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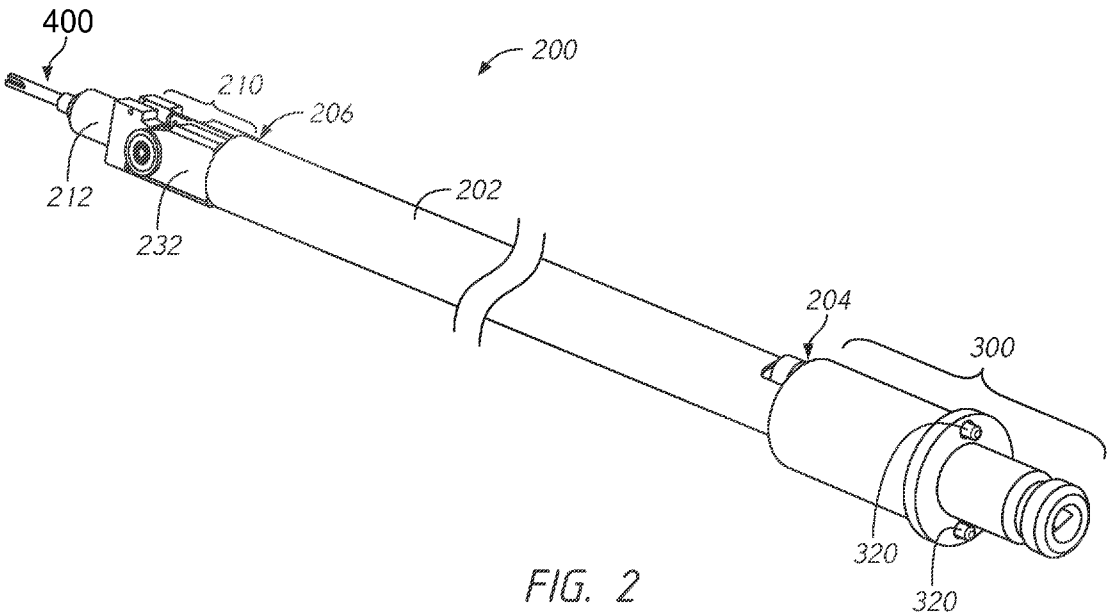

FIG. 2

(57) Abstract: Various articulating tools for endoscopic placement of fasteners are disclosed. The tool can comprise a multi-angle articulating screwdriver. The tool can have an elongate shaft with an articulating driver head at a distal end. The tool can rotate the articulating driver head to drive fasteners, such as screws, to a surgical site. The articulating driver head can articulate with respect to a longitudinal axis of the elongate shaft to enable the fastener to be driven at various angle. The tool can be coupled to a powered handpiece power and can transmit torque from the handpiece to the driver head.

[Continued on next page]

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ARTICULATING TOOL FOR ENDOSCOPIC PLACEMENT OF FASTENERS

CROSS-REFERENCE

[0001] This application claims the benefit of U.S. Patent Application No. 62/543,551, filed August 10, 2017; U.S. Patent Application No. 62/567,584, filed October 3, 2017; and U.S. Patent Application No. 62/590,122, filed November 22, 2017. The entirety of each of the aforementioned applications is incorporated by reference herein.

BACKGROUND

Field

[0002] This disclosure relates to an articulating tool for endoscopic placement of fasteners, such as screws.

Certain Related Art

[0003] Various surgical procedures (such as bone fracture surgeries) include inserting one or more screws into a bone to retain a structure, such as a plate (e.g., titanium osteosynthetic plates or others) on the bone. During insertion, the screw is threaded into the bone. For example, to treat a rib fracture, a surgeon can attach a plate with one or more fixation screws to an inner surface (on the side facing the lungs) of the broken rib. The surgery can be performed in a minimally invasive manner with the aid of a thoracoscope. The view from the thoracoscope can allow visualization of the inner side of the rib cage, including the fracture site(s). Thoracoscope-assisted internal fixation of fractured ribs can be more beneficial to a patient than certain other treatments, such as analgesia and/or ventilation.

SUMMARY OF CERTAIN FEATURES

[0004] Inserting screws into a bone can be challenging due to the location and/or orientation of the bone, the surrounding anatomical structures (for example, muscles, ligaments, tendons, blood vessel, nerves, or otherwise), and/or the shape of the bone. In certain surgical procedures, there can be limited access to a desired insertion location and/or angle for the screw on the bone. Retracting the fastening tool to adjust the insertion location and/or angle may be time consuming, cause trauma to the patient, and/or be inconvenient or impractical (such as when a direct entry path for the fastening tool is blocked by other anatomical structures).

[0005] An extension with flexible or elastomeric portions may aid in navigating a driver head in the patient's body. However, the flexible or elastomeric portions may not efficiently transmit a torque sufficient for inserting a screw into the cortex of the bone.

[0006] A rigid and/or non-flexible and/or non-elastomeric fastening tool that can change direction may aid in navigating a driver head in the patient's body while also efficiently transmitting a torque. In some embodiments, such an extension (e.g., a screwdriver) can include an articulating component that is configured to articulate at multiple angles in multiple axes. This can allow the fastening tool to adjust (e.g., bend or pivot) so as to access tight spaces, reduce a frequency of a user readjusting the position, and/or provide a desired orientation of the fastening tool. It can be beneficial that the fastening tool can at the same time maintain sufficient torque outputs to perform the intended function (e.g., to insert a fixation screw into the bone).

[0007] It can be beneficial to have an extension with an articulating component that has an outer profile comparable to a standard non-articulating fastening tool. A smaller outer profile can reduce the need for a larger-sized access portal (e.g., a trocar) and/or allow the fastening tool with the articulating component to access spaces that are usually accessible by the standard non-articulating fastening tool.

[0008] In some implementations, gearing (e.g., bevel or miter gears) can provide improved overall range for the articulating component, such as an articulating driver head. It can be desirable to use gears and gearing mechanisms that will fit into the available space while maintaining sufficient torque outputs to perform the original function.

[0009] Several embodiments of an articulating tool for endoscopic placement of fasteners are disclosed herein that provide one or more of the above-described benefits, or other benefits.

[0010] Any of the structures, materials, steps, or other features disclosed above, or disclosed elsewhere herein, can be used in any of the embodiments in this disclosure. Any structure, material, step, or other feature of any embodiment can be combined with any structure, material, step, or other feature of any other embodiment to form further embodiments, which are part of this disclosure.

[0011] The preceding summary, following detailed description, and associated drawings do not limit or define the scope of protection. The scope of protection is defined by the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The abovementioned and other features of the embodiments disclosed herein are described below with reference to the drawings of the embodiments. The illustrated embodiments are intended to illustrate, but not to limit the embodiments. Various features of the different disclosed embodiments can be combined to form further embodiments, which are part of this disclosure.

[0013] Figure 1A illustrates a side view of an example fastening tool coupled to a handpiece and an articulating driver head shown at different angles.

[0014] Figure 1B illustrates a front view of an example fastening tool interface of the handpiece.

[0015] Figure 2 illustrates a perspective view of an example fastening tool with an articulating driver head at about 0° with respect to a longitudinal axis of the fastening tool.

[0016] Figure 3A illustrates a longitudinal cross-sectional view of the fastening tool of Figure 2.

[0017] Figure 3B illustrates a detailed cross-sectional view of a proximal portion of the fastening tool of Figure 3A.

[0018] Figure 3C illustrates a side elevation view of a proximal end of the fastening tool of Figure 3A.

[0019] Figure 3D illustrates a perspective view of an example driver head adapter of the fastening tool of Figure 3A.

[0020] Figure 3E illustrates a perspective view of the driver head adapter of Figure 3C sectioned along a central longitudinal axis.

[0021] Figure 3F illustrates a perspective view of an example driver head.

[0022] Figure 4A illustrates a perspective view of an example distal portion of the fastening tool of Figure 2, with support walls and an outer housing not shown for illustration purposes.

[0023] Figure 4B illustrates operation of an example articulating (e.g., bevel gear) arrangement of the fastening tool of Figure 4A.

[0024] Figure 5A illustrate a perspective view of another example distal portion of the fastening tool of Figure 2, with the support walls and outer housing not shown for illustration purposes.

[0025] Figures 5B-5E illustrate various perspective views of an example bevel gear arrangement in the fastening tool of Figure 5A.

[0026] Figure 5F illustrates operation of the bevel gear arrangement of Figure 5A.

[0027] Figure 6A illustrates a perspective view of the fastening tool of Figure 2, with the outer housing not shown and a collet housing shown as transparent for illustration purposes.

[0028] Figure 6B illustrates a detailed view of the distal portion of the fastening tool of Figure 6A.

[0029] Figure 7A illustrates a perspective view of the fastening tool of Figure 2 coupled to an articulating driver head at an acute angle with respect to a longitudinal axis of the fastening tool.

[0030] Figure 7B illustrates a detailed view of the distal portion of the fastening tool of Figure 7A.

[0031] Figure 8 illustrates operation of another example articulating arrangement.

[0032] Figure 9 illustrates operation of another example articulating arrangement.

[0033] Figure 10A illustrates a top view of an example articulating gear arrangement with a head substantially not tilted.

[0034] Figure 10B illustrates a side view of the articulating arrangement of Figure 10A with a head tilted to a first angle.

[0035] Figure 10C illustrates a top view of the articulating arrangement of Figure 10A with the head tilted to a second angle.

[0036] Figure 10D illustrates a top view of another articulating arrangement.

[0037] Figure 10E illustrates a side view of the articulating arrangement of Figure 10C.

[0038] Figure 11 illustrates a perspective view of another example articulating arrangement.

[0039] Figure 12 illustrates a side view of another example articulating arrangement.

[0040] Figure 13 illustrates another example articulating arrangement.

[0041] Figure 14 illustrates an example worm gear arrangement.

[0042] Figure 15 illustrates an example cam and/or pin articulating arrangement.

[0043] Figure 16 illustrates an example swash plate or angled plate articulating arrangement.

[0044] Figure 17 illustrates a shaft rotating mechanism configured for rotating the driver head.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

[0045] A variety of articulating tools are described below to illustrate various examples that may be employed to achieve one or more desired improvements. These examples are illustrative only and not intended to restrict the general inventions presented and the various aspects and features of these inventions. The phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. No features, structure, or step disclosed herein is essential or indispensable.

