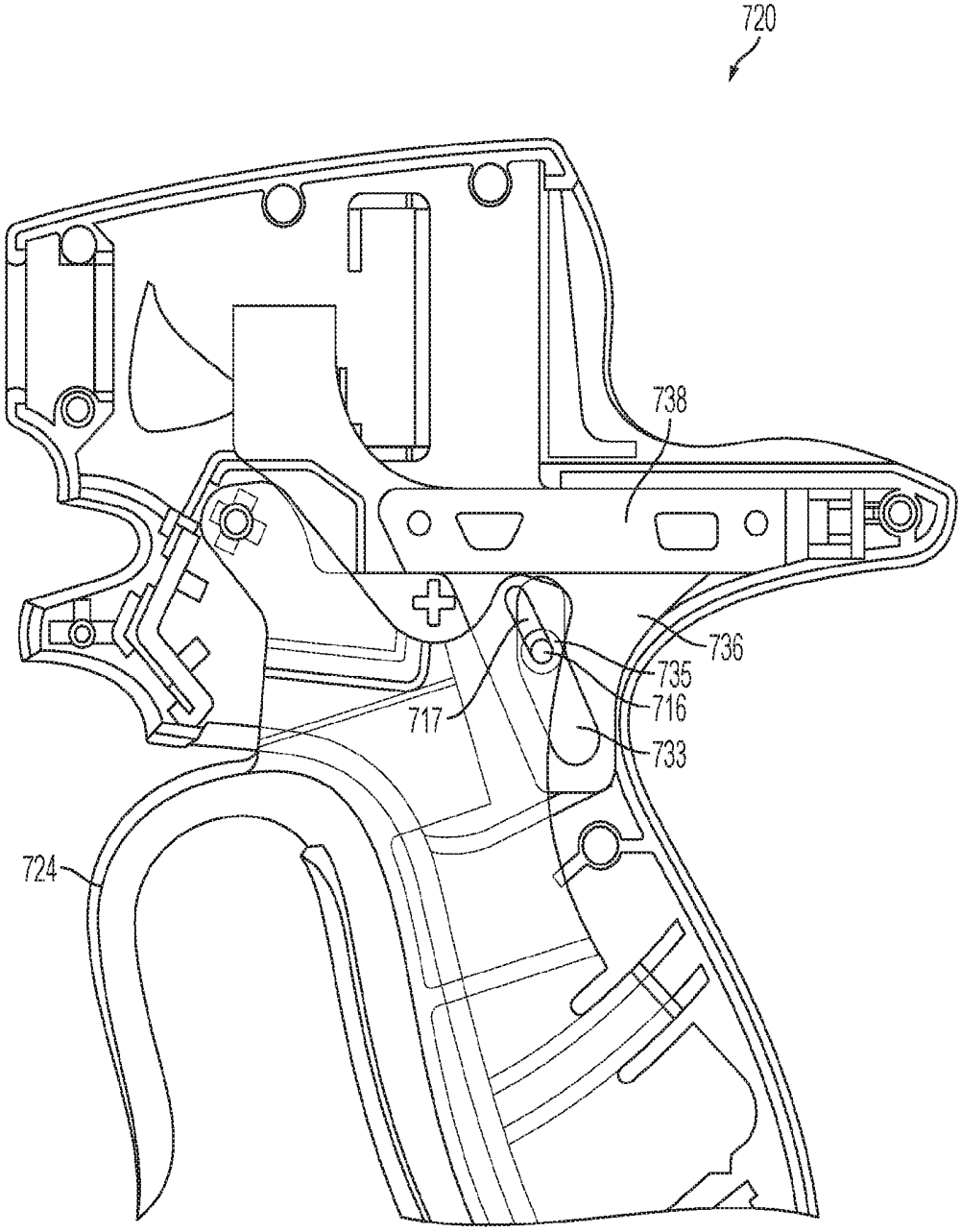

FIG. 15D

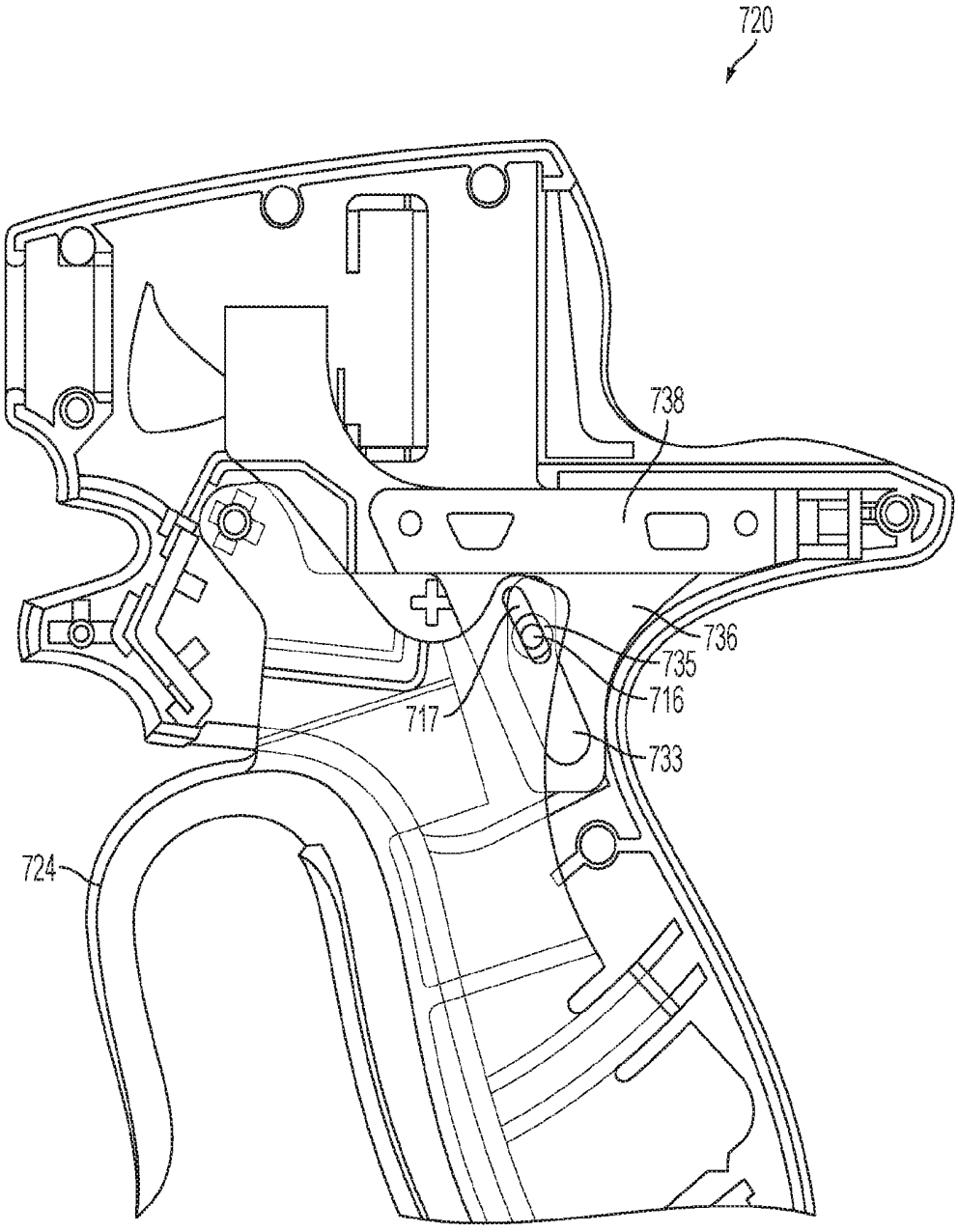

FIG. 15E

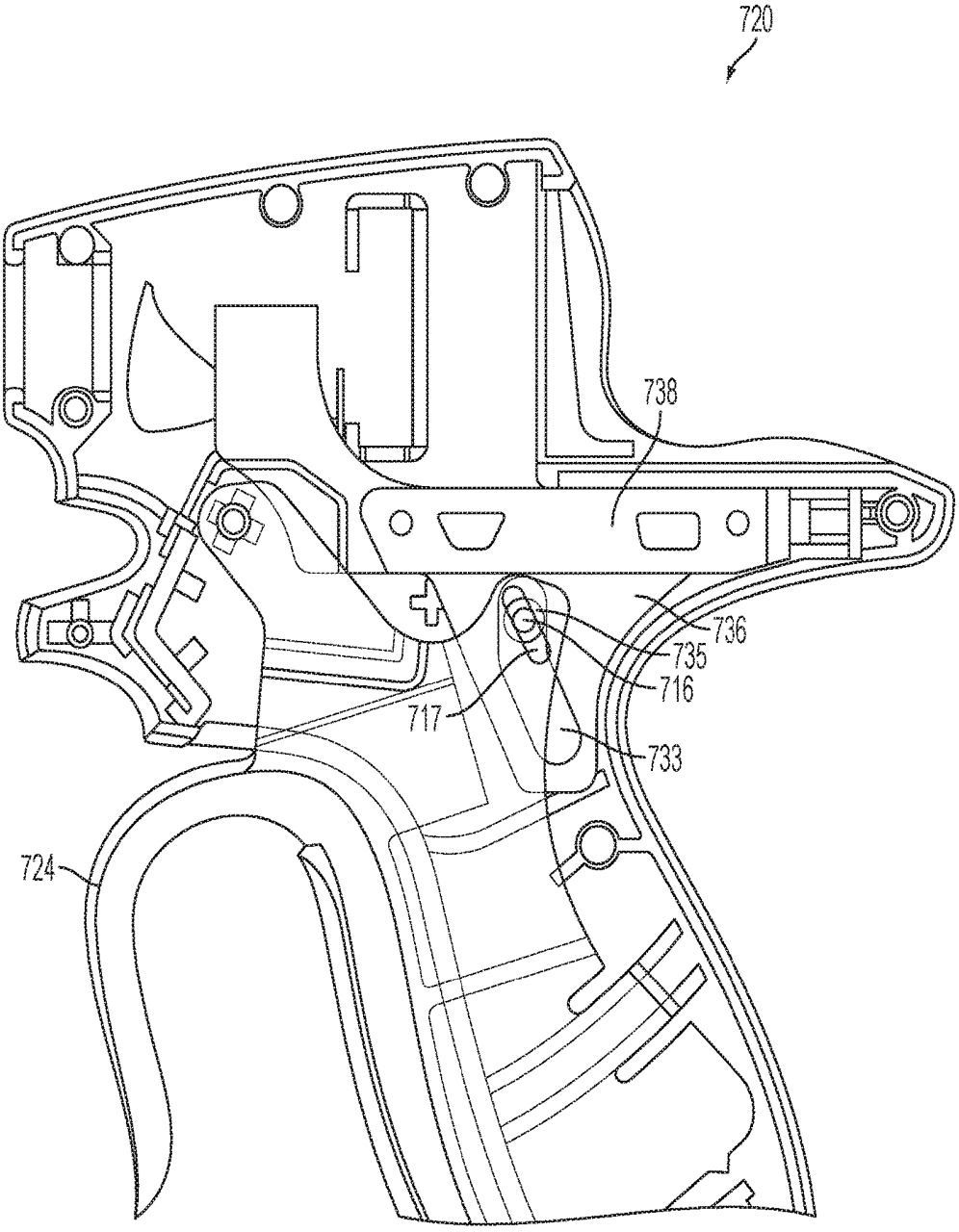

FIG. 15F

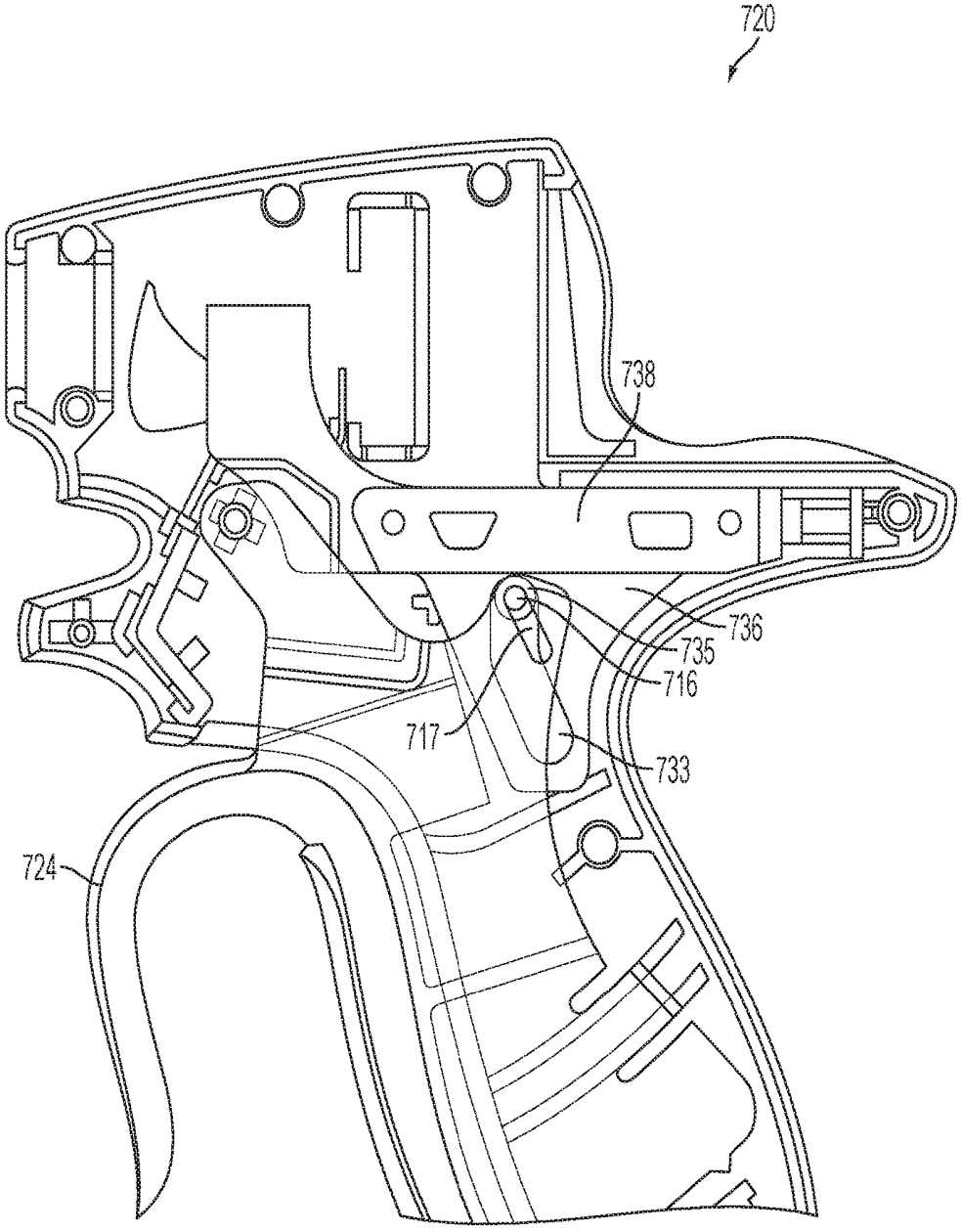

FIG. 15G

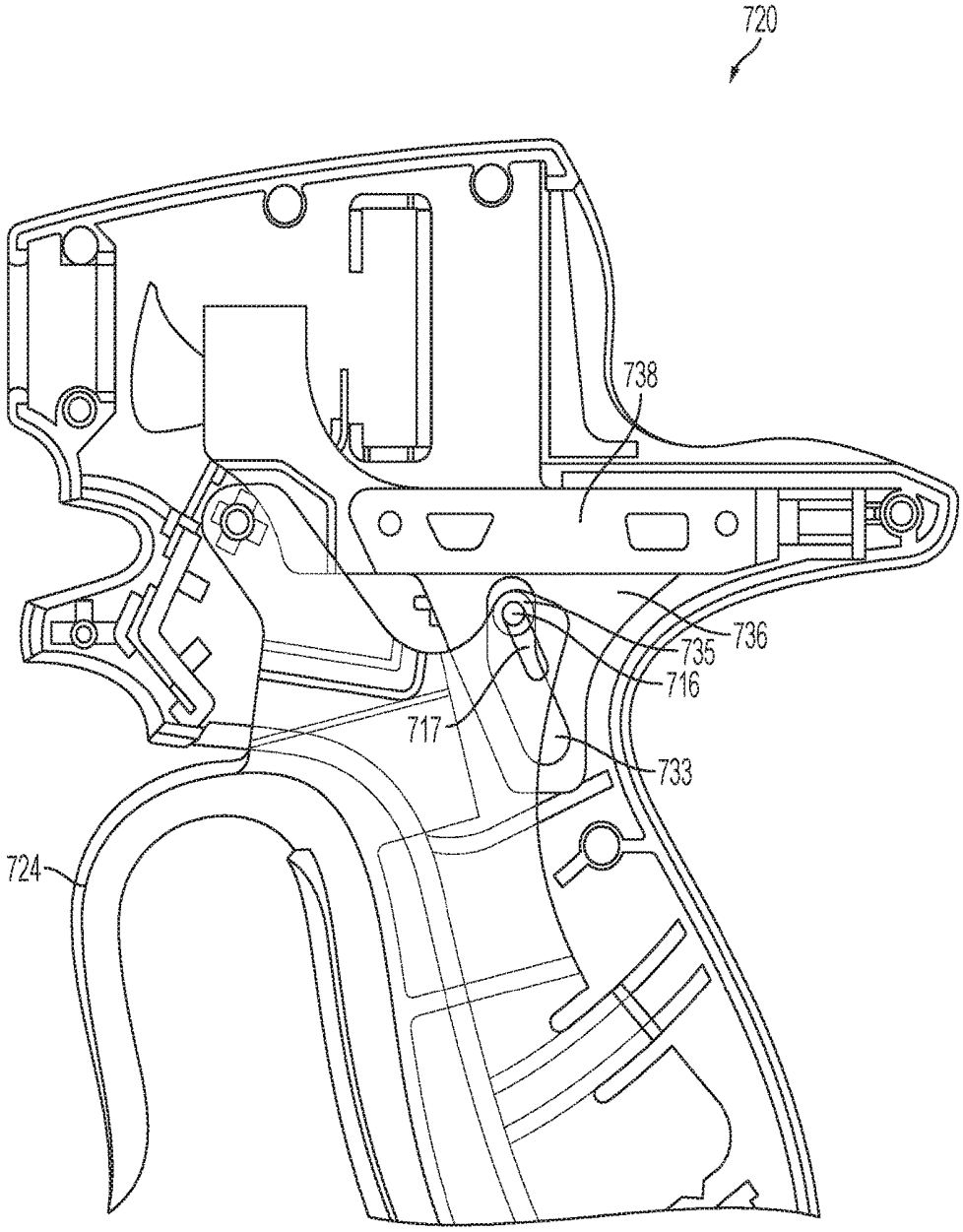

FIG. 15H

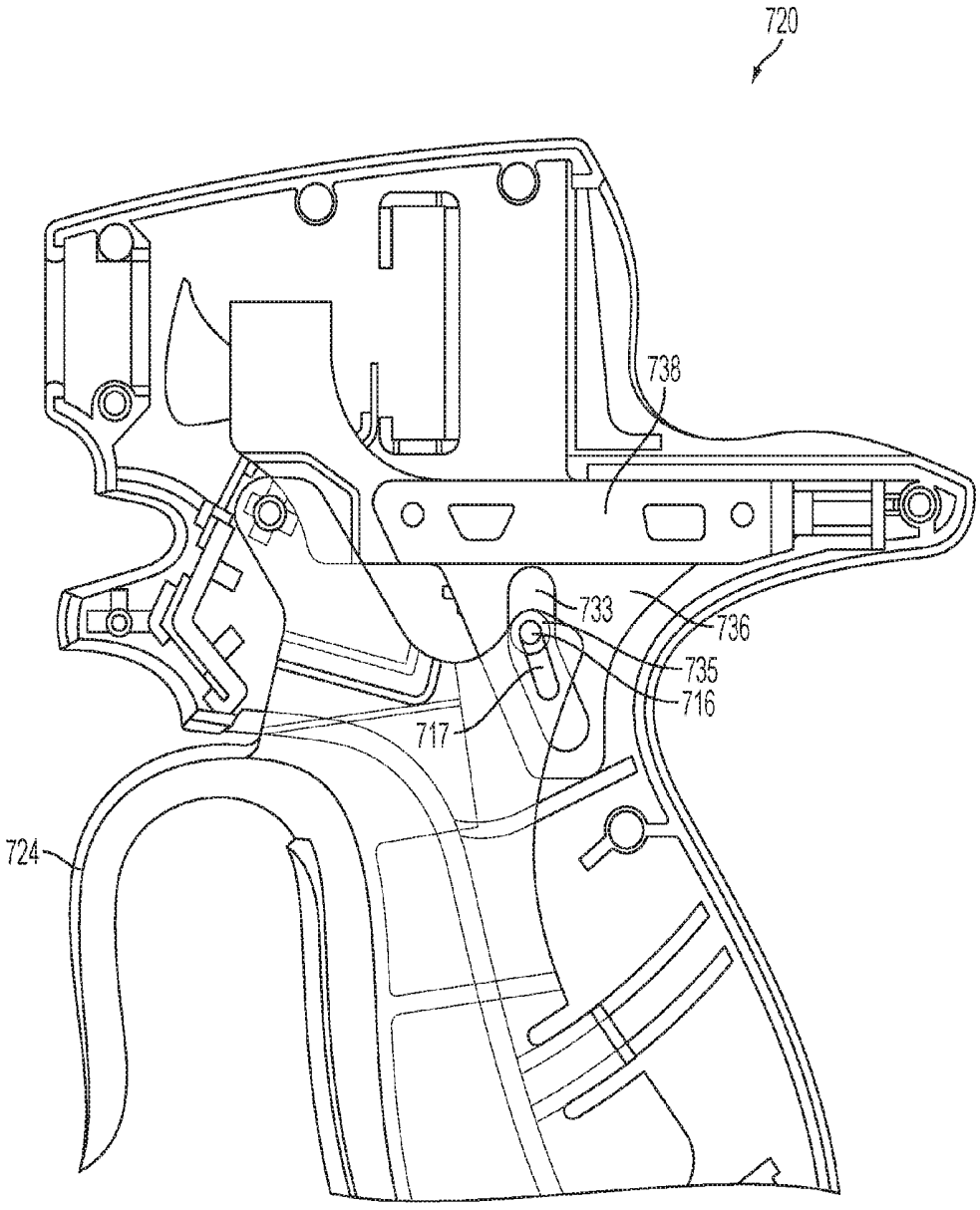

FIG. 15I

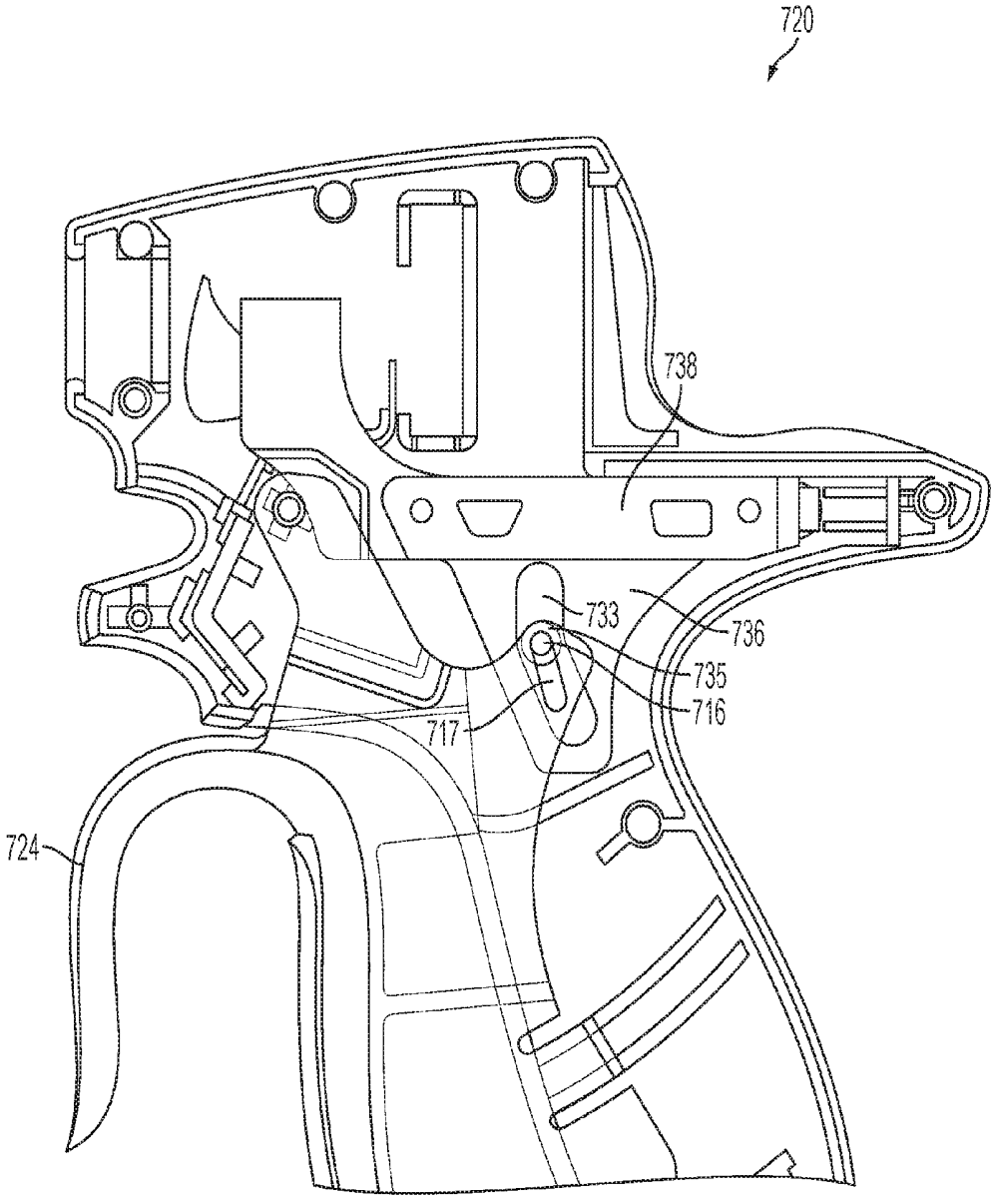

FIG. 15J

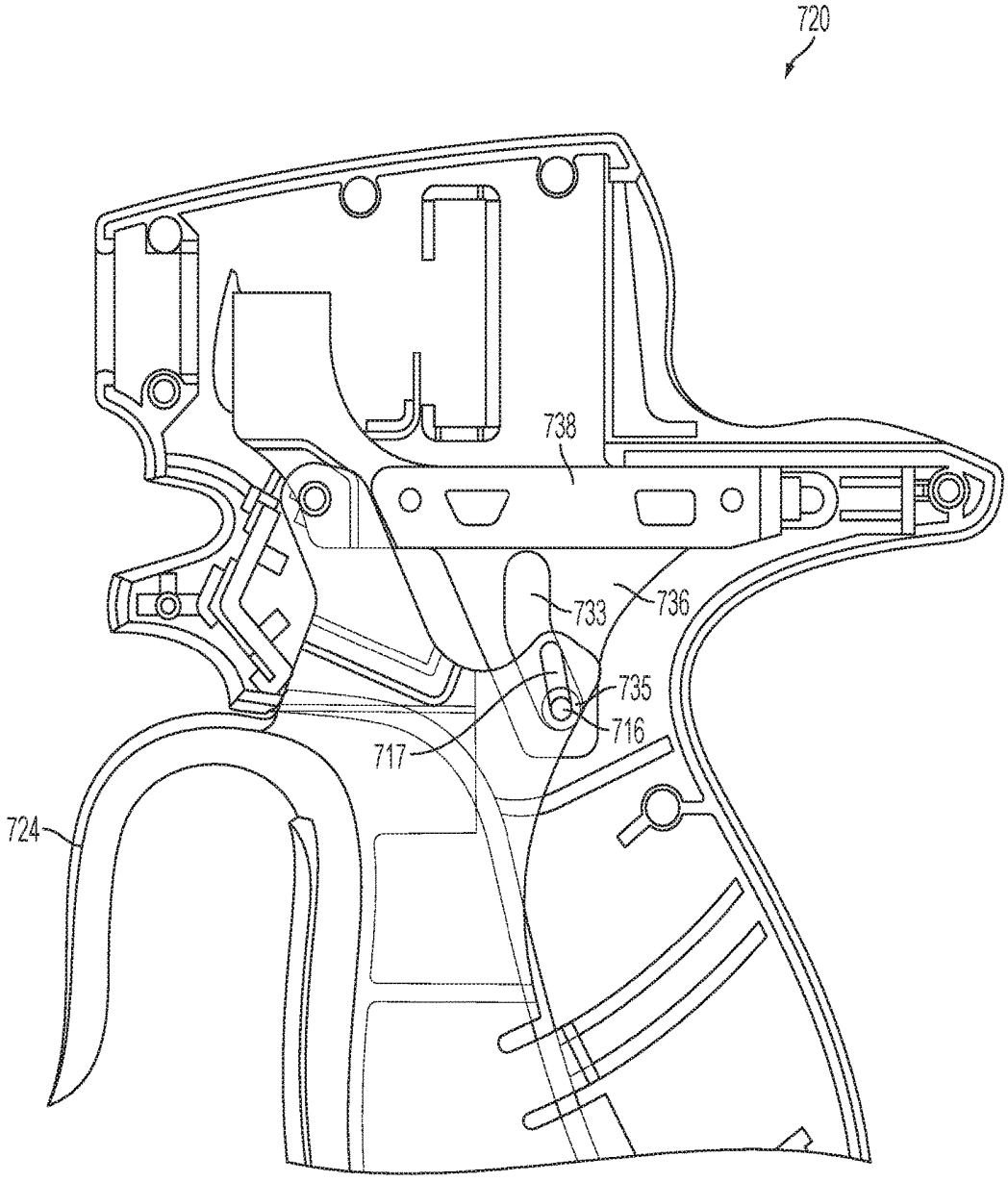

FIG. 15K

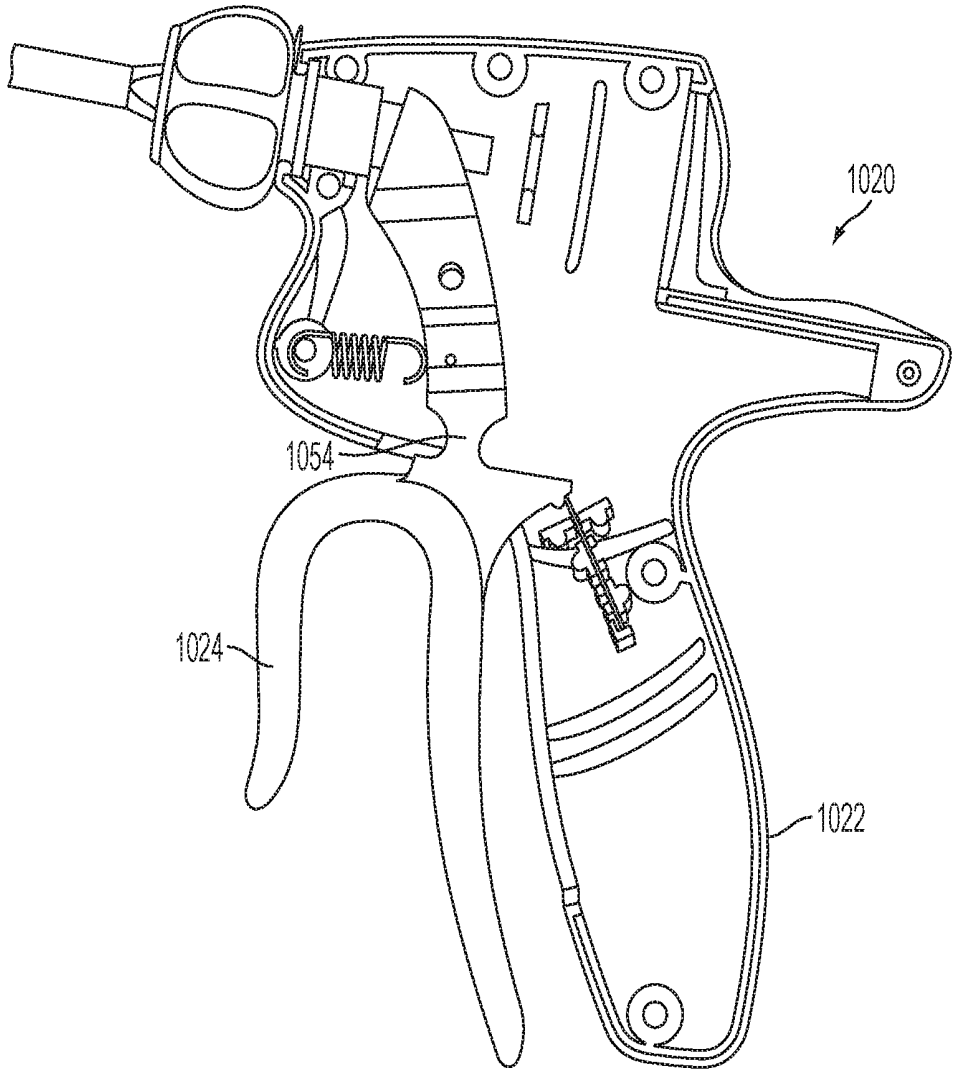

FIG. 16

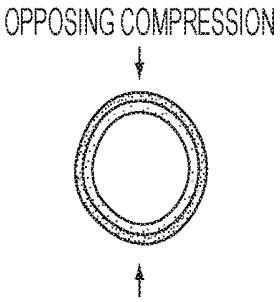

FIG. 17A

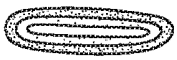

