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COMPRESSION ANASTOMOSIS RINGS WITH ADJUSTABLE COMPRESSION PROFILE

Abstract

A system for forming an anastomosis uses a compression ring assembly having a tubular support member and a first ring securely coupled to the tubular support member. The first ring is configured to engage a first segment of an alimentary tract portion. The compression ring assembly also includes a second ring slidably disposed on the tubular support member and movable along the tubular support member and relative to the first ring. The second ring is configured to engage a second segment of the alimentary tract portion. The system also includes a powered surgical device having a controller, a motor, and a transmission assembly coupled to the motor. The powered surgical device also includes an annular reload configured to support the second ring and an anvil assembly configured to engage the tubular support member. The anvil assembly is movable by the transmission assembly and configured to move the tubular support member and the first ring. The first ring and the second ring are configured to be approximated relative to each other to compress the first segment and the second segment to form an anastomosis.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application claims the benefit of and priority to U.S. Provisional Patent Application Ser. No. 63/330,483 filed on Apr. 13, 2022. The entire contents of which is incorporated by reference herein.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to surgical devices. More specifically, the present disclosure relates to electromechanical surgical systems for performing surgical procedures.

2. Background of Related Art

[0003] In the event that some portion of the alimentary tract is removed, and continuity needs to be restored with an anastomosis, surgeons currently use surgical staplers or handsewn sutures to create the anastomosis. However, such techniques may result in certain complications, e.g., malformed staples. Thus, there is a need for a surgical device configured to form anastomoses of the alimentary canal using alternative fastening methods.

SUMMARY

[0004] The present disclosure provides an anastomosis forming device that accounts for differences in tissue properties by adjusting the compression gap according to an internal feedback mechanism. In particular, a powered surgical anastomosis device is provided that is configured to clamp, compress, and lock a compression ring assembly to form an anastomosis. The compression ring assembly includes two opposing rings configured to connect two sections of an alimentary tract (e.g., intestine, colon, etc.) The powered surgical device includes a handle assembly having a power source and one or more motors coupled to the power source. The device also includes an adapter assembly having multiple transmission assemblies, e.g., drive shafts, which transmit actuation from the powered handle. The powered handle assembly and the adapter assembly may be reusable. The adapter assembly includes an end effector having an anvil and a reload configured to engage the compression ring assembly to move the two rings together. The end effector also includes compression and locking actuation mechanisms to secure the compression ring assembly to the alimentary tract thereby forming the anastomosis. The end effector also includes a cutting mechanism, i.e., an annular cutter, to restore the lumen of the alimentary tract.

[0005] The powered surgical device operates in four phases, namely, compressing, locking, cutting, and unclamping. Clamping is accomplished by moving the anvil in a proximal direction to compress tissue held within the compression ring assembly and/or moving a portion of the reload in a distal direction. During compression, the rings are further approximated until a desired compression pressure is reached. Locking is accomplished by securing the rings of the compression ring assembly at the compressed distance. The lumen of the tissue is restored by advancing a circular knife to cut tissue from the center of the rings during the cutting phase. During

unclamping, the anvil is disengaged from the compression ring assembly and is retracted, allowing for removal of the powered surgical device from the alimentary tract.

[0006] The compression ring assembly includes a pair of opposing compression rings that are used to form the anastomosis. The compression rings may advantageously provide 1) more uniform distribution of pressure across tissue, 2) a reduced number of puncture sites to the tissue (i.e., few locking pins for the compression device vs. multiple staples), and 3) an adjustable compression gap based on real-time feedback indicators. In addition, the compression ring assembly also optimizes tissue compression pressure, and depending on data collected compression speed may be optimized for various tissue types and health conditions. Real-time feedback may include data from one or more sensors such as strain gauges for force, light absorption detectors for optical properties, bioimpedance sensors for electrical properties, or other similar sensors. Such feedback provides the opportunity to evaluate real-time changes to tissue properties during the compression phase of the anastomosis such that the compression gap may be prescribed by the system to optimize these target properties. This allows for tailoring of the compression based on different tissue loads for similar compression values. In addition, using the feedback during compression of the compression ring also reduces the chances of mechanical failure of the tissue since tissue properties, i.e., failure properties, depend upon compression. This is also an added advantage of the feedback loop and adjustable compression profile. In particular, optical and electrical properties change with tissue compression, allowing for sensing and compression optimization using various tissue properties which can inform clinically relevant metrics such as structural tissue damage, tissue perfusion, etc.

[0007] For device operation, the compression ring assembly, including two rings are inserted into the tissue of interest using the powered surgical device. A proximal ring is advanced toward a distal ring (i.e., the ring farther from the handle assembly) and/or a distal ring may be retracted toward the proximal ring using a motor and drive assembly until a feedback mechanism dictates that the compression is sufficient based on real-time feedback indicator (e.g., force), at which point the distal ring is fixed in place. Each of the anvil and the proximal ring may be advanced by their corresponding mechanisms, e.g., motors and transmission assemblies. A separate driver may then be advanced to move a lock ring to lock the rings with the appropriate gap and ensure proper fixation of the rings to the tissue.

[0008] In embodiments, the distal ring may remain stationary following calibration and the proximal ring is advanced distally to compress the tissue. A lock ring is then advanced with a separate motor. This two-step (i.e., compress and lock) approach ensures that the tissue compression force measurement is accurate and does not contain the force required to advance the lock ring. In further embodiments, the proximal ring may remain stationary and the distal ring is advanced proximally to compress tissue. The lock ring is similarly advanced to lock the rings in place. In yet further embodiments, both rings may be approximated to compress tissue, followed by moving the lock ring.

[0009] In embodiments, other locking mechanisms may be used, such as locking pins, which are advanced through both compression rings to lock the rings with the appropriate gap and ensure proper fixation of the rings to the tissue. Similar to currently available circular staplers, compression rings could be manufactured with a variety of diameters and materials, e.g., bioabsorbable, to accommodate different lumen sizes in the clinical population.