Overview

[0046] In several embodiments, an articulating tool 1 is configured to facilitate endoscopic placement of fasteners. For example, the articulating tool 1 may be used to drive screws into bone during a surgical procedure. As shown in Figure 1A, the articulating tool 1 can include a handpiece 10 and a fastening tool 20. The handpiece 10 can be a powered device, such as having a battery and electric motor. The handpiece 10 can include a grip for a user to grasp and manipulate the articulating tool 1. The handpiece 10 can include controls (e.g., buttons) to operate the articulating tool 1, such as to direct driving action, speed, and/or direction (e.g., clockwise or counter clockwise). The fastening tool 20 can be coupled to the handpiece 10, such as at a proximal end of the fastening tool 20. The fastening tool 20 can be removably connected to the handpiece 10. In certain embodiments, the fastening tool 20 is coupled to the handpiece 10 with a quick-release mechanism. In some embodiments, the

quick-release mechanism comprises a release button or lever on the fastening tool 20 or the handpiece 10 so that actuating (e.g., depressing) the button or lever can release the attachment of the fastening tool 20 to the handpiece 10.

[0047] The fastening tool 20 can include an articulating driver head adapter 22 at a distal end of the fastening tool 20. The adapter 22 can couple to a driver head 30 (e.g., a bit configured to engage with the head of a screw). For example, the adapter 22 can couple to the driver head 30 releasably and/or via a quick-release mechanism, such as a detent.

[0048] In several embodiments, the adapter 22 is configured to rotate. As illustrated, the adapter 22 can be configured to rotate about a joint 26 and relative to a longitudinal axis L of the fastening tool 20. Rotation of the adapter 22 can enable the position and angle of the adapter 22 (and thus the driver head 30) to be adjusted, which can facilitate driving of a fastener at a desired position and angle. In some embodiments, the adapter 22 is rotatable in one plane and/or about an axis of rotation that is generally perpendicular to the longitudinal axis L. In certain embodiments, the adapter 22 can rotate approximately 0° to approximately 140° (such as shown in Figure 1A), or approximately 0° to approximately 110°, or approximately 0° to approximately 90°, or approximately 0° to approximately 45°. The fastening tool 20 can include an articulation actuator configured to adjust the angle of the adapter 22. In the example shown in Figure 1A, the articulation actuator comprises an adjustment dial 24, such as a manually operated wheel. The actuator can be located away from the driver head adapter 22, such as at or near the proximal end of the fastening tool 20.

[0049] The handpiece 10 or the fastening tool 20 can include a driver head actuator, such as a button, thumbwheel, lever, or otherwise. For example, the handpiece 10 can include one or more buttons 11 that operates the motor, which can be operatively connected to the driver head 30, such as to rotate the drive head 30 (e.g., clockwise and/or counterclockwise). In some embodiments, power from the motor is transmitted to the driver head 30 through an internal shaft of the fastening tool 20 and/or through the joint 26. In some embodiments, the handpiece 10 can include software and/or hardware for adaptively limiting torque applied to the driver head 30. Additional information about adaptive torque limiting can be found in U.S. Patent No. 9,265,551, the entirety of which is incorporated by reference herein.

[0050] In some embodiments, such as shown in Figure 1B, the fastening tool 20 can be indexed to the handpiece 10 in a variety of orientations. For example, the fastening tool 20 can be secured to the handpiece 10 in a plurality (e.g., 2, 3, 4, 6, 8, or more) of rotational positions, such as with mating features 15 (e.g., recesses and protrusions) in the handpiece 10 and fastening tool 20 . Rotating the fastening tool 20 to a new orientation relative to the handpiece 10 can rotate the driver head 30 to a new orientation as well. This can enable the drive head 30 to drive fasteners in a variety of orientations relative to the handpiece 10. In some implementations, by rotating the driver head 30, which can be configured to articulate in one plane, through the different orientations of the fastening tool 20, the articulating tool 1 can be configured to articulate in those different planes (such as being able to articulate in a half sphere of space in which the driver head 30 can be operated in). In various embodiments, the fastening tool 20 can be detached from the handpiece 10, rotated relative to the handpiece 10 to a new position, then reattached to the handpiece to allow for a new range of operation of the driver head 30.

Certain Embodiments of an Articulating Fastening Tool

[0051] Various embodiments of an articulating fastening tool 200 are disclosed. As shown in Figure 2, the fastening tool 200 can have any of the features of the fastening tool 20 in Figure 1A. For example, the tool 200 can be configured to couple to a body at a proximal end of the fastening tool 200 and to a driver head 300 at the distal end of the fastening tool 200.

[0052] The fastening tool 200 can include an elongate outer housing 202 having a proximal portion 204 and a distal portion 206. A body coupling assembly 300 can be located at a proximal end of the tool 200. The body coupling assembly 300 can include a collet housing 302 coupled to the proximal portion 204 of the elongate outer housing 202. As shown in Figures 3A and 3B, a terminal part of the proximal portion 204 of the outer housing 202 can be received within a first cavity of the collet housing 302 and can terminate at or near a transverse wall 310. The transverse wall 310 can include a generally central opening configured to allow a collet shaft 308 to pass through and freely rotate with respect to the opening of the wall 310. In certain embodiments, the housing 202 can be rotated relative to the handpiece 10 while connected to the handpiece 10.

[0053] The collet housing 302 can include a second cavity on an opposite side of the transverse wall 310 from the first cavity. The second cavity can house a body interface 304 that extends proximally from the collet housing 302. The collet housing 302 can be received in an opening in the handpiece 10. This can functionally connect the tool 200 and the handpiece 10, such as to allow the motor of the handpiece 10 to drive the driver head 300.

[0054] As shown in Figures 3A-3C, the body interface 304 can include a proximally facing surface 318. A perimeter of the proximally facing surface 318 extends radially outward from an outer surface of the collet housing 302. The proximally facing surface 318 can act as a stopper for the body, such as the handpiece 10, when installing the fastening tool 200 onto the body. One or more (for example, two, three, or more) orientation features, such as dowel pins 320, can extend proximally from the proximally facing surface 318. The dowel pins 330 can facilitate aligning the handpiece 10 with the body coupling assembly 300. The body interface 304 can include an outer groove 306 near a proximal end of the interface 304. In some embodiments, the outer groove 306 can be configured to facilitate in retaining the body.

[0055] As shown in Figures 3A-3C, the body interface 304 can have a lumen that is continuous from the lumens of the collet housing 302 and the elongate outer housing 202 and configured to accommodate the collet shaft 308. A proximal end of the collet shaft 308 can terminate inside the lumen of the body interface 304, which can protect the proximal end of the collet shaft 308 from external impacts. At least one (e.g., two, three, or more) ball bearings 322 can extend between an outer wall of the collet shaft 308 and a lumen wall of the body interface 304 to facilitate rotation of the collet shaft 308 in the lumen of the body interface 304 (e.g., by aiding in aligning an axis of rotation of the collet shaft 308 with a longitudinal axis of the lumen of the body interface 304). A biasing member, such as a wave washer 324, can be disposed between the transverse wall 310 and a distal ball bearing 322 (e.g., to inhibit or prevent the transverse wall 310 from impinging on the distal ball bearing 322).

[0056] The proximal end of the collet shaft 308 can be configured to couple with a handpiece drive shaft, which can be operably coupled to the motor. The collet shaft 308 can

include a rotation-limiting shape, such as at least one flat surface. In some embodiments, such as shown in Figures 3A and 3B, the rotation limiting shape can include two opposing flat surfaces 309. When the collet shaft 308 engages the drive shaft, rotation of the drive shaft causes rotation of the collet shaft 308.

[0057] A distal end of the collet shaft 308 can be coupled to a first shaft 208. As shown in Figures 3A and 3B, the distal end of the collet shaft 308 can include a recess configured to fixedly (e.g., via friction, adhesives, or otherwise) receive the first shaft 208. In some embodiments, the collet shaft 308 and the first shaft 208 can be fixedly engaged by other attachment features and/or mechanisms. As will be described below, the first shaft 208 is configured to transmit a rotation of the collet shaft 308 and/or torque to the driver head, such as the driver head 300.

[0058] The first shaft 208 can be positioned inside and/or extend through the lumen of the elongate outer housing 202. A distal portion of the first shaft 208 can extend distally from the elongate outer housing 202 and into an articulating torque transmission unit 210, such as a bevel gear assembly. The articulation unit can be located distally from the elongate outer housing 202. The articulating torque transmission unit 210 can include an output shaft 214 fixedly coupled to a driver head adapter 212 (e.g., via a press fit pin 216 extending through a pin hole in a distal portion of the output shaft 214 and a pin hole 218 on the adapter 212, or otherwise). As described below with reference to Figures 4A to 5F, the articulating torque transmission unit 210 is configured to transmit rotation of the shaft 208 and/or torque to the driver head adapter 212.

[0059] The driver head adapter 212 can be configured to removably receive a driver head 400, such as a bit (e.g., a flat-head bit, Philips bit, hex bit, star bit, or otherwise). In some embodiments, such as shown in Figures 3D and 3E, the adapter 212 can include a generally square opening 220 configured to receive a driver head having a shaft with a generally square cross-section. In certain embodiments, the driver head adapter 212 can include an opening of a different shape that is complementary to the shape of the driver head shaft and that causes rotation of the driver head adapter 212 to be transmitted to the driver head shaft. As shown, the driver head adapter 212 can include a second opening 221 that has a greater internal dimension than the square opening 220.

[0060] In various embodiments, a driver head shaft 402 can be retained in the adapter 212. For example, the driver head shaft 402 can be retained with a friction fit, detent mechanism, or otherwise. In some implementations, such as shown in Figure 3F, the driver head shaft 402 of the driver head 400 can include two or more opposing prongs 404 separated by a gap such that a distance between outer surfaces of the prongs 404 is greater than a width of the generally square opening 220. The prongs 404 can deflect slightly toward each other when inserted into the generally square opening 220. The tendency of the prongs 404 to spring apart back to the original gap size can aid in retaining the driver head shaft 304 inside the square opening 220. In some embodiments, the prong 404 can have a chamfer or tapering 406 at its free end to facilitate insertion of the prongs 404 into the generally square opening 220. The prongs 404 of the driver head shaft 402 can expand after the driver head shaft 402 advances past the square opening 220 into the second opening 221, which can aid in retaining the driver head shaft 402 within the driver head adapter 212. In some embodiments, the shaft of the driver head can include other types of retaining mechanism(s), such as spring-biased ball detent or others, so that the second opening 221 can retain the driver head shaft when the driver head shaft advances past the square opening 220 into the second opening 221. In various embodiments, the adapter 212 and driver head shaft 402 are spaced apart from the proximal end of the tool 200 and/or the handpiece 10, such as by at least about: 100mm, 150mm, 200mm, 250mm, or more.

