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(54) **WRIST ASSEMBLY FOR ARTICULATING LAPAROSCOPIC SURGICAL INSTRUMENTS**

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This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 13/442,524, filed on Apr. 9, 2012, now Pat. No. 9,211,134.

(51) **Int. Cl.**

A61B 17/29 (2006.01)
A61B 17/00 (2006.01)

(52) **U.S. Cl.**

CPC *A61B 17/29* (2013.01); *A61B 17/00234* (2013.01); *A61B 2017/00314* (2013.01); *A61B 2017/00323* (2013.01); *A61B 2017/2903* (2013.01); *A61B 2017/2905* (2013.01); *A61B 2017/2908* (2013.01); *A61B 2017/2929* (2013.01)

(58) **Field of Classification Search**

CPC A61B 1/0055; A61B 2017/320032; A61B 2017/003; A61B 19/26; A61B 17/29; A61B 2017/00314; A61B 2017/2903; A61B 2017/2929

See application file for complete search history.

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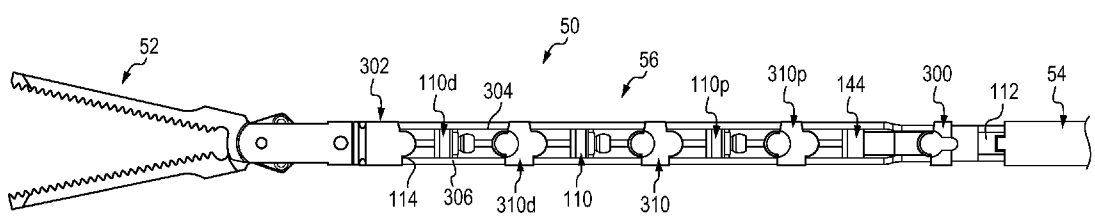
(57) **ABSTRACT**

An articulating laparoscopic instrument including a handle, an outer shaft, an end effector, and a wrist assembly. The wrist assembly connects the end effector to the shaft and includes torque and articulation mechanisms. The torque mechanism includes a plurality of links disposed over the rod and connected with one another in a pivotable yet rotationally locked fashion. The articulation mechanism includes a plurality of articulation member disposed over the rod to collectively define a deflection section. The links freely rotate relative to the articulation members, with the rod and links collectively bending in response to a change in shape of the deflection section.

20 Claims, 25 Drawing Sheets



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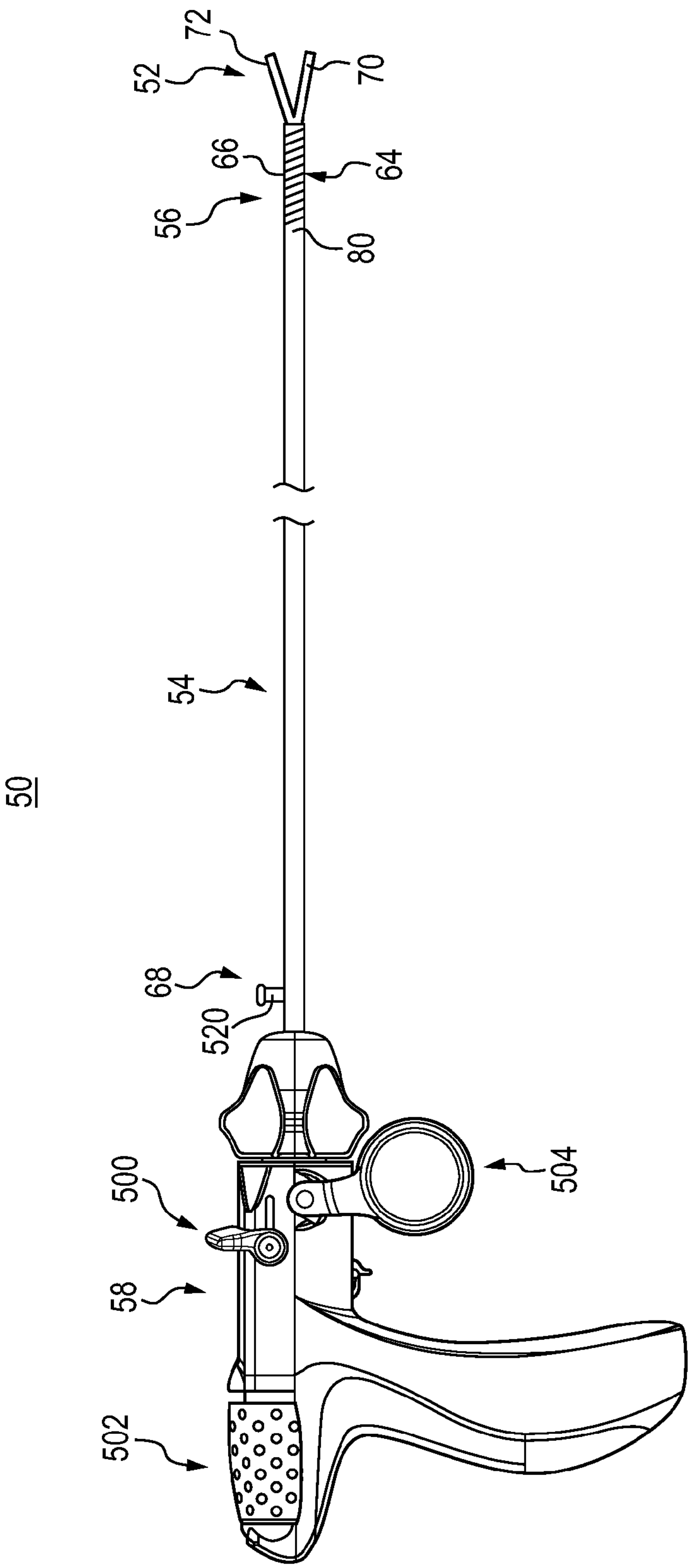

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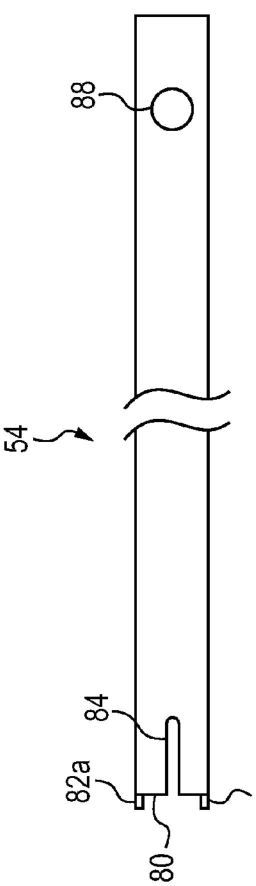

FIG. 2A

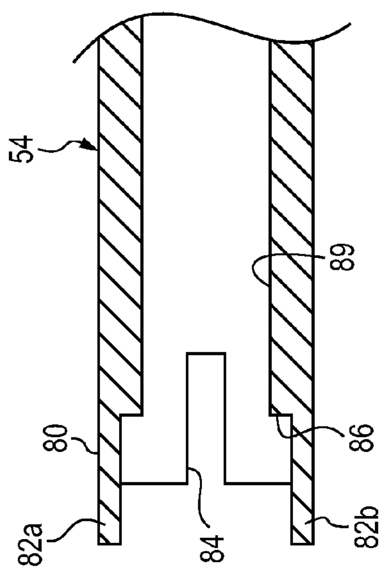

FIG. 2B

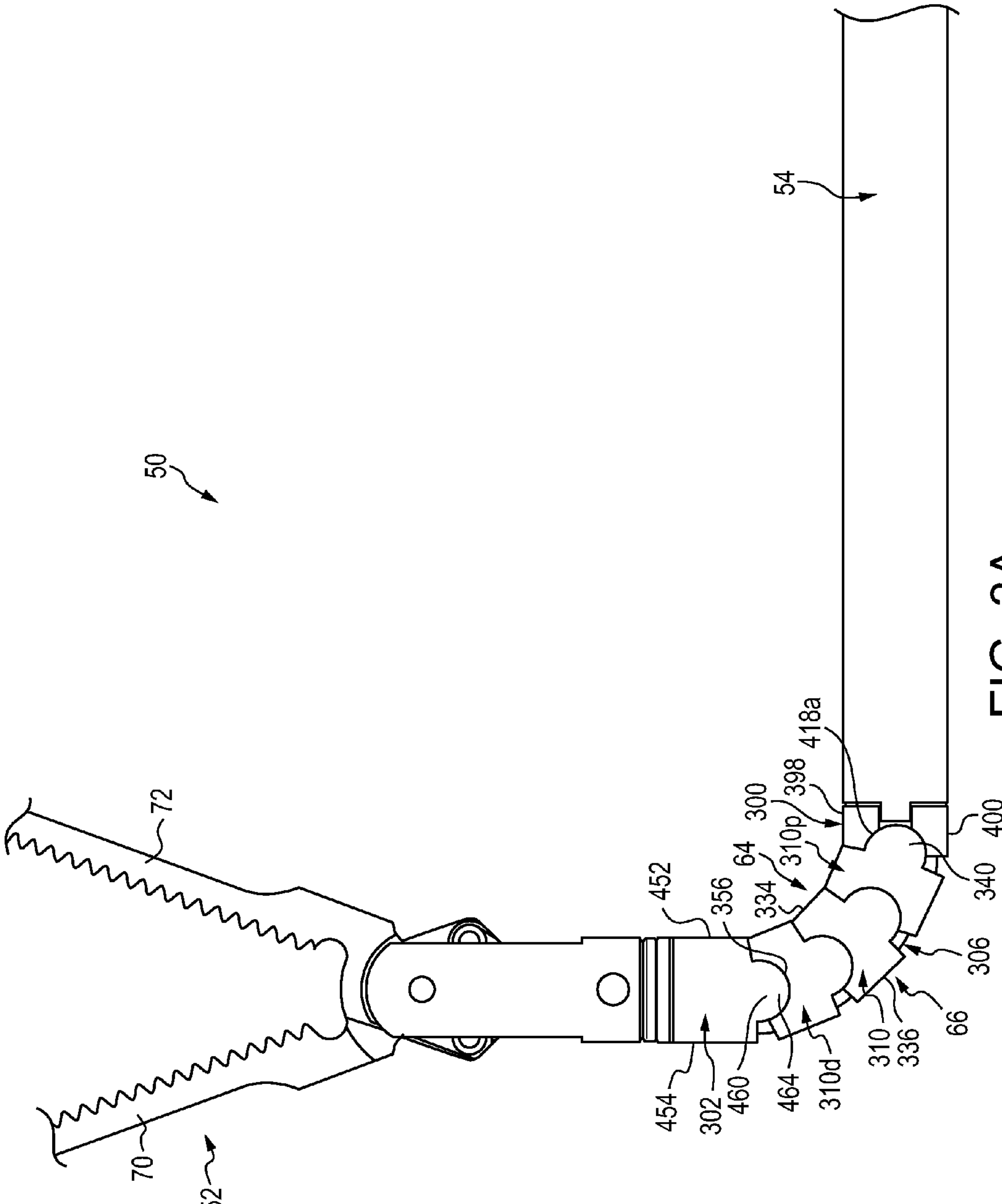
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FIG. 3A

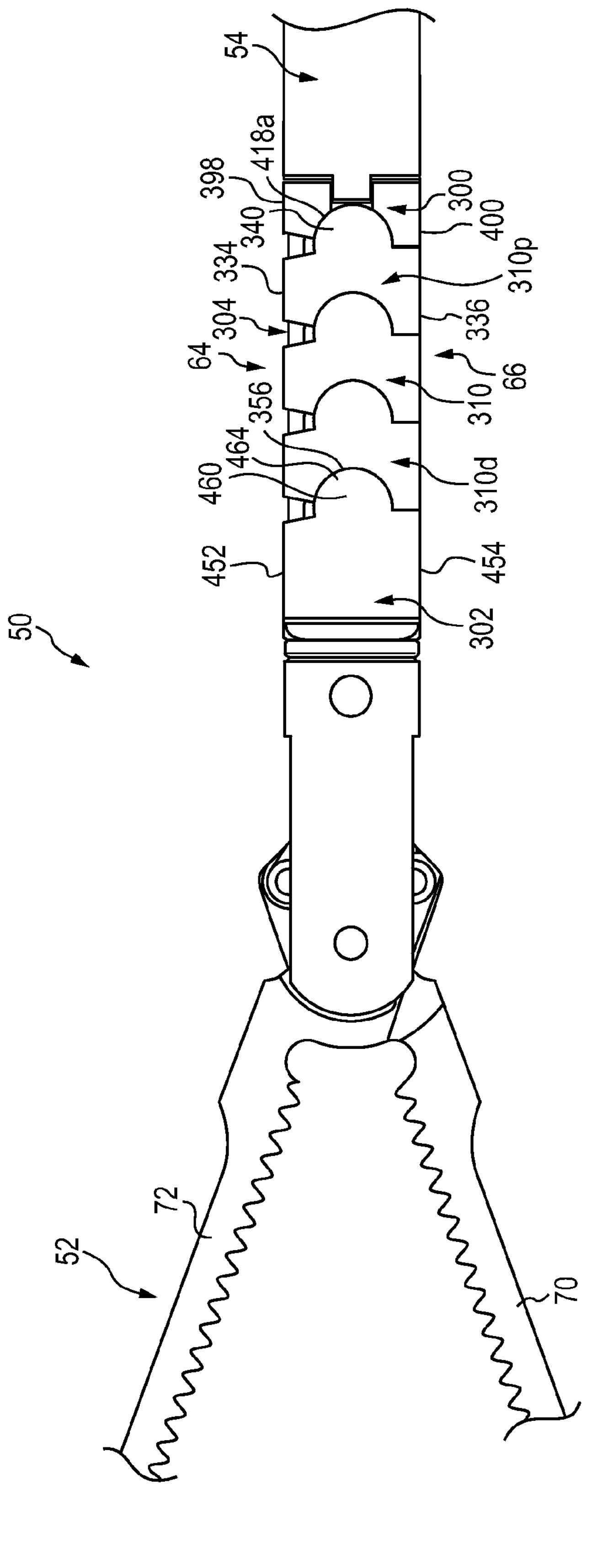
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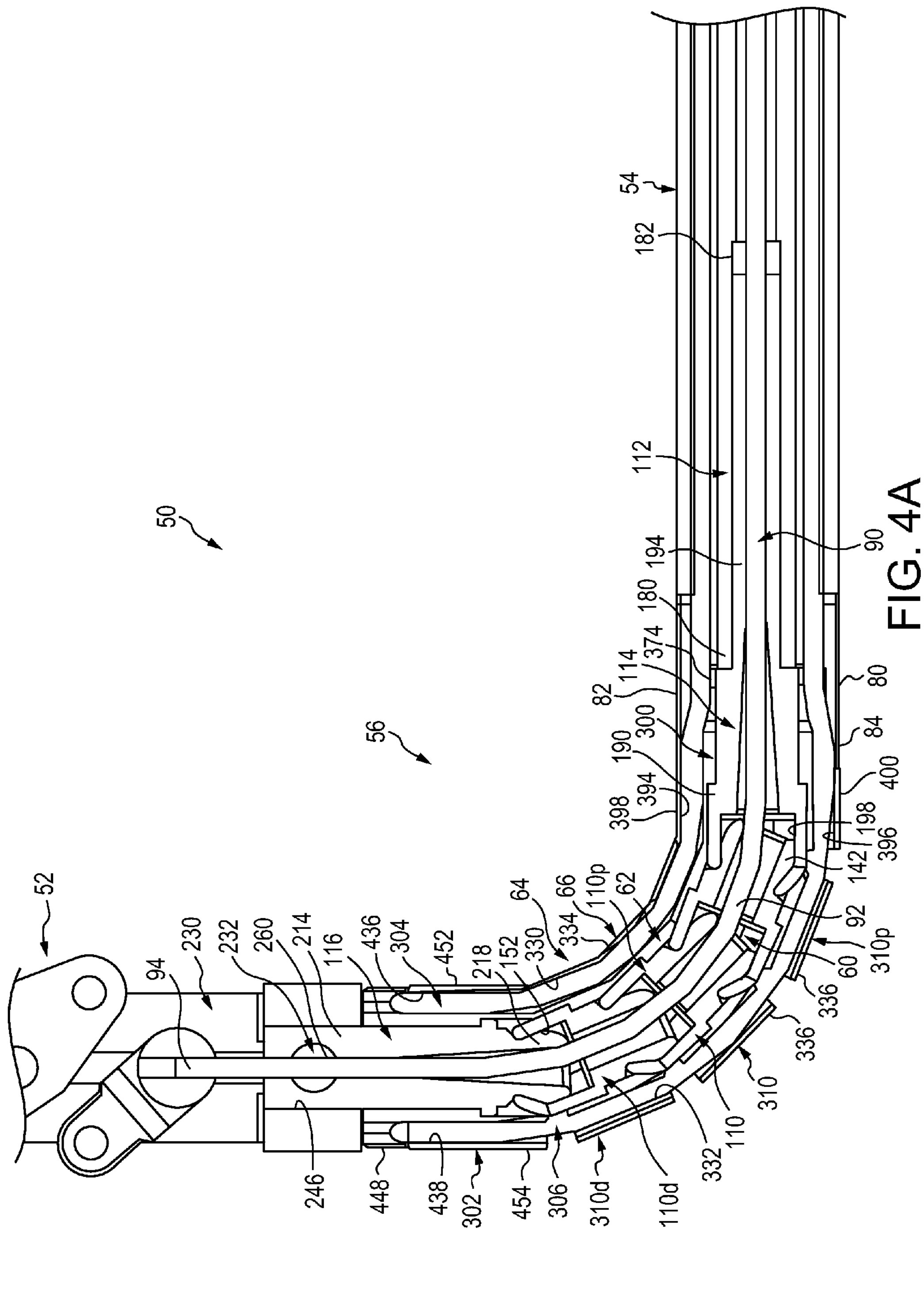
FIG. 3B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92
310p
60
336
336
310
110
332
110d
310d
306
454
302
438
448
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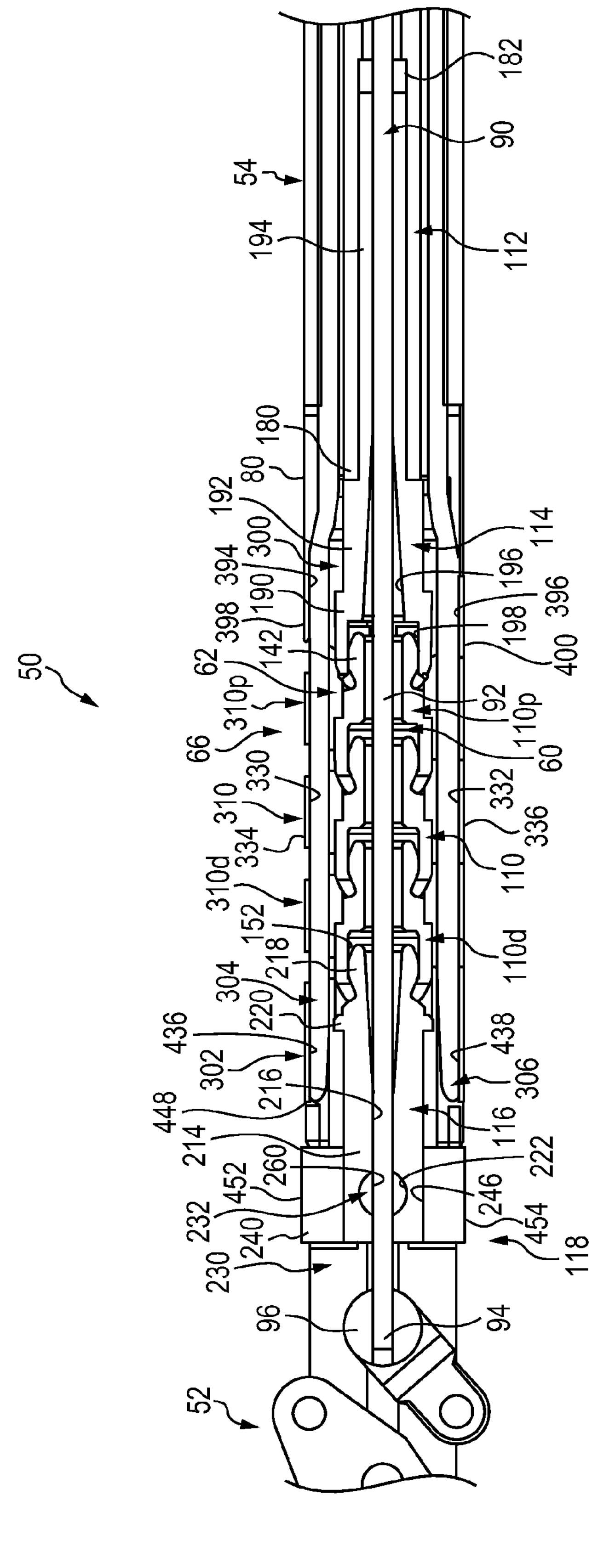
FIG. 4A