[0010] According to one embodiment of the present disclosure, a surgical device for forming an anastomosis is disclosed. The surgical device includes an anvil assembly having a head assembly coupled to a rod. The head assembly also includes an outer ring portion coupled to an inner portion via a connection portion. The device further includes an annular reload having a proximal ring with a plurality of pins movably disposed therein. The annular reload also includes a first driver movable distally and configured to engage the plurality of pins, an annular knife, and a second driver movable distally and configured to engage the annular knife. The device further includes a first transmission assembly coupled to and configured to move the anvil assembly proximally

toward the annular reload to clamp tissue between the anvil assembly and the annular reload. The device also includes a second transmission assembly coupled to and configured to move the first driver distally to move the plurality of pins through the proximal ring, the tissue, and into the outer ring portion to embed the plurality of pins in the outer ring portion. The device may include a third transmission assembly coupled to and configured to move the second drive and the annular knife through the tissue and the connection portion of the head assembly to separate the outer ring portion from the inner portion.

[0011] Implementations of the above embodiment may include one or more of the following features. According to one aspect of the above embodiment, the anvil assembly may be formed from a thermoplastic polymer. The surgical device may include at least one motor configured to move at least one of the first transmission assembly, the second transmission assembly, or the third transmission assembly. The surgical device may also include a sensor configured to measure at least one property of the tissue. The sensor may be configured to measure at least one of a mechanical property, optical property, or electrical property of the tissue. The surgical device may also include a controller configured to determine whether an anastomosis has been formed or optimal conditions for forming an anastomosis based on at least one property. The controller may be further configured to control at least one motor to move the third transmission assembly based on the determination that the anastomosis has been formed thereby advancing the annular knife through the tissue and the connection portion of the head assembly to separate the outer ring portion from the inner portion.

[0012] According to one aspect of the present disclosure, a compression ring assembly is disclosed. The compression ring assembly includes a tubular support member and a first ring securely coupled to the tubular support member. The first ring is configured to engage a first segment of an alimentary tract portion. The compression ring assembly also includes a second ring slidably disposed on the tubular support member and movable along the tubular support member and relative to the first ring. The second ring is configured to engage a second segment of the alimentary tract portion. The first ring and the second ring are configured to be approximated relative to each other to compress the first segment and the second segment to form an anastomosis.

[0013] Implementations of the above embodiment may include one or more of the following features. According to one aspect of the above embodiment, the tubular support member may be configured to engage an anvil assembly. The tubular support member may include at least one protrusion configured to engage the anvil assembly. The compression ring assembly may also include a lock ring disposed on the tubular support member. The lock ring is movable along the tubular support member and relative to the second ring. The lock ring is configured to retain the second ring. The tubular support member may include a barbed surface configured to permit movement of the lock ring in a direction toward the second ring.

[0014] According to another aspect of the present disclosure, a system for forming an anastomosis is disclosed. The system includes a compression ring assembly having a tubular support member and a first ring securely coupled to the tubular support member. The first ring is configured to engage a first segment of an alimentary tract portion. The compression ring assembly also includes a second ring slidably disposed on the tubular support member and movable along the tubular support member and relative to the first ring. The second ring is configured to engage a second segment of the alimentary tract portion. The system also includes a powered surgical device having an annular reload configured to support the second ring. An anvil assembly is configured to engage the tubular support member. The first ring and the second ring are configured to be approximated relative to each other to compress the first segment and the second segment to form an anastomosis.

[0015] Implementations of the above embodiment may include one or more of the following features. According to one aspect of the above embodiment, the tubular support member may

include at least one protrusion configured to engage the anvil assembly. The compression ring may also include a lock ring disposed on the tubular support member. The lock ring may be movable along the tubular support member and relative to the second ring. The lock ring may be configured to retain the second ring. The tubular support member may also include a barbed surface configured to permit movement of the lock ring in a direction toward the second ring. The annular reload may include a second driver longitudinally movable within the annular reload and configured to engage the lock ring. The powered surgical device may further include a first motor and a first transmission assembly coupled to the first motor and the anvil assembly, the first motor configured to move the anvil assembly. The annular reload may include a first driver longitudinally movable within the annular reload and configured to engage the second ring. The powered surgical device may further include a second motor and a second transmission assembly coupled to the second motor and the first driver. The second motor is configured to move the second ring. The powered surgical device may further include a third motor and a third transmission assembly coupled to the third motor and the second driver. The third motor is configured to move the lock ring.

[0016] According to a further aspect of the present disclosure, a system for forming an anastomosis is disclosed. The system includes a compression ring assembly having a tubular support member and a first ring securely coupled to the tubular support member. The first ring is configured to engage a first segment of an alimentary tract portion. The compression ring assembly also includes a second ring slidably disposed on the tubular support member and movable along the tubular support member and relative to the first ring. The second ring is configured to engage a second segment of the alimentary tract portion. The system also includes a powered surgical device having a controller, a motor, and a transmission assembly coupled to the motor. The powered surgical device also includes an annular reload configured to support the second ring and an anvil assembly configured to engage the tubular support member. The anvil assembly is movable by the transmission assembly and configured to move the tubular support member and the first ring. The first ring and the second ring are configured to be approximated relative to each other to compress the first segment and the second segment to form an anastomosis.

[0017] Implementations of the above embodiment may include one or more of the following features. According to one aspect of the above embodiment, the powered surgical device may include a sensor configured to measure strain imparted on the transmission assembly. The controller may be configured to determine whether the anastomosis has been formed or the optimal conditions for forming an anastomosis based on the measured strain. The tubular support member may include at least one protrusion configured to engage the anvil assembly. The compression ring may further include a lock ring disposed on the tubular support member. The lock ring may be movable along the tubular support member and relative to the second ring. The lock ring may be configured to retain the second ring. The tubular support member may include a barbed surface configured to permit movement of the lock ring in a direction toward the second ring.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Embodiments of the present disclosure are described herein with reference to the accompanying drawings, wherein:

[0019] FIG. 1 is a perspective view of a powered surgical device including a handle assembly, an adapter assembly, and an end effector, according to an embodiment of the present disclosure;

[0020] FIG. 2 is a perspective view of the end effector with a compression ring assembly (compression ring) assembly according to an embodiment of the present disclosure;

[0021] FIG. 3 is a perspective view of two separated sections of an alimentary tract portion with

the end effector and the compression ring assembly being inserted to form an anastomosis;