FIG. 17B

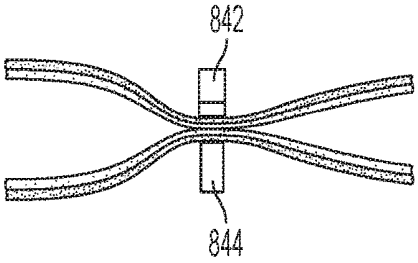

FIG. 17C

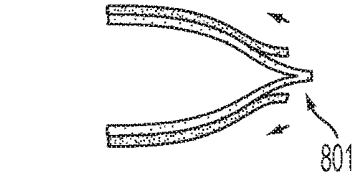

FIG. 17D

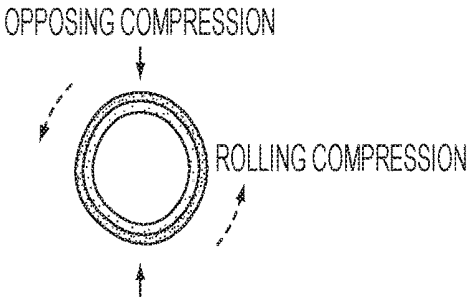

FIG. 17E

FIG. 17F

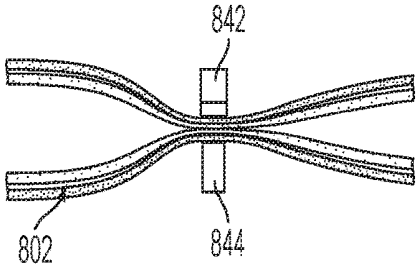

FIG. 17G

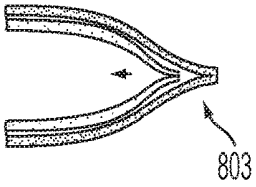

FIG. 17H

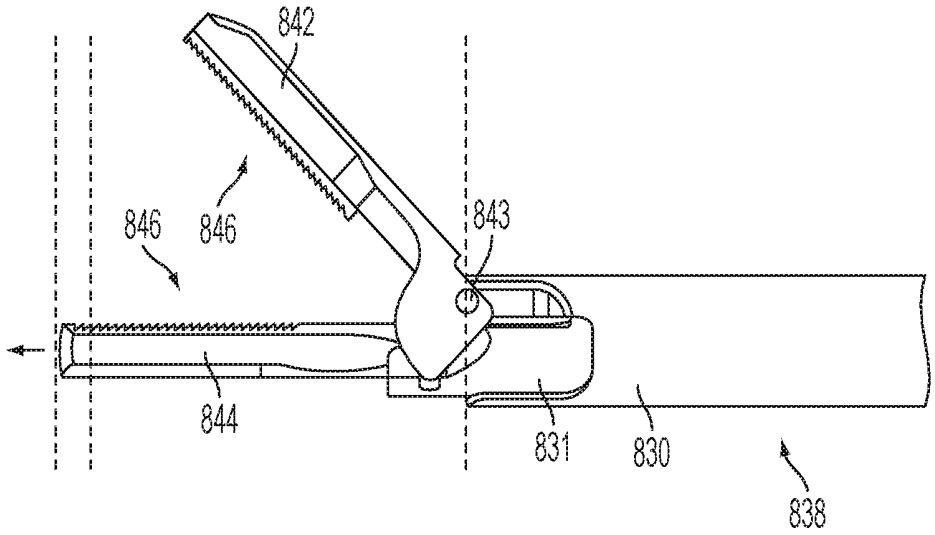

FIG. 18A

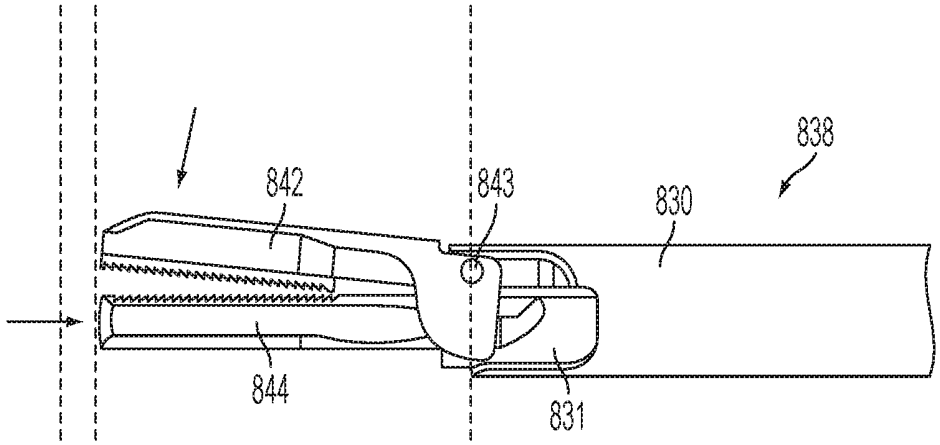

FIG. 18B

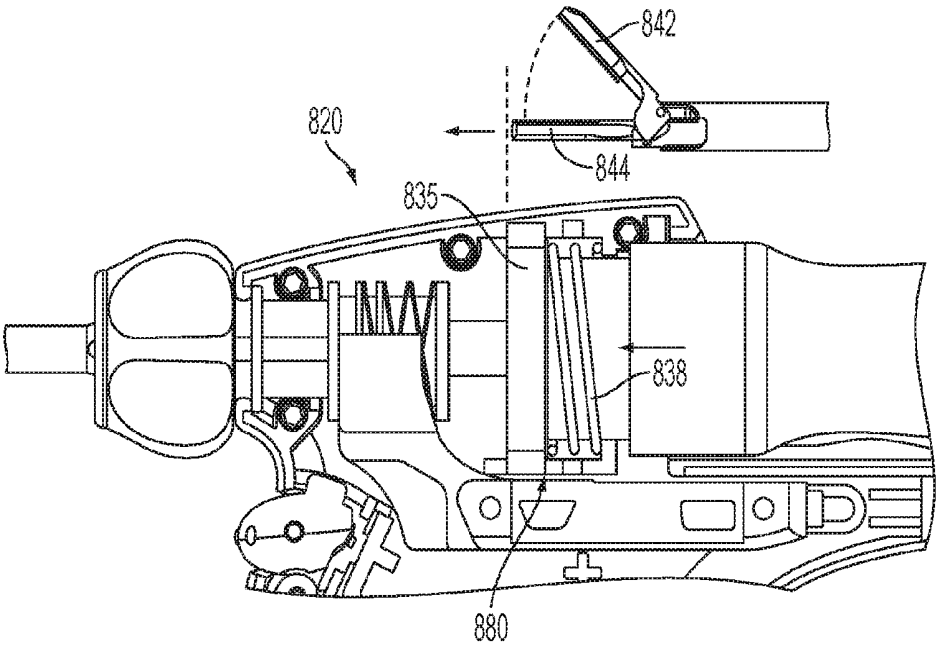

FIG. 19A

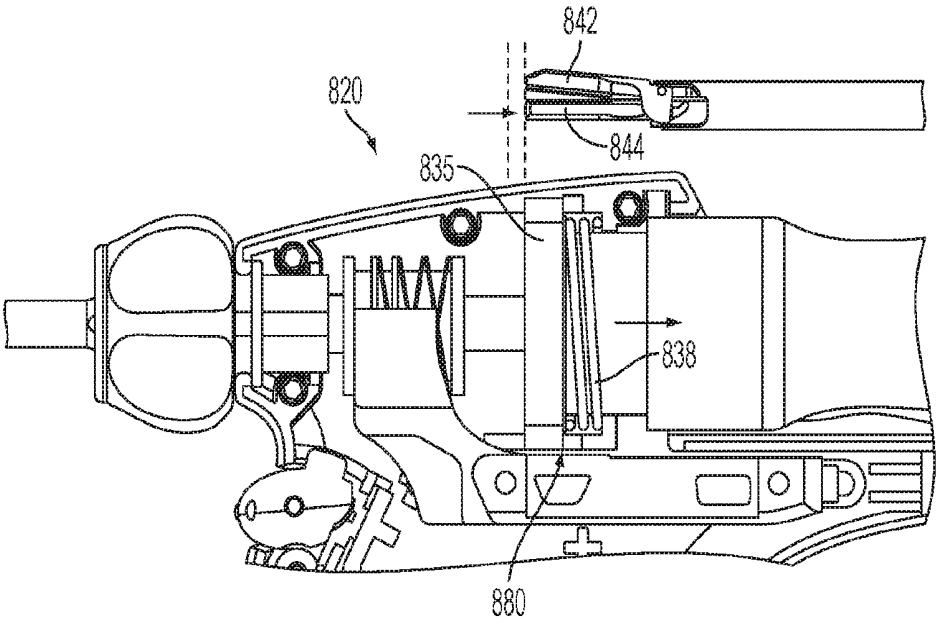

FIG. 19B

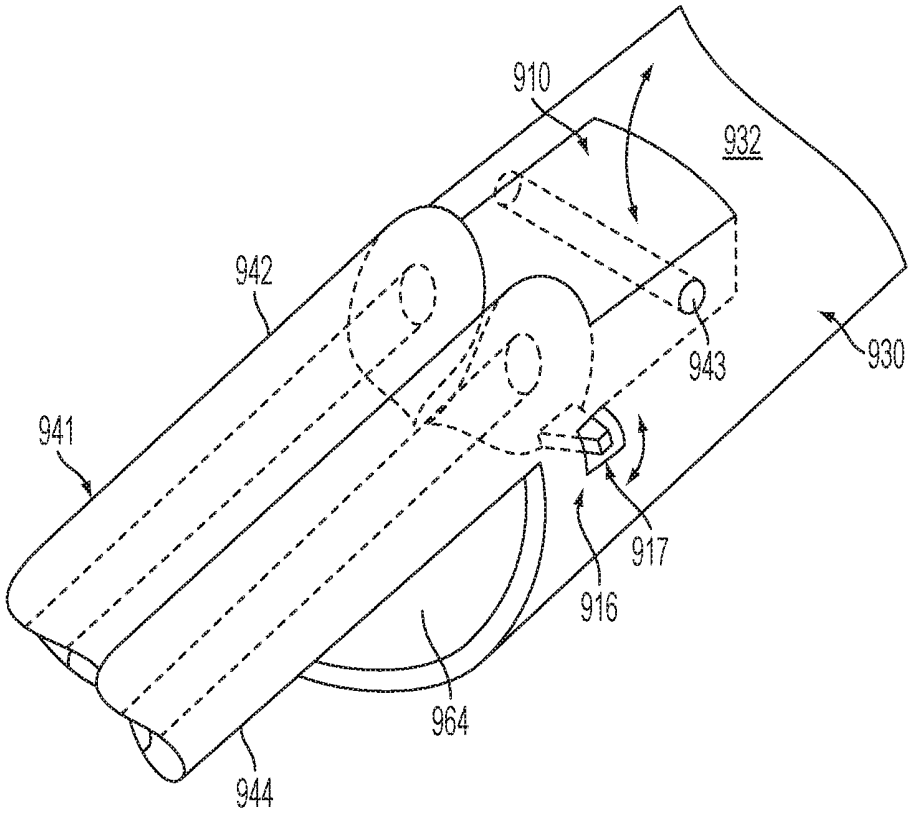