[0061] As shown in Figure 4A, the articulating torque transmission unit 210 can include a first bevel gear 226 fixedly coupled to the first shaft 208, a second bevel gear 228 fixedly coupled to a gear support shaft 224, and third bevel gear 230 fixedly coupled to the output shaft 214. The first bevel gear 226 interacts with the second bevel gear 228. The second bevel gear 228 interacts with the third bevel gear 230. In some embodiments, the bevel gears can include a metal, such as 440C stainless steel or otherwise. In certain embodiments, the gears can have a Rockwell hardness of at least about 60-65C. As shown in Figures 2 and 3A, the articulating torque transmission unit 210 can include one or more support walls 232, which can protect the bevel gears and/or the shafts from external impacts.

[0062] As shown in Figure 4B, as the first bevel gear 226 and the first shaft 208 rotate in a first direction (e.g., counterclockwise), the second bevel gear 228 and the gear

support shaft 224 rotate in a second direction perpendicular to the first direction (e.g., to the right as indicated in the figure). The rotation of the second bevel gear 228 causes the third bevel gear 230 and the output shaft 214 to rotate in a third direction that is opposite the first direction (e.g., clockwise). In various embodiments, an axis of rotation of the second bevel gear 228 is generally perpendicular to an axis of rotation of the first and/or third bevel gear 226, 230. In certain implementations, the axes of rotation of the first and third bevel gears 226, 230 are generally parallel and/or collinear when the driver head is not articulated.

[0063] In some embodiments, the fastening tool can include an articulation unit 211 such as shown in Figure 5A. The articulation unit 211 can include a first bevel gear 226 fixedly coupled to the first shaft 208, a second bevel gear 228 and a third bevel gear 229 fixedly coupled to two ends of a gear support shaft 224, and a fourth bevel gear 230 fixedly coupled to the output shaft 214. The first bevel gear 226 interacts with the second bevel gear 228. Rotation of the second bevel gear 228 is transmitted to the third bevel gear 229 via the gear support shaft 224. The third bevel gear 229 interacts with the fourth bevel gear 230. Figures 5B-5E show schematic illustrations of the articulating torque transmission unit 210 with four bevel gears, such as shown in Figure 5A.

[0064] In some embodiments, such as shown in Figure 5F, as the first bevel gear 226 and the first shaft 208 rotate in a first direction (e.g., counterclockwise), the second bevel gear 228, the gear support shaft 224, and the third bevel gear 229 rotate in a second direction perpendicular to the first direction (e.g., to the left). The rotation of the third bevel gear 229 causes the fourth bevel gear 230 and the output shaft 214 to rotate in the same direction as the first direction (e.g., counterclockwise).

[0065] The articulating torque transmission unit 210 in Figures 4A-4B and 5A-5F can allow for improved ranges of motion, such as between the first gear 226 and the third gear 230 in the embodiment shown in Figures 4A-4B and between the first gear 226 and the fourth gear 230 in the embodiment shown in Figures 5B-5D. An embodiment of the articulating torque transmission unit 210 with four bevel gears, such as shown in Figures 5A-5F, can advantageously allow the rotation of the output shaft 224 to be in the same direction as the first shaft 208. For example, input rotation in a direction from the handpiece 10 can result in output rotation in the same direction at the driver head 400.

[0066] An embodiment of the articulating torque transmission unit 210 with three bevel gears, such as shown in Figures 4A-4B, can result in the rotation of the output shaft 224 being reversed relative to the rotation of the first shaft 208. Having the output shaft 224 rotate in the opposite direction from the first shaft 208 may be confusing to a user. For example, a user may become familiar with a certain button that causes the articulating tool 1 to output clockwise rotation, so the user may be confused when, after the tool 200 is connected, the articulating tool 1 outputs counterclockwise rotation. Some embodiments are configured to automatically adapt to accommodate for the rotation reversal. For example, the handpiece 10 can reverse the drive direction of the motor for the button in response to the tool 200 being connected to the handpiece 10. In some variants, the button drives the handpiece drive shaft in a first direction (e.g., clockwise) before the tool 200 is connected to the handpiece 10 and, after the tool 200 is connected to the handpiece 10, the button drives the handpiece drive shaft in a second direction (e.g., counterclockwise), which in turn causes the driver head 300 to rotate in the first direction (e.g., clockwise). The reversal can be performed through software on a controller of the handpiece 10. The reversal can occur automatically in response to connection of the tool 200 and/or can be invisible to the user.

[0067] Various embodiments include an articulation mechanism. In some embodiments, such as shown in Figure 6A, the articulation mechanism includes a second shaft 234. The shaft 234 can be positioned inside and/or extend through the lumen of the elongate outer housing 202. The second shaft 234 can run generally parallel to the first shaft 208. A proximal portion of the second shaft 234 can include a rotation limitation feature 236 (e.g., one or more flat surfaces). The proximal portion of the second shaft 234 can extend through an opening of a stopper 238 that is located distally from and near a distal end of the collet housing 302. The opening of the stopper 238 that engages the proximal portion of the second shaft 234 can have a shape generally complementary to the rotation limitation feature 236. The stopper 238 can be fixedly attached to the distal end of the collet housing 302 such as the second shaft 234 is prevented substantially from rotational movements.

[0068] In some embodiments, at least part of the proximal portion of the second shaft 234 can include helical threads (e.g., external threads). An actuator (such as a wheel 240, a worm gear, or otherwise) can include corresponding helical threads (e.g., internal

threads or external threads) that engage the threads on the second shaft 234. As the second shaft 234 is substantially prevented from rotational movements due to the engagement between the rotation limitation feature 236 and the stopper 238, rotating the wheel 240 can cause axial movements of the second shaft 234. Rotating the wheel 240 in one direction can cause the second shaft 234 to advance distally toward the driver head adapter 212. Rotating the wheel 240 in the opposite direction can cause the second shaft 234 to retract proximally away from the driver head adapter 212.

[0069] A distal portion of the second shaft 234 can extend distally from the elongate outer housing 202 and into the articulating torque transmission unit 210. A linkage arm 242 can be coupled to a distal end of the second shaft 234 at a hinge 244. As shown in Figures 6A and 6B, the support walls 232 of the articulating torque transmission unit 210 can include a gap configured to slidably engage the second shaft 234 and the linkage arm 242. An end of the linkage arm 242 that is opposite the end coupled to the hinge 244 can be pivotally coupled to the support walls 232 (e.g., via a pivot pin extending generally transversely through the support walls and the linkage arm 242).

[0070] As shown in Figures 7A and 7B, the adapter 212 and/or the driver head 300 can be articulated relative to the housing 202. In some implementations, the articulation occurs as a result of movement of the second shaft 234, such due to rotation of the wheel 240 and the threaded engagement of the wheel 240 and the second shaft 234. As shown, proximal movement of the second shaft 234 (e.g., relative to housing 202 and/or wheel 240) can cause the linkage arm 242 to bend at the hinge 244 and rotate relative to the second shaft 234. The support walls 232 can include proximal and distal portions 245, 247 pivotally coupled at a second hinge 246, which is coupled to the gear support shaft 224. The distal portion 247 can be fixedly coupled to the output shaft 214. The bending of the linkage arm 242 can cause the distal portion 247, the driver head adapter 212 (and the driver head 300 coupled to the adapter 212) to pivotally rotate about the second hinge 246 and/or the gear support shaft 224. To straighten the linkage arm 242 relative to the second shaft 234, such as shown in Figure 6A, the second shaft 234 can be moved distally, for example, by rotating the wheel 240 in the opposite direction.

[0071] In various embodiments, the tool 200 can transmit rotation to the driver head 300 while also being able to articulate, such as about the hinge 246. The tool 200 can advantageously drive screws or other fasteners in a variety of positions. The tool 200 can adjust (e.g., bend or pivot) so as to access tight spaces and/or provide a desired orientation of placing and driving the fastener. In various embodiments the mechanism that controls the articulation of the tool is separate (e.g., independently operable) from the mechanism that transmits torque to drive the screws or other fasteners. In some variants, the mechanism that controls the articulation and the mechanism that transmits torque to the driver head can each include a distinct shaft and/or a distinct control device (e.g., actuator). For example, the mechanism that controls the articulation can include the second shaft 234 and/or the wheel 240, and the mechanism that transmits torque to the driver head can include the first shaft 208 and/or one or more buttons on the handpiece 10.

Other Embodiments of an Articulating Fastening Tool

[0072] Any of features of the embodiments described below can be incorporated into the fastening tool 200 described above.

[0073] In some embodiments, such as shown in Figure 8, the Input Shaft (1) is rigidly connected to Gear 'X'; the Idler Shaft (3) is rigidly connected to Gear 'A' (Gear 'A' is a double sided Bevel Gear); and the Output Shaft (2) is rigidly connected to Gear 'Z'. Gear 'X' interfaces with Gear 'A'. Gear 'A' also interfaces with Gear 'Z'. As Gear 'X' rotates CCW, Gear 'A' rotates to the Left, which causes Gear 'Z' to rotate CCW. An advantage of this arrangement is the increased articulation that can be achieved.

[0074] Some embodiments are configured to articulate the driver head adapter, (such as past about 45° or about 90°, without the bevel gears directly with one another. In some embodiments, such as shown in Figure 9, a articulation unit of an articulating fastening tool can include a chain or belt 950. The belt 950 can extend the point from with the motion is transferred from one set of bevel gears to the set of bevel gears. An input shaft 956 can act on a set of bevel gears 952, one of which can be rigidly connected to a belt pulley or chain cog 954. The belt 950 can be connected to a second belt pulley or chain cog 958, which can be connected to a second set of bevel gears 960, one of which acts on an output shaft 962. An advantage of this design is the motion transfer between the input and output bevel gears 952,

960 is effectively repositioned so that the articulating bevel gear will not interfere with the other gearing.

[0075] In some embodiments, such as shown in Figures 10A-10E, the addition of spur gears 1064 can transfer the motion of the input shaft 1056 to the articulating output shaft 1062. This has a similar effect to the belt and/or chain system discussed above, but does so using additional gears to move the bevel gears into a more effective location. Multiple gears (e.g., two, three, or more) can be added to further displace (e.g., space apart) the bevel gears, if needed. An advantage of this design is the motion transfer between the input and output bevel gears can be repositioned so that the articulating bevel gear does not interfere with the other gearing.

[0076] In some embodiments, the fastening tool can include bevel gears such as shown in Figure 11. Gear A can be coupled to the drive shaft. Rotation of Gear A gets transferred, via Idler Gear B, to Gear C, which can be coupled to the output shaft to drive the screws. At the same time, Gear C is free to re-orient in 3 dimensions. Some implementations can include a gear reduction or speed multiplication through the idler gear.