[0022] FIG. **4** is a perspective, partially transparent view of the compression ring assembly joining two separated sections of the alimentary tract portion;

[0023] FIG. **5** is a perspective view of the compression ring assembly according to an embodiment of the present disclosure;

[0024] FIG. **6** is a cross-sectional view of the compression ring assembly;

[0025] FIG. **7** is a perspective view, with parts disassembled, of the compression ring assembly;

[0026] FIG. **8** is a schematic diagram of the handle assembly, the adapter assembly, and the end effector of FIG. **1**;

[0027] FIG. **9** is a side perspective view of the adapter assembly and the end effector attached to the adapter assembly of FIG. **1** according to an embodiment of the present disclosure;

[0028] FIG. **10** is a perspective view of a first transmission assembly disposed within the adapter assembly of FIG. **1**, shown partially in phantom;

[0029] FIG. **11** is a perspective view of a second transmission assembly disposed within the adapter assembly of FIG. **1**, shown partially in phantom;

[0030] FIG. **12** is a perspective view of a third transmission assembly disposed within the adapter assembly of FIG. **1**, shown partially in phantom;

[0031] FIG. **13** is a perspective view of an end effector according to an embodiment of the present disclosure;

[0032] FIG. **14** is a side-cross sectional view of the end effector with the compression ring assembly in an unclamped configuration according to an embodiment of the present disclosure;

[0033] FIG. **15** is a side-cross sectional view of the end effector with the compression ring assembly in a clamped configuration according to an embodiment of the present disclosure;

[0034] FIG. **16** is a perspective view of the adapter assembly, shown partially disassembled, with a strain gauge assembly;

[0035] FIG. **17** is a cross-sectional view of the end effector with the compression ring assembly in the unclamped configuration inside the alimentary tract portion according to an embodiment of the present disclosure;

[0036] FIG. **18** is a cross-sectional view of the end effector with the compression ring assembly in the clamped configuration inside the alimentary tract portion according to an embodiment of the present disclosure;

[0037] FIG. **19** is a cross-sectional view of the end effector with the compression ring assembly in a locked configuration inside the alimentary tract portion according to an embodiment of the present disclosure;

[0038] FIG. **20** is a perspective view the compression ring assembly joining two sections of the alimentary tract portion;

[0039] FIG. **21** is a side, cross-sectional view the compression ring assembly joining two sections of the alimentary tract portion;

[0040] FIG. **22** is a perspective view of the end effector and an anvil assembly decoupled from the compression ring assembly joining two sections of the alimentary tract portion;

[0041] FIG. **23** is a perspective view of an end effector including an anvil assembly and a reload for deploying a compression ring assembly according to another embodiment of the present disclosure;

[0042] FIG. **24** is a side, cross-sectional view of the anvil assembly separated from the reload of FIG. **23**;

[0043] FIG. **25** is a perspective view with parts separated of the anvil assembly of FIG. **23**;

[0044] FIG. **26** is a perspective view with parts separated of the reload of FIG. **23**;

[0045] FIGS. **27A** and **B** are front and rear perspective views of a proximal ring of the compression ring assembly of FIG. **23**;

[0046] FIG. **28A** is a perspective view of the anvil assembly in inside a first alimentary tract

portion and the end effector in a second alimentary tract portion according to an embodiment of the present disclosure;

[0047] FIG. **28B** is a perspective view of the anvil assembly coupled to the end effector joining two alimentary tract portions according to an embodiment of the present disclosure;

[0048] FIG. **29** is a side view of the end effector with the compression ring assembly in a clamped configuration inside the alimentary tract portion according to an embodiment of the present disclosure;

[0049] FIG. **30** is a side, cross-sectional view of the end effector with the compression ring assembly in a clamped configuration inside the alimentary tract portion according to an embodiment of the present disclosure;

[0050] FIG. **31** is a side, cross-sectional view of the end effector with the compression ring assembly in the clamped configuration and a deployed knife assembly inside the alimentary tract portion according to an embodiment of the present disclosure;

[0051] FIG. **32** is a side, cross-sectional view of the compression ring assembly in the clamped configuration inside the alimentary tract portion according to an embodiment of the present disclosure; and

[0052] FIG. **33** is a perspective view of the compression ring assembly in the clamped configuration inside the alimentary tract portion according to an embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0053] Embodiments of the presently disclosed surgical devices, and adapter assemblies for surgical devices and/or handle assemblies are described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein the term “distal” refers to that portion of the surgical instrument, or component thereof, farther from the user, while the term “proximal” refers to that portion of the surgical instrument, or component thereof, closer to the user.

[0054] FIG. **1** illustrates a surgical device, such as, for example, a powered surgical device **10** for forming end-to-end anastomosis (“EEA”), including a handle assembly **100**, which is configured for selective connection with an adapter assembly **200**. The adapter assembly **200** is configured for selective connection with an end effector **300**, which includes an annular reload **400** and an anvil assembly **302**. The end effector **300** is configured to produce a surgical effect on tissue of a patient, namely, forming an anastomosis by connecting two portions of alimentary tract portion (e.g., intestine, colon, etc.).

[0055] The handle assembly **100** includes a power handle **101** and an outer shell housing **11** configured to selectively receive and encase power handle **101**. The shell housing **11** includes a distal half-section **11a** and a proximal half-section **11b** pivotably connected to distal half-section **11a**. When joined, distal and proximal half-sections **11a**, **11b** define a shell cavity therein in which power handle **101** is disposed.

[0056] While the powered surgical device **10** is described herein as a modular device including a plurality of interconnected components, such as the handle assembly **100**, the removable shell housing **11**, and the adapter assembly **200**, etc. The powered surgical device **10** may be formed as an integrated device with one or more of the components being securely attached to each other, e.g., during manufacturing of the powered surgical device.

[0057] Distal and proximal half-sections **11a**, **11b** of shell housing **11** are divided along a plane that traverses a longitudinal axis of adapter assembly **200**. Distal half-section **11a** of shell housing **11** defines a connecting portion **20** configured to accept a corresponding drive coupling assembly **210** (FIG. **9**) of adapter assembly **200**. Distal half-section **11a** of shell housing **11** supports a toggle control button **30**. Toggle control button **30** is capable of being actuated in four directions (i.e., a left, right, up, and down).