FIG. 20

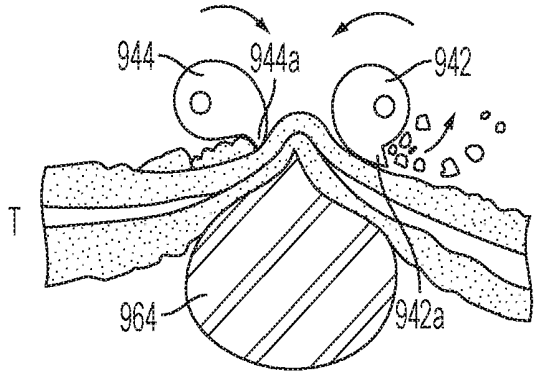

FIG. 21A

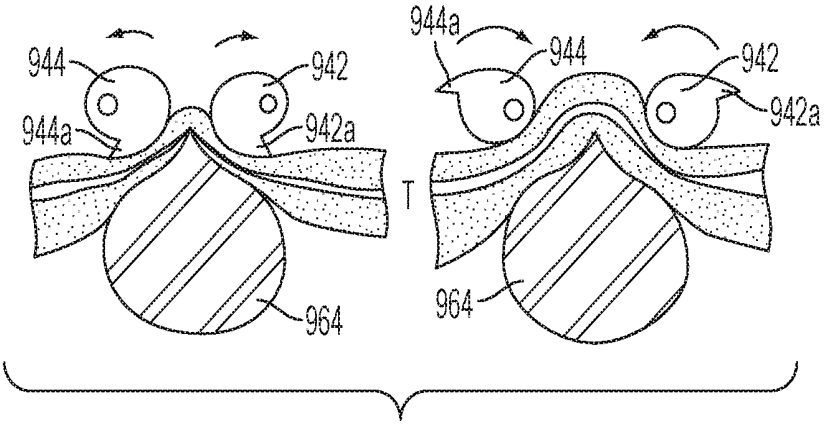

FIG. 21B

END EFFECTOR WITH A CLAMP ARM ASSEMBLY AND BLADE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application claiming priority under 35 U.S.C. §121 to U.S. patent application Ser. No. 13/833,706, entitled SURGICAL INSTRUMENT WITH MULTIPLE CLAMPING MECHANISMS, filed Mar. 15, 2013, which issued as U.S. Pat. No. 9,241,728 on Jan. 26, 2016, the entire disclosure of which is hereby incorporated by reference herein.