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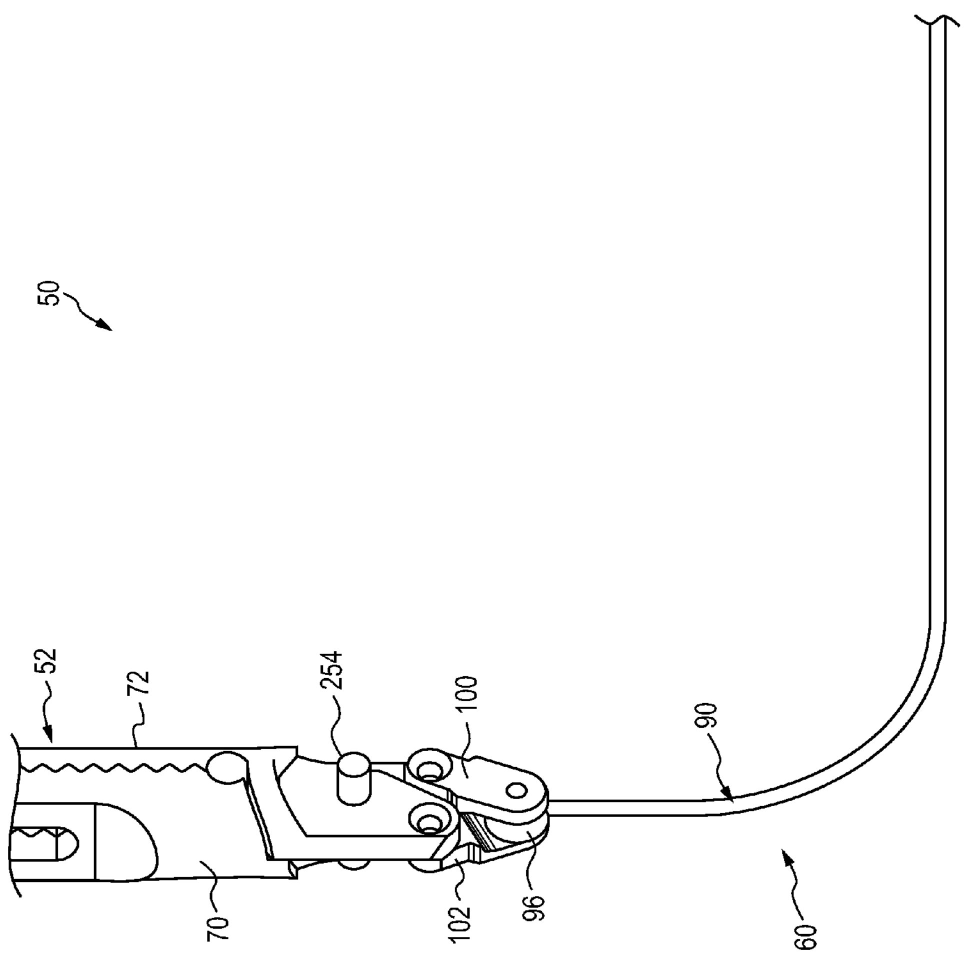