[0058] FIGS. **2-4** show a compression ring assembly **500** for forming an anastomosis between two

sections S1 and S2 of an alimentary tract AT. The two sections S1 and S2 may be formed using any suitable surgical technique and may including previously formed purse sutures. The compression ring assembly 500 includes a distal ring 502 configured to engage an opening in the distal section S1 and a proximal ring 504 configured to engage an opening in the proximal section S2 of the alimentary tract AT. The distal and proximal rings 502 and 504 are approximated together to clamp and compress the tissue of the two sections S1 and S2 in the compression ring assembly 500 thereby forming an anastomosis.

[0059] With reference to FIGS. 5-7, the compression ring assembly 500 includes a tubular support member 508 having a lip 510 for securing the distal ring 502 thereto. A retaining ring 512 may also be used to secure the distal ring 502 to the tubular support member 508. The tubular support member 508 defines lumen 514 allowing for the anvil assembly 302 to be inserted therein. In addition, one or more protrusions 516 are disposed within the lumen 514 and on an inner surface of the tubular support member 508. The protrusions 516 are configured to be engaged by the anvil assembly 302, such that as the anvil assembly 302 is moved longitudinally, the tubular support member 508 along with the distal ring 502 is moved correspondingly.

[0060] The proximal ring 504 of the compression ring assembly 500 is disposed on the tubular support member 508 and is configured to move slidingly on an outer surface of the tubular support member 508. A lock ring 518 is disposed proximally of the proximal ring 504 and is configured to move only in a distal direction thereby preventing proximal movement of the proximal ring 504, securing the compression ring assembly 500 in a clamped and locked configuration. Components of the compression ring assembly 500 may be formed from any suitable material including, but not limited to, metals, e.g., stainless steel, titanium, etc., bioabsorbable polymers or other suitable biocompatible thermoplastic polymers (e.g., polyether ether ketones).

[0061] With reference to FIG. 8, the power handle 101 includes a main controller circuit board 142, a rechargeable battery 144 configured to supply power to any of the electrical components of handle assembly 100, and a plurality of motors, i.e., a first motor 152a, a second motor 152b, a third motor 152c coupled to the battery 144. The power handle 101 also includes a display 146. In embodiments, the motors 152a, 152b, 152c may be coupled to any suitable power source configured to provide electrical energy to the motors 152a, 152b, 152c, such as an AC/DC transformer. Each of the motors 152a, 152b, 152c is coupled to a motor controller 143 which controls the operation of the corresponding motors 152a, 152b, 152c including the flow of electrical energy from the battery 144 to the motors 152a, 152b, 152c. A main controller 147 is provided that controls the power handle 101. The main controller 147 is configured to execute software instructions embodying algorithms disclosed herein, such as clamping, compressing, locking, and cutting algorithms which control operation of the power handle 101.

[0062] The motor controller 143 includes a plurality of sensors 408a . . . 408n, where “n” can be any number of sensors configured to measure operational states of the motors 152a, 152b, 152c and the battery 144. The sensors 408a-n include a strain gauge 408b and may also include voltage sensors, current sensors, temperature sensors, telemetry sensors, optical sensors, and combinations thereof. The sensors 408a-408n may measure voltage, current, and other electrical properties of the electrical energy supplied by the battery 144. The sensors 408a-408n may also measure angular velocity (e.g., rotational speed) as revolutions per minute (RPM), torque, temperature, current draw, and other operational properties of the motors 152a, 152b, 152c. The sensor 408a also includes an encoder configured to count revolutions or other indicators of the motors 152a, 152b, 152c, which is then use by the main controller 147 to calculate linear movement of components movable by the motors 152a, 152b, 152c. Angular velocity may be determined by measuring the rotation of the motors 152a, 152b, 152c or a drive shaft (not shown) coupled thereto and rotatable by the motors 152a, 152b, 152c. The position of various axially movable drive shafts may also be determined by using various linear sensors disposed in or in proximity to the shafts or extrapolated from the RPM measurements. In embodiments, torque may be calculated based on the regulated

current draw of the motors **152a**, **152b**, **152c** at a constant RPM. In further embodiments, the motor controller **143** and/or the main controller **147** may measure time and process the above-described values as a function of time, including integration and/or differentiation, e.g., to determine the rate of change in the measured values. The main controller **147** is also configured to determine distance traveled of various components of the adapter assembly **200** and/or the end effector **300** by counting revolutions of the motors **152a**, **152b**, **152c**.

[0063] The motor controller **143** is coupled to the main controller **147**, which includes a plurality of inputs and outputs for interfacing with the motor controller **143**. In particular, the main controller **147** receives measured sensor signals from the motor controller **143** regarding operational status of the motors **152a**, **152b**, **152c** and the battery **144** and, in turn, outputs control signals to the motor controller **143** to control the operation of the motors **152a**, **152b**, **152c** based on the sensor readings and specific algorithm instructions. The main controller **147** is also configured to accept a plurality of user inputs from a user interface (e.g., switches, buttons, touch screen, etc. coupled to the main controller **147**). The main controller **147** is also configured to receive optical and electrical sensor signals from sensors embedded in the reload **400**.

[0064] The main controller **147** is also coupled to a memory **141**. The memory **141** may include volatile (e.g., RAM) and non-volatile storage configured to store data, including software instructions for operating the power handle **101**. The main controller **147** is also coupled to the strain gauge **408b** of the adapter assembly **200** using a wired or a wireless connection and is configured to receive strain measurements from the strain gauge **408b** which are used during operation of the power handle **101**.

[0065] Turning now to FIG. **9**, adapter assembly **200** includes an outer knob housing **202** and an outer tube **206** extending from a distal end of knob housing **202**. Knob housing **202** and outer tube **206** are configured and dimensioned to house the components of adapter assembly **200**. The knob housing **202** includes an electrical connector **312** and a storage device **310** coupled thereto. The storage device **310** is configured to store various operating parameters pertaining to the adapter assembly **200**. Adapter assembly **200** is configured to convert rotation of coupling shafts (not explicitly shown) of handle assembly **100** into axial translations useful for operating the end effector **300**.