BACKGROUND

1. Field of the Invention

The present application generally relates to medical devices and methods, and in particular, surgical instruments configured to weld and/or incise tissue.

2. Description of the Related Art

In various circumstances, a surgical instrument can be configured to apply energy to tissue in order to treat and/or destroy the tissue. In certain circumstances, a surgical instrument can comprise one or more electrodes which can be positioned against and/or positioned relative to the tissue such that electrical current can flow through the electrodes and into the tissue. The surgical instrument can further comprise an electrical input, a supply conductor electrically coupled with the electrodes, and/or a return conductor which can be configured to allow current to flow from the electrical input, through the supply conductor, through the electrodes and tissue, and then through the return conductor to an electrical output, for example. In various circumstances, the energy can generate heat within the captured tissue to create one or more hemostatic seals within the tissue. Such embodiments may be particularly useful for sealing blood vessels, for example. The surgical instrument can comprise an ultrasonic blade, connected to an ultrasonic transducer, to couple mechanical vibration to tissue and create one or more hemostatic seals and divide the tissue simultaneously. Such embodiments may be particularly useful for sealing and dividing blood vessels, for example. Furthermore, other energy modalities may be contemplated, but not limited to, microwave, laser, thermal, and high intensity focused ultrasound. The surgical instrument can further comprise a cutting member which can be moved relative to the tissue and electrodes in order to transect the tissue.

The foregoing discussion is intended only to illustrate various aspects of the related art in the field of the invention at the time, and should not be taken as a disavowal of claim scope.

SUMMARY

In various embodiments, a surgical instrument may generally comprise a shaft comprising a proximal end and a distal end, an ultrasonic waveguide at least partially positioned within the shaft, the waveguide having a proximal end and a distal end, an ultrasonically actuated blade positioned at the distal end of the waveguide, and a clamp arm assembly pivotally connected to the distal end of the shaft, wherein the clamp arm assembly comprises at least two camming members rotationally attached to a clamp arm, wherein the clamp arm is movable between an open position and a closed position relative to the blade to compress tissue intermediate the clamp arm and the blade when in the closed position, and wherein the at least two camming members rotate relative to the clamp arm to separate tissue layers when the clamp arm moves between the open position and the closed position.

In various embodiments, an end effector may generally comprise a blade, and a clamp arm assembly configured to pivot relative to the blade, wherein the clamp arm assembly comprises a clamp arm movable between an open position and a closed position to compress tissue or a vessel intermediate the clamp arm assembly and the blade when in the closed position, and at least one camming member rotationally attached to the clamp arm, wherein the at least one camming member is configured to rotate relative to the blade as the clamp arm moves from the open position to the closed position to separate layers of the tissue or the vessel.

In various embodiments, an end effector may generally comprise a blade, and a clamp arm assembly comprising a clamp arm movable between an open position and a closed position relative to the blade, and at least one camming member rotationally attached to the clamp arm, wherein the at least one camming member is configured to rotate relative to the blade as the clamp arm moves from the open position to the closed position.

BRIEF DESCRIPTION OF THE FIGURES

Various features of the embodiments described herein are set forth with particularity in the appended claims. The various embodiments, however, both as to organization and methods of operation, together with advantages thereof, may be understood in accordance with the following description taken in conjunction with the accompanying drawings as follows.

FIG. **1** includes a side elevational view of a surgical instrument according to various embodiments.

FIG. **2** includes a perspective view of the end effector of the device of FIG. **1**, in an open configuration according to various embodiments.

FIG. **3** includes another perspective view of the end effector of the device of FIG. **1**, in an open configuration according to various embodiments.

FIG. **4** includes a cross-sectional end view of the end effector of FIG. **2**, in a closed configuration and with the blade in a distal position according to various embodiments.

FIG. **4**A includes a surgical instrument comprising an end effector comprising roller bearings according to various embodiments.

FIG. **5** includes a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIG. **6** includes a surgical instrument comprising a trigger bypass mechanism according to various embodiments.

FIG. **7** includes the trigger bypass mechanism illustrated in FIG. **6**.

FIGS. **8**A-G include a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIGS. **9**A-G include a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIGS. **10**A-D include a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIGS. **11**A-C include a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIG. **12** includes a cross sectional view of a rear yoke pin path in a surgical instrument according to various embodiments

FIG. **13** includes a cross sectional view of a rear yoke pin path in a surgical instrument according to various embodiments

FIGS. **14**A-C include a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIGS. **15**A-K include a surgical instrument comprising a trigger assembly in various positions according to various embodiments.

FIG. **16** includes a surgical instrument comprising a trigger assembly according to various embodiments.

FIGS. **17**A-H include cross-sectional views of a portion of a vessel subjected to a compressive force according to various embodiments.

FIGS. **18**A and **18**B include a surgical instrument comprising an end effector in various positions according to various embodiments.

FIGS. **19**A and **19**B include a side elevational view of the handle assembly of a surgical instrument with a housing half removed according to various embodiments.

FIG. **20** includes an end effector comprising rotational features according to various embodiments.

FIGS. **21**A and **21**B includes a camming member comprising a protrusion according to various embodiments

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate various embodiments of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION

Various embodiments are directed to apparatuses, systems, and methods for the treatment of tissue. Numerous specific details are set forth to provide a thorough understanding of the overall structure, function, manufacture, and use of the embodiments as described in the specification and illustrated in the accompanying drawings. It will be understood by those skilled in the art, however, that the embodiments may be practiced without such specific details. In other instances, well-known operations, components, and elements have not been described in detail so as not to obscure the embodiments described in the specification. Those of ordinary skill in the art will understand that the embodiments described and illustrated herein are non-limiting examples, and thus it can be appreciated that the specific structural and functional details disclosed herein may be representative and do not necessarily limit the scope of the embodiments, the scope of which is defined solely by the appended claims.

Reference throughout the specification to "various embodiments," "some embodiments," "one embodiment," or "an embodiment", or the like, means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases "in various embodiments," "in some embodiments," "in one embodiment," or "in an embodiment", or the like, in places throughout the specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. Thus, the particular features, structures, or characteristics illustrated or described in connection with one embodiment may be combined, in whole or in part, with the features structures, or characteristics of one or more other embodiments without limitation.

It will be appreciated that the terms "proximal" and "distal" may be used throughout the specification with reference to a clinician manipulating one end of an instrument used to treat a patient. The term "proximal" refers to the portion of the instrument closest to the clinician and the term "distal" refers to the portion located furthest from the clinician. It will be further appreciated that for conciseness and clarity, spatial terms such as "vertical," "horizontal," "up," and "down" may be used herein with respect to the illustrated embodiments. However, surgical instruments may be used in many orientations and positions, and these terms are not intended to be limiting and absolute.

Various embodiments of systems and methods relate to creating thermal "welds" or "fusion" within native tissue volumes. The alternative terms of tissue "welding" and tissue "fusion" may be used interchangeably herein to describe thermal treatments of a targeted tissue volume that result in a substantially uniform fused-together tissue mass, for example, in welding blood vessels that exhibit substantial burst strength immediately post-treatment. The strength of such welds is particularly useful for (i) permanently sealing blood vessels in vessel transection procedures; (ii) welding organ margins in resection procedures; (iii) welding other anatomic ducts wherein permanent closure is required; and also (iv) for performing vessel anastomosis, vessel closure or other procedures that join together anatomic structures or portions thereof. The welding or fusion of tissue as disclosed herein is to be distinguished from "coagulation", "hemostasis" and other similar descriptive terms that generally relate to the collapse and occlusion of blood flow within small blood vessels or vascularized tissue. For example, any surface application of thermal energy can cause coagulation or hemostasis-but does not fall into the category of "welding" as the term is used herein. Such surface coagulation does not create a weld that provides any substantial strength in the treated tissue.

At the molecular level, the phenomena of truly "welding" tissue as disclosed herein may result from the thermally-induced denaturation of collagen and other protein molecules in a targeted tissue volume to create a transient liquid or gel-like proteinaceous amalgam. A selected energy density is provided in the targeted tissue to cause hydrothermal breakdown of intra- and intermolecular hydrogen crosslinks in collagen and other proteins. The denatured amalgam is maintained at a selected level of hydration-without desiccation-for a selected time interval which can be very brief. The targeted tissue volume is maintained under a selected very high level of mechanical compression to insure that the unwound strands of the denatured proteins are in close proximity to allow their intertwining and entanglement. Upon thermal relaxation, the intermixed amalgam results in protein entanglement as re-crosslinking or renaturation occurs to thereby cause a uniform fused-together mass.

Ultrasonic surgical instruments are finding increasingly widespread applications in surgical procedures by virtue of the unique performance characteristics of such instruments. Depending upon specific instrument configurations and operational parameters, ultrasonic surgical instruments can provide substantially simultaneous cutting of tissue and hemostasis by coagulation, desirably minimizing patient trauma. The cutting action is typically effected by an end effector or blade tip at the distal end of the instrument, which transmits ultrasonic energy to tissue brought into contact with the end effector. Ultrasonic instruments of this nature

can be configured for open surgical use, laparoscopic or endoscopic surgical procedures including robotic-assisted procedures.

Ultrasonic surgical instruments have been developed that include a clamp mechanism to press tissue against the blade of the end effector in order to couple ultrasonic energy to the tissue of a patient. Such an arrangement (sometimes referred to as a clamp coagulator shears or an ultrasonic transector) is disclosed in U.S. Pat. Nos. 5,322,055, 5,873,873, and 6,325,811, all of which are incorporated herein by reference in their entireties. The surgeon activates the clamp arm to press the clamp pad against the blade by squeezing on the handgrip or handle.

Some current ultrasonic shears devices utilize tissue engaging pads or clamp pads that close in parallel with the surface of the blade. By this construction, tissue is grasped between the clamp pad and the blade. The clamp pad may comprise a low coefficient of friction polymer material, or any other suitable low-friction material. Although these designs have been adequate, they tend to suffer from longevity issues since the clamp pads tend to deteriorate over long surgical procedures. Additionally, newer designs of clamp coagulator shears increase blade amplitude and/or the loading of the clamp pad against the tissue and blade and overwhelm the clamp pad material, resulting in less than required clamp pad life. The clamp pad material limits the amount of force that may be applied against the tissue and blade, which in turn limits the tissue thickness or vessel size that some current clamp coagulator shears may effectively cut and coagulate.

It would be desirable to provide electrosurgical instruments that overcome some of the deficiencies of current ultrasonic surgical instruments. Various embodiments of the electrosurgical instruments described herein may overcome some of those deficiencies.

Enhancing the ability to seal vessels may be accomplished by placing the adventitial layers of the opposing sides of a coapted vessel in direct contact with each other. Preventing this direct contact is commonly the muscular (entima) layer of the vessel. The muscular layers may be "split" within a vessel without compromising the adventitia by applying a sufficient compressive force. The muscular layers may retract enough to allow direct adventitial contact. The direct adventitial seals demonstrate higher burst pressures. In various embodiments, an electrosurgical device may provide variable force control to allow the user to create a large compressive force for muscle separation and a smaller compressive force for application of ultrasonic energy and sealing and cutting.

In various embodiments, electrosurgical instruments may be configured to provide multiple trigger positions to deliver multiple levels of compressive force to the tissue. The compressive force may be generally established by a handle using one of two user-selectable clamping modes to provide variable force control: one for cutting and coagulating small blood vessels; and one for cutting and coagulating large blood vessels. The large vessel coagulating mode generally corresponds to a sequence where the end effector delivers a short-term high compressive force and then progresses to a position of lesser compressive force. For example, in various embodiments, the lesser compressive force may be about 50% to about 70% of the high compressive force. The high compressive force may compress a large vessel such that the inner layers of the vessel, i.e., the tunica intima and tunica media, are extruded and separated and only the outer layer of the vessel, i.e., the tunica adventitia, resides within the end effector.

Without wishing to be bound to any particular theory, it is believed that the adventitia contributes most significantly to the seal strength of an ultrasonically transected vessel, and the inner layers of the vessel contribute very little to the seal strength and, in fact, tend to flatten and structurally counteract the adventitia seal. Accordingly, electrosurgical instruments may be configured to provide a high compressive force to mechanically extrude the inner layers of the vessel and a low compressive force to allow direct adventitial contact and an adventitia-to-adventitia seal. Various embodiments of electrosurgical instruments described herein may provide certain advantages over current ultrasonic shears devices, including one or more of the following: obtaining a seal at a more manageable, lower clamping force; obtaining a seal at a lower generator drive power; lower generator power requirements; utilizing less durable clamp pad materials; improved large vessel sealing; improved clamp pad life; improved ergonomics by only using the high clamp force, which corresponds to high input force, when required; improved efficiency; and improved cost savings.

An electrosurgical instruments can be configured to supply energy, such as electrical energy, ultrasonic energy, and/or heat energy, for example, to the tissue of a patient. For example, various embodiments disclosed herein provide electrosurgical jaw structures adapted for transecting captured tissue between the jaws and for contemporaneously welding or sealing the captured tissue margins with controlled application of RF energy. In various embodiments, the electrosurgical jaw structures may be adapted to coagulate the captured tissues rather than weld the captured tissue. Electrosurgical instruments may also be configured to, for example, grasp, sever, and staple tissue. Electrosurgical instruments may be configured to supply other energy modalities and/or combinations thereof, such as, for example, microwave, laser, thermal, ultrasonic and high intensity focused ultrasound. All such arrangements and implementations are intended to be within the scope of this disclosure.

In various embodiments, referring to FIG. **1**, an electrosurgical instrument **10** may comprise a hand piece **20**, a shaft **30** extending distally from hand piece **20**, and an end effector **40** disposed at a distal end of shaft **30**. Hand piece **20** may comprise a pistol grip **22**, a pivoting trigger **24**, and an activation button **26**. Trigger **24** may be pivotable toward and away from pistol grip **22** to selectively actuate end effector **40** as will be described in greater detail below. Activation button **26** may be operable to selectively activate RF circuitry that is in communication with end effector **40**, as will also be described in greater detail below. In some versions, activation button **26** may also serve as a mechanical lockout against trigger **24**, such that trigger **24** cannot be fully actuated unless button **26** is being pressed simultaneously. Examples of how such a lockout may be provided are disclosed in one or more of the references cited herein. It should be understood that pistol grip **22**, trigger **24**, and button **26** may be modified, substituted, supplemented, etc. in any suitable way, and that the descriptions of such components herein are merely illustrative.

Shaft **30** may comprise any suitable cross-section, such as, for example, a cylindrical cross-section and/or rectangular cross-section. Shaft **30** may comprise an outer sheath **32** that extends from the hand piece **20**. A proximal end of shaft **30** may be attached to the hand piece **20**. In various embodiments, shaft **30** may be rotatable about the longitudinal axis defined by sheath **32**, relative to hand piece **20** via a knob **34**. Such rotation may provide rotation of end effector **40** and shaft **30** unitarily. In various embodiments,

knob **34** may be operable to rotate end effector **40** without rotating any portion of shaft **30**.