FIG. 5A

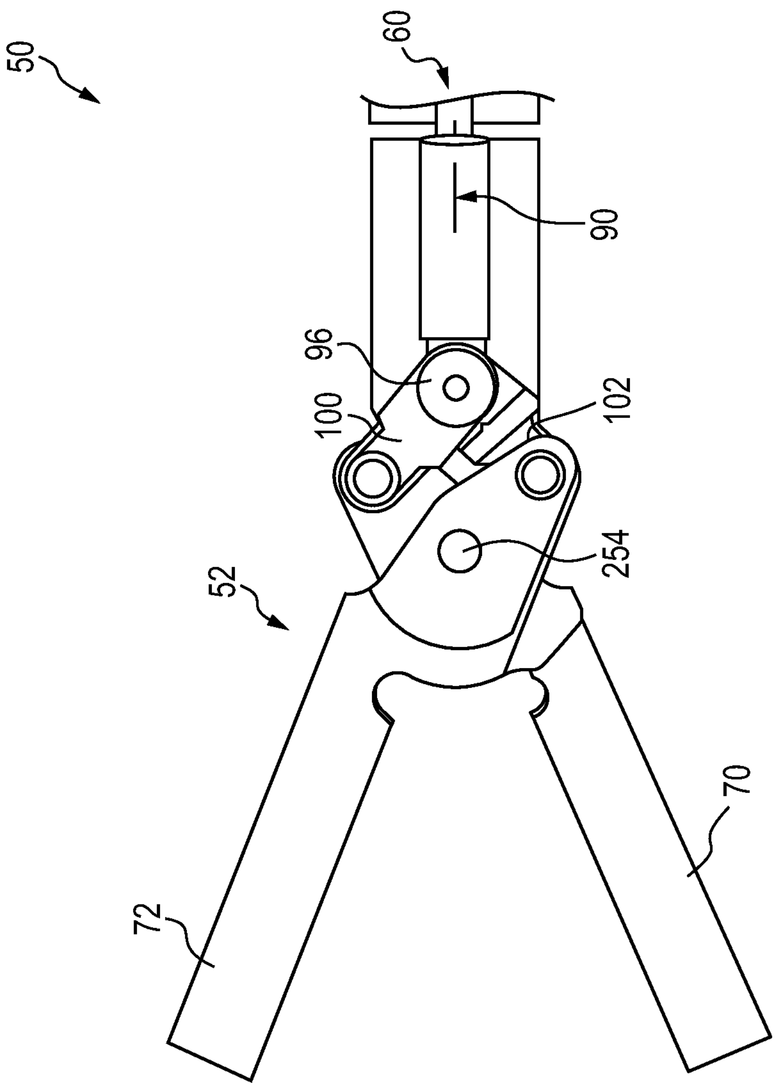

FIG. 5B

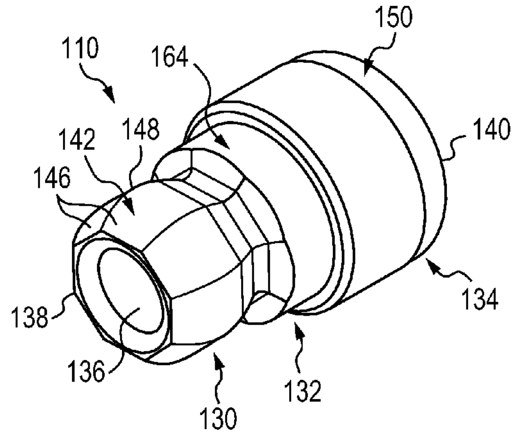

FIG. 6A

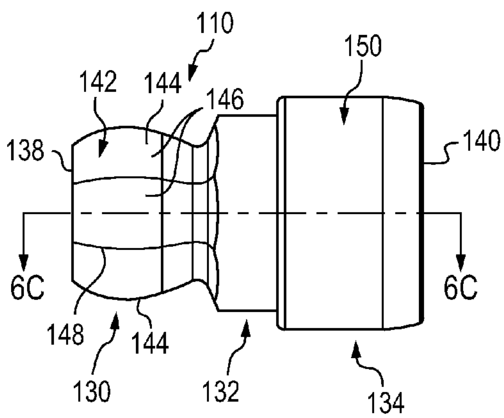

FIG. 6B

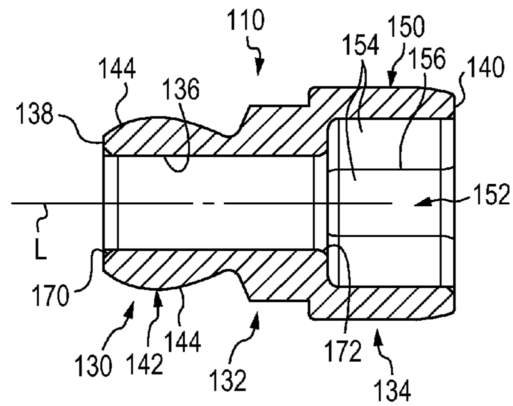

FIG. 6C

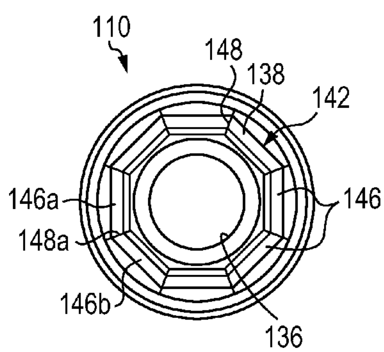

FIG. 6D

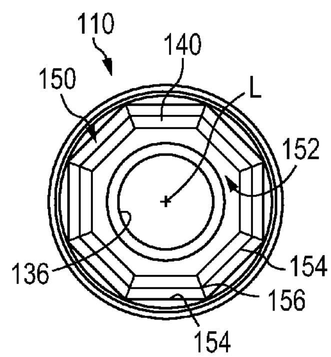

FIG. 6E

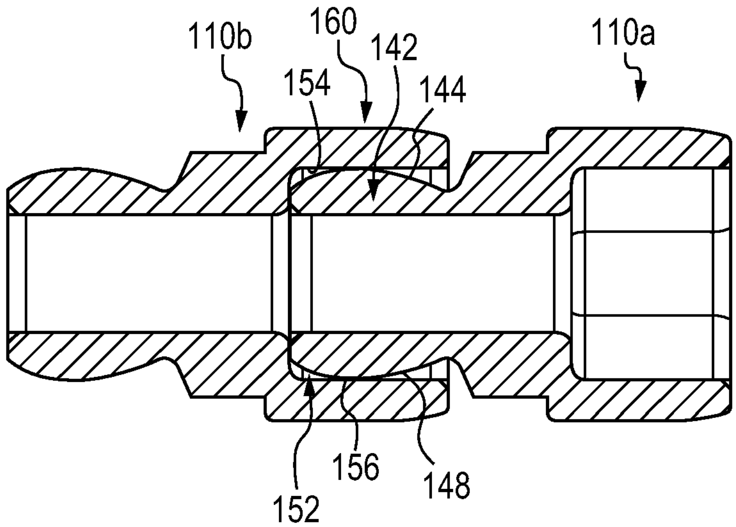

FIG. 7A

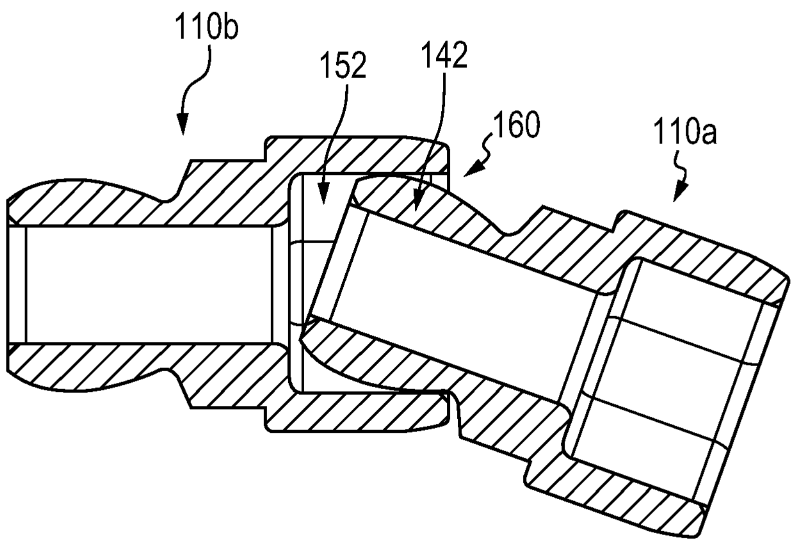

FIG. 7B

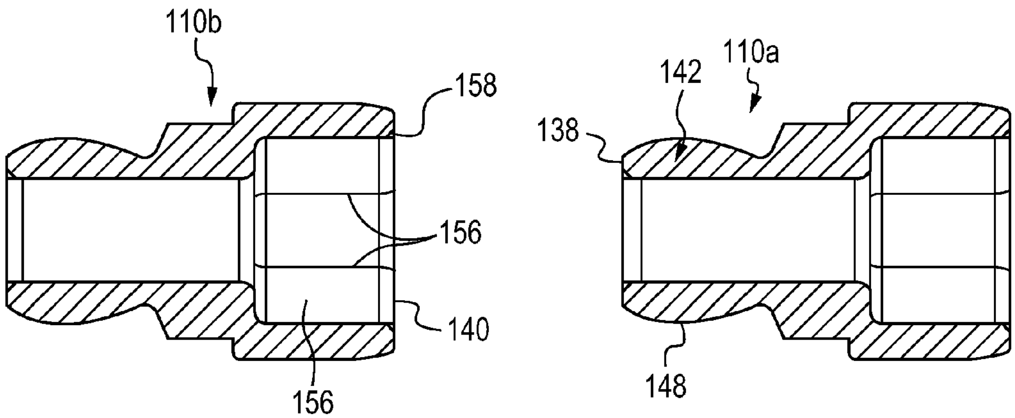

FIG. 7C

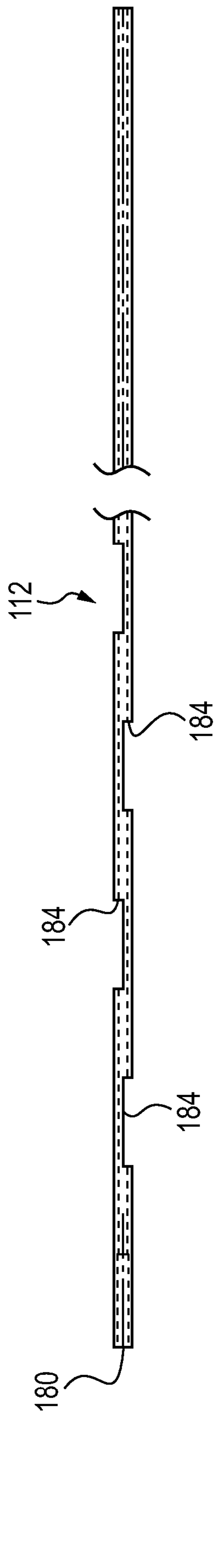

FIG. 8

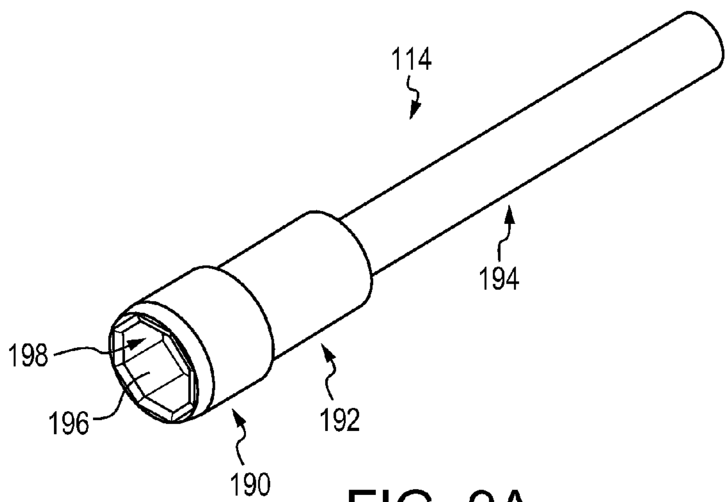

FIG. 9A

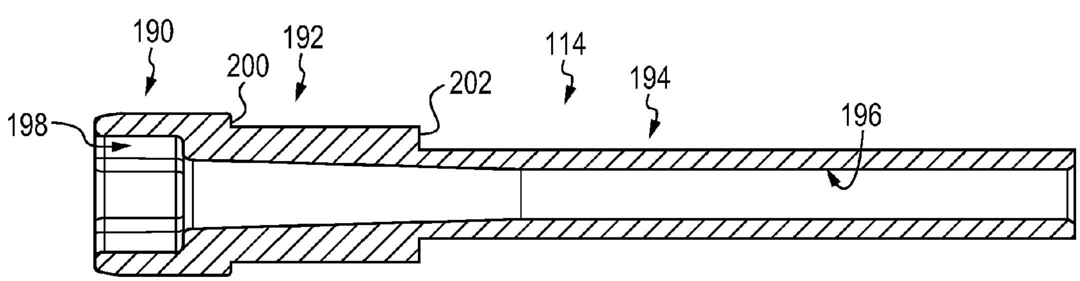

FIG. 9B

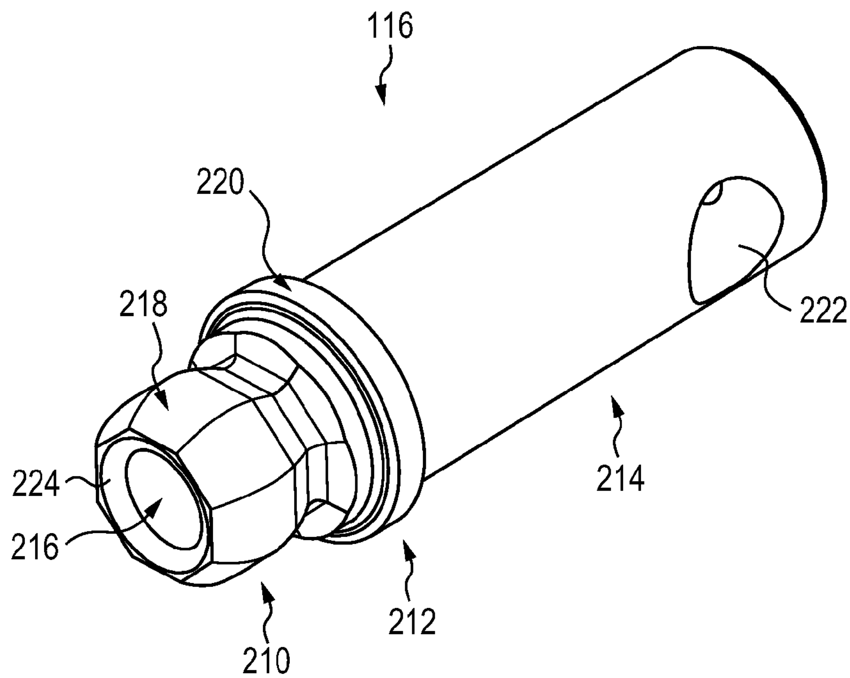

FIG. 10A

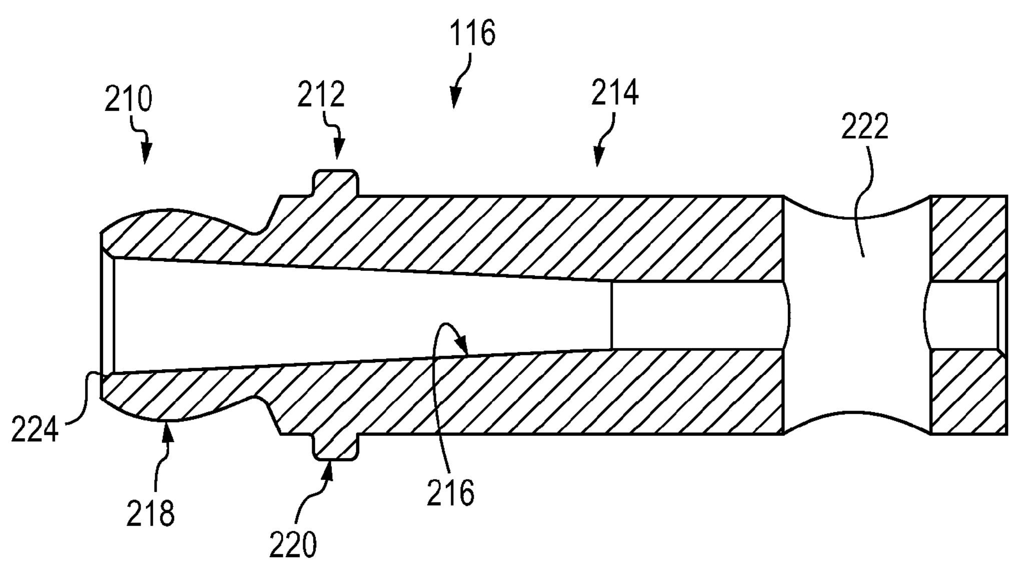

FIG. 10B

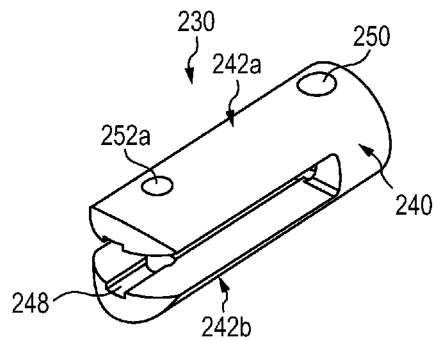

FIG. 11A

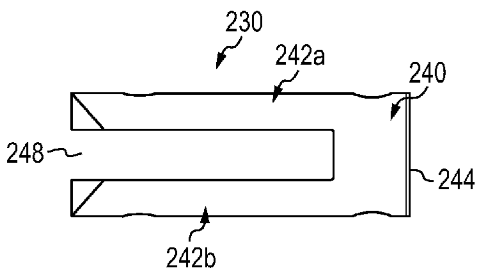

FIG. 11B

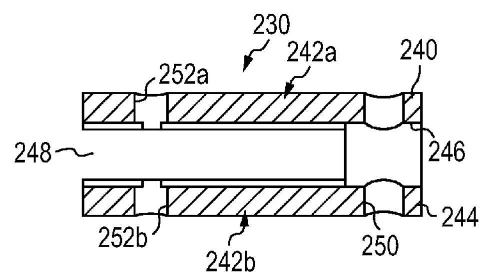

FIG. 11C

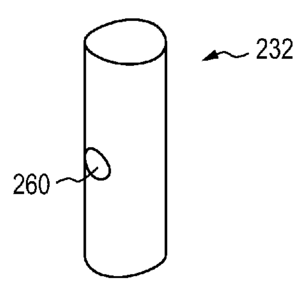

FIG. 12

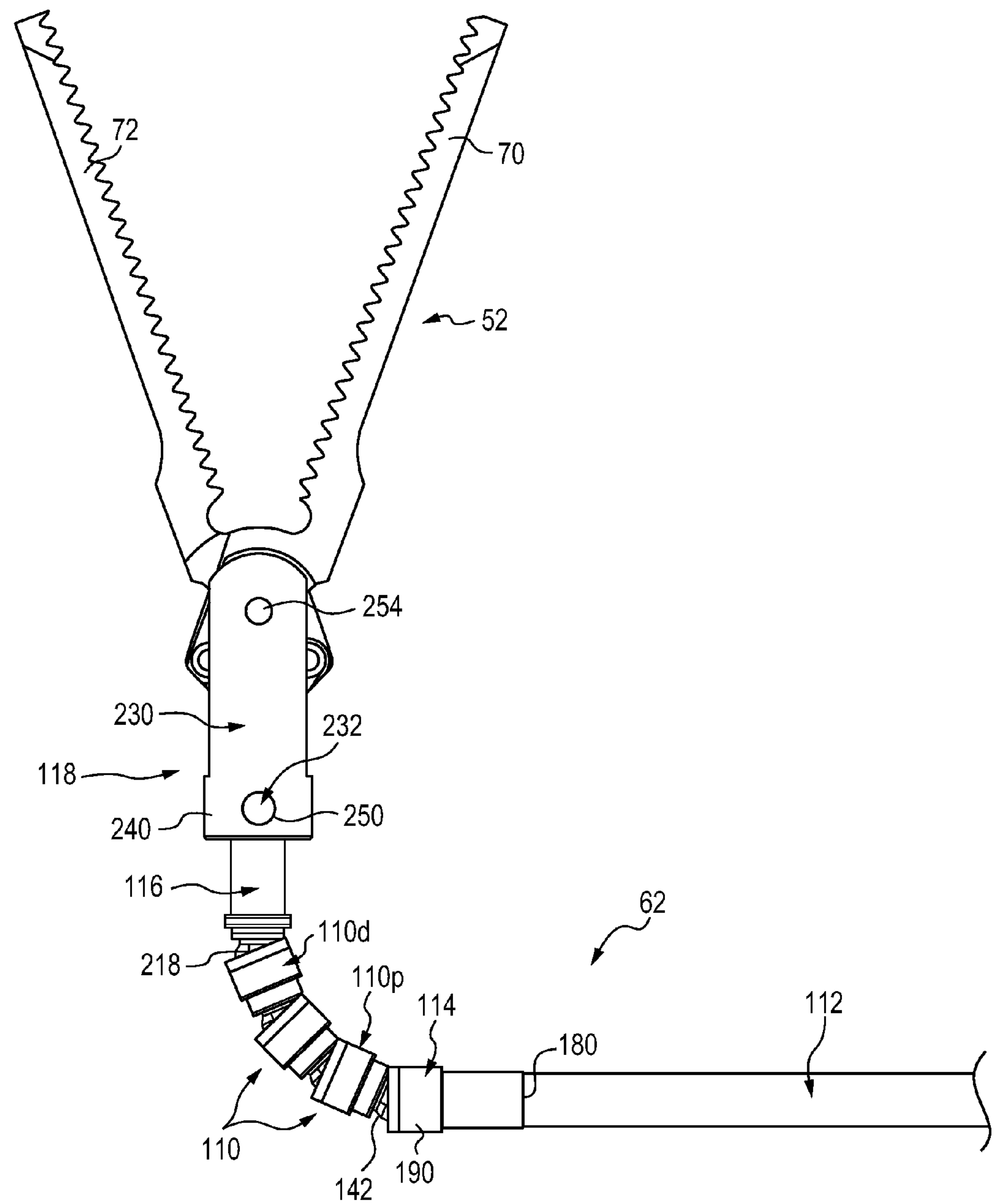
72
70
52
254
230
232
118
240
250
116
62
110d
218
110p
114
112
180
110
190
142