[0066] With reference to FIG. **10**, adapter assembly **200** further includes the anvil coupler **270** removably supported in a distal end of outer tube **206**. The anvil coupler **270** is axially and rotationally fixed within outer tube **206** of adapter assembly **200**. Anvil coupler **270** is configured to couple a drive screw **276** to the anvil assembly **302**, such that axial movement of anvil coupler **270**, via a rotation of drive screw **276**, results in a concomitant axial movement of anvil assembly **302**.

[0067] A first transmission assembly **240** includes first rotatable proximal drive shaft **212** coupled to the first motor **152a**, a second rotatable proximal drive shaft **281**, a rotatable distal drive shaft **282**, and a coupling member **286**, each of which are supported within the outer tube **206** of adapter assembly **200**. First transmission assembly **240** functions to extend/retract anvil assembly **302** of adapter assembly **200**, and to retract the distal ring **502** of the compression ring assembly **500** when anvil assembly **302** is engaged with the tubular support member **508**.

[0068] With reference to FIG. **11**, the adapter assembly **200** includes a second transmission assembly **250** for interconnecting the second motor **152b** and a first driver **430** of reload **400**, wherein the second transmission assembly **250** converts and transmits a rotation of the second motor **152b** to an axial translation of an outer flexible band assembly **255** of adapter assembly **200**, and in turn, to move the first driver **430** of the reload **400** to move the proximal ring **504** in a distal axial direction.

[0069] The second transmission assembly **250** of adapter assembly **200** includes the outer flexible band assembly **255** secured to driver coupler **254**. A second rotatable proximal drive shaft **220** is coupled to the second motor **152b** and is configured to actuate that driver coupler **254**, which

converts rotational movement into longitudinal movement. Outer flexible band assembly **255** includes first and second flexible bands **255a**, **255b** laterally spaced and connected at proximal ends thereof to a support ring **255c** and at distal ends thereof to a proximal end of a distal pusher **255d**. Each of the first and second flexible bands **255a**, **255b** is attached to support ring **255c** and distal pusher **255d**. Outer flexible band assembly **255** further includes first and second connection extensions **255e**, **255f** extending proximally from support ring **255c**. First and second connection extensions **255e**, **255f** are configured to operably connect outer flexible band assembly **255** to driver coupler **254** of second transmission assembly **250**.

[0070] With reference to FIG. **12**, the adapter assembly **200** also includes a third transmission assembly **260** having a third rotatable proximal drive shaft **222** for interconnecting the third motor **152c** and a second driver **440** of reload **400**, wherein the third transmission assembly **260** converts and transmits a rotation of the third motor **152c** to an axial translation of an outer flexible band assembly **265** of adapter assembly **200**, and in turn, to advance the second driver **440** of the reload **400** to move the lock ring **518**.

[0071] Inner flexible band assembly **265** includes first and second flexible bands **265a**, **265b** laterally spaced and connected at proximal ends thereof to a support ring **265c** and at distal ends thereof to a proximal end of a support base **265d**. Each of first and second flexible bands **265a**, **265b** are attached to support ring **265c** and support base **265d**. Inner flexible band assembly **265** further includes first and second connection extensions **265e**, **265f** extending proximally from support ring **265c**. First and second connection extensions **265e**, **265f** are configured to operably connect inner flexible band assembly **265** to driver **264** of third transmission assembly **260**. Support base **265d** extends distally from flexible bands **265a**, **265b** and is configured to connect with a second driver **440** of reload **400**.

[0072] With reference to FIGS. **13-15**, the anvil assembly **302** includes an anvil head **304** having one or more grooves or slots **306** that are configured to engage the protrusions **516** in a bayonet connection manner. This allows for securing of the tubular support member **508** to the anvil head **304**. The anvil assembly **302** also includes a shaft **303** configured to interconnect the anvil assembly **302** to the anvil coupler **270**. Axial movement of anvil coupler **270**, via a rotation of drive screw **276**, results in a concomitant axial movement of anvil assembly **302**, which in turn moves the anvil head **304** along with the tubular support member **508** and the distal ring **502**.

[0073] With reference to FIGS. **14** and **15**, the tubular support member **508** is configured to be inserted into the reload **400** and the shaft **303** to be movable through the tubular support member **508**. The reload **400** includes a first driver adapter **432** engaging the first driver **430**. A proximal end **432a** of the first driver adapter **432** is configured for selective contact and abutment with distal pusher **255d** of outer flexible band assembly **255** of second transmission assembly **250** of adapter assembly **200**. In operation, during distal advancement of outer flexible band assembly **255**, as described above, distal pusher **255d** of outer flexible band assembly **255** contacts proximal end **432a** of the first driver adapter **432** to advance the first driver adapter **432** and first driver **430** from a first or proximal position to a second or distal position. Advancement of first driver **430** moves proximal ring **504** in the distal axial direction.

[0074] The reload **400** also includes a second driver adapter **442** engaging the second driver **440**. A proximal end **442a** of second driver adapter **442** is configured to engage the support base **265d** of inner flexible band assembly. In operation, during distal advancement of inner flexible band assembly **265**, support base **265d** of inner flexible band assembly **265** connects with proximal end **442a** of second driver adapter **442** to advance second driver adapter **442** and second driver **440** from a first or proximal position to a second or advanced position to move the lock ring **518** into a locking position. The tubular support member **508** also includes a barbed surface **509** configured to engage the lock ring **518** and prevent proximal movement thereof to secure the lock ring **518** once the lock ring **518** is advanced distally.

[0075] Forces during an actuation of compression ring assembly **500** may be measured by the

strain gauge **408b** in order to monitor and control various processes, such as clamping, compression, and locking of the compression ring assembly **500**. With reference to FIG. **16**, the strain gauge **408b** of adapter assembly **200** is disposed within a strain gauge housing **320**. In particular, the adapter assembly **200** includes a support block **292** fixedly disposed within outer tube **206**. The strain gauge housing **320** is disposed between the support block **292** and a connector sleeve **290**. The reload **400** is removably coupled to the connector sleeve **290**.