[0077] In some embodiments, such as shown in Figure 12, other configurations of bevel gears can transfer the rotation through the articulating joint. In the configuration shown in Figure 11, Gear A can constrain (e.g., due to a physical interference) the rotation of Gear C. In contrast, in the bevel gear mechanism such as shown in Figure 12, Gears A and B are arranged symmetrically about the Idler Gear B. As the planes of articulation no longer intersect, the mechanism in Figure 12 can allow for an increased range of motion compared to, for example, the mechanism in Figure 11.

[0078] In some embodiments, such as shown in Figure 13, the tip of the driver head adapter can be substantially collinear with the drive axis of an input shaft 1356. The bevel gear mechanism in Figure 12 introduces an offset. Certain embodiments, such as shown in Figure 13, the gear mechanism of Figure 12 can be connected to a spur gear 1364 to adjust the offset. As shown, tip of the driver head adapter 1312 can be substantially collinear with the tip of the input shaft 1356.

[0079] Various embodiments of an articulating fastening tool can be configured to control the orientation of the driver head adapter 212 at a location away from the driver head

adapter 212 and/or closer to the handpiece 10. Some embodiments, such as shown in Figure 14, can include a worm gear 1466 acting on a gear or adapter adjustment dial 1468. The adjustment dial 1468 can serve as a user interface (e.g., located near a proximal end of the fastening tool or on the handpiece). Rotating the adjustment dial 1468 can articulate (e.g., open or close) the mechanical linkage on the left side of the adjustment dial 1468 (e.g., from about 0° to about 90°). In certain embodiments, the linkage can translate rotational motion about the shaft axis to an axis generally perpendicular to the shaft axis and about which the driver head can rotate or articulate. In some variants, rotation of the adapter adjust dial 1468 can rotate the worm gear 1466 and the driver head adapter accordingly.

[0080] Some embodiments can have a stationary cam or pin 1570 such as shown in Figure 15, for articulating the driver head adapter and/or the driver head. Gear B and the cam or pin 1570 are mounted to the same shaft or axis, but are free to rotate independently of one another. The cam or pin 1570 is connected to the shaft, while Gear B has a bearing that allows Gear B to rotate independently of the shaft. The center of Gear C is fixed to the end of the cam or pin 1570. The cam or pin 1570 can protrude into the moveable output bevel gear (such as Gear C described above), but does not rotate with respect to the rotation of the moveable output bevel gear. When the cam or pin 1570 is rotated about the connected shaft, Gear C can rotate with the cam or pin 1570 along the surface of Gear B. However, the cam or pin 1570 is fixed to the center of Gear C such that Gear C is free to spin about the center axis of the shaft. The cam or pin 1570 can be actuated via a rod sliding back and forth similar to the rod 1674 in Figure 16. A gear similar to the gear 1678 but smaller in size can connect to the shaft to which the cam or pin 1570 is mounted to.

[0081] Certain implementations can use mechanical linkages that are activated by a rod that pushes and pulls on the adapter, for example, such as shown in Figure 16. The rod can be activated by advancing the adjustment dial on a threaded track. Some embodiments, such as shown in Figure 16, can have a swash plate 1672 (or angled plate). The swash plate 1672 can be angled relative to the longitudinal axis of the tool 200. The swash plate 1672 can be configured to abut against and/or articulate the driver head adapter 212 and/or the driver head 300. In some embodiments, the swash plate 1672 acts against a push rod 1674. For example, the swash plate 1672 can rotate relative to the push rod 1674, which due to the

angle of the swash plate 1672, causes the push rod 1674 to move longitudinally. In implementations, the push rod 1674 translates a rack gear 1676, which activates a gear 1678 that is used to control the orientation of the driver head adapter 212 and/or the driver head 300. In some embodiments, the shaft 208 extends through the swash plate 1672 and/or can rotate relative to the swash plate 1672.

[0082] Several embodiments of the fastening tool can enable the input shaft to be rotated 360°. In some embodiments, the 360° rotation of the input shaft is achieved by retracting the pins allowing for discrete rotation of the driver head adapter with respect to the driver unit. In some embodiments, rotation of the input shaft is achieved with a friction fit between the input shaft and the body interface (e.g., the housing 202) so that the input shaft can be manually rotated to the desired orientation. In some embodiments, such as shown in Figure 17, the 360° rotation of the input shaft 1756 can be achieved by utilizing a gear type system by which an adjustment dial 1770 (e.g., in a direction perpendicular to the rotation of the input shaft 1756) can be used to rotate a gear 1772. The gear 1772 can control the orientation of the shaft 1756 with respect to the driver unit. In the embodiments such as shown in Figure 17, the driver head can stay fixed to the fastening tool as the gear 1772 is rotated to rotate the driver head.

Certain Terminology

[0083] Terms of orientation used herein, such as "top," "bottom," "horizontal," "vertical," "longitudinal," "lateral," and "end" are used in the context of the illustrated embodiment. However, the present disclosure should not be limited to the illustrated orientation. Indeed, other orientations are possible and are within the scope of this disclosure. Terms relating to circular shapes as used herein, such as diameter or radius, should be understood not to require perfect circular structures, but rather should be applied to any suitable structure with a cross-sectional region that can be measured from side-to-side. Terms relating to shapes generally, such as "circular" or "cylindrical" or "semi-circular" or "semi-cylindrical" or any related or similar terms, are not required to conform strictly to the mathematical definitions of circles or cylinders or other structures, but can encompass structures that are reasonably close approximations.

[0084] Conditional language, such as "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, and/or steps are included or are to be performed in any particular embodiment.

[0085] The terms "approximately," "about," and "substantially" as used herein represent an amount close to the stated amount that still performs a desired function or achieves a desired result. For example, in some embodiments, as the context may permit, the terms "approximately", "about", and "substantially" may refer to an amount that is within less than or equal to 10% of the stated amount. The term "generally" as used herein represents a value, amount, or characteristic that predominantly includes or tends toward a particular value, amount, or characteristic. As an example, in certain embodiments, as the context may permit, the term "generally parallel" can refer to something that departs from exactly parallel by less than or equal to 15 degrees. As another example, in certain embodiments, as the context may permit, the term "generally perpendicular" can refer to something that departs from exactly perpendicular by less than or equal to 15 degrees.

Conclusion

[0086] While a number of variations of the disclosure have been shown and described in detail, other modifications, which are within the scope of this disclosure, will be readily apparent to those of skill in the art based upon this disclosure. For example, although several embodiments are discussed above with bevel gears, other types of gears (e.g., spur gears, spline gears, spiral bevel gears, miter gears, helical gears, etc.) and other torque transmission devices are contemplated. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments may be made and still fall within the scope of the disclosure. Accordingly, it should be understood that various features and aspects of the disclosed embodiments can be combined with or substituted for one another in order to form varying modes of the disclosed.

[0087] Furthermore, certain features that are described in this disclosure in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations, one or more features from a claimed combination can, in some cases, be excised from the combination, and the combination may be claimed as a subcombination or variation of a subcombination.

[0088] Features, materials, characteristics, or groups described in conjunction with a particular aspect, embodiment, or example are to be understood to be applicable to any other aspect, embodiment or example described in this section or elsewhere in this specification unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings) may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The protection is not restricted to the details of any foregoing embodiments. The protection extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination so disclosed.

[0089] For purposes of this disclosure, certain aspects, advantages, and novel features are described herein. Not necessarily all such advantages may be achieved in accordance with any particular embodiment. Thus, for example, those skilled in the art will recognize that the disclosure may be embodied or carried out in a manner that achieves one advantage or a group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

[0090] Some embodiments have been described in connection with the accompanying drawings. The figures are drawn to scale where appropriate, but such scale should not be limiting, since dimensions and proportions other than what are shown are contemplated and are within the scope of the disclosed invention. Distances, angles, etc. are merely illustrative and do not necessarily bear an exact relationship to actual dimensions and layout of the devices illustrated. Components can be added, removed, and/or rearranged.

Further, the disclosure herein of any particular feature, aspect, method, property, characteristic, quality, attribute, element, or the like in connection with various embodiments can be used in all other embodiments set forth herein. Additionally, any methods described herein may be practiced using any device suitable for performing the recited steps.

[0091] Although this invention has been disclosed in the context of certain embodiments and examples, the scope of this disclosure extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the invention and obvious modifications and equivalents thereof. Any system, method, and device described in this application can include any combination of the preceding features described in this and other paragraphs, among other features and combinations described herein, including features and combinations described in subsequent paragraphs. While several variations of the invention have been shown and described in detail, other modifications, which are within the scope of this invention, will be readily apparent to those of skill in the art based upon this disclosure. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments may be made and still fall within the scope of the invention. Various features and aspects of the disclosed embodiments can be combined with, or substituted for, one another in order to form varying modes of the disclosed invention. Thus, it is intended that the scope of the present invention herein disclosed should not be limited by the particular disclosed embodiments described above, but should be determined only by a fair reading of the claims that follow.

THE FOLLOWING IS CLAIMED:

1. An articulating tool for driving a fastener into a bone during an endoscopic surgical procedure, the articulating tool comprising:

an elongate outer housing comprising a proximal end, a distal end, a lumen, and a longitudinal axis, the elongate outer housing configured to engage with a handpiece comprising a motor;

a torque transmission mechanism comprising:

a first shaft that extends through the lumen of the outer housing;

an articulating torque transmission unit having a first end and a second end, the first end being coupled to a distal portion of the first shaft; and

a driver head adapter that is positioned at the second end of the articulating torque transmission unit, the driver head adapter configured to removably engage with a bit and to rotate the bit around a bit axis, the bit configured to engage with the fastener;

wherein torque transmission mechanism is configured to transmit torque from the motor to the driver head and the bit, thereby driving the fastener engaged with the bit into the bone; and

an articulation mechanism that is separate from the torque transmission mechanism, the articulation mechanism comprising:

a second shaft extending through the lumen of the outer housing;

an actuator connected to a proximal portion of the second shaft, the actuator configured to move the second shaft proximally and distally; and

a link connected to a distal portion of the second shaft, the link connected to the driver head adapter and pivoted at a hinge, wherein:

in response to distal movement of the second shaft, the link rotates about the hinge such that an angle between the longitudinal axis and the bit axis increases; and

in response to proximal movement of the second shaft, the link rotates about the hinge such that the angle between the longitudinal axis and the bit axis decreases.