FIG. 13

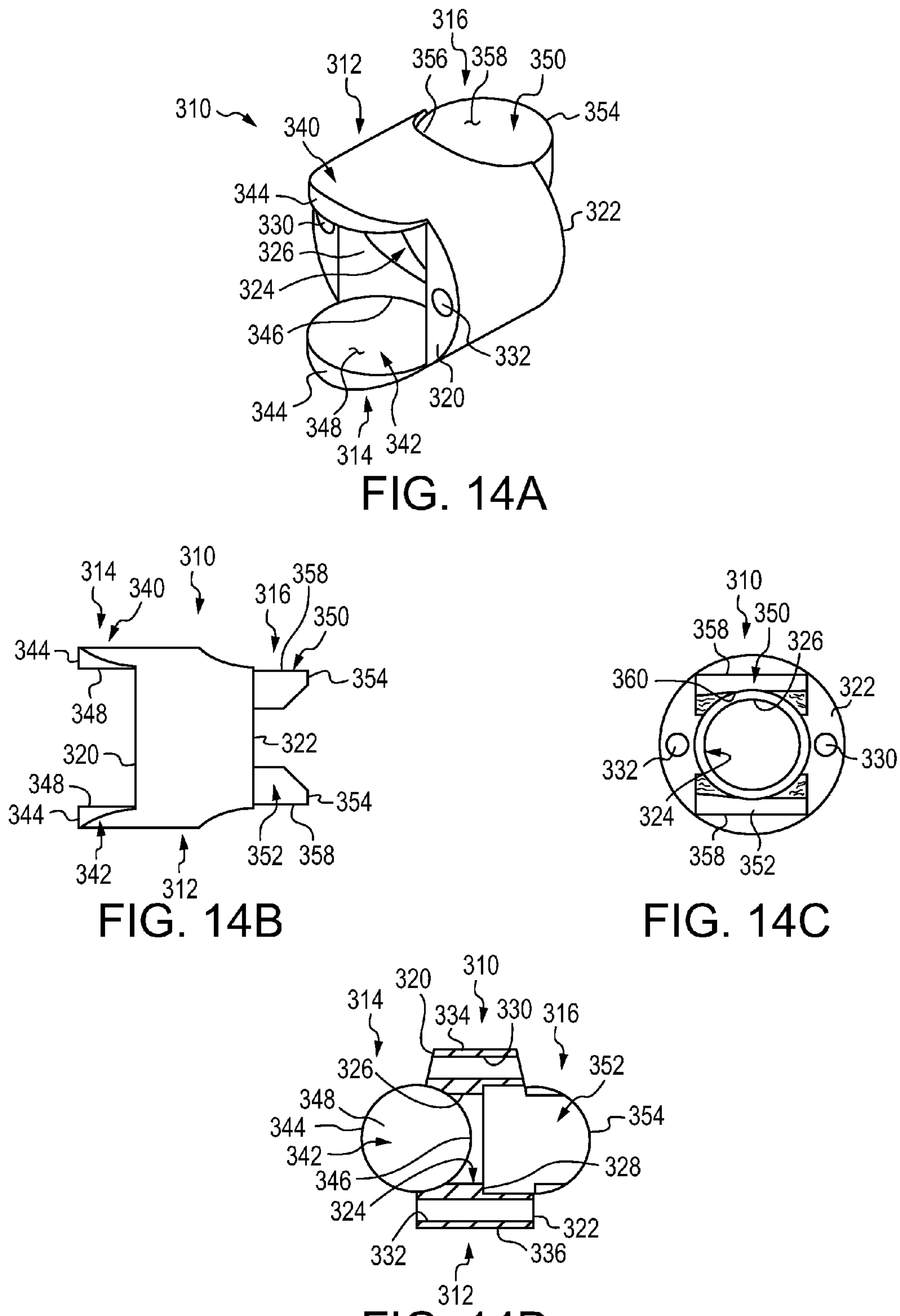

FIG. 14A

FIG. 14B

FIG. 14C

FIG. 14D

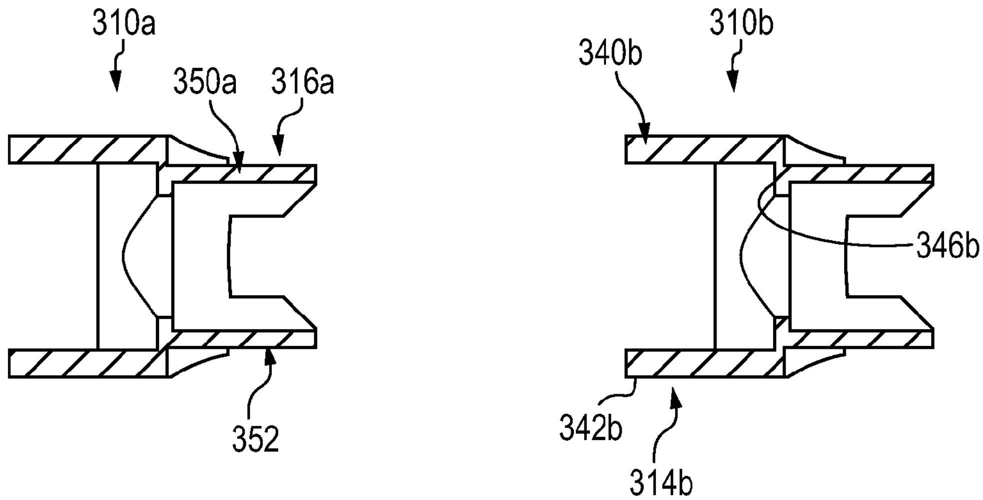

FIG. 15A

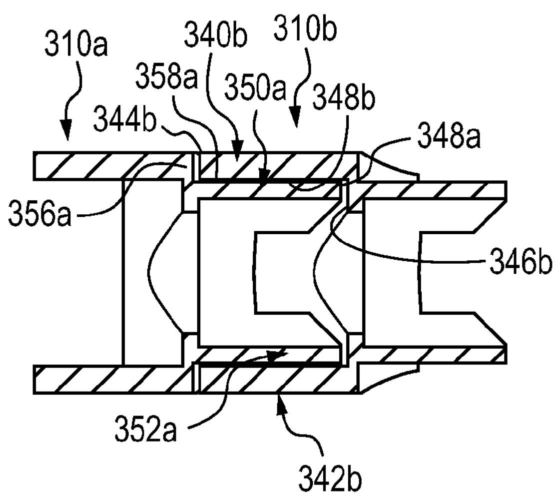

FIG. 15B

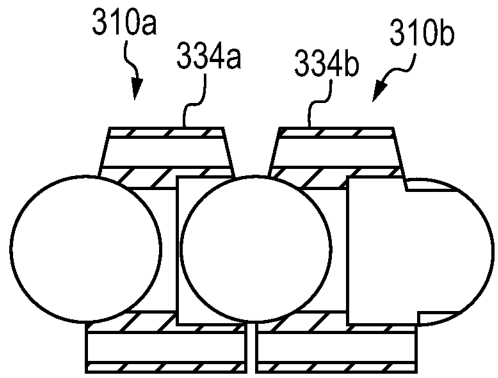

FIG. 15C

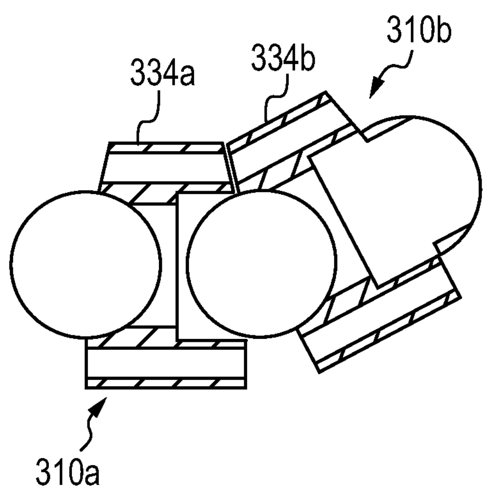

FIG. 15D

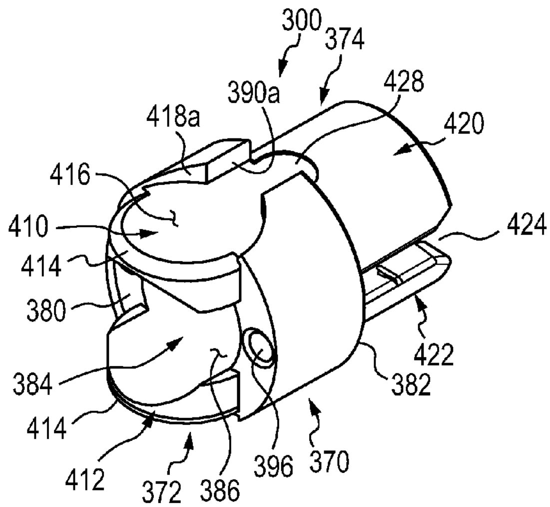

FIG. 16A

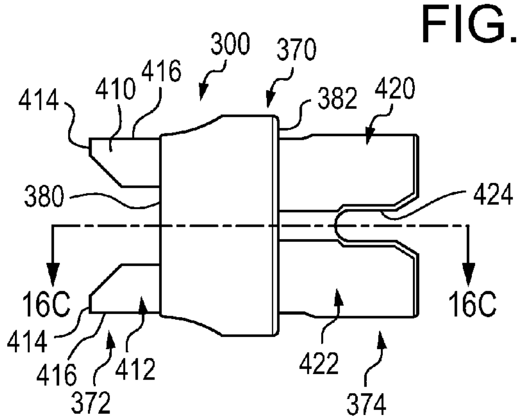

FIG. 16B

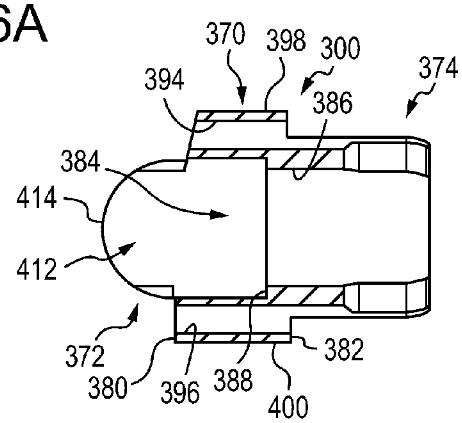

FIG. 16C

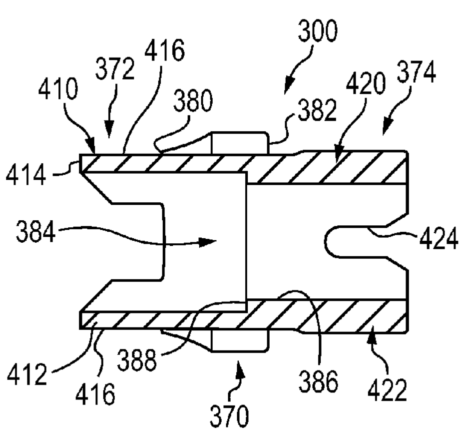

FIG. 16D

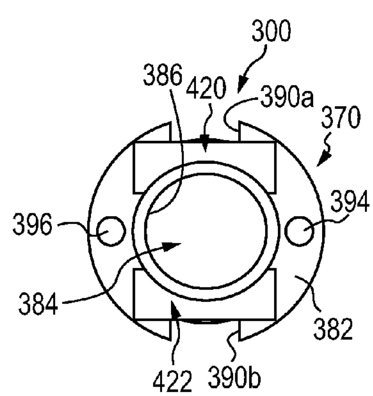

FIG. 16E

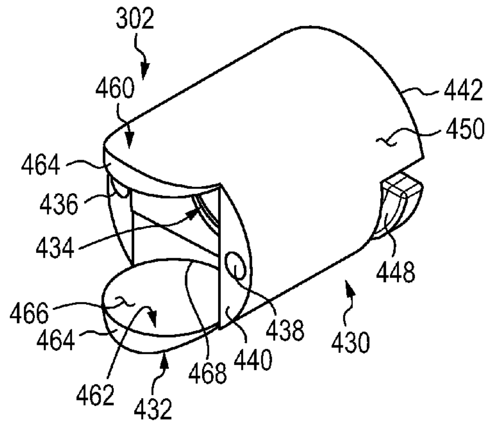

FIG. 17A

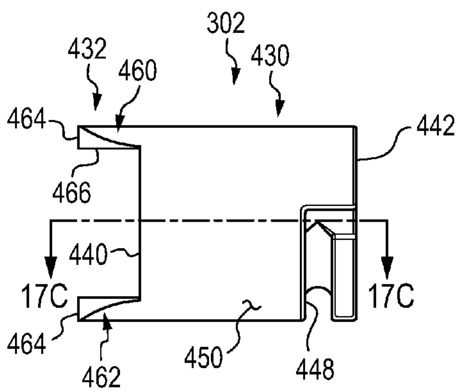

FIG. 17B

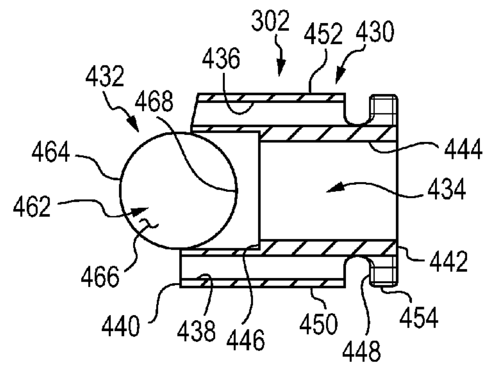

FIG. 17C

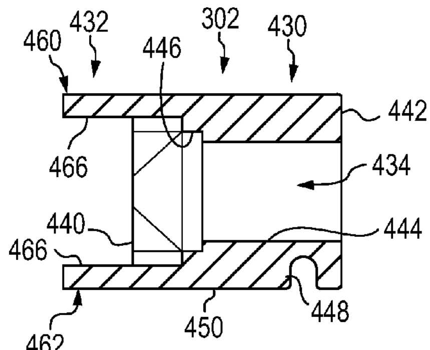

FIG. 17D

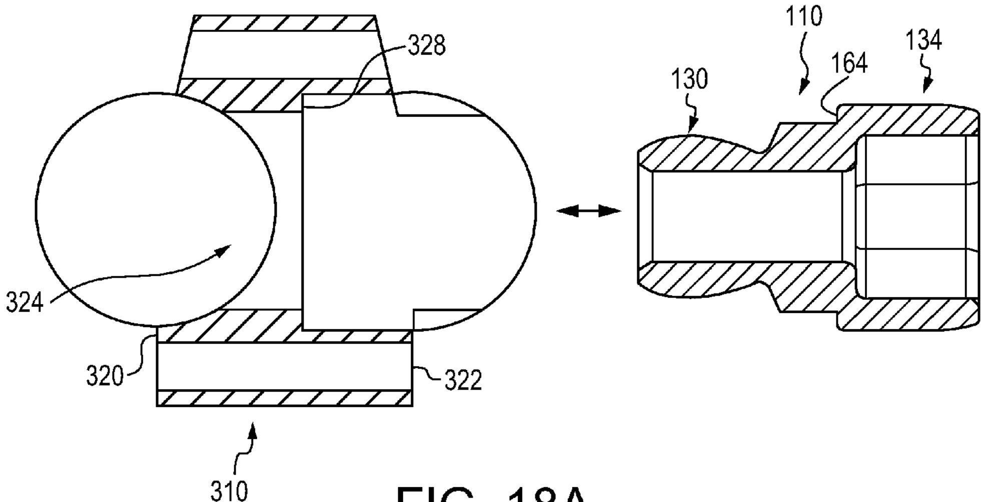

FIG. 18A

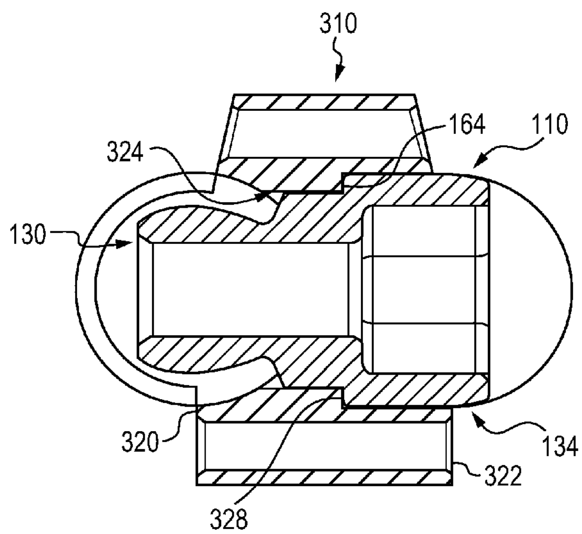

FIG. 18B

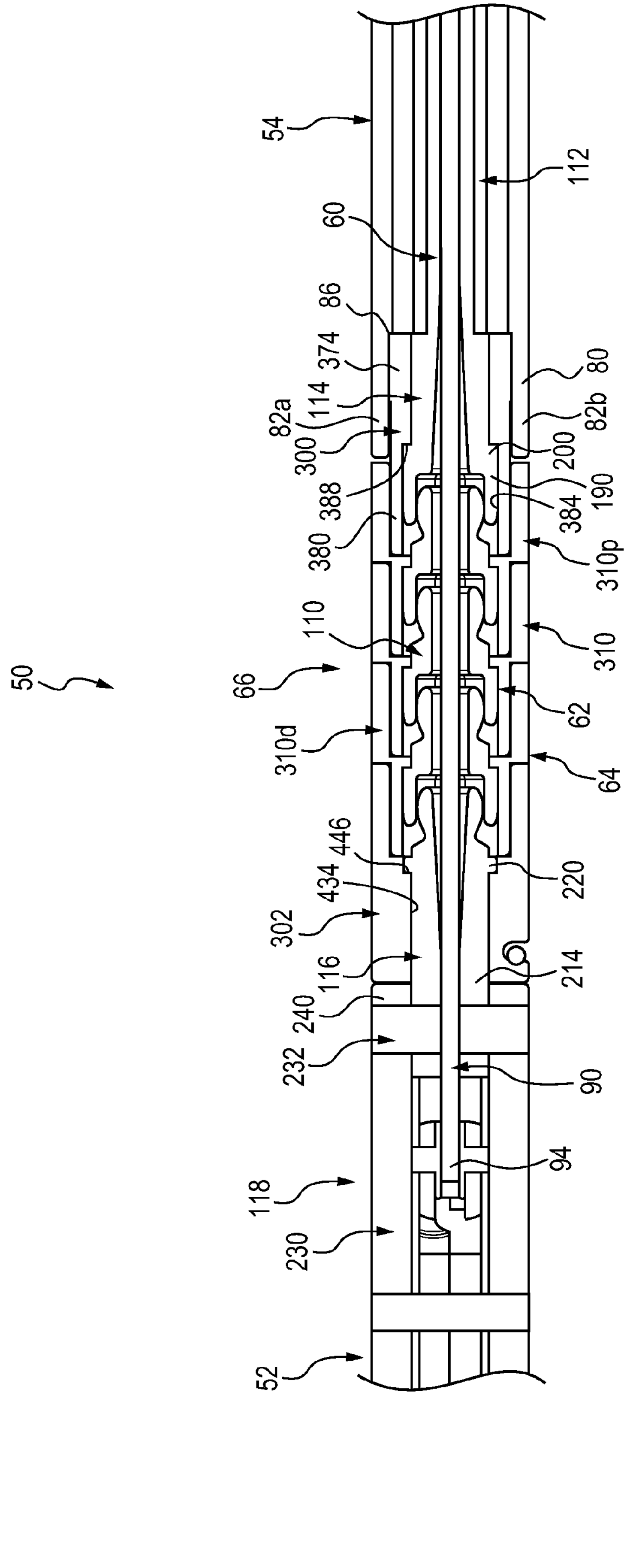
54
112
60
86
374
80
114
82a
82b
300
200
388
190
384
380
310p
110
310
50
66
62
310d
64
446
434
220
302
214
116
240
232
90
94
118
230
52

FIG. 19

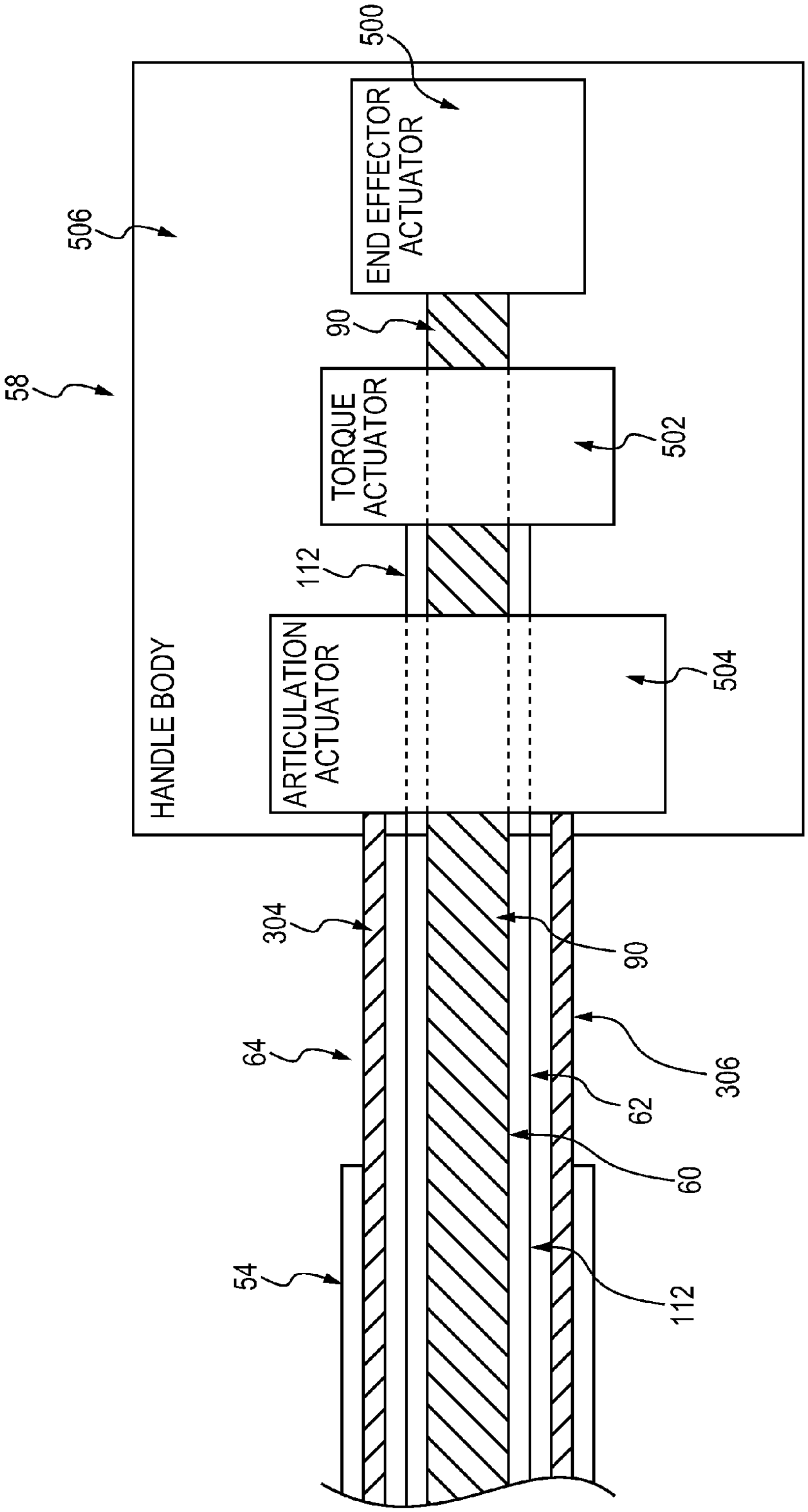
500
END EFFECTOR ACTUATOR
506
90
58
TORQUE ACTUATOR
502
112
HANDLE BODY
ARTICULATION ACTUATOR
504
304
90
64
306
62
60
54
112

FIG. 20

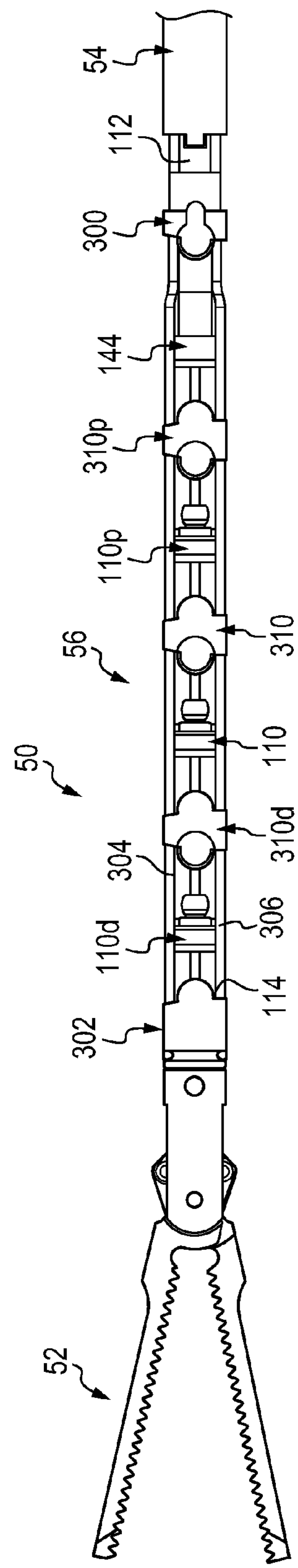
54
112
300
144
310p
110p
56
310
50
110
310d
304
306
110d
114
302
52

FIG. 21

WRIST ASSEMBLY FOR ARTICULATING LAPAROSCOPIC SURGICAL INSTRUMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of and claims priority under 35 USC §120 to U.S. patent application Ser. No. 13/442,524, filed Apr. 9, 2012, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present disclosure relates to articulating laparoscopic surgical instruments. More particularly, it relates to articulating laparoscopic surgical instruments having a low profile wrist assembly providing user control over operation and spatial positioning of an end effector carried by the instrument so as to be useful in performing, for example, single incision laparoscopic procedures.