[0076] In operation, strain gauge **408b** of adapter assembly **200** measures and monitors the retraction of anvil assembly **302**, since the anvil coupler **270** passes through the strain gauge **408b**. The strain gauge **408b** of adapter assembly **200** also measures and monitors movement of the proximal ring **504** and the lock ring **518**, since the first and second flexible bands **255a**, **255b** also pass through the strain gauge **408b**. During clamping, compression, and locking, a reaction force is exerted on anvil assembly **302** and the reload **400**, which is communicated to support block **292**, which then communicates the reaction force to a strain sensor of the strain gauge **408b**.

[0077] Strain sensor of strain gauge **408b** may be any device configured to measure strain (a dimensionless quantity) on an object that it is adhered to (e.g., support block **292**), such that, as the object deforms, a metallic foil of the strain sensor is also deformed, causing an electrical resistance thereof to change, which change in resistance is then used to calculate loads experienced by anvil coupler **270**.

[0078] The strain gauge **408b** measures and monitors the retraction of anvil assembly **302** as well as movement of the proximal ring **504** and the lock ring **518**. This distally directed reaction force is communicated from anvil assembly **302** to the strain gauge **408b**. Strain gauge **408b** is also electrically connected to the electrical connector **312** (FIG. **9**) via proximal and distal harness assemblies **314**, **316**. The strain gauge **408b** then communicates signals to main controller circuit board **142** of power handle **101** of handle assembly **100**. This information may then be displayed on display **146** of handle assembly **100** to provide the user with real-time information related to the status of the handle assembly **100**.

[0079] The reload **400** includes a storage device **402** and the circular adapter assembly **200** also includes a storage device **310** (FIG. **9**). The storage devices **402** and **310** include non-volatile storage medium (e.g., EEPROM) that is configured to store any data pertaining to the reload **400** and the circular adapter assembly **200**, respectively, including but not limited to, usage count, identification information, model number, serial number, stroke length, maximum actuation force, minimum actuation force, factory calibration data, and the like. In embodiments, the data may be encrypted and is only decryptable by devices (e.g., main controller **147**) having appropriate keys. The data may also be used by the main controller **147** to authenticate the circular adapter assembly **200** and/or the reload **400**. The storage devices **402** and **310** may be configured in read only or read/write modes, allowing the main controller **147** to read as well as write data onto the storage device **402** and **310**.

[0080] Prior to operation of the powered surgical device **10**, the power handle **101** is enclosed within the shell housing **11** and the adapter assembly **200** is coupled to handle assembly **100**. After attachment of circular adapter assembly **200**, handle assembly **100** initially verifies that circular adapter assembly **200** is coupled thereto by establishing communications with the storage device **310** of the circular adapter assembly **200** and authenticates circular adapter assembly **200**. The data (e.g., usage count) stored on the storage device **310** is encrypted and is authenticated by the power handle **101** prior to determining whether the usage count stored on the storage device **310** exceeds the threshold (e.g., if the adapter assembly **200** has been previously used). Power handle **101** then performs verification checks (e.g., end of life checks, anvil assembly **302** missing, etc.) and calibrates circular adapter assembly **200** after the handle assembly **100** confirms that the anvil assembly **302** is attached.

[0081] The user commences a surgical procedure by attaching the compression ring assembly **500** to the anvil assembly **302**. This may be done by aligning the protrusions **516** with the slots **306** and

turning the anvil assembly **302** and/or the compression ring assembly **500**. The anvil assembly **302** may be calibrated against a spacer to set a predetermined gap (e.g., approximately 6 mm) to accept the tissue.

[0082] Thereafter, the user inserts the adapter assembly **200**, including the anvil assembly **302** and the compression ring assembly **500**, within the alimentary tract AT as shown in FIGS. **3** and **4**, to ensure that the ends of the sections **S1** and **S2** of the alimentary tract AT are disposed between the distal and proximal rings **502** and **504** of the compression ring assembly **500** as shown in FIG. **17**. The user presses the toggle control button **30** to begin the clamping process on the tissue interposed between the distal and proximal rings **502** and **504** by pressing on the bottom portion of the toggle control button **30**.

[0083] The clamping process may be accomplished by approximating the distal and proximal rings **502** and **504** relative to each other, either both or one of the rings **502** and **504**. In one embodiment, the anvil assembly **302** may remain stationary, while the proximal ring **504** is advanced distally by the first driver **430** to clamp tissue against the distal ring **502**. In another embodiment, the proximal ring **504** may remain stationary, while the anvil assembly **302** is retracted, thereby moving the distal ring **502** proximally and clamping the tissue. In further embodiment, both of the distal and proximal rings **502** and **504** may be moved toward each other, either simultaneously or in a sequential manner to compress tissue.

[0084] The clamping process may continue until a clamping threshold is reached, after which, the process may transition to controlled tissue compression until a compression threshold is reached. In addition to monitoring the clamping threshold through the strain gauge **408b**, clamping may be also monitored using light absorption detectors for monitoring optical properties of the tissue and/or bioimpedance sensors for monitoring electrical properties of the tissue. The detectors may be incorporated into the proximal ring **504** and/or **904**. In further embodiments, clamping may be performed until the calibrated gap is reached. The thresholds and the gap may be adjustable during the compression process based on the feedback from the sensors.

[0085] Compression of the tissue may include moving either both or one of the distal and proximal rings **502** and **504**. In one embodiment, compression includes advancing the proximal ring **504** distally to further compress the clamped tissue as shown in FIG. **18**. In another embodiment, compression may be achieved by retracting one or both of the distal ring **502** and the proximal ring **504**.

[0086] Once tissue is compressed, the locking process may be initiated manually by pressing the toggle control button **30** or automatically once tissue compression is confirmed by the main controller **147**, i.e., compression threshold is reached. The locking process includes advancing the lock ring **518** along the tubular support member **508** until a locking force threshold is reached that is indicative of the lock ring **518** abutting the proximal ring **504** as shown in FIG. **19**. The lock ring **518** is secured to the tubular support member **508** upon reaching the barbed surface **509**. This secures the two sections **S1** and **S2** of the alimentary tract AT within the compression ring assembly **500** as shown in FIGS. **20** and **21**. The anvil assembly **302** is then decoupled from the compression ring assembly **500** by twisting and retracting the anvil assembly **302** and/or the adapter assembly **200** as shown in FIG. **22**.