2. The articulating tool of Claim 1, wherein the articulating torque transmission unit comprises first, second, and third bevel gears, wherein the first bevel gear is fixedly coupled to the first shaft, the second bevel gear is coupled to a gear support shaft, and the third bevel gear is coupled to an output shaft.

3. The articulating tool of Claim 2, wherein the first bevel gear intersects with the second gear and the second gear intersects with the third gear.

4. The articulating tool of Claim 2 or 3, wherein rotation of the shaft causes rotation of the driver head adapter in an opposite direction.

5. The articulating tool of Claim 1, wherein the articulation unit comprises first, second, third, and fourth bevel gears, wherein the first bevel gear is fixedly coupled to the first shaft, the second and third bevel gears are coupled to the gear support shaft, and the fourth bevel gear is coupled to the output shaft.

6. The articulating tool of Claim 5, wherein the first bevel gear intersects with the second bevel gear and the third bevel gear intersects with the fourth bevel gear.

7. The articulating tool of Claim 5 or 6, wherein rotation of the second bevel gear is transmitted via the gear support shaft to rotation of the third bevel gear.

8. The articulating tool of any of Claims 5-7, wherein rotation of the first shaft is configured to cause rotation of the driver head adapter in the same direction.

9. The articulating tool of any of Claims 1-8, comprising support walls extending over portions of the articulation unit.

10. The articulating tool of Claim 9, wherein the support walls comprise an opening configured to accommodate the second shaft and the link.

11. The articulating tool of Claim 10, wherein the link bends outward from the longitudinal axis of the tool when the second shaft moves proximally.

12. The articulating tool of Claim 9 or 10, wherein the support walls comprising distal and proximal portions pivotally connected at a second hinge coupled to the gear support shaft, the distal portion coupled to the output shaft, wherein the distal portion rotates relative to the proximal portion about the second hinge and/or the gear support shaft responsive to axial movements of the second shaft.

13. The articulating tool of any of Claims 1-12, wherein the driver head adapter comprises a lumen configured to receive a shaft of the bit.

14. The articulating tool of Claim 13, wherein lumen of the driver head adapter comprises a rotation limiting surface.

15. The articulating tool of any of Claims 1-14, wherein the elongate outer housing further comprises a body coupling assembly that is configured to releasably couple to the handpiece.

16. The articulating tool of Claim 15, wherein the body coupling assembly comprises a collet shaft operably coupled to a proximal end of the first shaft, a free end of the collet shaft configured to be coupled to a drive shaft of the handpiece.

17. The articulating tool of Claim 16, wherein the free end of the collet shaft comprises a rotation-limiting shape so that rotation of the drive shaft causes rotation of the first shaft.

18. The articulating tool of any of Claims 15-17, wherein the body coupling assembly comprises a body interface operably coupled to the proximal end of the elongate outer housing.

19. The articulating tool of Claim 18, wherein the body interface comprises a groove on an outer surface of the body interface.

20. The articulating tool of Claim 18 or 19, wherein at least one orientation feature extends proximally from a proximally facing surface of the body interface.

21. The articulating tool of any of Claims 1-20, further comprising an actuator threadedly engaging threads on a portion of the second shaft near a distal end of the second shaft, wherein the actuator is configured to cause axial movements of the second shaft.

22. The articulating tool of Claim 21, wherein a distal portion of the second shaft comprises a rotation limiting surface slidably received in a rotation limiting stopper near the distal end of the second shaft so that the second shaft is substantially prevented from rotational movements.

23. The articulating tool of Claim 22, wherein the actuator comprises a wheel, wherein rotation of the wheel causes axial movements of the second shaft.

24. The articulating tool of Claim 22 or 23, wherein the rotation limiting surface on the second shaft comprises a substantially flat surface.

25. The articulating tool of any of Claims 1-24, wherein the driver head adapter is configured to rotate relative to the outer housing between about 0° to about 45°.

26. A system for endoscopic placement of fasteners, wherein the system comprises the articulating tool of any of Claims 1-25, and either or both of the bit and the handpiece.