In various embodiments, end effector **40** may comprise a first jaw **42** and a second jaw **44**. Second jaw **44** may be substantially fixed relative to shaft **30**; while first jaw **42** may pivot relative to shaft **30**, toward and away from second jaw **42**. In various embodiments, actuators, such as, for example, rods and cables, may extend through sheath **32** and be joined with first jaw **42** at a pivotal coupling **43** such that longitudinal movement of the actuator through shaft **30** provides pivoting of first jaw **42** relative to shaft **30** and relative to second jaw **44**. In various embodiments, jaws **42**, **44** may comprise any other suitable kind of movement and may be actuated in any other suitable fashion. For example, as will be described in greater detail below, jaws **42**, **44** may be actuated and thus closed by longitudinal translation of a firing beam **60** such that actuators may simply be eliminated in certain embodiments.

In various embodiments, referring to FIGS. **2-4**, first jaw **42** defines a longitudinally extending elongate slot **46** and second jaw **44** defines a longitudinally extending elongate slot **48**. The top side of first jaw **42** may comprise a first electrode surface **50** and the underside of second jaw **44** may comprise a second electrode surface **52**. Electrode surfaces **50**, **52** may be in communication with an electrical source **80** via one or more conductors (not shown) that extend along the length of shaft **30**. Electrical source **80** may be operable to deliver RF energy to first electrode surface **50** at a first polarity and to second electrode surface **52** at a second (opposite) polarity, such that RF current flows between electrode surfaces **50**, **52** and thereby through tissue captured between jaws **42**, **44**. In various embodiments, firing beam **60** may serve as an electrical conductor that cooperates with electrode surfaces **50**, **52**, e.g., as a ground return for delivery of bipolar RF energy captured between jaws **42**, **44**. Electrical source **80** may be external to electrosurgical instrument **10** or may be integral with electrosurgical instrument **10**, e.g., in hand piece **20**. A controller **82** may regulate delivery of power from electrical source **80** to electrode surfaces **50**, **52**. Controller **82** may be external to electrosurgical instrument **10** or may be integral with electrosurgical instrument **10**, e.g., in hand piece **20**. It should also be understood that electrode surfaces **50**, **52** may be provided in a variety of alternative locations, configurations, and relationships.

Referring to FIG. **4**, the lower side of first jaw **42** may comprise a longitudinally extending recess **58** adjacent to slot **46** and the upper side of second jaw **44** may comprise a longitudinally extending recess **58** adjacent to slot **48**. FIG. **2** shows the upper side of first jaw **42** including a plurality of teeth serrations **46**. It should be understood that the lower side of second jaw **44** may include complementary serrations that nest with serrations **46** to enhance gripping of tissue captured between jaws **42**, **44** without necessarily tearing the tissue. FIG. **3** shows an example of serrations **46** in first jaw **42** as mainly recesses; with serrations **48** in second jaw **44** as mainly protrusions. Of course, serrations **46**, **48** may take any other suitable form or may be simply omitted altogether. It should also be understood that serrations **46**, **48** may be formed of an electrically non-conductive, or insulative, material, such as plastic, glass, and/or ceramic, for example, and may include a treatment such as polytetrafluoroethylene, a lubricant, or some other treatment to substantially prevent tissue from getting stuck to jaws **42**, **44**.

When jaws **42**, **44** are in a closed position, shaft **30** and end effector **40** may be sized and configured to fit through trocars having various inner diameters, such that electrosurgical instrument **10** may be usable in minimally invasive surgery, though of course electrosurgical instrument **10** could also be used in open and endoscopic procedures if desired. By way of example only, shaft **30** and end effector **40** may present an outer diameter of approximately 5 mm when jaws **42**, **44** are in a closed position. Alternatively, shaft **30** and end effector **40** may present any other suitable outer diameter, such as, for example, from about 2 mm to about 20 mm.

In various embodiments, either jaw **42**, **44** or both of jaws **42**, **44** may include at least one port, passageway, conduit, and/or other feature that is operable to draw steam, smoke, and/or other gases from the surgical site. Such a feature may be in communication with a source of suction, such as, for example, an external source or a source within hand piece **20**. In addition, end effector **40** may comprise one or more tissue cooling features (not shown) that reduce the degree or extent of thermal spread caused by end effector **40** on adjacent tissue when electrode surfaces **50**, **52** are activated. Various suitable forms that such cooling features may take will be apparent to those of ordinary skill in the art in view of the teachings herein.

In various embodiments, end effector **40** may comprise one or more sensors (not shown) that are configured to sense a variety of parameters at end effector **40**, including but not limited to, jaw position, temperature of adjacent tissue, electrical resistance or impedance of adjacent tissue, voltage across adjacent tissue, forces exerted on jaws **42**, **44** by adjacent tissue. In various embodiments, end effector **40** may include one or more positive temperature coefficient (PTC) thermistor bodies **54**, **56**, e.g., a PTC polymer, located adjacent to electrodes **50**, **52** and/or elsewhere. Data from sensors may be communicated to controller **82**. Controller **82** may process such data in a variety of ways. In various embodiments, controller **82** may modulate or otherwise change the RF energy being delivered to electrode surfaces **50**, **52**, based at least in part on data acquired from one or more sensors at end effector **40**. In various embodiments, controller **82** may alert the user to one or more conditions via an audio and/or visual feedback device, e.g., speaker, lights, display screen, etc., based at least in part on data acquired from one or more sensors at end effector **40**. It should also be understood that some kinds of sensors need not necessarily be in communication with controller **82**, and may simply provide a purely localized effect at end effector **40**. In various embodiments, PTC thermistor bodies **54**, **56** at end effector **40** may automatically reduce the energy delivery at electrode surfaces **50**, **52** as the temperature of the tissue and/or end effector **40** increases, thereby reducing the likelihood of overheating. In various embodiments, a PTC thermistor element may be in series with power source **80** and electrode surface **50**, **52**; and the PTC thermistor may provide an increased impedance to reduce flow of current in response to temperatures exceeding a threshold. Furthermore, it should be understood that electrode surfaces **50**, **52** may be used as sensors, e.g., to sense tissue impedance. Various kinds of sensors that may be incorporated into electrosurgical instrument **10** will be apparent to those of ordinary skill in the art in view of the teachings herein. Similarly various things that can be done with data from sensors, by controller **82** or otherwise, will be apparent to those of ordinary skill in the art in view of the teachings herein. Other suitable variations for end effector **40** will also be apparent to those of ordinary skill in the art in view of the teachings herein.

In various embodiments, referring to FIGS. **2-4**, electrosurgical instrument may comprise a firing beam **60** that is longitudinally movable along part of the length of end effector **40**. Firing beam **60** may be coaxially positioned within shaft **30**, extends along the length of shaft **30**, and translates longitudinally within shaft **30**, though it should be understood that firing beam **60** and shaft **30** may have any other suitable relationship. Firing beam **60** may comprise a sharp distal blade **64**, an upper flange **62**, and a lower flange **66**. As illustrated in FIG. **4**, distal blade **64** extends through slots **46**, **48** of jaws **42**, **44**, with upper flange **62** being located above jaw **44** in recess **59** and lower flange **66** being located below jaw **42** in recess **58**. The configuration of distal blade **64** and flanges **62**, **66** provides an "I-beam" type of cross section at the distal end of firing beam **60**. In various embodiments, flanges **62**, **66** may extend longitudinally along any suitable length of firing beam **60**. In various embodiments, flanges **62**, **66** may be positioned along the exterior of jaws **42**, **44**, or disposed in corresponding slots formed within jaws **42**, **44**. For example, each jaw **42**, **44** may define a "T"-shaped slot, with portions of distal blade **64** being disposed in one vertical portion of each "T"-shaped slot and with flanges **62**, **66** being disposed in the horizontal portions of the "T"-shaped slots. Referring to FIG. **4**A, in various embodiments, distal blade **64** may comprise at least one roller bearing **38** to compress tissue T and/or fracture calcium formed within or externally to the vessel. Roller bearing **38** may comprise a conical cylinder have a decreasing diameter laterally away from distal blade **64**, as shown in FIG. **4**A. In various embodiments, roller bearing **38** may comprise a conical cylinder have a increasing diameter laterally away from distal blade **64**. In various embodiments, roller bearing **38** may comprise a straight cylinder. In various embodiments, roller bearing **38** may comprise a curved cross-sectional shape, such as, for example, a circle and an ellipse. As shown in FIG. **4**A, roller bearings **38** may be positioned on opposing sides of distal blade **64** intermediate jaws **42**, **44**. In various embodiments, distal blade **64** may comprise a pin (not shown) to rotate roller bearing **38** relative to distal blade **64**. In various embodiments, distal blade may comprise a vertical slot including a pin slideably disposed in the vertical slot to rotate roller bearing **38** and/or move roller bearing **38** perpendicularly relative to distal blade **64** Various other suitable configurations and relationships will be apparent to those of ordinary skill in the art in view of the teachings herein.

Distal blade **64** may be substantially sharp, such that distal blade **64** may readily sever tissue that is captured between jaws **42**, **44**. Distal blade **64** may be electrically grounded to provide a return path for RF energy as described elsewhere herein. In various embodiments, distal blade **64** may serve as an active electrode. In various embodiments, distal blade **64** may be selectively energized with ultrasonic energy, such as, for example, harmonic vibrations at about 55.5 kHz.

In various embodiments, the "I-beam" type of configuration of firing beam **60** may provide closure of jaws **42**, **44** as firing beam **60** is advanced distally. In particular, flange **62** urges jaw **44** pivotally toward jaw **42** as firing beam **60** is advanced from a proximal position, as shown in FIGS. **1-3**, to a distal position, as shown in FIG. **4**, by bearing against recess **59** formed in jaw **44**. This closing effect on jaws **42**, **44** by firing beam **60** may occur before distal blade **64** reaches tissue captured between jaws **42**, **44**. Such staging of encounters by firing beam **60** may reduce the force required to squeeze grip **24** to actuate firing beam **60** through a full firing stroke. In other words, in various embodiments, firing beam **60** may have already overcome an initial resistance required to substantially close jaws **42**, **44** on tissue before encountering resistance from severing the tissue captured between jaws **42**, **44**. Of course, any other suitable staging may be provided.

In various embodiments, flange **62** may be configured to cam against a ramp feature at the proximal end of jaw **44** to open jaw **42** when firing beam **60** is retracted to a proximal position and to hold jaw **42** open when firing beam **60** remains at the proximal position. This camming capability may facilitate use of end effector **40** to separate layers of tissue, to perform blunt dissections, etc., by forcing jaws **42**, **44** apart from a closed position. In various embodiments, jaws **42**, **44** may be resiliently biased to an open position by a spring or other type of resilient feature. While jaws **42**, **44** close or open as firing beam **60** is translated, it should be understood that other embodiments may provide independent movement of jaws **42**, **44** and firing beam **60**. In various embodiments, one or more cables, rods, beams, or other features may extend through shaft **30** to selectively actuate jaws **42**, **44** independently of firing beam **60**. Such jaw **42**, **44** actuation features may be separately controlled by a dedicated feature of hand piece **20**. In various embodiments, such jaw actuation features may be controlled by trigger **24** in addition to having trigger **24** control firing beam **60**. It should also be understood that firing beam **60** may be resiliently biased to a proximal position, such that firing beam **60** retracts proximally when a user relaxes their grip on trigger **24**.

In various embodiments, in use, end effector **40** may be inserted into a patient via a trocar to a desired position and orientation relative to an anatomical structure within the patient. Two layers of tissue of the anatomical structure are then captured between jaws **42**, **44** by squeezing trigger **24** toward pistol grip **22**. Such layers of tissue may be part of the same natural lumen defining anatomical structure, such as, for example, blood vessel, portion of gastrointestinal tract, portion of reproductive system, etc., in a patient. In various embodiments, one tissue layer may comprise the top portion of a blood vessel and the other tissue layer may comprise the bottom portion of the blood vessel, along the same region of length of the blood vessel. In various embodiments, the fluid path through the blood vessel before use of electrosurgical instrument **10** may be perpendicular to the longitudinal axis defined by end effector **40**. The lengths of jaws **42**, **44** may be oriented perpendicular to or at least generally transverse to the length of the blood vessel. As described above, flanges **62**, **66** cammingly act to pivot jaw **44** toward jaw **42** when firing beam **60** is actuated distally by squeezing trigger **24** toward pistol grip **22**.

In various embodiments, with tissue layers captured between jaws **42**, **44**, firing beam **60** may continue to advance distally by the user squeezing trigger **24** toward pistol grip **22**. As firing beam **60** advances distally, distal blade **64** simultaneously severs the clamped tissue layers, resulting in separated upper layer portions being apposed with respective separated lower layer portions. This results in a blood vessel being cut in a direction that is generally transverse to the length of the blood vessel. It should be understood that the presence of flanges **62**, **66** immediately above and below jaws **42**, **44**, respectively, may help keep jaws **42**, **44** in a closed and tightly clamping position. In particular, flanges **62**, **66** may help maintain a significantly compressive force between jaws **42**, **44**. With severed tissue layer portions being compressed between jaws **42**, **44**, electrode surfaces **50**, **52** may be activated with bipolar RF energy by the user depressing activation button **26**. In various embodiments, electrodes **50**, **52** may be selectively

coupled with power source **80**, for example by the user depressing button **26**, such that electrode surfaces **50**, **52** of jaws **42**, **44** are activated with a common first polarity while firing beam **60** is activated at a second polarity that is opposite to the first polarity. Thus, a bipolar RF current flows between firing beam **60** and electrode surfaces **50**, **52** of jaws **42**, **44** through the compressed regions of severed tissue layer portions. In various embodiments, electrode surface **50** has one polarity while electrode surface **52** and firing beam **60** both have the other polarity. Bipolar RF energy may be delivered by power source **80** to thermally weld the tissue layer portions on one side of firing beam **60** together and the tissue layer portions on the other side of firing beam **60** together.

In certain circumstances, the heat generated by activated electrode surfaces **50**, **52** can denature the collagen within the tissue layer portions and, in cooperation with compressive force provided by jaws **42**, **44**, the denatured collagen can form a seal within the tissue layer portions. Thus, the severed ends of the natural lumen defining anatomical structure are hemostatically sealed shut, such that the severed ends will not leak bodily fluids. In various embodiments, electrode surfaces **50**, **52** may be activated with bipolar RF energy before firing beam **60** begins to translate distally and thus before the tissue is even severed. For example, such timing may be provided in versions where button **26** serves as a mechanical lockout relative to trigger **24** in addition to serving as a switch between power source **80** and electrode surfaces **50**, **52**.

While several of the teachings below are described as variations to electrosurgical instrument **10**, it should be understood that various teachings below may also be incorporated into various other types of devices. By way of example only, in addition to being readily incorporated into electrosurgical instrument **10**, various teachings below may be readily incorporated into the devices taught in any of the references cited herein, other types of electrosurgical devices, alternative energy modality devices, surgical staplers, surgical clip appliers, and tissue graspers, among various other devices. Other suitable devices into which the following teachings may be incorporated will be apparent to those of ordinary skill in the art in view of the teachings herein.

In various embodiments, the surgical instrument may comprise a two stage clamping mechanism configured to provide a higher clamp force to part the muscular layer of a blood vessel and a lower clamp force to seal across the adventitia. Without wishing to be bound to any particular theory, it is believe that the lower clamp force facilitates the proper heating rate to generate a higher strength seal across the adventitia layers relative to the higher clamp force.