[0087] With reference to FIGS. **23-33**, another embodiment of an end effector **600**, which includes an annular reload **700** and an anvil assembly **800** is shown. As shown in FIGS. **23-25**, the anvil assembly **800** includes a head assembly **810** secured to a rod **820**. The head assembly **810** may be coupled to the rod **820** via one or more bolts **817** or any other suitable attachment mechanisms. The rod **820** includes a centrally defined lumen **818** configured to receive a trocar **830** (FIG. **28**), which is coupled to the coupling member **286** of the first transmission assembly **240** (FIG. **10**). The trocar **830** is configured to be inserted into the rod **820**, such that axial movement of trocar **830**, via the first transmission assembly **240**, results in a concomitant axial movement of anvil assembly **800**.

[0088] The end effector **600** houses a compression ring assembly **900**, which includes a distal ring

902 forming an outer portion **816** of the head assembly **810** and a proximal ring **904** disposed in the reload **700**. The head assembly **810** also includes an inner portion **814**, which is attached to the rod **820**, as described above. The outer portion **816** (i.e., the distal ring **902**) is separably coupled, e.g., via cutting, to the inner portion **814** of the head assembly **810**. The head assembly **810** may be formed from any material that may be cut to detach the outer portion **816** from the inner portion **814**. Suitable materials for the head assembly **810** may be any thermoplastic polymer. The inner portion **814** is connected to the outer portion **816** via a connection portion **815** which is thinner than the inner portion **814** and the outer portion **816**. The inner portion **814** is coupled to the rod **820** as described above, such that after separating the outer portion **816**, the inner portion **814** remains attached to the rod **820**, allowing for its withdrawal.

[0089] As shown in FIGS. **23**, **24**, and **26**, the annular reload **700** is removably coupled to the connector sleeve **290**. The reload **700** includes a first driver **730**, which is configured to engage the distal pusher **255d** of the second transmission assembly **250**. With reference to FIG. **11**, the second transmission assembly **250** interconnects the second motor **152b** and the first driver **730** of reload **700**, wherein the second transmission assembly **250** converts and transmits a rotation of the second motor **152b** to an axial translation of an outer flexible band assembly **255** of adapter assembly **200**, and in turn, to move the first driver **730** of the reload **700** to move distally and engage the proximal ring **904** disposed in the reload **700**.

[0090] The reload **700** also includes a second driver **740**, which is configured to engage the support base **265d** of the third transmission assembly **260**. With reference to FIG. **12**, the third transmission assembly **260** interconnects the third motor **152c** and the second driver **740** of reload **700**, wherein the third transmission assembly **260** converts and transmits a rotation of the third motor **152c** to an axial translation of an outer flexible band assembly **265** of adapter assembly **200**, and in turn, to move the second driver **740** of the reload **700** to move distally and to move an annular knife **744** disposed concentrically within the proximal ring **904**.

[0091] With reference to FIGS. **23**, **24**, **26**, **27A-B**, the proximal ring **904** includes a plurality (e.g., 2 or more) of locking pins **906**. The proximal ring **904** includes a plurality of proximal openings configured to securely hold the locking pins **906**, such that the locking pins **906** are movable by the first driver **730**. The locking pins **906** may include an engagement surface configured about the first driver **730**.

[0092] With reference to FIGS. **28-31**, forming an end-to-end anastomosis between separated alimentary tract portions **S1** and **S2** using the compression ring assembly **900** includes inserting and attaching the anvil assembly **800** to a distal portion **S1** of the alimentary tract **AT**. The reload **700** while attached to the adapter assembly **200** is inserted into a proximal portion **S2** of the alimentary tract **AT**. The trocar **830** is then inserted into the rod **820** to attach the anvil assembly **800**. The user presses the toggle control button **30** to begin the clamping process on the tissue interposed between the distal and proximal rings **902** and **904** by pressing on the bottom portion of the toggle control button **30**.

[0093] The clamping process may be accomplished by approximating the distal and proximal rings **902** and **904** relative to each other. The anvil assembly **800** is retracted by the first transmission assembly **240**, thereby moving the distal ring **902** proximally and clamping the tissue. The clamping process may continue until a clamping threshold is reached, after which, the process may transition to controlled tissue compression until a compression threshold is reached. In addition to monitoring the clamping threshold through the strain gauge **408b**, clamping may be also monitored using light absorption detectors for monitoring optical properties of the tissue and/or bioimpedance sensors for monitoring electrical properties of the tissue. In further embodiments, clamping may be performed until the calibrated gap is reached. The thresholds and the gap may be adjustable during the compression process based on the feedback from the sensors. Compression of the tissue may follow clamping by continued retraction of the anvil assembly **800** until a desired tissue compression is reached, which may also be determined based on measured strain through the strain

gauge **408b**. The powered surgical device **10** may indicate (e.g., on the display **146**) that clamping and/or compression is complete.

[0094] Once tissue is compressed, the locking process may be initiated manually, by pressing the toggle control button **30**, or automatically once tissue compression is confirmed by the main controller **147**, i.e., compression threshold is reached. The locking process includes advancing the first driver **730** distally, which pushes the locking pins **906** through the proximal ring **904** and into the distal ring **902**. More specifically, the locking pins **906** may be aligned with a plurality of corresponding distal openings **910**, which are configured to receive and retain the locking pins **906** therein. The alignment of the distal openings **910** may be accomplished by aligning the anvil assembly **800** to the trocar **830** via splines or other mechanical features disposed on the rod **820**. The locking pins **906** may include barbs, ridges, or other unidirectional features to allow for the locking pins **906** to be secured within the distal openings **910**, thereby securing the distal and proximal rings **902** and **904** once the locking pins **906** are embedded inside the distal ring **902**. The locking pins **906** may be advanced until a locking force threshold is reached. The powered surgical device **10** may indicate (e.g., on the display **146**) that locking is complete. This secures the two sections **S1** and **S2** of the alimentary tract **AT** within the compression ring assembly **900** as shown in FIGS. **29** and **30**.