27. The system of Claim 26, wherein the motor of the handpiece comprises an electric motor.

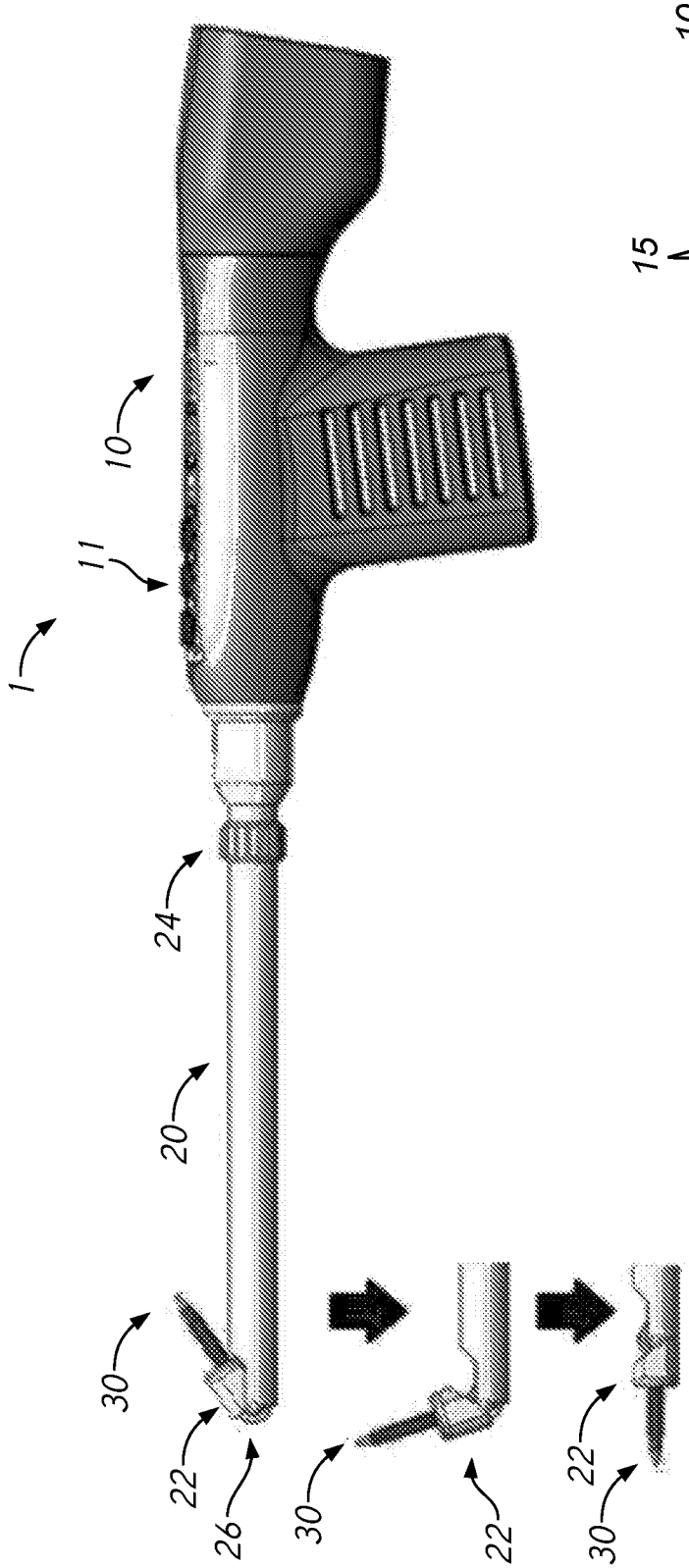


FIG. 1A

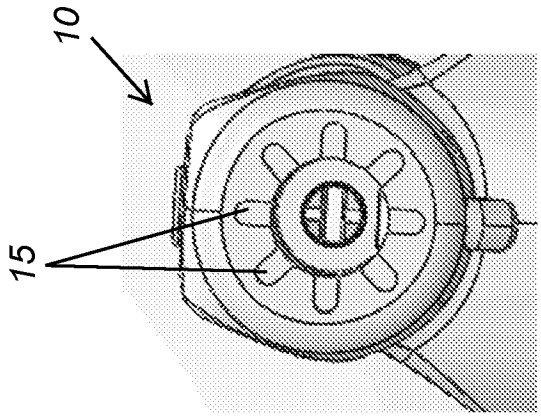


FIG. 1B

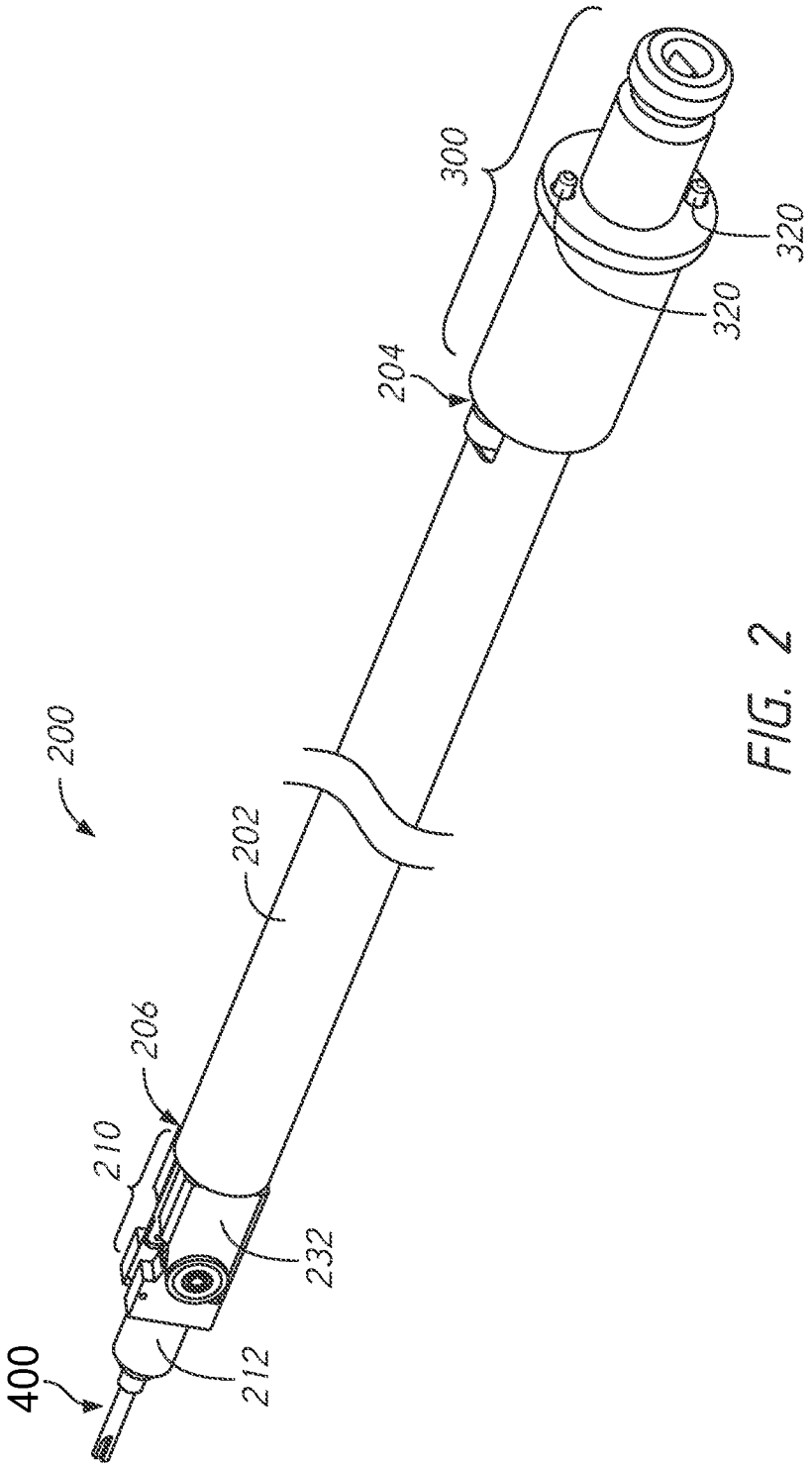


FIG. 2

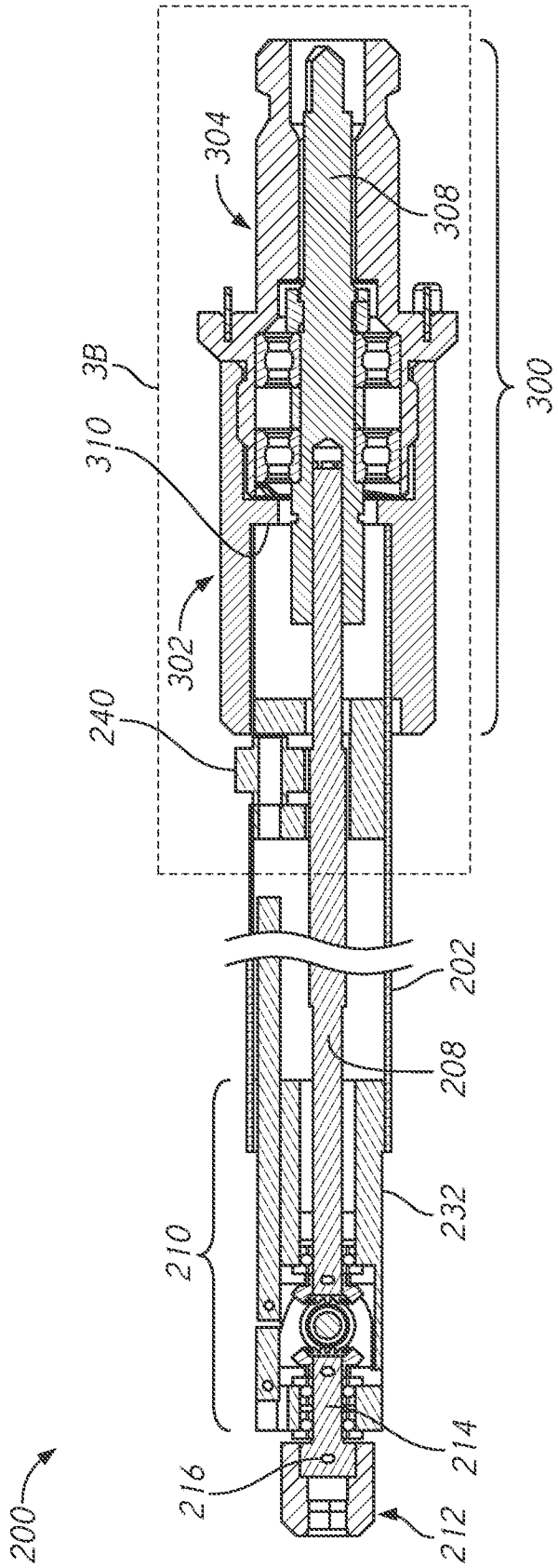


FIG. 3A

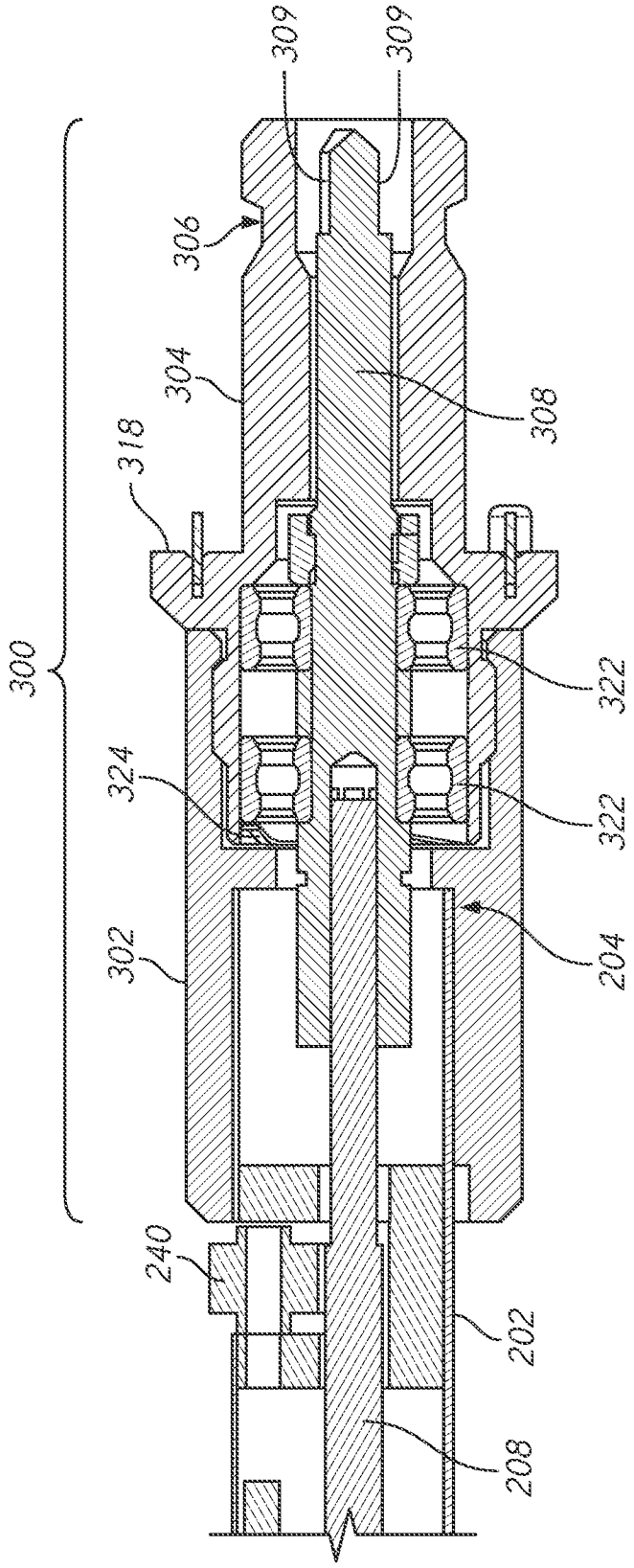


FIG. 3B