BACKGROUND

There is a growing trend in laparoscopic surgery to be as minimally invasive as possible. This has pushed surgeons to perform procedures with fewer and smaller incisions. With more recent protocols, only one incision is made (in the umbilicus) through which all of the instrumentation and even the camera are inserted. While highly promising, this technique presents many obstacles including lack of triangulation, instrument reach, handle clashing, etc.

Various articulating laparoscopic surgical instruments have been developed in an attempt to address one or more of the above concerns. In general terms, an articulating laparoscopic surgical instrument includes an elongated shaft carrying an end effector (or "working end") at the shaft's distal end. The end effector can assume various forms, such as scissors, graspers, needle holders, dissectors, clamps, electrocautery implements, electrode probes, etc. A wrist portion of the instrument (typically proximate the end effector) can be caused to deflect or bend. A handle at the proximal end of the shaft affords user control over the end effector and the articulating wrist. When employed with laparoscopic procedures, articulating instruments allow the surgeon to regain triangulation during single port surgery by aiming the shaft of the surgical instrument slightly away and then curving the working end (or end effector) back toward the operative site. In addition, their longer lengths provide the surgeon the reach needed for organs further away from the umbilicus. Further, their low profile handles minimize handle clashing at the entrance site.

To be truly viable, the articulating laparoscopic instrument should afford user control, via actuators along the instrument's handle, over operation of the end effector, rotation of the end effector, and articulation of the wrist or shaft. The mechanisms necessary to provide these multiple control features at the small scales associated with laparoscopic instrumentation are inherently intricate and dramatically increase the instrument's cost. In this regard, surgeons desire the ability to control, via actuators carried on or near the handle, all three movements (i.e., end effector operation, end effector rotation, and shaft articulation) independent of one another. An additional control feature provided with some laparoscopic instruments is an ability to rotate the outer shaft (thus re-orienting a spatial of location of any bend formed along the wrist or shaft). These requirements give rise to much technical difficulty, especially when accounting for the independent transmission of torque (for end effector rotation) from the handle actuator and through or around a bend in the wrist or shaft. While existing articulating laparoscopic surgical instruments may provide one or more of these features, they are limited to one-time use or are otherwise disposable because their design does not allow for proper cleaning and sterilization. Nor are they robust enough to stand up to repeated use. Due to the high cost, single-use nature of existing articulating laparoscopic instruments, a caregiver may unfortunately decide against purchasing or using such instruments. As a result, the single incision laparoscopic surgical procedures performed by the caregiver will be more complicated or even avoided.

In light of the above, a need exists for improved articulating laparoscopic instruments having a wrist joint assembly that facilitates desired surgeon control over instrument operation, articulation, and rotation.

SUMMARY

Some aspects of the present disclosure relate to an articulating surgical instrument including a handle, an outer shaft, an end effector, and a wrist assembly. The outer shaft extends from the handle to a shaft end. The wrist assembly connects the end effector to the shaft end, and includes a torque mechanism and an articulation mechanism. In some embodiments, the wrist assembly further comprises an end effector operation mechanism. With optional constructions in which the end effector includes two moveably connected bodies, the end effector operation mechanism includes a rod extending through the shaft and coupled to the end effector such that longitudinal movement of the rod relative to the end effector causes the first body to move relative to the second body. The torque mechanism includes a plurality of links disposed between the shaft and the effector. The links are collectively adapted to transfer a rotational force from a proximal-most link to the effector. Finally, the articulation mechanism includes a plurality of articulation members disposed between the shaft and the end effector to collectively define a deflection section. In this regard, the articulation mechanism is adapted to spatially articulate the end effector relative to the shaft end. The wrist assembly is configured such that the links articulate with articulation of the deflection section, and the links rotate independent of the articulation members. With the above construction, the wrist assembly can have a low profile while providing a user with the ability to operate and rotate the effector, and to articulate the effector relative to the outer shaft. In some embodiments, each of the links is seated within a corresponding one of articulation members in a manner permitting the link to rotate relative to the corresponding articulation member. Further, cable segments provided with the articulation mechanism interconnect the articulation members, with tensioning of the cable segments bringing the articulation members into operative connection with one another, as well as bringing the links into operative connection to one another. In an optional cleaning mode provided with some embodiments of the surgical instrument, sufficient slack is created in the cable segments to permit the articulation members to be physically separated from one another, and the links to be physically separated from one another. In other embodiments, each of the links defines a male end portion and a female end portion, with the male end portion forming a polygonal ball head and the female end portion forming a corresponding, polygonal socket.

Other aspects of the present disclosure relate to an articulating laparoscopic surgical instrument including the handle,

outer shaft, end effector, and wrist assembly components described above. The wrist assembly is configured such that during actuation of the optional end effector operation mechanism in operating the end effector, the rod slides longitudinally relative to the links and the articulation members. During actuation of the torque mechanism in rotating the end effector, the links rotate relative to the articulation members and the optional rod (where provided). Finally, during actuation of the articulation mechanism in spatially moving the end effector relative to the shaft end, a bending force generated by the deflection of the assembly is applied to the plurality of links and the optional rod (where provided). Thus, the wrist assembly provides for independent operation of each of the end effector operation mechanism, torque mechanism, and articulation mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of a surgical instrument in accordance with principles of the present disclosure;

FIG. **2**A is a side view of an outer shaft component useful with the surgical instrument of FIG. **1**;

FIG. **2**B is a cross-sectional view of a portion of the outer shaft of FIG. **2**A;

FIG. **3**A is an enlarged, top plan view of a portion of the surgical instrument of FIG. **1**, illustrating a distal region of a wrist assembly useful with the instrument, including a deflection section in a curved or articulated state;

FIG. **3**B is the enlarged top plan view of FIG. **3**A with the deflection section in a straightened state;

FIG. **4**A is a cross-sectional view of the instrument portion of FIG. **3**A;

FIG. **4**B is a cross-sectional view of the instrument portion of FIG. **3**B;

FIG. **5**A is a perspective view of portions of the wrist assembly of FIG. **4**A, including components of an end effector operation mechanism useful with the wrist assembly;

FIG. **5**B is a side view of a portion of the instrument of FIG. **4**A, illustrating a relationship between the end effector and the end effector operation mechanism;

FIG. **6**A is a perspective view of a link component of a torque mechanism useful with the wrist assembly of FIG. **4**A;

FIG. **6**B is a side view of the link of FIG. **6**A;

FIG. **6**C is a cross-sectional view of the link of FIG. **6**B, taken along the line **6**C-**6**C;

FIG. **6**D is an end view of the link of FIG. **6**A;

FIG. **6**E is an opposite end view of the link of FIG. **6**A;

FIGS. **7**A-**7**C are cross-sectional views illustrating coupling between two of the links of FIG. **6**A;

FIG. **8** is a side view of an alternative embodiment torque tube useful with the torque mechanism of FIG. **4**A;

FIG. **9**A is perspective view of a proximal drive body useful with the torque mechanism of FIG. **4**A;

FIG. **9**B is a cross-sectional view of the proximal dry body of FIG. **9**A;

FIG. **10**A is a perspective view of a distal drive body useful with the torque mechanism of FIG. **4**A;

FIG. **10**B is a cross-sectional view of the distal drive body of FIG. **10**A;

FIG. **11**A is a perspective view of a clevis useful with a coupling assembly of the torque mechanism of FIG. **4**A;

FIG. **11**B is a side view of the clevis of FIG. **11**A;

FIG. **11**C is a cross-sectional view of the clevis of **11**A;

FIG. **12** is a perspective view of a king pin useful with the torque mechanism coupling assembly of FIG. **4**A;

FIG. **13** is a side view of a portion of the instrument of FIG. **4**A, illustrating assembly of the torque mechanism;

FIG. **14**A is a perspective view of an articulation member useful with an articulation mechanism of the wrist assembly of FIG. **3**A;

FIG. **14**B is a side view of the articulation member of FIG. **14**A;

FIG. **14**C is an end view of the articulation member of FIG. **14**A;

FIG. **14**D is cross-sectional view of the articulation member of FIG. **14**A;

FIGS. **15**A-**15**D are cross-sectional views illustrating connection between two of the articulation members of FIG. **14**A;

FIG. **16**A is perspective view of a proximal joint connector useful with the articulation mechanism of FIG. **3**A;

FIG. **16**B is side view of the proximal joint connector of FIG. **16**A;

FIG. **16**C is a cross-sectional view of the proximal joint connector of FIG. **16**B, taken along the line **16**C-**16**C;

FIG. **16**D is another cross-sectional view of the proximal joint connector of FIG. **16**A taken in a plane 90 degrees from that of FIG. **16**C;

FIG. **16**E is an end view of the proximal joint connector of FIG. **16**A;

FIG. **17**A is a perspective view of a distal joint connector useful with the articulation mechanism of FIG. **3**A;

FIG. **17**B is a side view of the distal joint connector of FIG. **17**A;

FIG. **17**C is a cross-sectional view of the distal joint connector of FIG. **16**B, taken along the lines **17**C-**17**C;

FIG. **17**D is another cross-sectional view of the distal joint connector of FIG. **17**A taken in a plane 90 degrees to that of FIG. **17**C;

FIGS. **18**A and **18**B illustrate connection between one of the links of FIG. **6**A and one of articulation member of FIG. **14**A;

FIG. **19** is an enlarged, cross-sectional view of the wrist assembly of FIG. **3**B taken in a plane 90 degrees to that of FIG. **4**B and illustrating various component relationships upon final assembly;

FIG. **20** is a schematic illustration of components of a handle assembly useful with the instrument of FIG. **1**; and

FIG. **21** is a side view of a portion of the instrument of FIG. **1** in an optional cleaning mode.

DETAILED DESCRIPTION

One embodiment of an articulating laparoscopic surgical instrument **50** in accordance with principles of the present disclosure is shown in FIG. **1**. The surgical instrument **50** includes an end effector **52**, an outer shaft **54**, a wrist assembly **56**, and a handle assembly **58**. Details on the various components are provided below. In general terms, however, the shaft **54** extends from the handle assembly **58** and maintains or is connected to the end effector **52** by the wrist assembly **56**. While primarily hidden in the view of FIG. **1**, the wrist assembly **56** includes in some embodiments an end effector operation mechanism **60** (hidden in FIG. **1**, but shown, for example, in FIG. **4**A), a torque mechanism **62** (hidden in FIG. **1**, but shown, for example, in FIG. **4**A), and an articulation mechanism **64** (referenced generally). Each of the mechanisms **60**-**64** are described below, and independently facilitate operation of the end effector **52**, rotation of the end effector **52** relative to the shaft **54**, and articulation of a deflection section **66** component of the articulation mechanism **64**. In some embodiments, the instrument **50** further includes or forms a flush port assembly **68** through which internal cleaning and sterilization of portions of the instrument **50** (e.g., a lumen of the shaft **54**) can be performed. Thus, in some embodiments, not only does the instrument **50** provide a user with all operational control desired for single incision laparoscopic procedures (e.g., end effector operation, rotation, and articulation), but also is reusable.

The end effector **52** can assume various forms useful with laparoscopic surgical procedures, such as scissors, grasper, clamp, dissector, needle holder, electrocautery implement, electrode probe, etc. In more general terms, the end effector **52** can include first and second bodies **70**, **72** as shown, with at least the first body **70** being moveably coupled relative to the second body **72**. This movable coupling can be effectuated in various forms, such as by a pinned or pivoting interface, a cammed interface, various linkages, etc., as are known to those of skill in the art. With other end effector constructions envisioned by the present disclosure, the end effector **52** consists of only a single primary body that does not move during operation thereof (e.g., an electrocautery implement, electrode probe, etc.). Regardless, the end effector **52** is configured for connection with one or more components of the end effector operation mechanism **60** in a manner that facilitates operation of the end effector **52** (e.g., user-caused and controlled spatial arrangement of the first body **70** relative to the second body **72**, user-prompted energization of an electrocautery probe, etc.). In light of the wide variety of different end effector constructions implicated by the surgical instruments of the present disclosure, "operation" of the end effector is in reference to the movement(s) or other functions conventionally associated with the particular end effector design. Thus, "operation" of a scissors, grasper, or clamp-type end effector includes opening and closing of two opposing jaws relative to one another; "operation" of an electrode probe includes delivery of energy to (or receiving a signal from) the probe; etc. Other types of end effectors entail differing movements, and the present disclosure is not limited to any particular end effector design or corresponding operative movements.

The shaft **54** can also assume various forms appropriate for delivery through a conventional trocar (e.g., the shaft **54** has a maximum outer diameter of not more than 5.5 mm in some embodiments), and is generally tubular in shape. The tubular shaft **54** extends distally from the handle assembly **58** and terminates at a shaft distal end **80**. As shown, portions of the wrist assembly **56** extend from the shaft end distal **80** including, for example, the deflection section **66**. The shaft **54** is relatively rigid, whereas the deflection section **66** is configured to reversibly articulate/bend and straighten in response to an applied force or tension as described below. As a point of reference, the term "longitudinal" as used throughout the present disclosure is in reference to or based upon the linear central axis of the shaft **54**.

In some embodiments, the outer shaft **54** can incorporate one or more features at the distal end **80** that facilitate mounting with corresponding component(s) of the wrist assembly **56**. As shown in FIGS. **2**A and **2**B, for example, the outer shaft **54** can form or carry opposing tines **82***a*, **82***b* at the distal end **80**, along with opposing slots **84** (one of which is visible in FIGS. **2**A and **2**B). The tines **82***a*, **82***b* are configured for connection to a wrist assembly component, with a wall thickness of the shaft **54** being reduced adjacent the distal end **80** (e.g., a counter-bore is formed along an inner diameter of the shaft **54**) to define a stop surface **86** for seated engagement with wrist assembly component. The slots **84** facilitate passage of wrist assembly cable segments as described below. A wide variety of other mounting techniques are also acceptable that may or may not include the tines **82***a*, **82***b* and/or the slots **84**. Finally, FIG. **2**A shows an optional bore **88** formed in the shaft **54**. Where provided, the bore **88** is aligned with the flush port assembly **68** (FIG. **1**) for delivery of cleaning liquid into a lumen **89** of the shaft **54**.

FIGS. **3**A-**4**B illustrate a distal region of the surgical instrument **50**, showing portions of the wrist assembly **56** in greater detail. In particular, FIGS. **3**A and **3**B are top plan views of the distal region in a curved or articulated (FIG. **3**A) and straightened (FIG. **3**B) arrangement of the deflection section **66**. FIGS. **4**A and **4**B are cross-sectional views of the arrangements of FIGS. **3**A and **3**B, respectively. Included in the views are components of the end effector operation mechanism **60**, the torque mechanism **62**, and the articulation mechanism **64**, relative to the end effector **52** and the shaft distal end **80**. As a point of reference, the mechanisms **60**-**64** each extend to, and/or include additional components at, a proximal region of the surgical instrument (e.g., at the handle assembly **58** (FIG. **1**)) to facilitate user-controlled actuation of each mechanism **60**-**64**. The distal region portions of each of the mechanisms **60**-**64** are described below, followed by a description of connections of the mechanisms **60**-**64** at the handle assembly **58**.

End Effector Operation Mechanism **60**

The end effector operation mechanism **60** is best seen in FIGS. **4**A and **4**B, and includes a rod **90** that is received within the shaft **54**, and extends distally from the shaft distal end **80**. A distal portion **92** of the rod **90** is disposed within the deflection section **66**, and terminates at a distal end **94** that is coupled to the end effector **52**. At least the distal portion **92** of the rod **90** exhibits sufficient flexibility to bend/straighten in response to corresponding forces applied by the deflection section **66** (it being understood that in some embodiments, articulation forces generated by the deflection section **66** are transferred to the rod **90** via components of the torque mechanism **62** as described below). The distal portion **92** thus follows the shape or curvature defined by the deflection section **66**, and will not permanently deform with repeated bending and straightening. For example, the distal portion **92** is shown to have been forced to a curved or bent shape by the deflection section **66** in the arrangement of FIG. **4**A; under circumstances where the deflection section **66** is caused to assume a more straightened shape as in FIG. **4**B, the rod distal portion **92** is forced to and will readily assume a corresponding shape.

The rod **90** can be homogenously formed of a durable yet flexible material such as Nitinol™ or other material(s) that is robustly capable of repeated bending/straightening along the distal portion **92**. In other constructions, the rod **90** can consist of two (or more) discrete materials, such as a proximal portion formed of stainless steel and the distal portion **92** (or section of the distal portion **92** otherwise disposed within the deflection section **66**) formed of Nitinol. The durable yet flexible construction of the rod **90** is sufficient to not only accommodate the articulation/bending described above, but also the axial compression/extension forces encountered during use of the instrument **50**. For example, the rod **90** can be capable of maintaining its structural integrity in the presence of a tension force on the order of 150 lbf and a compression force on the order of 30 lbf. Further, material(s) selected for the rod **90** are optionally able to maintain their structural integrity when subjected to repeated sterilization.