[0095] After the compression ring assembly **900** is locked, the connected sections **S1** and **S2** may be cut along with the head assembly **810** to separate the outer portion **816** (i.e., the distal ring **902**) from the inner portion **814**. The cutting process may be initiated manually, by pressing the toggle control button **30**, or automatically once the locking process is confirmed by the main controller **147**, i.e., locking threshold is reached. The cutting process includes advancing the second driver **740** distally, which moves the annular knife **744** disposed concentrically within the proximal ring **904**. The annular knife **744** cuts through the connected portions **S1** and **S2** and thin and/or perforated portion **815** interconnecting the outer portion **816** (i.e., the distal ring **902**) and the inner portion **814** of the head assembly **810**. This separates the anvil assembly **800** from the outer portion **816** allowing for retraction of the trocar **830** along with inner portion **814** from the locked compression ring assembly **900** that is forming the EEA as shown in FIGS. **32** and **33**.

[0096] It will be understood that various modifications may be made to the embodiments of the presently disclosed devices. Therefore, the above description should not be construed as limiting, but merely as exemplifications of embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the present disclosure.

[0097] In one or more examples, the described techniques may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a computer-readable medium and executed by a hardware-based processing unit. Computer-readable media may include non-transitory computer-readable media, which corresponds to a tangible medium such as data storage media (e.g., RAM, ROM, EEPROM, flash memory, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer).

[0098] Instructions may be executed by one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, the term “processor” as used herein may refer to any of the foregoing structure or any other physical structure suitable for implementation of the described techniques. Also, the techniques could be fully implemented in one or more circuits or logic elements.

Claims

1. A surgical device for forming an anastomosis, the device comprising: an anvil assembly including a head assembly coupled to a rod, the head assembly including an outer ring portion

coupled to an inner portion via a connection portion; an annular reload including: a proximal ring having a plurality of pins movably disposed therein; a first driver movable distally and configured to engage the plurality of pins; an annular knife; and a second driver movable distally and configured to engage the annular knife; a first transmission assembly coupled to and configured to move the anvil assembly proximally toward the annular reload to clamp tissue between the anvil assembly and the annular reload; a second transmission assembly coupled to and configured to move the first driver distally to move the plurality of pins through the proximal ring, the tissue, and into the outer ring portion to embed the plurality of pins in the outer ring portion; and a third transmission assembly coupled to and configured to move the second drive and the annular knife through the tissue and the connection portion of the head assembly to separate the outer ring portion from the inner portion.

2. The surgical device according to claim 1, wherein the anvil assembly is formed from a thermoplastic polymer.

3. The surgical device according to claim 1, further comprising at least one motor configured to move at least one of the first transmission assembly, the second transmission assembly, or the third transmission assembly.

4. The surgical device according to claim 3, further comprising: a sensor configured to measure at least one property of the tissue.

5. The surgical device according to claim 4, wherein the sensor is configured to measure at least one of a mechanical property, optical property, or electrical property of the tissue.

6. The surgical device according to claim 4, further comprising: a controller configured to determine whether an anastomosis has been formed or optimal conditions for forming an anastomosis based on the at least one property

7. The surgical device according to claim 6, wherein the controller is further configured to control the at least one motor to move the third transmission assembly based on the determination that the anastomosis has been formed thereby advancing the annular knife through the tissue and the connection portion of the head assembly to separate the outer ring portion from the inner portion.

8. A compression ring assembly comprising: a tubular support member; a first ring securely coupled to the tubular support member, the first ring configured to engage a first segment of an alimentary tract portion; and a second ring slidably disposed on the tubular support member and movable along the tubular support member and relative to the first ring, the second ring configured to engage a second segment of the alimentary tract portion, wherein the first ring and the second ring are configured to be approximated relative to each other to compress the first segment and the second segment to form an anastomosis.

9. The compression ring assembly according to claim 8, wherein the tubular support member is configured to engage an anvil assembly.

10. The compression ring assembly according to claim 9, wherein the tubular support member includes at least one protrusion configured to engage the anvil assembly.

11. The compression ring assembly according to claim 8, further comprising: a lock ring disposed on the tubular support member, the lock ring movable along the tubular support member and relative to the second ring, the lock ring configured to retain the second ring.

12. The compression ring assembly according to claim 11, wherein the tubular support member includes a barbed surface configured to permit movement of the lock ring in a direction toward the second ring.

13. A system for forming an anastomosis, the system comprising: a compression ring assembly including: a tubular support member; a first ring securely coupled to the tubular support member, the first ring configured to engage a first segment of an alimentary tract portion; and a second ring slidably disposed on the tubular support member and movable along the tubular support member and relative to the first ring, the second ring configured to engage a second segment of the alimentary tract portion; and a powered surgical device including: an annular reload configured to

support the second ring; an anvil assembly configured to engage the tubular support member, wherein at least one of the first ring and the second ring are configured to be approximated relative to each other to compress the first segment and the second segment to form an anastomosis; a sensor configured to measure at least one property of the alimentary tract portion; and a controller configured to determine whether the anastomosis has been formed based on the at least one property.

14. The system according to claim 13, wherein the tubular support member includes at least one protrusion configured to engage the anvil assembly.

15. The system according to claim 13, wherein the compression ring assembly further includes a lock ring disposed on the tubular support member, the lock ring movable along the tubular support member and relative to the second ring, the lock ring configured to retain the second ring.

16. The system according to claim 15, wherein the tubular support member includes a barbed surface configured to permit movement of the lock ring in a direction toward the second ring.

17. The system according to claim 13, wherein the powered surgical device further includes: a first motor; and a first transmission assembly coupled to the first motor and the anvil assembly, the first motor configured to move the anvil assembly.

18. The system according to claim 13, wherein the annular reload includes: a first driver longitudinally movable within the annular reload and configured to engage the second ring.

19. The system according to claim 18, wherein the powered surgical device further includes: a second motor; and a second transmission assembly coupled to the second motor and the first driver, the second motor configured to move the second ring.

20. The system according to claim 15, wherein the annular reload includes: a second driver longitudinally movable within the annular reload and configured to engage the lock ring.

21-27. (canceled)