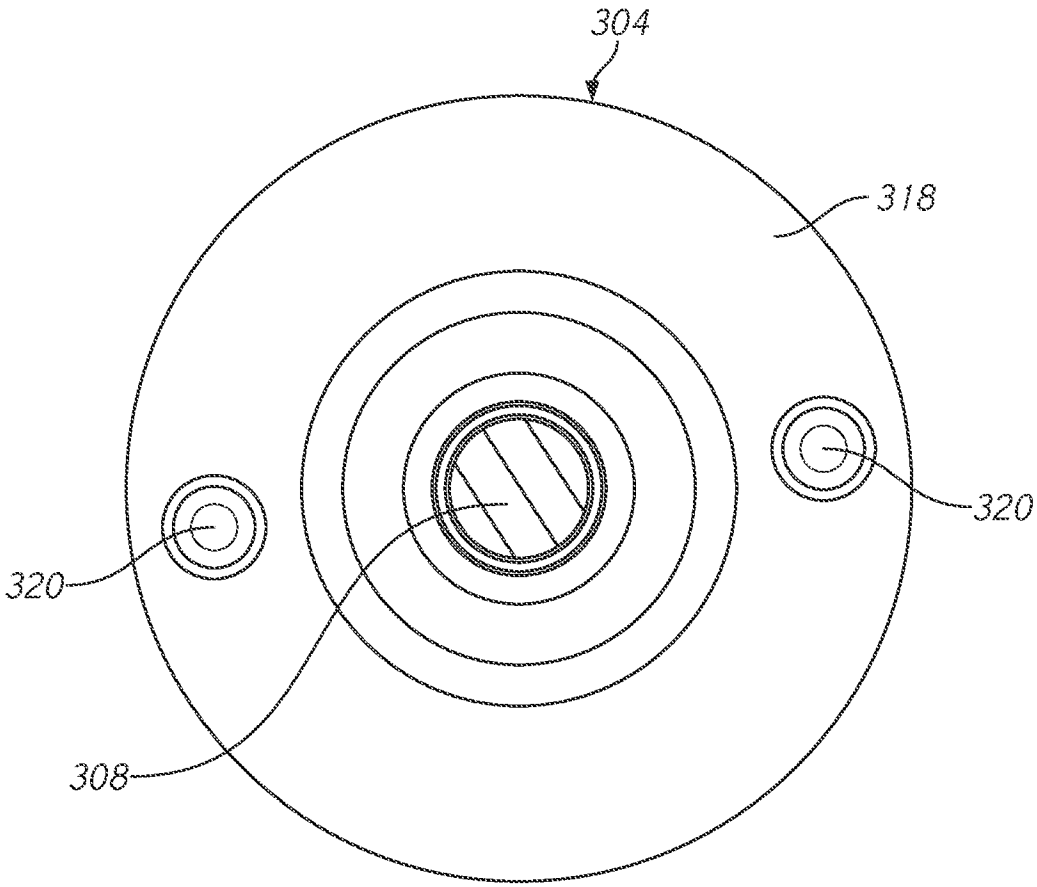


FIG. 3C

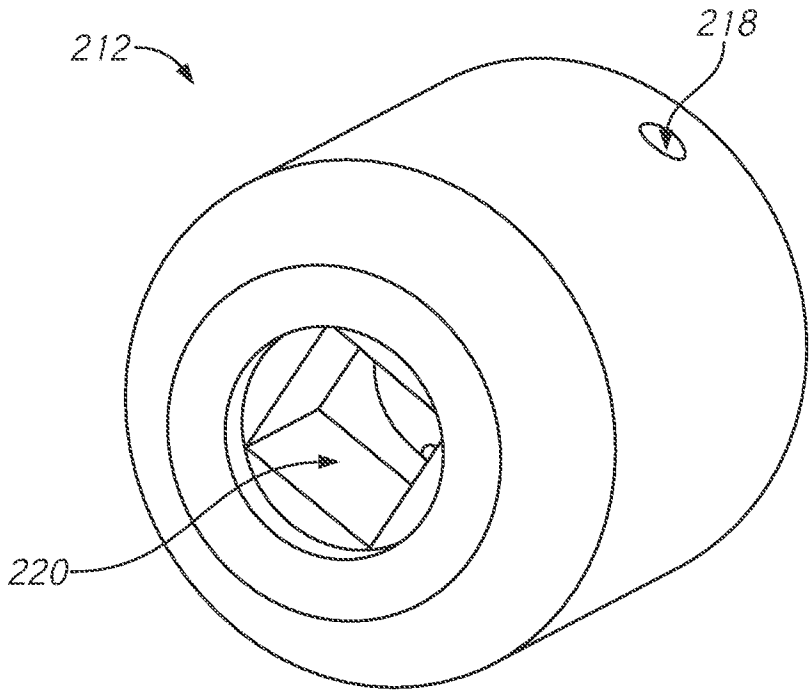


FIG. 3D

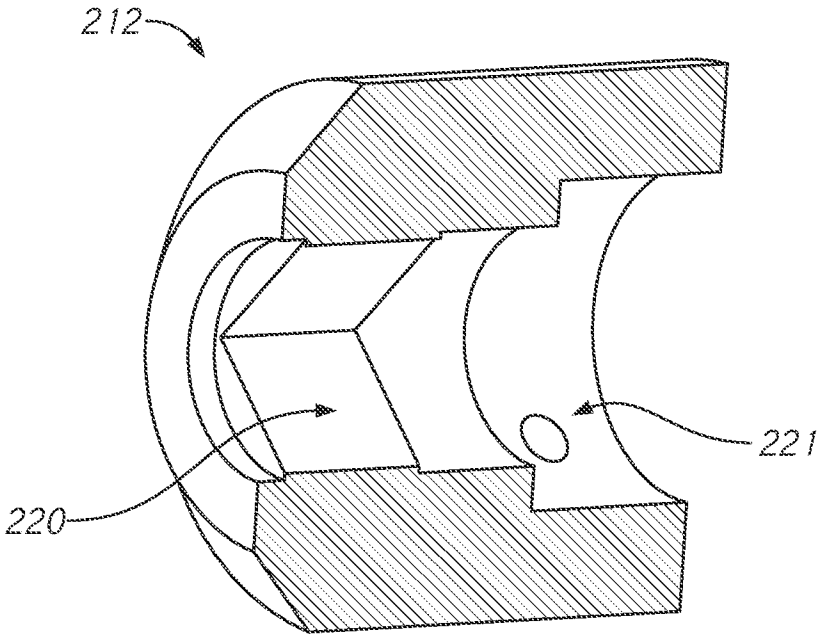


FIG. 3E

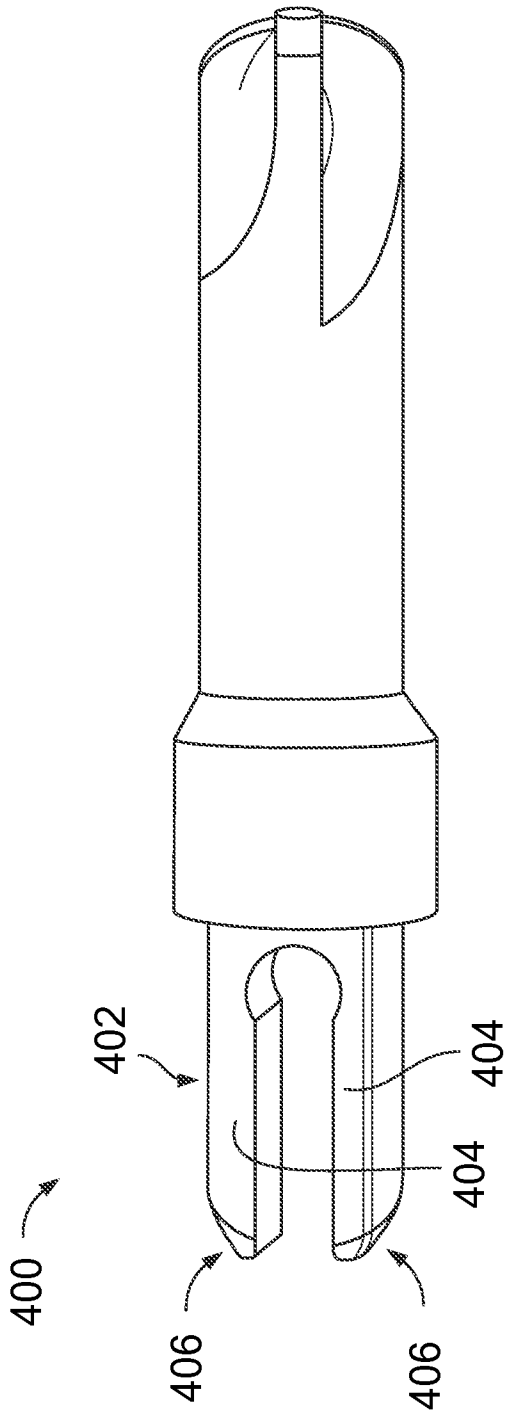


FIG. 3F

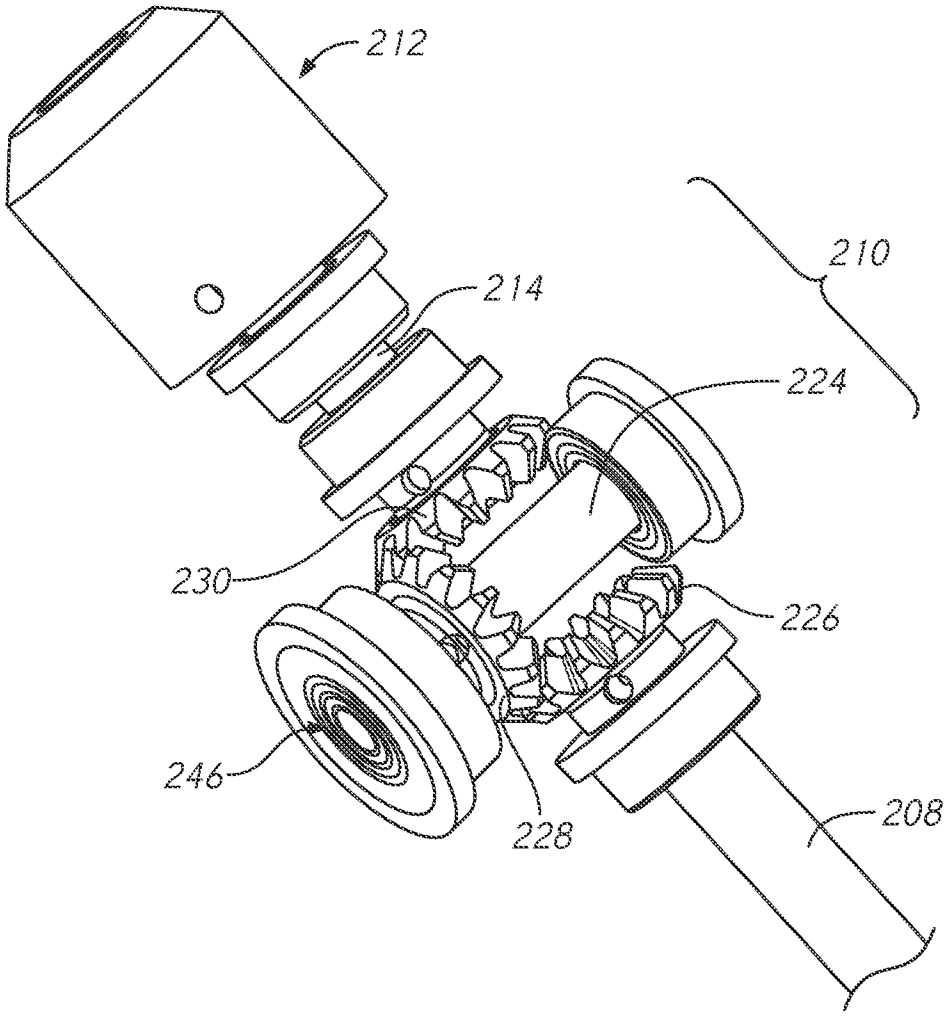


FIG. 4A

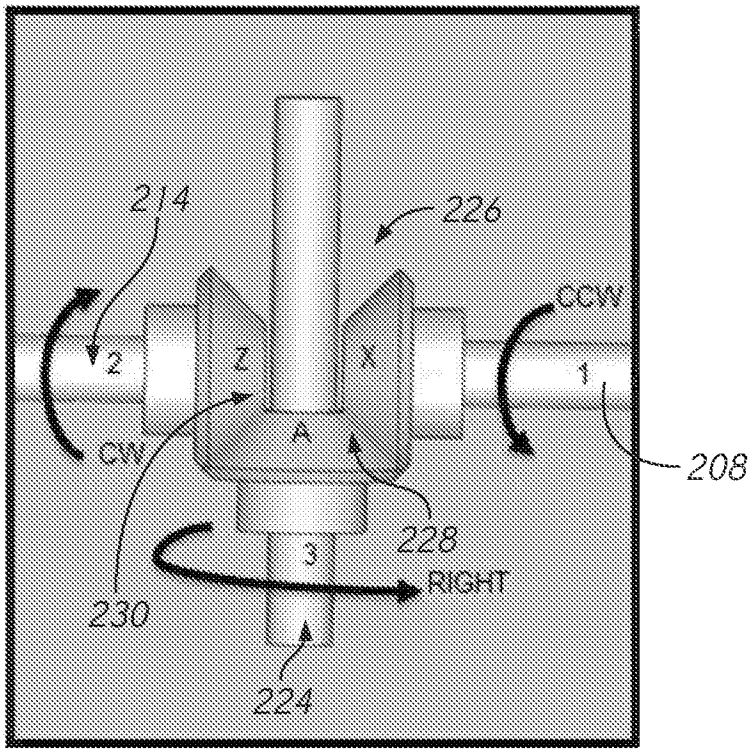


FIG. 4B

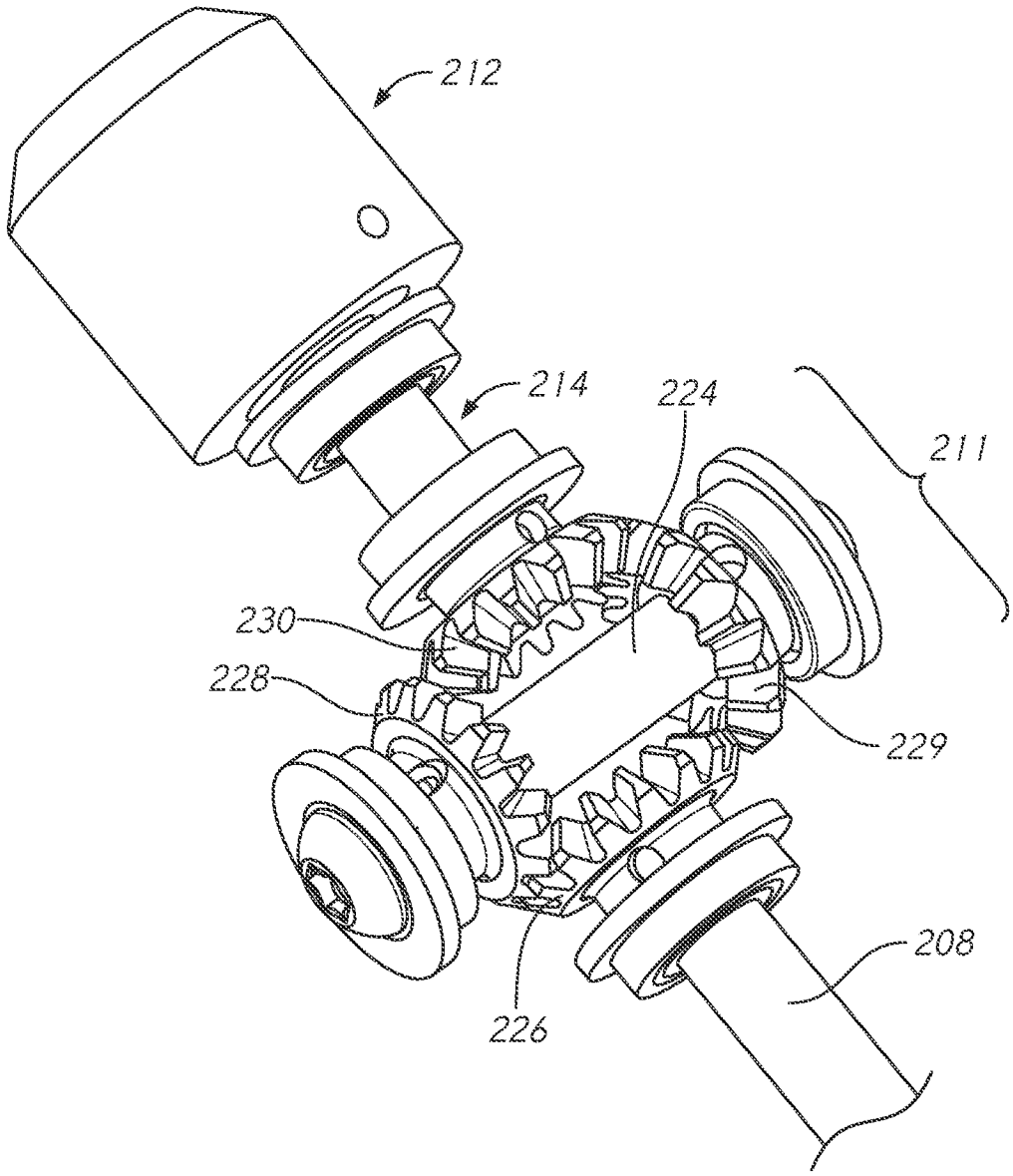


FIG. 5A