In various embodiments, as shown in FIG. **5**, trigger **24** may be movable relative to hand piece **20** between an unactuated position and one or more actuated positions. In various embodiments, trigger **24** is movable through a first range of motion from an unactuated position **1** to a first actuated position **2**. In various embodiments, the first range of motion may be from an unactuated position **1** to position **3** and/or position **4**, and from position **3** and/or position **4** to first actuated position **2**. In various embodiments, trigger **24** is movable through a second range of motion from the first actuated position **2** to a second actuated position **3**. In various embodiments, trigger **24** is movable through a third range of motion from the second actuated position **3** to the unactuated position **1**. In various embodiments, trigger **24** is movable through a fourth range of motion from the unactuated position **1** to the third actuated position **4**. In various embodiments, trigger **24** is movable through a fifth range of motion from the third actuated position **4** to the unactuated position **1**. In various embodiments, the second actuated position **3** and third actuated position **4** may be the same or different.

In various embodiments, as described above, jaws **42**, **44** may apply compressive force, or coaptation force, to tissue captured therebetween. In various embodiments, jaws **42**, **44** may apply a first compressive force when trigger **24** is in the first actuated position **2**, a second compressive force when trigger **24** is in the second actuated position **3**, and a third compressive force when trigger **24** is in the third actuated position **4**. In various embodiments, referring to FIG. **5**, jaws **42**, **44** may be in a closed position characterized by a first compressive force when trigger **24** is in the first actuated position. In various embodiments, jaws **42**, **44** may be in a closed position characterized by a second compressive force when trigger **24** is in the second actuated position. In various embodiments, jaws **42**, **44** may be in a closed position characterized by a third compressive force when trigger **24** is in the third actuated position. In various embodiments, jaws **42**, **44** may be in an open position when trigger **24** is in the unactuated position.

In various embodiments, the first compressive force, second compressive force, and third compressive force may be different. In various embodiments, the first compressive force may be greater than the second compressive force. In various embodiments, the second compressive force may be greater than or equal to the third compressive force. In various embodiments, the first compressive force, second compressive force, and third compressive force may be individually selected from up to about 10 pounds per square inch ("psi"), such as, for example, about 1 psi to about 10 psi, about 2 psi to about 8 psi, about 3 psi to about 5 psi, and about 4 psi to about 6 psi. In various embodiments, the first compressive force may be about 4 psi to about 6 psi and the second compressive force may be about 2 psi to about 4 psi. In various embodiments, the first compressive force may be about 6 psi and the second compressive force may be about 4 psi. In various embodiments, the first compressive force may be about 4 psi and the second compressive force may be about 2 psi. In various embodiments, the first compressive force may be about 3 psi to about 5 psi and the second compressive force may be about 1 psi to about 3 psi. In various embodiments, the first compressive force may be about 5 psi and the second compressive force may be about 3 psi. In various embodiments, the first compressive force may be about 3 psi and the second compressive force may be about 1 psi. In various embodiments, jaws **42**, **44** may not apply compressive force to the tissue when trigger **24** is in the unactuated position.

In various embodiments, electrosurgical instrument **10** may comprise a trigger assembly configured to actuate end effector **40** to provide variable compressive force to tissue captured between jaws **42**, **44** when trigger **24** is in the first actuated position, second actuated position, and/or third actuated position, as described in greater detail below. In various embodiments, the trigger assembly may be configured to limit the compressive force to a first compressive force when trigger **24** is in the first actuated position and limit the compressive force to a second compressive force when trigger **24** is in the second actuated position. In various embodiments, the trigger assembly may be configured to limit the compressive force to a third compressive force when trigger **24** is in the third actuated position.

In various embodiments, electrosurgical instrument **10** may comprise a trigger assembly configured to actuate end

effector **40** to provide variable compressive force to tissue captured between jaws **42**, **44** through the first range of motion, second range of motion, and/or third range of motion, as described in greater detail below. In various embodiments, the trigger assembly may be configured to limit the compressive force to a first compressive force through the first range of motion and limit the compressive force to a second compressive force through the second range of motion. In various embodiments, the trigger assembly may be configured to limit the compressive force to a third compressive force through the fourth range of motion.

In various embodiments, the trigger assembly may comprise one or more detent features and/or other kind of feature(s) to provide an audible and/or tactile indication of the angular position of end effector about the longitudinal axis defined by sheath. Referring to FIG. **16**, in various embodiments, trigger **1024** may be pivotally attached to hand piece **1020**. Trigger **1024** may comprise a living hinge **1054**. In various embodiments, the living hinge may provide an audible and/or tactile indication to the user. For example, a trigger **1024** may be squeezed toward a pistol grip **1022** to actuate an end effector (not shown). The living hinge may provide the audible and/or tactile indication when trigger **1024** is in an actuated position. Various examples of devices comprising audible and/or tactile indicators are described in U.S. patent application Ser. No. 12/842,565, filed Jul. 23, 2010, entitled "ELECTROSURGICAL CUTTING AND SEALING INSTRUMENT", now U.S. Pat. No. 9,011,437, the disclosure of which is incorporated by reference herein.

In various embodiments, in use, end effector **40** may be inserted into a patient via a trocar to a desired position and orientation relative to an anatomical structure within the patient. In various embodiments, the user may operate trigger **24** through the first range of motion to capture two layers of tissue of the anatomical structure **42**, **44** when the anatomical structure has a diameter greater than about 3 mm. As described above, flanges **62**, **66** cammingly act to pivot jaw **44** toward jaw **42** when firing beam **60** is actuated distally by squeezing trigger **24** from the unactuated position to the first actuated position. Jaws **42**, **44** may apply the first compressive force to the layers of tissue captured therebetween when trigger **24** is in the first actuated position. In various embodiments, the first compressive force may compress the anatomical structure such that the inner layers of the anatomical structure are extruded and separated and only the outer layer of the anatomical structure is between jaws **42**, **44**. In various embodiments, activation button **26** may serve as a mechanical lockout against trigger **24** such that a bipolar RF current may not flow to electrode surfaces **50**, **52** when trigger **24** is in the first actuated position.

In various embodiments, the user may operate trigger **24** through the second range of motion to sever the clamped tissue layers between jaws **42**, **44** and thermally weld the severed tissue layers. As described above, distal blade **64** severs the clamped tissue layers as firing beam **60** continues to advance distally by the user squeezing trigger **24** from the first actuated position to the second actuated position. Jaws **42**, **44** may apply the second compressive force to the layers of tissue captured therebetween when trigger **24** is in the second actuated position. In various embodiments, the second compressive force may allow the inner severed tissue layer portions directly contact each other. With jaws **42**, **44** applying the second compressive force to the severed tissue layer portions, electrode surfaces **50**, **52** are activated with bipolar RF energy by the user depressing activation button **26**. As described above, a bipolar RF current flows between firing beam **60** and electrode surfaces **50**, **52** through the compressed regions of severed tissue layer portions to thermally welds the tissue layer portions on one side of firing beam **60** together and the tissue layer portions on the other side of firing beam **60** together. In various embodiments, the inner severed tissue layer portions of the anatomical structure may be thermally welded to each other. In various embodiments, activation button **26** may serve as a mechanical lockout against trigger **24** such that a bipolar RF current may not flow to electrode surfaces **50**, **52** unless trigger **24** is in the second actuated position and button **26** is being pressed simultaneously.

In various embodiments, in use, end effector **40** may be inserted into a patient via a trocar to a desired position and orientation relative to an anatomical structure within the patient. In various embodiments, the user may operate trigger **24** through the third range of motion to capture two layers of tissue of the anatomical structure **42**, **44** when the anatomical structure has a diameter up about 3 mm. As described above, flanges **62**, **66** cammingly act to pivot jaw **44** toward jaw **42** when firing beam **60** is actuated distally by squeezing trigger **24** from the unactuated position to the third actuated position. The user may continue to operate trigger **24** through the third range of motion to sever the clamped tissue layers between jaws **42**, **44** and thermally weld the severed tissue layers. As described above, distal blade **64** severs the clamped tissue layers as firing beam **60** continues to advance distally by the user squeezing trigger **24** from the first actuated position to the third actuated position. Jaws **42**, **44** may apply the third compressive force to the layers of tissue captured therebetween when trigger **24** is in the third actuated position.

With jaws **42**, **44** applying the third compressive force to the severed tissue layer portions, electrode surfaces **50**, **52** are activated with bipolar RF energy by the user depressing activation button **26**. As described above, a bipolar RF current flows between firing beam **60** and electrode surfaces **50**, **52** through the compressed regions of severed tissue layer portions to thermally welds the tissue layer portions on one side of firing beam **60** together and the tissue layer portions on the other side of firing beam **60** together. In various embodiments, activation button **26** may serve as a mechanical lockout against trigger **24** such that a bipolar RF current may not flow to electrode surfaces **50**, **52** unless button trigger is in the third actuated position and button **26** is being pressed simultaneously.

As described above, in various embodiments, electrosurgical instrument **10** may comprise a trigger assembly operable to control jaws **44**, **42** to thereby selectively compress tissue between jaws **42**, **44** at various compressive forces. Various embodiments, of the trigger assembly and other components of hand piece **20** are described in greater detail below, while further examples will be apparent to those of ordinary skill in the art in view of the teachings herein.

As described above, in various embodiments, firing beam **60** may be advanced distally by squeezing trigger **24** toward pistol grip **22** to the actuated position; while firing beam **60** may be retracted proximally by releasing trigger **24** and/or by actively moving trigger **24** away from pistol grip **22** to the unactuated position. In various embodiments, the trigger assembly may comprise a yoke to couple trigger **24** to firing beam **60**. In various embodiments, the trigger assembly may further comprise a link arm to couple trigger **24** to firing beam **60**. Of course, firing beam **60** may be moved in any other suitable fashion.

In various embodiments, an electrosurgical instrument may generally comprise a shaft comprising a proximal end and a distal end, an end effector extending from the distal

end of the shaft, wherein the end effector is operable to grasp tissue, a hand piece extending from the proximal end, wherein the hand piece comprises a pistol grip and a trigger assembly extending from the hand piece, wherein the trigger assembly comprises a trigger movable relative to the pistol grip between an unactuated position and a first actuated position and a second actuated position, wherein the trigger is operable to control the end effector to selectively grasp tissue at a first compressive force when the trigger is in the first actuated position and a second compressive force when the trigger is in the second actuated position.

In various embodiments, referring to FIGS. **6** and **7**, electrosurgical instrument **110** may generally comprise a bypass latch or over-center mechanism configured to define a bypass pathway **113** for trigger **124**. In various embodiments, hand piece **120** comprises pistol grip **122**, bypass latch leaf spring **111**, and a trigger assembly comprising trigger **124** pivotally attached to yoke **138**. Trigger **124** may comprise extension arm **125** comprising slot **113** defining a bypass pathway. One end of bypass latch leaf spring **111** may be fixedly attached to hand piece **120** and the free end of bypass latch leaf spring **111** may be disposed in slot **113**. As shown in FIG. **7**, the free end of bypass latch leaf spring **111** engages a first portion of slot **113** when trigger **124** is in the unactuated position **1**, a second portion of slot **113** when trigger **124** is in the first actuated position **2**, and a third portion of slot **113** when trigger **124** is in the second actuated position **3**.

In use for tissues having large diameters or thicknesses, bypass latch leaf spring **111** may be configured to pass through the first actuated position **2** and release to or near the second actuated position **3** when electrosurgical instrument **110** is activated to seal the tissue between jaws (not shown). In this way, the user crushes the tissue at the first actuated position **2** such that the inner tissue layers may be extruded laterally before end effector (not shown) is activated to cut and coagulate the outer tissue layers at the second actuated position **3**. In use for tissues have small diameters, bypass latch leaf spring **111** may be configured to pass directly to the third actuated position **4** when electrosurgical instrument **110** is activated to capture, cut, and/or seal the tissue between jaws (not shown). Without wishing to be bound to any particular theory, it is believed that electrosurgical instruments according to the present disclosure may utilize substantially similar power and clamp force to coagulate larger blood vessels as current ultrasonic shear devices use to coagulate smaller blood vessels.

In various embodiments, referring to FIGS. **8**A-G, hand piece **220** may generally comprise yoke **238** longitudinally slideable relative to hand piece **220**, trigger **224** slideably attached to yoke **238** and rotationally attached to hand piece **220**, and link arm **236** fixedly attached to yoke **238** and rotationally attached to hand piece **220**. Link arm **236** may comprise slot **233**. Trigger **224** may be coupled to link arm **236** by trigger pin **216**. One end of trigger pin **216** may be disposed in slot **233**. In various embodiments, slot **233** may comprise a radial feature configured to act as a cam and trigger pin **216** may be configured to act as a cam follower. In various embodiments, slot **233** may comprise a first portion and a second portion. In various embodiments, the first portion of slot **233** may comprise a radial feature and the second portion of slot **233** may comprise a longitudinal feature. For example, as shown in FIG. **8**A, slot **233** may comprise an L-shape wherein the first portion of slot **233** a extends proximally and radially from a plane including the longitudinal axis of hand piece **220**, and the first portion of slot **233** extends parallel to the plane including the longitudinal axis of hand piece **220**.

In use, referring to FIGS. **8**A-G, when trigger **224** moves from an unactuated position (FIG. **8**A) through the first range of motion (FIGS. **8**B, **8**C) to the first actuated position (FIG. **8**C), trigger pin **216** slides along the first portion of slot **233** to convert the movement of trigger **224** into proximal linear movement of yoke **238**. Trigger **224** may continue to move from the first actuated position through a second range of motion (FIG. **8**D) to the second actuated position (FIG. **8**D) when trigger pin **216** slides along a second portion of slot **233** to convert the movement of trigger **224** into distal linear movement of yoke **238**. In various embodiments, yoke **238** may travel a first distance through the first range of motion and a second distance through a second range of motion. In various embodiments, the first distance may be greater than or equal to the second distance. In various embodiments, the difference between the first distance and second distance may decrease the compressive force applied to captured tissue from the first compressive force to the second compressive force.

Referring to FIGS. **8**D-**8**G, when trigger **224** moves from the second actuated position (FIG. **8**D) through the third range of motion (FIGS. **8**E-G) to the unactuated position, a spring (not shown) may return trigger **224** to an unactuated position where it is pivoted away from the longitudinal axis. In various embodiments, referring to FIG. **8**E, trigger **224** is pivotable about a pivot point that is fixed relative to hand piece **220**. When trigger **224** rotates away from the longitudinal axis, trigger pin **216** slides along the second portion of slot **233** to the first portion of slot **233**. As shown in FIG. **8**F, as trigger **224** continues to rotate away from the longitudinal axis, trigger pin **216** slides along the first portion of slot **233** to convert the movement of trigger **224** into proximal linear movement of yoke **238**. The unactuated position is illustrated in FIG. **8**G.

In various embodiments, the trigger assembly may comprise mechanical assistance to trigger **24** as it approaches the end of its return stroke. In various embodiments, it may also be desirable to provide a substantially constant amount of resistance to the user squeezing trigger during the entire range of motion such that the resistance forces encountered by the user are not substantially greater during certain stages of the firing stroke and return stroke.

In various embodiments, referring to FIGS. **9**A-G, hand piece **320** may generally comprise yoke **338** longitudinally slideable relative to hand piece **320**, trigger **324** slidingly attached to yoke **338** and rotationally attached to hand piece **320**, and link arm **336** pivotally attached to yoke **338** and rotationally attached to trigger **324**. Trigger **324** may be coupled to link arm **336** by trigger pin **316** as described above. In various embodiments, trigger **324** may be configured to act as a cam and slot **333** and link **336** may comprise a projection configured to act as a cam follower **337**. In various embodiments, link **336** may comprise projection **337** to engage portion **325** of trigger **324** comprising trigger pin **316**. In various embodiments, projection **337** may engage a first portion of trigger **324** when trigger **324** is in the first actuated position and a second portion of trigger **324** when trigger **324** is in the second actuated position. In various embodiments, projection **337** may comprise an angled surface. For example, as shown in FIG. **9**A, projection **337** may comprise a pentagon-shape including an angled surface **337***a*. In various embodiments, angled surface **337***a* of projection **337** may engage a first portion **325** of trigger **324**

when trigger **324** is in the first actuated position and a second portion **326** of trigger **324** when trigger **324** is in the second actuated position.