Coupling between the distal end **94** and the end effector **52** can be achieved in various manners, and is more generally described as establishing a push/pull type link with the end effector **52** in some embodiments. With constructions in which the end effector **52** includes two bodies **70**, **72** that can move relative to one another, because the end effector **52** is effectively longitudinally fixed relative to the shaft **54** and because the rod **90** can longitudinally slide relative to the shaft **54**, longitudinal movement of the rod **90** relative to the end effector **52** causes the first body **70** to move relative to the second body **72**. With additional reference to FIGS. **5**A and **5**B, the end effector operation mechanism **62** can include an adaptor **96** that pivotably couples the distal end **94** with arms **100**, **102**. The arms **100**, **102** can alternatively be viewed as being components of the end effector **52**. Regardless, the arms **100**, **102** are connected to a corresponding one of the end effector bodies **70**, **72**. With the one example end effector construction shown, the arms **100**, **102** are pivotably coupled to the corresponding end effector body **70**, **72**. Distal or longitudinally forward movement (i.e., pushing force) of the rod **90** causes the bodies **70**, **72** to pivot open relative to one another (i.e., transition from the arrangement of FIG. **5**A to that of FIG. **5**B), whereas proximal or longitudinally rearward movement (i.e., pulling force) of the rod **90** causes the bodies **70**, **72** to close (i.e., transition from the arrangement of FIG. **5**B to that of FIG. **5**A). It will be understood that the end effector **52** can incorporate a variety of other mechanisms or components that are operable in response to push/pull movement of the rod **90** (e.g., camming interface, etc.). Even further, with non-moving end effector constructions (e.g., electrode probe), a push/pull-type relationship with the rod **90** may be unnecessary, such that the rod **90** is directly mounted to the end effector **52**.

Torque Mechanism **62**

Returning to FIGS. **4**A and **4**B, the torque mechanism **62** includes a plurality of links **110**, a torque shaft **112**, a proximal drive body **114**, a distal drive body **116**, and a coupling assembly **118** (referenced generally). The plurality of links **110** are consecutively arranged and the proximal drive body **114** connects the torque shaft **112** to the proximal-most link **110***p*. Similarly, the distal drive body **116** connects the distal-most link **110***d* to the coupling assembly **118** that in turn is connected to the end effector **52**. With this construction, rotation of the end effector **52** can be effectuated via a user-applied torque or rotational force at the torque shaft **112**, with the plurality of links **110** accommodating and transferring the torque along any bend dictated by the deflection section **66**.

The torque mechanism **62** is depicted as including three of the links **110**; in other embodiments, a greater or lesser number of the links **110** are provided. The links **110** are discrete from one another, and are constructed such that upon final assembly, successive ones of the links **110** are rotationally locked to one another in a manner that permits adjacent links **110** to pivot relative to one another while maintaining the rotational lock.

The links **110** can be identical, with FIGS. **6**A-**6**E illustrating one of the links **110** in greater detail. The link **110** is an integral body formed of a hardened, surgically safe material (e.g., surgical grade stainless steel) that optionally is able to maintain its structural integrity with subjected to repeated sterilization. The link **110** is shaped to define a male end portion **130**, an intermediate portion **132**, a female end portion **134**, and a central bore **136** extending along a longitudinal axis L of the link **110**. The central bore **136** is open at opposing, first and second ends **138**, **140** of the link **110**.

The male end portion **130** and the female end portion **134** are generally configured to provide corresponding, mating features that facilitate pivotable, rotationally locked connection between successive links **110** (e.g., the male end portion **130** of one link is matingly-received within the female end portion **134** of a consecutively-next link). With this in mind, an exterior of the male end portion **130** forms a polygonal ball head **142** in extension from the first end **138** toward the intermediate portion **132**. The ball head **142** has a generally spherical shape, initially expanding in diameter from the first end **138**, then contracting in diameter toward the intermediate portion **132**. As best shown in FIGS. **6**B and **6**C, relative to a plane passing through the longitudinal axis L, the ball head **142** has curved lateral edges **144**. As best shown in FIG. **6**D, relative to a plane perpendicular to the longitudinal axis L, the ball head **142** has a polygonal shaped cross-section. Stated otherwise, and with reference to FIGS. **6**A, **6**B, and **6**D, the polygonal shape of the ball head **142** is generated by flats **146**, with adjacent ones of the flats **146** forming a corner **148** (e.g., as identified in the view of FIG. **6**D, a corner **148***a* is formed at an intersection between first and second flats **146***a*, **146***b*). However, each of the flats **146** (as well as the corners **148**) has a convex curvature in a direction of the longitudinal axis L.

While the ball head **142** is shown as having an octagonal shape (i.e., eight of the flats **146** and eight of the corners **148**), other polygonal shapes are also acceptable. For example, the ball head **142** shape can be hexagonal, decagonal, etc.

The female end portion **134** extends from the second end **140** toward the intermediate portion **132** and forms or defines a polygonal socket head **150**. In particular, the socket head **150** provides a receptacle **152** (best shown in FIG. **6**C) that is contiguous with the central bore **136** and has a polygonal shape corresponding with that of the ball head **142** (e.g., where the ball head **142** is octagonal in shape, the receptacle **152** is also octagonal). As reflected in FIGS. **6**C and **6**E, the polygonal shape of the receptacle **152** is defined by or includes flattened surfaces **154**, adjacent ones of which intersect at a corner **156**. The number of flattened surfaces **154** corresponds with the number of flats **146** provided on the ball head **142**, but the flattened surfaces **154** do not have the convexly-curved shape in longitudinal cross-section. A diameter of the receptacle **152** corresponds with a maximum outer diameter of the ball head **142**.

The corresponding constructions of the male and female end portions **130**, **134** facilitates a pivotable yet rotationally locked interface between two of the links **110**. For example, FIG. **7**A illustrate a first one of the links **110***a* connected to a second one of the links **110***b*. The ball head **142** of the first link **110***a* is received within the receptacle **152** of the second link **110***b*. The ball head corners **148** of the first link **110***a* nest within the receptacle corners **156** of the second link **110***b*. Thus, a link interface **160** (referenced generally) is established at which rotation of the first link **110***a* is transferred to the second link **110***b* (and vice-versa). The link interface **160** permits the first link **110***a* to pivot relative to the second link **110***b* (and vice-versa), with the ball head curved edges **148** of the first link **110***a* traversing along a corresponding one of the receptacle flattened surfaces **154** of the second link **110***b*. Thus, and as shown in FIG. **7**B, the first and second links **110***a*, **110***b* can be pivoted relative to one another while still maintaining the rotationally locked link interface **160**.

For reasons made clear below, in some embodiments of the surgical instruments **50** (FIG. **1**) of the present disclosure, the adjacent links **110***a*, **110***b* are periodically separated from one another (e.g., the first link **110***a* is physically distanced from the second link **110***b*) and then re-connected. The links **110** optionally incorporate one or more features that promote self-aligning of the ball head **142** of the first link **110***a* with the receptacle **152** of the second link **110***b* during re-assembly of the links **110***a*, **110***b* to one another. For example, and with reference to FIG. **7**C, the ball head **142** tapers in outer diameter (or other outer dimension) toward the first end **138**, whereas a slightly enlarged guide surface **158** is formed at the second end **140** having a tapered shape leading to the receptacle **152**. With this but one acceptable construction, as the ball head **142** of the first link **110***a* is directed toward the receptacle **152** of the second link **110***b*, the guide surface **158** guides the first end **138** of the ball head **142** into the receptacle **152** while allowing the ball head **142** to rotate relative to the receptacle **152**. Thus, if the ball head corners **148** of the first link **110***a* are not exactly aligned with the receptacle corners **156** of the second link **110***b*, the first link **110***a* will rotate slightly relative to the second link **110***b* (and vice versa) until the corners **148**, **156** are aligned.

Returning to FIGS. **6**A-**6**E, the intermediate portion **132** is formed between the male and female end portions **130**, **134**, and forms a shoulder or flange **164** proximate the female end portion **134**. The shoulder **164** provides a radially-projecting surface configured for seated engagement with a corresponding component feature of the articulation mechanism **64** (FIG. **3**A) as described below.

The central bore **136** extends the entire length of the link **110**, and has a minimum diameter along the male end portion **130** and the intermediate portion **132** that is sized to slidably receive at least the rod distal portion **92** (FIG. **4**A). To accommodate deflection of the rod **90** during use, the link **110** can form chamfered or rounded edges **170**, **172** at which the bore **136** has an expanding diameter in longitudinal extension. Finally, the bore **136** diameter expands at the female end portion **134** in forming the receptacle **152**.

Returning to FIGS. **4**A and **4**B, the torque shaft **112** is sized to be received within the outer shaft **54**, and has a length commensurate with that of the outer shaft **54**. The torque shaft **112** terminates at a distal end **180**, and can be a tubular body forming a lumen **182**. The torque shaft **112** is formed of a structurally robust material (e.g., surgical grade stainless steel), and is configured to provide sufficient rigidity to maintain its structural integrity in the presence of expected torsion forces. For example, the torque shaft **112** can be constructed to maintain its structural integrity in the presence of a torsion force on the order of 0.41 in-lbf. Further, material(s) and construction selected for the torque shaft **112** are optionally able to maintain their structural integrity when subjected to repeated sterilization. In this regard, the torque shaft **112** can incorporate one or more additional features that facilitate cleaning with embodiments in which the torque shaft **112** is tubular. For example, as shown in FIG. **8**, the torque shaft **112** can have several longitudinally-spaced side slots **184** through which a cleaning/sterilization fluid can be introduced for cleaning an interior of the shaft **112**. Alternatively, the torque shaft **112** can be a continuous tube.

Returning to FIGS. **4**A and **4**B, and with additional reference to FIGS. **9**A and **9**B, the proximal drive body **114** defines a leading segment **190**, an intermediate segment **192**, a trailing segment **194** and a central passage **196**. The proximal drive body **114** can be a homogeneous structure formed of a hardened, surgically-safe material (e.g., surgical grade stainless steel) that optionally is able to maintain its structural integrity when subjected to repeated sterilization.

The leading segment **190** is configured to connect with the proximal-most link **110***p* in a manner akin to the link interface **160** (FIG. **7**A) described above. Thus, the leading segment **190** can be identical to the female end portion **134** provided with each of the links **110**, forming a receptacle **198** that can be identical to the receptacle **152** described above (e.g., octagonal shape). The receptacle **198** is configured to receive the ball head **142** of one of the links **110** in a pivotable yet rotationally locked relationship. Alternatively, the leading segment **190** can form a ball head akin to the ball head **142** of the links **110** (and thus configured to be received within the receptacle **152** of the links **110**).

The intermediate segment **192** has a reduced outer diameter as compared to the leading segment **190** and an increased outer diameter as compared to the trailing segment **194** to form first and second shoulders **200**, **202**. In some embodiments, the intermediate segment **192** is configured for seated assembly to a corresponding component of the articulation mechanism **64**. The trailing segment **194** extends from the intermediate segment **192**, and can have a relatively uniform outer diameter as shown. In this regard, an outer diameter of the trailing segment **194** corresponds with an inner diameter of the torque tube **112** for press-fitted coupling between the components **112**, **114**.

The central passage **196** is sized to slidably receive the rod **90** (FIG. **4**A), and thus defines a minimum diameter that is greater than an outer diameter of the rod **90**. To accommodate deflection of the rod **90** during use, the central passage **196** can have or define an increasing diameter from the trailing segment **194** to the leading segment **190**.

With reference to FIGS. **4**A, **4**B, **10**A and **10**B, the distal drive body **116** defines a leading region **210**, an intermediate region **212**, a trailing region **214** and a central passageway **216**. The distal drive body **116** can be a homogeneous structure formed of a hardened, surgically-safe material (e.g., surgical grade stainless steel) that optionally is able to maintain its structural integrity when subjected to repeated sterilization.

The leading region **210** is configured for connection with the distal-most link **110***d* in a manner akin to the link interface **160** (FIG. **7**A) described above. Thus, the leading region **210** can be identical to the male end portion **130** provided with each of the links **110**, forming a polygonal ball head **218** that can be identical to the polygonal ball head **142** described above (e.g., octagonal ball shape). The ball head **218** is configured to be received within the receptacle **152** of one of the links **110** in a pivotable yet rotationally locked relationship. Alternatively, the leading region **210** can form a receptacle akin to the receptacle **152** of the links **110** (and thus configured to receive the ball head **142** of the links **110**).

The intermediate region **212** forms a ring **220** having an outer diameter greater than an outer diameter of the leading and trailing regions **210**, **214**. As described below, the ring **220** is configured for seated assembly to a corresponding component of the articulation mechanism **64**. Finally, the trailing region **214** extends from the intermediate region **212** and can have the relatively uniform outer diameter as shown. To facilitate mounting with the coupling assembly **118**, an optional bore **222** is formed along the trailing region **214**, extending in a direction generally perpendicular to that of the passageway **216**. For reasons made clear below, the bore **222** is open to the passageway **216**, and extends through an entire thickness of the drive body **116**.

The passageway **216** is sized to slidably receive the rod **90**, and thus has a minimum diameter at least slightly larger than an outer diameter of the rod distal portion **92**. To accommodate deflection of the rod **90** during use, the passageway **216** can taper from an enlarged diameter along the leading region **210**, and a leading end **224** can be rounded or chamfered.

With specific reference to FIGS. **4**A and **4**B, the coupling assembly **118** can assume a wide variety of forms appropriate for connecting the distal drive body **116** to the end effector **52** in a rotationally fixed manner. In one embodiment appropriate for use with moveable-type end effector constructions, the coupling assembly **118** includes a clevis **230** and a king pin **232**. In general terms, the king pin **232** connects the distal drive body **116** with the clevis **230**, and the clevis **230**, in turn, is coupled to the end effector **52**. As with other components of the torque mechanism **62**, the clevis **230** and the king pin **232** are formed from a hardened, surgically-safe material (e.g., surgical grade stainless steel) that optionally is able to maintain its structural integrity when subjected to repeated sterilization.

The clevis **230** is shown in greater detail in FIGS. **11**A-**11**C, and includes or defines a base **240** and opposing legs **242***a*, **242***b*. The base **240** terminates at a bearing surface **244** opposite the legs **242***a*, **242***b*, and defines a longitudinal pathway **246** that is open at the bearing surface **244** and to a gap **248** formed between the legs **242***a*, **242***b*. The pathway **244** is sized to receive the rod distal portion **92** (FIG. **4**A). Further, a radially extending through-hole **250** is defined in the base **240**, extending generally transversely to the pathway **244**. The through-hole **250** is open to the pathway **244**, and extends through an entire thickness of the base **240**. As described below, the through-hole **250** is configured to receive the king pin **232** (FIG. **4**A).

The legs **242***a*, **242***b* extend from the base **240** in a mirror-like fashion to form the gap **248**. A size and shape of the legs **242***a*, **242***b*, and thus of the gap **248**, corresponds with various features of the end effector **52** (FIG. **3**A), and in particular the bodies **70**, **72** (FIG. **3**A) and corresponding linkages (e.g., the arms **100**, **102** (FIGS. **5**A and **5**B)). More particularly, components of the end effector **52** are disposed within the gap **248**, with the gap **248** being sized and shaped to accommodate necessary component movement during actuation of the end effector **52**. With some embodiments in which the end effector **52** is akin to a grasping tool, the legs **242***a*, **242***b* are configured to facilitate pivoting connection between the end effector bodies **70**, **72**, such as by holes **252***a*, **252***b* formed in the legs **242***a*, **242***b*, respectively, through which a pin **254** (identified in FIG. **5**B) otherwise pivotably connecting the bodies **70**, **72** is captured. Due the inter-related features of the clevis **230** and the end effector **52**, the clevis **230** can alternatively be viewed as being a component of the end effector **52**.

Returning to FIGS. **4**A and **4**B and with additional reference to FIG. **12**, the king pin **232** is a solid, cylindrical body having an outer diameter commensurate with that of the clevis through-hole **250** (FIG. **11**A) and of the distal drive body bore **222** (FIG. **10**A). Further, a length of the king pin **232** approximates a diameter of the clevis base **240**. In addition, the king pin **232** defines a radially extending rod hole **260**. The rod hole **260** is sized to slidably receive the rod **90**, and thus has a diameter at least slightly greater than that of the rod distal portion **92**.

With cross reference between FIGS. **4**A, **4**B and **13**, assembly of the torque mechanism **62** generally includes the proximal drive body **114** being secured to the torque shaft **112** (e.g. press fit), with the leading segment **190** projecting distal the distal end **180** of the torque shaft **112**. The torque shaft **112** and the proximal drive body **114** are thus affixed to one another (i.e., rotationally and axially fixed). The distal drive body **116** is mounted to the end effector **52** via the coupling assembly **118**. For example, the end effector bodies **70**, **72** are pivotably secured to one another and to the clevis **230** by the pin **254** (e.g., the pin **254** can be welded or otherwise affixed to the clevis legs **242***a*, **242***a* and rotatably connected the bodies **70**, **72**). The trailing region **214** of the distal drive body **116** is disposed within the clevis pathway **246**, and is captured relative to the clevis base **240** by the king pin **232** (e.g., the king pin **232** is lodged within the clevis through-hole **250** and the distal drive body bore **222** via a slip fit). The king pin **232** is arranged such that the king pin rod hole **260** (best shown in FIG. **12**) is aligned with the distal drive body passageway **216**. The rod **90** is inserted through the passageway **216** and the rod hole **260** thereby preventing lateral removal of the king pin **232** from the clevis through-hole **250** and the distal drive body bore **222**. Alternatively, other configurations and/or assembly techniques can be employed to rotationally fix the distal drive body **116** with the end effector **52**. For example, where the end effector **52** has a non-moving construction (e.g., electrode probe), a simple direct mounting between the end effector **52** and the distal drive body **116** can be employed. Finally, the links **110** are consecutively arranged between the proximal and distal drive bodies **114**, **116**. As shown, the ball head **142** of the proximal-most link **110***p* is received within the receptacle **198** of the proximal drive body **114**, and the ball head **218** of the distal drive body **116** is received within the receptacle **152** of the distal-most link **110***d*. The remaining intermediate links **110** are arranged in the end-to-end fashion shown.

In the connected or chain arrangement of the links **110**, a pivoting, rotationally fixed joint is established between the proximal-most link **110***p* and the proximal drive body **114**, between adjacent ones of the links **110**, and between the distal-most link **110***d* and the distal drive body **116**. Thus, the connected links **110** can readily transition through various shapes or curvatures collectively defined by the links **110** yet still transmit a torque or rotational force from the torque shaft **112** to the end effector **52**. Although the links **110** are shown as physically connected to one another in the views of FIGS. **4**A, **4**B and **13**, it will be understood that the links **110** are discrete components and in some embodiments, are not permanently connected or coupled to one another. That is to say, the proximal-most link **110***p* can be physically removed from engagement with the proximal drive body **114**, adjacent ones of the links **110** can be physically separated from one another, and the distal-most link **110***d* can be physically separated from the distal drive body **116**, such as in an optional cleaning mode of the instrument **50** described below. As a point of reference, in some embodiments the links **110** are collectively brought into, and held in, engagement with one another and the drive bodies **114**, **116** by features of the articulation mechanism **64** as described below.