In use, referring to FIGS. **9**A-G, when trigger **324** moves from an unactuated position (FIG. **9**A) through the first range of motion to the first actuated position (FIG. **9**B), a first portion of angled surface **337***a* of projection **337** engages a first portion of trigger **324** to convert the movement of trigger **324** into proximal linear movement of yoke **338**. Trigger **324** may continue to move from the first actuated position through a second range of motion (FIG. **9**C) to the second actuated position (FIG. **9**D) when a second portion of angled surface **337***a* of projection **337** engages a second portion of trigger **324** to convert the movement of trigger **324** into distal linear movement of yoke **338**. As shown in FIG. **9**C, in various embodiments, the second portion of angled surface **337***a* may comprise a complementary angle to the second portion of trigger **324**. The complementary surface of trigger **324** may contact the complementary surface of projection **337***a* when trigger **324** moves from the first actuated position through the second range of motion to the second actuated position. As described above, in various embodiments, yoke **338** may travel a first distance through the first range of motion and a second distance through a second range of motion such that the difference between the first distance and second distance may decrease the compressive force applied to captured tissue from the first compressive force to the second compressive force. As described above, the user may release trigger **324**, and the spring (not shown) may return trigger **324** to an unactuated position. When trigger **324** moves from the second actuated position (FIG. **9**E) through the third range of motion (FIG. **9**F) to the unactuated position (FIG. **9**G), in various embodiments, trigger **324** may be coupled to link arm **336** by trigger pin **316** disposed in slot **333** to prevent trigger **324** from over travel and locking.

In various embodiments, referring to FIGS. **10**A-D, hand piece **420** may generally comprise yoke **438** longitudinally slideable relative to hand piece **420**, trigger **424** pivotally attached to yoke **338**, and link arm **436** pivotally attached to yoke **438**. Trigger **424** may be coupled to link arm **436** by trigger pin **416** disposed in trigger slot **417**. Trigger **424** may comprise a surface comprising relief notch **425** configured to act as a cam and link arm **436** may comprise a projection **437** configured to act as a cam follower. A return spring (not shown) may be coupled to yoke **438** by pin (not shown) configured to resiliently bias yoke **438** distally and projection **437** of link arm **436** to contact the surface of trigger **424**. In various embodiments, projection **437** of link arm **436** may engage the surface of trigger **424** lacking relief notch **425** when trigger **424** is in the first actuated position and engage relief notch **425** when trigger **424** is in the second actuated position. In various embodiments, projection **437** of link arm **438** may comprise a complementary shape to relief notch **425**. For example, as shown in FIG. **10**D, projection **437** of link arm **438** may comprise a complementary shape to relief notch **425**.

In use, referring to FIGS. **10**A-D, when trigger **424** moves from an unactuated position (FIG. **10**A) through the first range of motion to the first actuated position (FIGS. **10**B and **10**C), projection **437** of link arm **438** engages a surface of trigger **424** lacking relief notch **425** to compress return spring (not shown) and convert the movement of trigger **424** into proximal linear movement of yoke **438**. Trigger **424** may continue to move from the first actuated position through a second range of motion to the second actuated position (FIG. **10**D) when projection **437** of link arm **438** engages relief notch **425** to decompress return spring (not shown), and to convert the movement of trigger **424** into distal linear movement of yoke **438**. In various embodiments, trigger pin **417** may contact a first portion of trigger slot **417** when trigger **424** is in the first actuated position. Trigger pin **417** may slide along trigger slot **417** through the second range of motion to a second portion of trigger slot **417** when trigger **423** is in the second actuated position. As described above, in various embodiments, yoke **438** may travel a first distance through the first range of motion and a second distance through a second range of motion such that the difference between the first distance and second distance may decrease the compressive force applied to captured tissue from the first compressive force to the second compressive force. In various embodiments, as shown in FIG. **10**D, the second distance may relate to the depth of relief notch **425** and/or length of trigger slot **417**. As described above, the user may release trigger **424**, and trigger pin **416** may slide along trigger slot **417** to the first portion of trigger slot **417**, and projection **437** of link are **438** may rotate out of relief notch **425** to return trigger **324** to an unactuated position.

In various embodiments, referring to FIGS. **11**A-C, hand piece **520** may generally comprise yoke **538** longitudinally slideable relative to hand piece **520**, trigger **524** pivotally attached to yoke **538**, and link arm **536** pivotally attached to yoke **538**. In various embodiments, hand piece **520** may comprise a handle shroud slot **544**. Trigger **524** may be coupled to link arm **536** by trigger pin **516** disposed in trigger slot **517**. Link arm **537** may comprise a projection comprising a link pin **537**. Link pin **537** may be disposed in handle shroud slot **544**. In various embodiments, link pin **537** may slide along handle shroud slot **544**. As discussed above, a return spring (not shown) may be coupled to yoke **538** by pin (not shown) configured to resiliently bias yoke **538** distally. In various embodiments, link pin **537** may contact a first portion of handle shroud slot **544** when trigger **524** is in the first actuated position and a second portion of handle shroud slot **544** when trigger **524** is in the second actuated position.

In use, referring to FIGS. **11**A-C, when trigger **524** moves from an unactuated position (FIG. **11**A) through the first range of motion to the first actuated position (FIG. **11**B), link pin **537** slides along slot **544** to compress return spring (not shown) and convert the movement of trigger **524** into proximal linear movement of yoke **538**. As shown in FIG. **11**B, link pin **537** may engage a first portion of slot **544** when trigger **524** is in the first actuated position. Trigger **524** may continue to move from the first actuated position through a second range of motion to the second actuated position (FIG. **11**C) when link pin **537** continues to travel along slot **544** to decompress return spring (not shown), and to convert the movement of trigger **524** into distal linear movement of yoke **538**. As shown in FIG. **11**B, link pin **537** may engage a second portion of slot **544** when trigger **524** is in the second actuated position. As described above, in various embodiments, yoke **538** may travel a first distance through the first range of motion and a second distance through a second range of motion such that the difference between the first distance and second distance may decrease the compressive force applied to captured tissue from the first compressive force to the second compressive force. In various embodiments, as shown in FIG. **11**C, the second distance may relate to the configuration of slot **544** and/or length of trigger slot **517**. As described above, the user may release trigger **524**, and trigger pin **516** may slide along trigger slot **517**, link pin **537** may slide along slot **544** to the

first portion of slot **544** to return trigger **524** to an unactuated position. In various embodiments, slot **544** may prevent trigger **524** from over travel and locking.

In various embodiments, referring to FIGS. **14**A-C, hand piece **620** may generally comprise yoke **638** longitudinally slideable relative to hand piece **620**, trigger **624** slideably attached to yoke **638** and pivotally attached to hand piece **620**, and link arm **636** pivotally attached to yoke **638** and trigger **624**. In various embodiments, referring to FIGS. **12** and **13**, hand piece **620** may comprise slot **644** comprising first portion **644***a* and second portion **644***b*, and yoke **638** may comprise notch **617** comprising first portion **617***a* and second portion **617***b*. Rear yoke pin **618** may link hand piece **620**, link arm **636**, and yoke **638**. A first end of rear yoke pin **618** may be disposed in slot **644** and a second end of rear yoke pin may be disposed in notch **617**. In various embodiments, a first end of the rear yoke pin may engage a first portion **644***a* of slot **644** when the trigger is in the first actuated position, an upward step of slot **644** between first portion **644***a* and second portion **644***b* when the trigger is moved through a second range of motion, and a second portion **644***b* of slot **644** when the trigger is in the second actuated position. In various embodiments, the upward step may comprise an angled portion of the first portion **644***a* of slot **644**. In various embodiments, a second end of the rear yoke pin may engage a first portion **617***a* of notch **617** when the trigger is in the first actuated position and second portion **617***b* when the trigger is in the second actuated position.

In use, referring to FIGS. **14**A-C, when trigger **624** moves from an unactuated position (FIG. **14**A) through the first range of motion to the first actuated position (FIG. **14**B), the first end of the rear yoke pin may slide along the first portion **644***a* of slot **644** to convert the movement of trigger **624** into proximal linear movement of yoke **638**. The second end of the rear yoke pin may rest in the first portion **617***a* of notch **617** when the trigger moves from an unactuated position through the first range of motion to the first actuated position. The first actuated position is illustrated in FIG. **14**B. Trigger **624** may continue to move from the first actuated position through a second range of motion to the second actuated position (FIG. **14**C) when the first end of the rear yoke pin slides along the upward step of slot **644** to the second portion **644***b* of slot **644** and the second end of the rear yoke pin may move from the first portion **617***a* to the second portion **617***b* of notch **617** to convert the movement of trigger **624** into distal movement of yoke **638**. In various embodiments, yoke **638** may travel in an upward, distal direction when the first end of the rear yoke pin slides along the upward step of slot **644** and a linear distal direction when the first end of the rear yoke pin slides along the second portion **644***b* of slot **644**. In various embodiments, the angular movement yoke **638** along slot **644** relative to the longitudinal axis and/or the movement of the rear yoke pin in notch **617** during the second range of motion may provide an audible and/or tactile indication to the user that trigger (not shown) is in the second actuated position. As discussed above, a return spring (not shown) may be coupled to yoke **638** by pin (not shown) configured to resiliently bias yoke **638** distally. As described above, the user may release the trigger, and the first end of the rear yoke pin may slide along slot **644** from the second portion **644***b* to the first portion **644***a* of slot **644** and the second end of the rear yoke pin may move from the second portion **617***b* to the first portion **617***a* of notch **617** to return the trigger to an unactuated position. In various embodiments, slot **644** may prevent the trigger from over travel and locking.

In various embodiments, referring to FIGS. **15**A-K, hand piece **720** may generally comprise yoke **738** longitudinally slideable relative to hand piece **720**, trigger **724** pivotally attached to yoke **738**, and link arm **736** fixedly attached to yoke **738**. Link arm **736** may comprise slot **733**. Trigger **724** may comprise trigger slot **717**. Trigger **724** may be coupled to link arm **736** by trigger pin **716**. Trigger pin **716** may be disposed in link pin **732**. One end of trigger pin **716** may be disposed in trigger slot **717**. One end of link pin **732** may be disposed in trigger slot **717** and the other end of link pin **732** may be disposed in slot **733**. In various embodiments, slots **717**, **733** may be configured to act as a cam and trigger pin **716** and link pin **732** may be configured to act as a cam follower. In various embodiments, slots **716**, **733** may individually comprise a first portion and a second portion. In various embodiments, the first portion of slot **733** may comprise an angled feature and the second portion of slot **733** may comprise a vertical feature relative to the longitudinal axis. For example, as shown in FIG. **15**A, the first portion of slot **733** may extend distally and vertically from a plane including the longitudinal axis of hand piece **220**, and the second portion of slot **733** may extend perpendicular parallel to the plane including the longitudinal axis of hand piece **220**.

In use, referring to FIGS. **15**A-K, when trigger **724** moves from an unactuated position (FIG. **15**A) through the first range of motion (FIGS. **15**B, **15**C) to the first actuated position, link pin **732** slides along the first portion of slot **733** to convert the movement of trigger **724** into proximal linear movement of yoke **738**. In various embodiments, link pin **732** may contact a first portion of trigger slot **717** when trigger **724** is in the unactuated position and first actuated position. In various embodiments, trigger pin **717** may not move in trigger slot **716** when trigger **724** moves through the first range of motion. The first actuated position is illustrated in FIG. **15**D. Trigger **724** may continue to move from the first actuated position through a second range of motion (FIG. **15**E, **15**F) to the second actuated position when trigger pin **716** slides along a second portion of slots **717**, **733** to convert the movement of trigger **724** into distal linear movement of yoke **738**. The second actuated position is illustrated in FIG. **15**G. As described above, in various embodiments, yoke **738** may travel a first distance through the first range of motion and a second distance through a second range of motion such that the difference between the first distance and second distance may decrease the compressive force applied to captured tissue from the first compressive force to the second compressive force. In various embodiments, as shown in FIGS. **15**D, **15**G, the second distance may relate to the length of trigger slot **717**.

Referring to FIGS. **15**G-K, when trigger **724** moves from the second actuated position (FIG. **15**G) through the third range of motion (FIGS. **15**H-J) to the unactuated position (FIG. **15**K), a spring (not shown) may return trigger **724** to an unactuated position where it is pivoted away from the longitudinal axis. In various embodiments, referring to FIGS. **15**H and **15**I, the user may release trigger **724**, and trigger pin **716** may slide along the second portion of slot **733** to the first portion of slot **733** while remaining stationary in the second portion of trigger slot **717**. Referring to FIG. **15**J, when trigger pin **716** contacts the first portion of slot **733**, trigger pin **716** may slide along the second portion of trigger slot **717** to the first portion of slot **717**. As trigger **724** continues to rotate away from the longitudinal axis, link pin **732** slides along the first portion of slots **733** to convert the movement of trigger **724** into distal linear movement of yoke **738**. The unactuated position is illustrated in FIG. **15**K.

In various embodiments, at least one of slots **717**, **733** may prevent trigger **724** from over travel and locking.

In various embodiments, a surgical instrument may be configured to apply a compressive force to captured tissue. As described above, for example, jaws may be apply a compressive force to tissue captured therebetween. In various embodiments, referring to FIGS. **17**A-H, the compressive force may comprise an opposing compressive force and/or a rolling compressive force. As shown in FIGS. **17**A-D, the inner and outer layers of a vessel may remain adhered when subjected to opposing compressive force and energy is applied to the tissue. The adventitia layer may retract under heat resulting in an inner muscle layer bond. The inner muscle layer bond may be weaker than an adventitia-adventitia bond. In various embodiments, jaws may apply opposing compressive force and rolling compressive force to mechanically separate the inner and outer vessel layers when jaws close. As shown in FIGS. **17**E-H, the inner and outer layers of the vessel may separate when subject to opposing compressive force and rolling compressive force. The separated inner muscle layer may retract before the adventitia layer, and thereby, an adventitia-adventitia bond may be formed when energy is applied to the tissue. The separation of the inner muscle layer may reduce the occurrence of the adventitia layer retracting during sealing by allowing the inner muscle layer to retract inside the vessel as heat begins to build. In various embodiments, sealing and/or welding compressed and rolled tissue layers may form a stronger adventitia-adventitia bond relative to sealing and/or welding compressed tissue layers.

Referring to FIGS. **18**A and **18**B, in various embodiments, end effector **840** may comprise first jaw **842** and second jaw **844**. Second jaw **844** is longitudinally slideable relative to shaft **830**; while first jaw **842** pivots relative to shaft **830**, toward and away from second jaw **844**. First jaw **842** and second jaw **844** may comprise a plurality of teeth serrations **846**. The teeth serrations **846** may allow tissue to be grasped, manipulated, coagulated, and/or cut without slipping between jaws **842**, **844**. In various embodiments, hand piece **820** may comprise connector base **835** configured to retract second jaw **844** relative to shaft **830**. Referring to FIGS. **19**A and **19**B, connector base **835** and second jaw **844** may be resiliently biased to a distal position by spring **838**. As shown in the insert in FIG. **19**A, jaw **842** may not extend to the tip of jaw **844**. Connector base is configured to cam against a ramp features in hand piece **820** to retract second jaw **844** relative to shaft **830** when firing beam is retracted to a proximal position. Hand piece **820** may include stop members **880** located proximal to connector base **835** and spring **838**. As shown in FIG. **19**B, stop member **880** is configured to engage a proximal face of connector base **835** when firing beam advances distally to close jaws **842**, **844**. This camming capability may facilitate use of end effector **840** to separate layers of tissue, such as, for example, the adventitia layer and inner muscle layers of a vessel. As shown in the insert in FIG. **19**B, jaw **844** may move proximally to contact the tip of jaw **842** in the closed position. In various embodiments, longitudinal movement of the actuator may provide pivoting of first jaw **842** relative to shaft **830** and relative to second jaw **844** and retraction of second jaw **844** relative to shaft **830**.