Articulation Mechanism **64**

Returning to FIGS. **4**A and **4**B, the articulation mechanism **64** includes the deflection section **66**, a proximal joint connector **300**, a distal joint connector **302**, a first cable segment **304** and a second cable segment **306**. In general terms, the proximal joint connector **300** connects the deflection section **66** with the outer tube **54**, and the distal joint connector **302** connects the deflection section **66** with the end effector **52**. The cable segments **304**, **306** associate components of the deflection section **66** with one another and the joint connectors **300**, **302**, and are operable in a reciprocating manner to effect a change in shape or articulation along the deflection section **66**.

The deflection section **66** includes or is comprised of a plurality of articulation members **310**. The articulation members **310** can be identical, and FIGS. **14**A-**14**D illustrate one of the articulation members **310** in greater detail. The articulation member **310** can be an integrally formed, homogeneous structure formed of a hardened, surgically-safe material (e.g., surgical grade stainless steel) that is optionally able to maintain its structural integrity when subjected to repeated sterilization. The articulation member **310** includes or defines a central section **312**, a female section **314** and a male section **316**. The female and male sections **314**, **316** extend in opposing directions from the central section **312** and are generally configured such that the female section **314** of one articulation member **310** mates with the male section **316** of a second articulation member **310**.

The central section **312** can be generally cylindrical, and forms opposing, first and second faces **320**, **322**. A center passage **324** extends through the central section **312**, and is open at the opposing faces **320**, **322**. The passage **324** is defined by an interior surface **326** of the central section **312**, and is sized and shaped to receive one of the links **110** (FIG. **6**A). It will be recalled that the links **110**, in turn, are configured to slidably receive the rod distal portion **92** (FIG. **4**A); thus, the passage **324** is also larger than a diameter of the rod distal portion **92**. As best shown in FIG. **14**D, the central section **312** defines a shelf **328** along a length of the interior surface **326**, with the passage **324** having an increased diameter from the shelf **328** to the second face **322**. The shelf **328** is configured to interface or mate with a corresponding feature of the links **110** as described below.

In addition to the center passage **324**, the central section **312** forms first and second side channels **330**, **332**. The side channels **330**, **332** extend between, and are open at, the faces **320**, **322**, and are located opposite one another relative to the center passage **324**. In some embodiments, the side channels **330**, **332** are centrally located relative to projecting features of the female section **314** and of the male section **316**. Regardless, each of the side channels **330**, **332** is sized to slidably receive a corresponding one of the cable segments **304**, **306** (FIG. **4**A).

Relative to a transverse cross-sectional plane through the articulation member **310** (i.e., FIG. **14**D), the central section **312** can be viewed as defining opposing sides **334**, **336**. In some embodiments, the central section **312** is shaped such that the first side **334** is shorter than the second side **336**. In other words, a length of the first side **334** between the opposing faces **320**, **322** is less than a length of the second side **336** between the opposing faces **320**, **322**. As shown, the reduced length of the first side **334** can include the central section **312** tapering in length to the first side **334**. Regardless, the reduced length of the first side **334** can facilitate formation of a more pronounced curvature in the deflection section **66** (FIG. **3**A) as described below. Alternatively, the central section **312** can be uniform in length.

The female section **314** includes opposing, first and second fingers **340**, **342** that project longitudinally outwardly from the first face **320** at opposite sides of the center passage **324**. The fingers **340**, **342** can be identical in size and shape, and each terminate in a rounded or circular end **344**. As best reflected in FIG. **14**D, the rounded end **344** can have a uniform radius of curvature approximating a semicircle. A circular shape defined by the rounded end **344** is optionally continued into the interior surface **326** of the central section **312**, resulting in a curved ridge **346** (best shown in FIG. **14**A relative to the second finger **342**). An inner face **348** of each of the fingers **340**, **342** is thus effectively continuous from the corresponding end **344** to the corresponding ridge **346**.

The male section **316** includes opposing, first and second tabs **350**, **352** that project longitudinally outwardly from the second face **322** at opposite sides of the center passage **324**. The tabs **350**, **352** can be identical in size and shape, and each terminate in a rounded or curved tip **354** opposite the second face **322**. The rounded tip **354** can have the same, uniform radius of curvature of the fingers **340**, **342**. Similarly, the circular shape is continued into a thickness of the central section **312**, generating a curved edge **356** (best shown in FIG. **14**A relative to the first tab **350**). An outer surface **358** of each of the tabs **350**, **352** is substantially flat, whereas an inner surface **360** can have a curvature approximating that of the center passage **324** as shown in FIG. **14**C.

A lateral spacing between the fingers **340**, **342** corresponds with a lateral spacing between the tabs **350**, **352**. For example, the lateral distance between the inner faces **348** of the fingers **340**, **342** is the same as, or slightly larger than, the lateral distance between the outer surfaces **358** of the tabs **350**, **352**. This matched spacing, as well as corresponding shapes of the fingers **340**, **342**, the ridges **346**, the tabs **350**, **352**, and the edges **356**, facilitates a pivoting interface or connection between two adjacent ones of the articulation members **310**. FIG. **15**A illustrates first and second articulation members **310***a*, **310***b* poised for connection with one another (with references numbers provided below for each of the articulation members **310***a*, **310***b* including the corresponding designation of "a" or "b"). The male section **316***a* of the first articulation member **310***a* faces the female section **314***b* of the second articulation member **310***b*. Upon final connection as in FIG. **15**B, the first finger **340***b* rides over the first tab **350***a*, including the finger inner face **348***b* abutting the tab outer surface **358***a*. The rounded end **344***b* of the first finger **340***b* nests against the rounded edge **356***a* associated with the first tab **350***a*. Further, the rounded tip **354***a* of the first tab **350***a* nests against the ridge **346** associated with the first finger **340***b*. A similar interface is provided between the second finger **342***b* and the second tab **352***a*. With this connection, the first and second articulation members **310***a*, **310***b* can pivot relative to one another, rotating about a hypothetical centerline passing through the aligned, circular shapes of the fingers **340***b*, **342***b* and the tabs **350***a*, **352***a*. As a point of reference, FIG. **15**C illustrates the assembly of FIG. **15**B but from a plane perpendicular to that of FIG. **15**B and reflects that the articulation members **310***a*, **310***b* are arranged to align the shorter first sides **334***a*, **334***b* with one another. A longitudinal spacing between the first sides **334***a*, **334***b* provides sufficient clearance for pivoting of the articulation members **310***a*, **310***b* relative to one another in a direction of the first sides **334***a*, **334***b*. For example, FIG. **15**D shows the second articulation member **310***b* pivoted relative to the first articulation member **310***a*, with the first sides **334***a*, **334***b* allowing for a relatively large range of articulation between the two members **310***a*, **310***b*.

Returning to FIGS. **4**A and **4**B and with additional reference to FIGS. **16**A-**16**E, the proximal joint connector **300** can be a homogeneous body formed of a hardened, surgically-safe material (e.g., surgical grade stainless steel) that is optionally able to maintain its structural integrity when subjected to repeated sterilization. The proximal joint connector **300** can be akin to the articulation members **310**, and includes or defines a hub **370**, a leading portion **372** and a trailing portion **374**.

The hub **370** can be generally cylindrical, and forms opposing first and second faces **380**, **382**. A central passageway **384** extends longitudinally through the hub **370** and is open at the opposing faces **380**, **382**. The passageway **384** is defined by an interior surface **386**. A step **388** is formed along the interior surface **386**, with the passageway **384** having an increased diameter from the step **388** to the first face **380**. The step **388** is configured to receive a feature provided with the proximal drive body **114** as described below. The hub **370** further forms optional slots **390***a*, **390***b* at an exterior thereof for receiving respective ones of the outer shaft tines **82***a*, **82***b* (FIG. **2**A). Opposing side channels **394**, **396** are defined at opposite sides of the central passageway **384**, and are sized to slidably receive a respective one of the cable segments **304**, **306**. Finally, and as best shown in FIG. **16**C, the hub **370** can be configured to define (relative to the cross-sectional plane illustrated) a first side **398** that is shorter than an opposite, second side **400**.

The leading portion **372** can be identical to the articulation member male section **316** (FIG. **14**A) and thus includes opposing tabs **410**, **412** projecting from the first face **380** and each terminating in rounded or curved tip **414** defining the semi-circular shape mentioned above. An outer surface **416** of each of the tabs **410**, **412** is flattened, with a curvature defined by the rounded tip **414** continuing into a thickness of the hub **370** so as to form curved edge segments **418***a*, **418***b* (shown with respect to the first tab **410** in FIG. **16**A). The edge segments **418***a*, **418***b* are separated by the corresponding slot **390***a* or **390***b*, but collectively define a radius of curvature corresponding with that of the rounded tip **404**.

The trailing portion **374** includes opposing arms **420**, **422** projecting from the second face **382**. The arms **420**, **422** are circumferentially separated from one another by a gap **424** sized to provide clearance about a respective one of the cable segments **304**, **306**. In this regard, the arms **420**, **422** are arcuate in shape (best shown in FIG. **16**A) and collectively define an outer diameter approximating an inner diameter of the outer shaft lumen **89** (FIG. **2**B) and the distal end **80** (FIG. **2**B) thereof. To facilitate a rotationally locked assembly with the outer shaft **54** in which the outer shaft tines **82***a*, **82***b* (FIG. **2**A) are received within a corresponding hub slot **390***a*, **390***b*, an exterior **426** of each of the arms **420**, **422** optionally forms a flattened surface **428** (identified in FIG. **16**A) adjacent the hub **370**. Where provided, the flattened surface **428** can facilitate sliding insertion of the outer shaft tines **82***a*, **82***b* into the corresponding slot **390***a*, **390***b*.

The distal joint connector **302** is shown in greater detail in FIGS. **17**A-**17**D, and is provided as a homogeneous body formed of a hardened, surgically-safe material (e.g., surgically grade stainless steel) that is optionally able to maintain its structural integrity when subjected to repeated sterilization. The distal joint connector **302** defines or forms a head **430** and a rearward region **432**. The head **430** can have the generally cylindrical shape shown. A central passage **434** and opposing side channels **436**, **438** extend through a length of the head **430**, and are open at opposing first and second faces **440**, **442** thereof. The central passage **434** is configured to mate with surface features of the distal drive body **116** (FIG. **10**A). For example, the central passage **434** is defined by an interior surface **444** that forms a trough **446**. A diameter of the passage **434** is increased at the trough **446** in a direction of the first face **440**. An optional circumferential slot **448** is formed adjacent the second face **442** and is open to the side channels **436**, **438** as well as to an exterior **450** of the head **430**. As described below, where provided, the slot **448** is sized and shaped for guiding a cable between the side channels **436**, **438**. Finally, in some embodiments, the head **430** is shaped to define a first side **452** having a length less than a length of an opposing second side **454**, as best reflected in the cross-sectional view of FIG. **17**C.

The rearward region **432** can be akin to the articulation member female section **314** (FIG. **14**A) and includes opposing, first and second fingers **460**, **462**. The fingers **460**, **462** project longitudinally outwardly from the first face **440** and each terminate in a rounded end **464**. The fingers **460**, **462** are arranged at opposite sides of the central passage **434**, and each define an interior face **466** configured to receive a corresponding one of the articulation member tabs **350**, **352** (FIG. **14**A). As with the articulation members **310**, the circular shape of the rounded end **464** continues along the interior surface **444** of the head **430**, forming a curved ridge **468**.

With specific reference to FIGS. **4**A and **4**B, the cable segments **304**, **306** are sized to be slidably received within one of the side channels **330**, **332**, **394**, **396**, **436**, **438** of the articulation members **310**, the proximal joint connector **300** and the distal joint connector **302**, respectively. In some embodiments, the cable segments **304**, **306** are defined by a single cable that is partially wound about the distal joint connector **302** as described below. In other embodiments, the cable segments **304**, **306** can be separate, discrete cables. Regardless, the segments **304**, **306** are configured to apply necessary tension onto the deflection section **66**, and can be metal wires, braids, flat bands, etc.

Assembly of the articulation mechanism **64** between the outer shaft **54** and the end effector **52** is, in some embodiments, directly related to the torque mechanism **62** and corresponding assembly of the torque mechanism **62** between the outer shaft **54** and the end effector **52**. This optional relationship is described in detail below. In more general terms and as reflected in FIGS. **3**A and **3**B, the proximal joint connector **300** is connected to the outer shaft **54**, the distal joint connector **302** is coupled to the end effector **52**, and the plurality of articulation members **310** are consecutively arranged between the joint connectors **300**, **302** in an end-to-end fashion. The proximal-most articulation member **310***p* is arranged relative to the proximal joint connector **300** such that the fingers **340**, **342** (one of which is visible in FIGS. **3**A and **3**B) of the proximal-most articulation member **310***p* are received over (or can be received over) a corresponding one of the tabs **410**, **412** (FIG. **16**A) of the proximal joint connector **300** in a manner akin to the arrangement described above with respect to FIGS. **15**A and **15**B. As with the arrangement between adjacent ones of the articulation members **310**, the fingers **340**, **342** slidingly abut the corresponding curved edge segments **418***a*, **418***b* (one of which is visible in FIGS. **3**A and **3**B) such that the proximal-most articulation member **310***p* readily pivots relative to the proximal joint connector **300** upon final assembly. Similarly, the distal-most articulation member **310***d* is arranged relative to the distal joint connector **302** such that the fingers **460**, **462** (one of which is visible in FIGS. **3**A and **3**B) of the distal joint connector **302** are received over a corresponding one of the tabs **350**, **352** (FIG. **14**A) of the distal-most articulation member **310***d*. The rounded end **464** of each of the fingers **460**, **462** slidingly abuts the corresponding curved edge **356** such that the distal-most articulation member **310***d* readily pivots relative to the distal joint connector **300** upon final assembly. Intermediate ones of the articulation members **310** are consecutively arranged between the proximal-most and distal-most articulation members **310***p*, **310***d* as described above. As best shown in FIGS. **4**A and **4**B, the first cable segment **304** is disposed within the first side channel **330**, **394**, **436** of the articulation members **310**, the proximal joint connector **300** and the distal joint connector

302, respectively; and the second cable segment **306** is disposed within the second side channel **332**, **396**, **438** of the articulation members **310**, the proximal joint connector **300** and the distal joint connector **302**, respectively. In this regard, where the cable segments **304**, **306** are formed by a single cable, the cable is threaded through the slot **448** of the distal joint connector **302**. Regardless, and as shown in FIGS. **3**A-**4**B, the components **300**, **302**, **310** are arranged such that the shorter, first sides **334**, **398**, **452** are aligned with one another, as are the longer, second sides **336**, **400**, **454**.

Wrist Assembly General Construction and Operation

In general terms, construction of the wrist assembly **56** can include connecting the torque mechanism **62** and the articulation mechanism **64** with the outer shaft **54**. The rod **90** is inserted through the torque shaft **112** to locate the distal end **94** distal the deflection section **66**. The distal drive body **116** is secured to the clevis **320** via the king pin **232**. The rod distal end **94** is inserted through the distal drive body **114** and the king pin **232**, and the rod distal end **94** is secured to the end effector **52**.

Assembly of the torque mechanism **62** and the articulation mechanism **64** are inter-related in some embodiments, with the resultant construction permitting operation of each mechanism **62**, **64** independent of the other (and of the end effector operation mechanism **60**). One aspect of the inter-related relationship is reflected in FIGS. **18**A and **18**B that otherwise illustrate assembly of one of the links **110** with one of the articulation members **310**. The link **110** is received within the passage **324** of the articulation member **310**, with the link shoulder **164** seated against the articulation member shelf **328**. The male end portion **130** of the link **110** projects beyond, and is accessible relative to, the first face **320** of the articulation member **310**, whereas the female end portion **134** projects beyond, and is accessible relative to, the second face **322**. The seated relationship between the link **110** and the articulation member **310** is such that the link **110** freely rotates relative to the articulation member **310**. However, the components **110**, **310** are longitudinally coupled such that a longitudinal force applied to the articulation member **310** in one direction (e.g., rightward in the orientation of FIG. **18**B) is transferred directly to the link **110**, dictating that the link **110** will move with any movement of the articulation member **310** in that one direction. Conversely, the link **110** can be removed from the articulation member **310** in an opposite longitudinal direction (e.g., relative to the orientation of FIG. **18**B, the link **110** can be dislodged from the articulation member **310** when the link **110** is pulled rightward and the articulation member **310** is held stationary).

A similar relationship is established between the distal drive body **116** and the distal joint connector **302** as shown in FIG. **19** and effectuates, in some embodiments, coupling of the distal joint connector **302** with the end effector **52**. As previously described, in some embodiments, coupling of the distal drive body **116** with the end effector **52** is accomplished with the clevis **230** of the coupling assembly **118**. Prior to assembly of the distal drive body trailing region **214** within the clevis base **240**, the distal joint connector **302** is assembled to the distal drive body **116**. For example, the distal drive body **116** is received within the distal joint connector central passage **434**, with the ring **220** of the distal drive body **116** seating against the trough **446** of the distal joint connector **302**. Once again, the seated arrangement is such that the distal drive body **116** can freely rotate relative to the distal joint connector **302**. However, a longitudinal force imparted upon the distal joint connector **302** in one direction is transferred to the distal drive body **116** such that the distal drive body **116** will move in the direction of the so-applied force (or, more particularly, can serve to resist movement of the distal joint connector **302** in response to the so-applied force). Upon subsequent assembly of the distal drive body **116** to the coupling assembly **118**, then, the distal joint connector **302** is coupled to the end effector **52**.

A similar, seated assembly is provided, in some embodiments, between the proximal drive body **114** and the proximal joint connector **300**. For example, the proximal drive body **114** is received within the proximal joint connector passageway **384**, with the leading segment **190** of the proximal drive body **114** being accessible relative to the first face **380** of the proximal joint connector **300**. The shoulder **200** of the proximal drive body **114** is seated against the step **388** of the proximal joint connector **300**, with the seated arrangement such that the proximal drive body **114** can freely rotate relative to the proximal joint connector **300**.