In various embodiments, a surgical instrument may generally comprise a shaft comprising a proximal end and a distal end; an ultrasonic waveguide at least partially positioned within the shaft, the waveguide having a proximal end and a distal end; an ultrasonically actuated blade positioned at the distal end of the waveguide; a clamp arm assembly pivotally connected to the distal end of the shaft, wherein the clamp arm assembly comprises at least two camming members rotationally attached to a clamp arm, wherein the clamp arm is movable between an open position and a closed position relative to the blade to compress tissue intermediate the clamp arm and blade when in the closed position, and wherein the at least two camming members rotate in opposite directions when the clamp arm moves from the open position and a closed position. In various embodiments, the at least two camming members may selectively compress tissue at a first compressive force when a first portion of the camming member contacts tissue and a second compressive force when a second portion of the camming member contacts tissue. In various embodiments, the first compressive force may be different from the second compressive force. In various embodiments, the first compressive force may be greater than or equal to the second compressive force. It may be contemplated to combine the aforementioned configuration with alternative energy modalities or combinations thereof as mentioned earlier in this specification.

In various embodiments, referring to FIG. **20**, an end effector **910** may comprise clamp arm assembly **941** to grip tissue and/or compress tissue against ultrasonic blade **964**. Clamp arm assembly **941** may be pivotally attached to the distal end of shaft **930** by pivot pin **943**. In various embodiments, clamp arm assembly **941** pivots relative to blade **964**, toward and away from blade **964**. As described above, actuators (not shown) may extend through sheath **932** and be joined with clamp arm **941** and at pivotal coupling **943** such that longitudinal movement of the actuator through shaft **930** provides pivoting of clamp arm **941** relative to shaft **930** and relative to blade **964**. Of course, clamp arm **941** may instead have any other suitable kind of movement and may be actuated in any other suitable fashion. In various embodiments, clamp arm assembly may comprise at least one camming member **942**, **944** rotationally attached to clamp arm **941**. Each the camming member **942**, **944** may independently rotate in one of a clockwise direction and a counter clockwise direction relative to shaft **930** and blade **964** when clamp arm **941** is moved from the open position to the closed position. In various embodiments, camming members **942**, **944** may rotate in opposite directions. In various embodiments, the camming members **942**, **944** may rotate in the same direction. In various embodiments, camming members **942**, **944** may rotate simultaneously. In various embodiments, camming members **942**, **944** may rotate separately.

In various embodiments, clamp arm **941** may comprise actuating pin **917** for rotating camming member **944** relative to waveguide **964**. Actuating pin **917** may be located at a proximal end of camming member **944**. Actuating pin **917** may operatively engage with notch **916** of shaft **930** when clamp arm **941** pivots to rotate camming member **944**. For example, actuating pin **917** may engage notch **916** when clamp arm **941** pivots toward blade **964** to rotate camming member **944** counterclockwise. Actuating pin **917** may engage notch **916** when clamp arm **941** pivots away from blade **964** to rotate camming member **944** clockwise. In various embodiments, each camming member **942**, **944** may comprise actuating pin to individually engage with a corresponding notch in shaft **930**. In various embodiments, camming member **944** may comprise actuating pin **917** to engage with notch **916** of shaft **930** and gears (not shown) to operatively engage with gears (not shown) of at least one other camming member **942**, **944** such that rotational movement of camming member **944** rotates camming member

942. Of course, camming members 942, 944 may instead have any other suitable kind of movement and may be actuated in any other suitable fashion.

In various embodiments, the camming member may selectively compress tissue at a first compressive force when a first portion of the camming member contacts tissue and a second compressive force when a second portion of the camming member contacts tissue, wherein the first compressive force is different from the second compressive force. In various embodiments, the first compressive force is greater than the second compressive force. In various embodiments, referring to FIGS. 21A and 21B, camming members 942, 944 may comprise a generally circumferential tissue T contacting surface comprising at least one protrusion 942*a*, 944*a*. The protrusions 942*a*, 944*a* may extend above the surface of the camming members 942, 944, respectively. In various embodiments, protrusion 942*a*, 944*a* may comprise a curved portion of a generally comma-shape. In various embodiments, camming members 942, 944 may selectively compress tissue T at a first compressive force when a first portion of camming member 942, 944 comprising protrusion 942*a*, 944*a* contacts tissue T and a second compressive force when a second portion of the camming member 942, 944 lacking the protrusion contacts tissue T. In various embodiments, the camming members 942, 944 may contact the tissue T and rotationally engage the tissue T to shear and/or scrape any calcification on the external and/or internal surfaces of the tissue T.

While various embodiments described above include a pistol grip, it should be understood that the foregoing teachings may be readily applied to devices having various other kinds of grips. By way of example only, a variation of trigger and cam lever may be provided in accordance with the above teachings in a device having a scissor grip. Various examples of devices comprising a scissor grip is described in U.S. patent application Ser. No. 13/426,084, filed Mar. 21, 2012, entitled "ENERGY-BASED SCISSORS DEVICE", now U.S. Pat. No. 8,974,447, the disclosure of which is incorporated by reference herein. Other kinds of grips that may be combined with the above teachings will be apparent to those of ordinary skill in the art. Furthermore, a variation of trigger and cam lever may be readily incorporated into devices having various other kinds of end effectors, including but not limited to tissue graspers, tissue retrieval pouch deploying instruments, surgical staplers, ultrasonic surgical instruments, etc.

It should also be understood that any of the devices described herein may be modified to include a motor or other electrically powered device to drive an otherwise manually moved component. Various examples of such modifications are described in U.S. Patent Application Publication No. 2012/0116379, entitled "MOTOR DRIVEN ELECTRO-SURGICAL DEVICE WITH MECHANICAL AND ELECTRICAL FEEDBACK", published May 10, 2012, now U.S. Pat. No. 9,161,803, the disclosure of which is incorporated by reference herein. Various other suitable ways in which a motor or other electrically powered device may be incorporated into any of the devices herein will be apparent to those of ordinary skill in the art in view of the teachings herein.

It should also be understood that any of the devices described herein may be modified to contain most, if not all, of the required components within the medical device itself. More specifically, the devices described herein may be adapted to use an internal or attachable power source instead of requiring the device to be plugged into an external power source by a cable. Various examples of how medical devices may be adapted to include a portable power source are disclosed in U.S. Provisional Application Ser. No. 61/410,603, filed Nov. 5, 2010, entitled "ENERGY-BASED SURGICAL INSTRUMENTS", the disclosure of which is incorporated by reference herein. Various other suitable ways in which a power source may be incorporated into any of the devices herein will be apparent to those of ordinary skill in the art in view of the teachings herein.

The devices disclosed herein may be designed to be disposed of after a single use, or they may be designed to be used multiple times. In either case, however, the device may be reconditioned for reuse after at least one use. Reconditioning may include a combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device may be disassembled, and any number of particular pieces or parts of the device may be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device may be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those of ordinary skill in the art will appreciate that the reconditioning of a device may utilize a variety of different techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of this application.

Preferably, the various embodiments of the devices described herein will be processed before surgery. First, a new or used instrument is obtained and if necessary cleaned. The instrument can then be sterilized. In one sterilization technique, the instrument is placed in a closed and sealed container, such as a plastic or TYVEK® bag. The container and instrument are then placed in a field of radiation that can penetrate the container, such as gamma radiation, x-rays, or high-energy electrons. The radiation kills bacteria on the instrument and in the container. The sterilized instrument can then be stored in the sterile container. The sealed container keeps the instrument sterile until it is opened in the medical facility. Other sterilization techniques can be done by any number of ways known to those skilled in the art including beta or gamma radiation, ethylene oxide, and/or steam.

Although the various embodiments of the devices have been described herein in connection with certain disclosed embodiments, many modifications and variations to those embodiments may be implemented. For example, different types of end effectors may be employed. Also, where materials are disclosed for certain components, other materials may be used. Furthermore, according to various embodiments, a single component may be replaced by multiple components, and multiple components may be replaced by a single component, to perform a given function or functions. The foregoing description and following claims are intended to cover all such modification and variations.

Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth

herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

What is claimed is:

1. A surgical instrument, comprising:

a shaft comprising a proximal end and a distal end;

an ultrasonic waveguide at least partially positioned within the shaft, the waveguide having a proximal end and a distal end;

an ultrasonically actuated blade positioned at the distal end of the waveguide; and

a clamp arm assembly pivotally connected to the distal end of the shaft, wherein the clamp arm assembly comprises at least two camming members rotationally attached to a clamp arm, wherein the clamp arm is movable between an open position and a closed position relative to the blade to compress tissue intermediate the clamp arm and the blade when in the closed position, wherein the at least two camming members rotate relative to the clamp arm to separate tissue layers when the clamp arm moves between the open position and the closed position, wherein the at least two camming members selectively compress the tissue at a first rolling compressive force when a first portion of the camming members contact the tissue and a second rolling compressive force when a second portion of the camming members contact the tissue, wherein the first rolling compressive force is greater than the second rolling compressive force, and wherein the at least two camming members each comprise:

a circumferential surface comprising the first portion and the second portion, wherein the first portion comprises a protrusion, and wherein the protrusion compresses the tissue at the first rolling compressive force.

2. The surgical instrument of claim **1**, wherein the at least two camming members independently rotate relative to each other when the clamp arm moves between the open position and the closed position.

3. The surgical instrument of claim **1**, wherein the at least two camming members simultaneously rotate relative to each other when the clamp arm moves between the open position and the closed position.

4. The surgical instrument of claim **1**, wherein the at least two camming members rotate in one of the same direction and the opposite direction when the clamp arm moves between the open position and the closed position.

5. The surgical instrument of claim **1**, wherein separating the tissue layers comprises separating an adventitia layer from a muscular layer without compromising the adventitia layer.

6. A surgical instrument, comprising:

a shaft comprising a proximal end and a distal end;

an ultrasonic waveguide at least partially positioned within the shaft, the waveguide having a proximal end and a distal end;

an ultrasonically actuated blade positioned at the distal end of the waveguide; and

a clamp arm assembly pivotally connected to the distal end of the shaft, wherein the clamp arm assembly comprises at least two camming members rotationally attached to a clamp arm, wherein the clamp arm is movable between an open position and a closed position relative to the blade to compress tissue intermediate the clamp arm and the blade when in the closed position, wherein the at least two camming members rotate relative to the clamp arm to separate tissue layers when the clamp arm moves between the open position and the closed position, wherein the at least two camming members selectively compress the tissue at a first rolling compressive force when a first portion of the camming members contact the tissue and a second rolling compressive force when a second portion of the camming members contact the tissue, wherein the first rolling compressive force is greater than the second rolling compressive force, wherein the first rolling compressive force is sufficient to separate a muscular layer of the tissue from an adventitia layer of the tissue, and wherein the second rolling compressive force is sufficient for application of ultrasonic energy to cut the tissue and to seal the tissue via an adventitia-adventitia bond.

7. A surgical instrument, comprising:

a shaft comprising a proximal end and a distal end;

an ultrasonic waveguide at least partially positioned within the shaft, the waveguide having a proximal end and a distal end;

an ultrasonically actuated blade positioned at the distal end of the waveguide; and

a clamp arm assembly pivotally connected to the distal end of the shaft, wherein the clamp arm assembly comprises at least two camming members rotationally attached to a clamp arm, wherein the clamp arm is movable between an open position and a closed position relative to the blade to compress tissue intermediate the clamp arm and the blade when in the closed position, wherein the at least two camming members rotate relative to the clamp arm to separate tissue layers when the clamp arm moves between the open position and the closed position, wherein the at least two camming members selectively compress the tissue at a first rolling compressive force when a first portion of the camming members contact the tissue and a second rolling compressive force when a second portion of the camming members contact the tissue, wherein the first rolling compressive force is greater than the second rolling compressive force, wherein the first portion comprises at least one protrusion, and wherein the at least one protrusion compresses the tissue at the first rolling compressive force.

8. The surgical instrument of claim **1**, wherein at least one of the camming members comprises an actuating member configured to operatively engage the shaft as the clamp arm moves from the open position to the closed position to rotate the at least one camming member relative to the clamp arm.

9. A surgical instrument, comprising:

a shaft comprising a proximal end and a distal end;

an ultrasonic waveguide at least partially positioned within the shaft, the waveguide having a proximal end and a distal end;

an ultrasonically actuated blade positioned at the distal end of the waveguide; and

a clamp arm assembly pivotally connected to the distal end of the shaft, wherein the clamp arm assembly comprises at least two camming members rotationally attached to a clamp arm, wherein the clamp arm is movable between an open position and a closed position relative to the blade to compress tissue intermediate the clamp arm and the blade when in the closed position, wherein the at least two camming members rotate relative to the clamp arm to separate tissue layers when the clamp arm moves between the open position and the closed position, wherein at least one of the camming members comprises an actuating member

configured to operatively engage the shaft as the clamp arm moves from the open position to the closed position to rotate the at least one camming operatively engage the shaft as the clamp arm moves from the closed position to the open position to rotate the at least one camming member relative to the clamp arm.

10. The surgical instrument of claim **6**, wherein the at least two camming members independently rotate relative to each other when the clamp arm moves between the open position and the closed position.

11. The surgical instrument of claim **6**, wherein the at least two camming members simultaneously rotate relative to each other when the clamp arm moves between the open position and the closed position.

12. The surgical instrument of claim **6**, wherein the at least two camming members rotate in one of the same direction and the opposite direction when the clamp arm moves between the open position and the closed position.

13. The surgical instrument of claim **6**, wherein separating the tissue layers comprises separating an adventitia layer from a muscular layer without compromising the adventitia layer.

14. The surgical instrument of claim **7**, wherein the at least two camming members independently rotate relative to each other when the clamp arm moves between the open position and the closed position.

15. The surgical instrument of claim **7**, wherein the at least two camming members simultaneously rotate relative to each other when the clamp arm moves between the open position and the closed position.

16. The surgical instrument of claim **7**, wherein the at least two camming members rotate in one of the same direction and the opposite direction when the clamp arm moves between the open position and the closed position.

17. The surgical instrument of claim **7**, wherein separating the tissue layers comprises separating an adventitia layer from a muscular layer without compromising the adventitia layer.

18. The surgical instrument of claim **9**, wherein the at least two camming members independently rotate relative to each other when the clamp arm moves between the open position and the closed position.

19. The surgical instrument of claim **9**, wherein the at least two camming members simultaneously rotate relative to each other when the clamp arm moves between the open position and the closed position.

20. The surgical instrument of claim **9**, wherein the at least two camming members rotate in one of the same direction and the opposite direction when the clamp arm moves between the open position and the closed position.

21. The surgical instrument of claim **9**, wherein separating the tissue layers comprises separating an adventitia layer from a muscular layer without compromising the adventitia layer.

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摘要(译)

外科手术器械的末端执行器通常可包括刀片，和夹持臂组件，夹持臂组件包括可相对于刀片在打开位置和关闭位置之间移动的夹持臂，以及至少一个可旋转地连接到夹持臂的凸轮构件，其中当夹紧臂从打开位置移动到关闭位置时，至少一个凸轮构件构造成相对于刀片旋转。