As described above, the proximal drive body **114** is coupled to the torque shaft **112**. The proximal joint connector **300** is assembled over the proximal drive body **114**, and then coupled to the outer shaft **54**. For example, the trailing portion **374** of the proximal joint connector **300** is seated within the distal end **80** of the outer shaft **54**, with the tines **82***a*, **82***b* nesting within the slots **390***a*, **390***b*(hidden in FIG. **19**, but shown in FIG. **16**E). An end of the proximal joint connector **300** is received against the stop surface **86** of the outer shaft **54**. Notably, however, the proximal joint connector **300** and the outer shaft **54** are only rotationally engaged. The proximal joint connector **300** can be removed longitudinally (in the distal direction) from the outer shaft distal end **80**.

Commensurate with the above explanations and with additional reference to FIGS. **4**A and **4**B, following coupling of the rod distal end **94** to the end effector **52** (it being recalled that the distal drive body **116** and the distal joint connector **302** were previously mounted to the end effector **52**), the cable segments **304**, **306** are extended proximally from the side channels **436**, **438**, respectively, of the distal joint connector **302**. Where the cable segments **304**, **306** are formed from a single, continuous cable, the cable can be wrapped through and slidably retained within the circumferential slot **448** (FIG. **17**B). Regardless, articulation member **310**/link **110** pairs are consecutively loaded to the cable segments **304**, **306** via the articulation member side channels **330**, **332**. The proximal joint connector **300** is mounted over the proximal drive body **114**, and the cable segments **304**, **306** threaded through the proximal joint connector side channels **394**, **396**. The proximal drive body **114** is attached to the torque shaft **112**, and the proximal joint connector **300** is seated in the outer shaft **54** (with the cable segments **304**, **306** extending in the proximal direction between the torque shaft **112** and the outer shaft **54**).

In light of the above, in some embodiments, surgical instruments of the present disclosure include an equal number of links **110** and articulation members **310**. In other words, each one of the links **110** is assembled to a corresponding one of the articulation member **310**. The cable segments **304**, **306** effectively complete the operational connection of not only the remaining articulation mechanism **64** components, but also operational connection of the torque mechanism **62** components. In particular, the cable segments **304**, **306** inter-connect the articulation members **310** with each other and with the joint connectors **300**, **302**. Because the articulation members **310** are longitudinally coupled with corresponding ones of the links **110** (and the joint connectors **300**, **302** with the corresponding drive bodies **114**, **116**), the cable segments **304**, **306** thus effectively inter-connect the links **110** with the drive bodies **114**, **116**. As result, when the cable segments **304**, **306** are placed into tension, the distal joint connector **302** is tensioned or pulled toward the proximal joint connector **300**; this tensioning force, in turn, is transferred onto to the distal-most articulation member **310***d* via the distal joint connector **302** being drawn into physical contact with the distal-most articulation member **310***d*. The remaining articulation members **310** are similarly acted upon, drawing the articulation members **310** into physical contact with one another, and the proximal-most articulation member **310***p* into physical contact with the proximal joint connector **300**. The distal drive body **116** and the links **110** are similarly drawn toward the proximal drive body **114**, with the links **110** and the proximal drive body **114** sliding over the rod **90**. Thus, with tensioning of the cable segments **304**, **306**, the links **110** are operatively connected with one another and with the drive bodies **114**, **116**.

Articulation or bending of the deflection section **66** is achieved by pulling on the first (e.g., ventral) cable segment **304** (while possibly lessening tension in the second cable segment **306**), whereas straightening of the deflection section **66** is achieved by pulling on the second (e.g., dorsal) cable segment **306** (while possibly lessening tension in the first cable segment **304**). The so-applied tension or force is transferred to the distal joint connector **302**, causing the articulation members **310** to collectively move or pivot relative to one another along the "side" at which the tension is applied.

The torque mechanism **62** can operate independent of the articulation mechanism **64**, including the links **110** and drive bodies **114**, **116** freely rotating relative to the corresponding articulation members **310** and joint connectors **300**, **302**. While the articulation mechanism **64** also operates independent of the torque mechanism **62** (i.e., the articulation mechanism **64** is operable regardless of an operational state of the torque mechanism **62**), the functional effects of the articulation mechanism operation are transferred to the torque mechanism **62** in certain respects. More particularly, any deflection or bending of the deflection section **66** (as effectuated by pivoting movement of individual ones of the articulation members **310** relative to one another) is transferred to the links **110** (with corresponding, individual ones of the links **110** pivoting relative to one another in a similar fashion).

In some embodiments, the wrist assembly **56** is configured to permit rotation of the outer shaft **54** relative to the torque shaft **112** and the rod **90**. Rotation of the outer shaft **54** is transferred to the articulation mechanism **64** and thus to the end effector **52**, with the articulation mechanism **64** rotating relative to the torque mechanism **62** and the end effector operation mechanism **60**. The articulation mechanism **64** retains the shape or curvature defined along the deflection section **66** while spatially rotating with rotation of the outer shaft **54**.

Handle Assembly **58**

As previously mentioned, each of the mechanisms **60-64** can include one or more additional proximal components formed at and/or carried by the handle assembly **58** (FIG. **1**). In general terms, the handle assembly **58** can assume a wide variety of forms. In some embodiments, the handle assembly **58** is configured for direct physical handling by one or both of the surgeon's hands. In other embodiments, the handle assembly **58** is configured for remote interface by the surgeon and is not necessarily constructed for direct physical handling.

With this in mind, FIG. **20** schematically illustrates one embodiment of a handle assembly **58** in accordance with principles of the present disclosure, and includes an end effector actuator **500**, a torque actuator **502**, and an articulation actuator **504**. The actuators **500-504** can be carried by a common handle body **506**, and can be considered to be a component of the corresponding mechanism **60-64**. For example, the end effector actuator **500** can be a switch or trigger that imparts a longitudinal pulling or pushing force (or other action such as delivery of energy) on to the rod **90**. As described above, with embodiments in which the end effector **52** (FIG. **1**) has a moveable-type construction, longitudinal movement of the rod **90** causes the end effector bodies **70**, **72** (FIG. **1**) to move relative to one another. The torque actuator **502** can also be a switch, trigger, wheel, bar, etc., the movement of which causes the torque shaft **112** to rotate. As described above, rotation of the torque shaft **112** causes the end effector **52** (FIG. **1**) to rotate. Finally, the articulation actuator **504** can be a switch, trigger, wheel, bar, etc., the movement of which applies opposing tension forces on to the cable segments **304**, **306**. As described above, opposing tension forces in the cable segments **304**, **306** cause the deflection section **66** (FIG. **1**) to collectively articulate or bend, thus articulating the end effector **52** relative to the outer shaft **54**. Additional actuators (not shown) can also be provided that promote user-prompted rotation of the outer shaft **54**. With embodiments in which the surgical instrument **50** is intended to be directly and physically manipulated by the surgeon, the handle body **506** can be shaped and constructed to be held in the user's hand, for example as described in U.S. application Ser. No. 12/916,142 entitled "Articulating Laparoscopic Surgical Instruments," filed Oct. 29, 2010 and the teachings of which are incorporated herein by reference in its entirety. As one non-limiting example, the actuators **500-504** are generally labeled in FIG. **1**. In other embodiments, the actuators **500-504** can be remotely controlled (e.g., electronically controlled, electro-mechanically controlled, pneumatically controlled, etc.) by the surgeon.

Usage Mode of Operation

Returning to FIGS. **3A-4B**, during use, the surgical instruments **50** of the present disclosure can be employed to perform a variety of laparoscopic procedures, including single incision laparoscopic procedures. In a usage mode of the instrument **50**, the torque mechanism **62** components are operatively connected with one another, and the articulation mechanism **64** components are operatively connected with one another, such as when the cable segments **302**, **304** are placed under sufficient tension to draw the articulation members **310** into physical, operative contact with one another and the joint connectors **302**, **304** (and thus the links **110** into physical, operative contact with one another and the drive bodies **114**, **116**).

In the usage mode, the end effector operation mechanism **60** can be actuated to operate the end effector **52** in the desired fashion. In this regard, the rod **90** moves independent of the torque and articulation mechanisms **62**, **64**, such that operation of the end effector **52** is in no way limited by the torque and articulation features of the instrument **50**. Similarly, the torque mechanism **62** can be actuated to rotate the end effector **52** in a desired fashion, with the links **110**, torque shaft **112**, and drive bodies **114**, **116** rotating independent of the end effector operation and articulation mechanisms **60**, **64**. Thus, rotation of the end effector **52** is in no way limited by the end effector operation and articulation features of the instrument **50**. Finally, the articulation mechanism **64** can be actuated to articulate or bend the deflection section **66** in a desired fashion to spatially locate the end effector **52** relative to the outer shaft **54** as desired. Operation of the articulation mechanism **64** is independent of the end effector operation and torque mechanisms **60**, **62**, but causes a corresponding change in shape in one or more components of each mechanism **60**, **62**. For example, articulation or deflection of the deflection section **66** causes the individual links **110** to pivot relative to one another. Even with this pivoted movement, though, the links **110** remain operatively connected to one another (and to the drive bodies **114**, **116**) such that the torque mechanism **62** can be actuated to rotate the end effector **52** at any deflection shape. Similarly, rearrangement of the links **110** with articulation of the deflection section **66** is transferred as a force on to the rod **90**. The rod **90** bends in response to this combination of forces, and remains available to transfer any push/pull force on to the end effector **52**.

To facilitate traditional, single incision laparoscopic procedures, the instrument **50** has a low profile distal the handle assembly **58** (FIG. **1**), in some embodiments. For example, the single incision procedure is oftentimes performed through a reduced-sized access port that effectively limits the maximum outer transverse dimension of any body inserted there through to be on the order of 5.5 mm consistent with this end-use limitation and as described above, the outer shaft **54** has an outer diameter of not more than 5.5 mm, and the end effector **52** and the wrist assembly **56** are configured so as to not exceed this 5.5 mm outer transverse dimension footprint. The end effector **52** can be manipulated to a closed state having a maximum transverse dimension of not greater than 5.5 mm. The clevis **230**, the distal joint connector **302**, the articulation members **310** and the proximal joint connector **300** effectively define a maximum transverse dimension of the wrist assembly **56** between the end effector **52** and the outer shaft **54**, and do not present any transverse outer dimension greater than 5.5 mm. In other embodiments, one or more of the components has an outer transverse dimension greater than 5.5 mm.

Cleaning Mode of Operation

The optional flush port assembly **68** of FIG. **1** promotes cleaning and sterilization of portions of the instrument. For example, the flush port assembly **68** can include a flush port **520** attached to the outer shaft **54** proximate the handle assembly **58**. The flush port **520** is fluidly open to a lumen of the shaft **54**; cleaning liquid can thus be delivered through the flush port **520**. In other embodiments, the flush port **520** can be assembled to other components of the instrument **50** otherwise fluidly open to the lumen of the outer shaft **54**.

Cleaning and sterilization of the instrument **50** can be further enhanced by permitting selective separation of various components of the wrist assembly **56**. For example, the handle assembly **58** can be configured to provide a user-selected cleaning mode in which the tension in one or both of the cable segments **304**, **306** (FIG. **4**A) is reduced or removed, generating slack in the cable segments **304**, **306**. This slack, in turn, allows adjacent ones of the articulating members **310** to be more completely separated from each other. The optional cleaning mode is reflected in FIG. **21**. As shown, due to the slack in the cable segments **304**, **306** the distal-most articulation member **310***d* can be physically spaced from the distal joint connector **302**, the successive articulation members **310** can be physically spaced from one another, and the proximal-most articulation member **310***p* can be physically spaced from the proximal joint connector **300**. Due to the seated couplings described above, this spacing also physically separates the distal-most link **110***d* from the distal drive body **114**, the individual links **110** from one another, and the proximal-most link **110***p* from the proximal drive body **144**. Further, the proximal joint connector **300** can be physically separated from the outer shaft **54** (e.g., with distal advancement of the torque shaft **112**/proximal drive body **144** relative to the outer shaft **54**). Surfaces of the now physically separated components are easily accessed for direct cleaning. Once cleaning is complete, the handle assembly **56** is returned to the usage mode reflected in the figures.

The articulating laparoscopic surgical instruments of the present disclosure provide marked improvements over previous designs. All operational features desired by surgeons for performing a single incision laparoscopic procedure are facilitated by a low profile wrist assembly connecting the end effector to the outer shaft. Further, instruments of the present disclosure are uniquely designed for reuse, including cleaning and sterilization.

Although the present disclosure has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the present disclosure. For example, while the wrist assembly has been described as connecting the articulation members over the torque links, in other constructions, a reverse relationship can be employed. Additionally, while the instruments have been described as including an end effector operation mechanism otherwise providing the elongated push/pull rod, in other embodiments, the rod can be replaced with different structure; with yet other constructions of instruments in accordance with principles of the present disclosure, the end effector operation mechanism is entirely omitted.

We claim:

1. An articulating surgical instrument comprising:

an end effector attached to a distal end of a wrist assembly, where the wrist assembly includes:

a torque mechanism including a plurality of links disposed between the shaft end and the end effector, where the links are constructed and operate to transfer a rotational force from a proximal-most link to the end effector, and

an articulation mechanism including a plurality of articulation members that collectively define a deflection section, where the articulation mechanism is configured and operates to spatially articulate the end effector along a single plane relative to a proximal-most articulation member;

where the wrist assembly is configured such that the links spatially articulate with articulation of the deflection section relative to a common longitudinal axis of the wrist assembly, and the links rotate independently of articulation of the articulation members;

where each of the articulating members defines a central bore, a first side channel and a second side channels opposite the first side channel relative to the central bore, the articulation mechanism further including a first cable segment threaded through the first side channel of each of the articulation members; and a second cable segment threaded through the second side channel of each of the articulation members;

where the articulation mechanism is configured such that increased tension in the first cable segment causes the deflection section to deflect in a direction of the first cable segment;

where the wrist assembly is configured to provide:

a usage mode in which the cable segments are tensioned sufficiently such that adjacent articulation members physically contact each other and adjacent links physically contact each other, wherein each of the links is associated with a corresponding one of the articulation members; and

a cleaning mode in which sufficient slack in the cable segments provides that adjacent links are longitudinally spaced but not disassembled from one another and that adjacent articulation members are longitudinally spaced but not disassembled from one another, where the spacing is sufficient to permit direct cleaning.

2. The surgical instrument of claim **1**, configured such that, in the usage mode, a first link is forced to laterally translate by lateral translation of a first articulation member during operation of the articulation mechanism that causes the deflection section to articulate, and further wherein the first link rotates relative to the first articulation member during an operation of the torque mechanism that causes the end effector to rotate.

3. The surgical instrument of claim **2**, where, in the usage mode, at least a portion of the first link is moveably disposed within the first articulation member.

4. The surgical instrument of claim **3**, wherein the torque mechanism further includes a torque shaft connected to the proximal-most link.

5. The surgical instrument of claim **1**, wherein the wrist assembly further includes:

an end effector operation mechanism including a flexible rod extending through the torque shaft and coupled to the end effector.

6. The surgical instrument of claim **5**, wherein the links and the articulation members are disposed over the flexible rod.

7. The surgical instrument of claim **6**, wherein the flexible rod is slidably disposed within the torque shaft.

8. The surgical instrument of claim **5**, wherein the end effector includes a first body moveably associated with a second body and further wherein the end effector operation mechanism is configured such that longitudinal movement of the flexible rod relative to the end effector causes the first body to move relative to the second body.

9. The surgical instrument of claim **1**, wherein each of the links defines a male end portion opposite a female end portion, and further wherein when adjacent links are physically connected in direct contact with one another, the male end portion of a first link is received within the female end of an immediately adjacent second link at a link interface such that the first link can laterally pivot relative the second link at the link interface so that a rotational force applied to the first link is transferred to the second link at the link interface.

10. The surgical instrument of claim **9**, wherein the male end portion includes a polygonal ball head, and the female end portion forms a polygonal socket head configured to selectively receive the ball head.

11. The surgical instrument of claim **10**, wherein each link defines a longitudinal axis, and further wherein the polygonal ball head has a polygonal shaped cross-section in a plane perpendicular to the longitudinal axis.

12. The surgical instrument of claim **10**, wherein a cross-section of the ball head in a plane passing through the longitudinal axis has curved lateral edges.

13. The surgical instrument of claim **12**, wherein the socket head defines a receptacle having the polygonal shape such that when the male end portion of the first link is received within the female end portion of the second link, rotation of the of the first link is directly transferred to the second link via a locked interface between the polygonal shapes, and the first link can pivot relative to the second link via the curved lateral edges sliding relative to the receptacle.

14. The surgical instrument of claim **9**, wherein the torque mechanism further includes a connector fixed to and extending proximally from the end effector, the connector forming one of the male end portion and the female end portion.

15. The surgical instrument of claim **1**, wherein each of the plurality of links is discrete from a remainder of the plurality of links.

16. The surgical instrument of claim **1**, wherein the cable segments are comprised by a single cable.

17. The surgical instrument of claim **1**, wherein the wrist assembly is configured such that, during operation of the articulation mechanism to change a shape of the deflection section, the deflection section applies a force on to the plurality of links so that the plurality of links collectively assume a shape of the deflection section.

18. The surgical instrument of claim **17**, wherein the wrist assembly further includes:

an end effector operation mechanism including a flexible rod extending through the torque shaft and coupled to the end effector such that longitudinal movement of the rod relative to the end effector causes a first end effector body to move relative to a second end effector body;

being configured such that, during operation of the articulation mechanism to change a shape of the deflection section, a portion of the flexible rod surrounded by the deflection section assumes a shape of the deflection section.

19. The surgical instrument of claim **1**, further comprising actuators carried by a handle, each actuator being configured to facilitate user-controlled operation of each corresponding mechanism.

20. The surgical instrument of claim **1**, wherein the links are configured such that upon transitioning from the cleaning mode to the usage mode in response to increased tension of the cable segments, adjacent links self-align and engage in physical contact with one another.

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