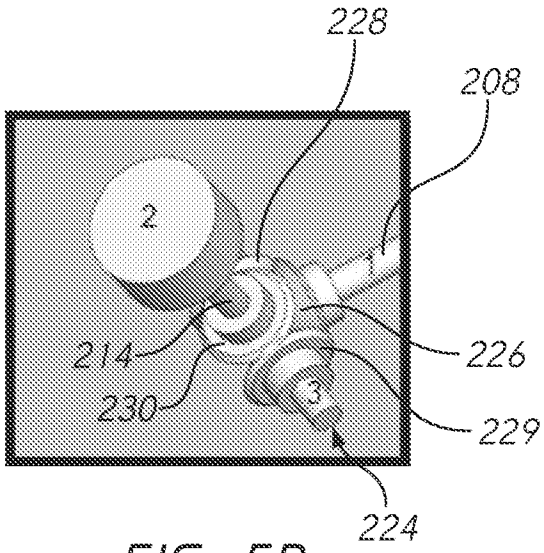


FIG. 5B

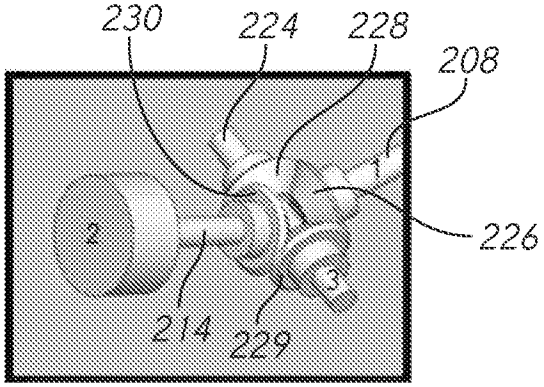


FIG. 5C

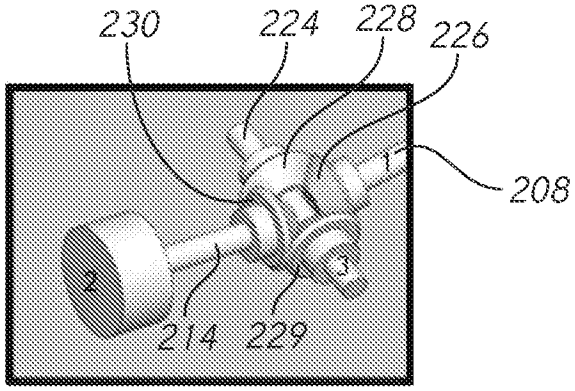


FIG. 5D

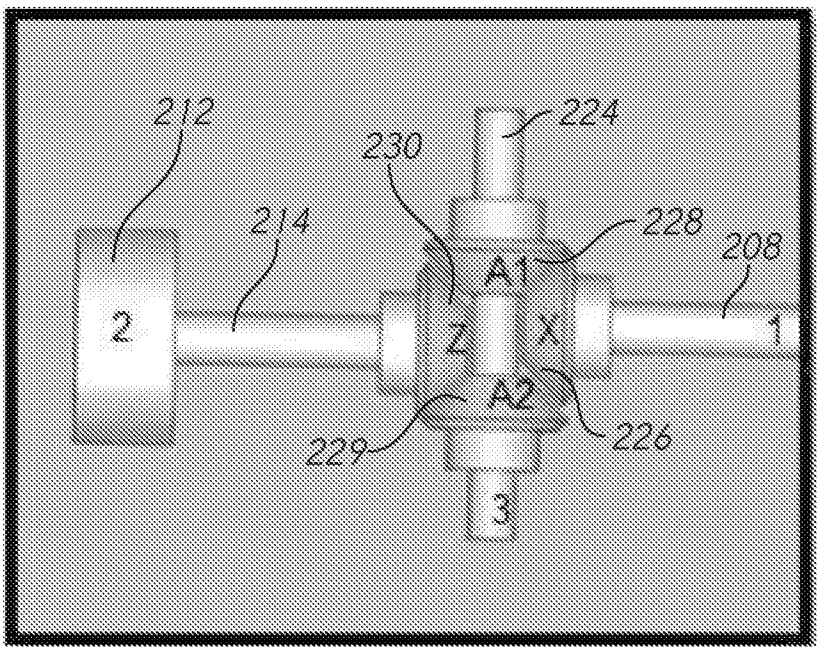

212
224
230
214
228
208
A1
2
Z
X
1
A2
229
226
3

FIG. 5E

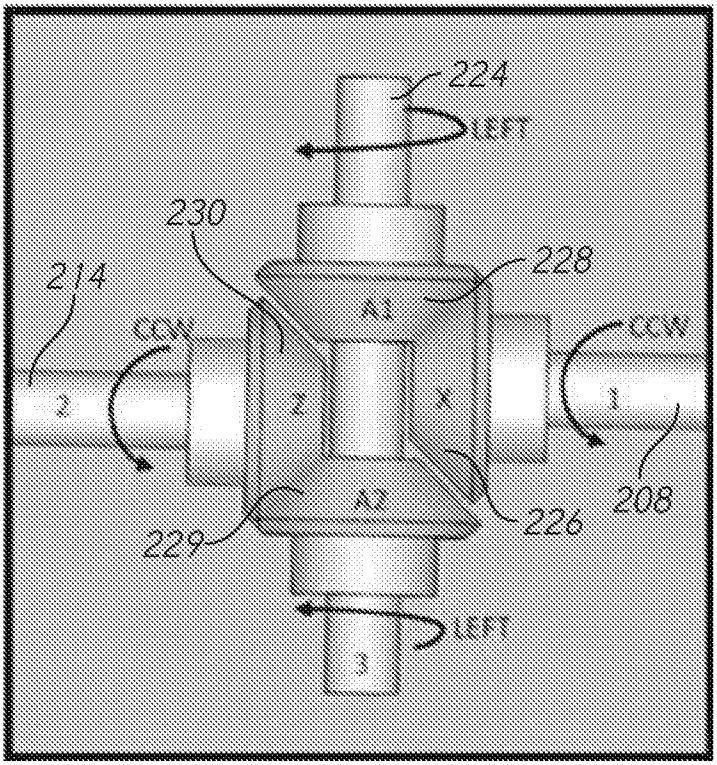

224
LEFT
230
228
214
A1
CCW
CCW
2
Z
X
1
208
A2
229
226
LEFT
3

FIG. 5F

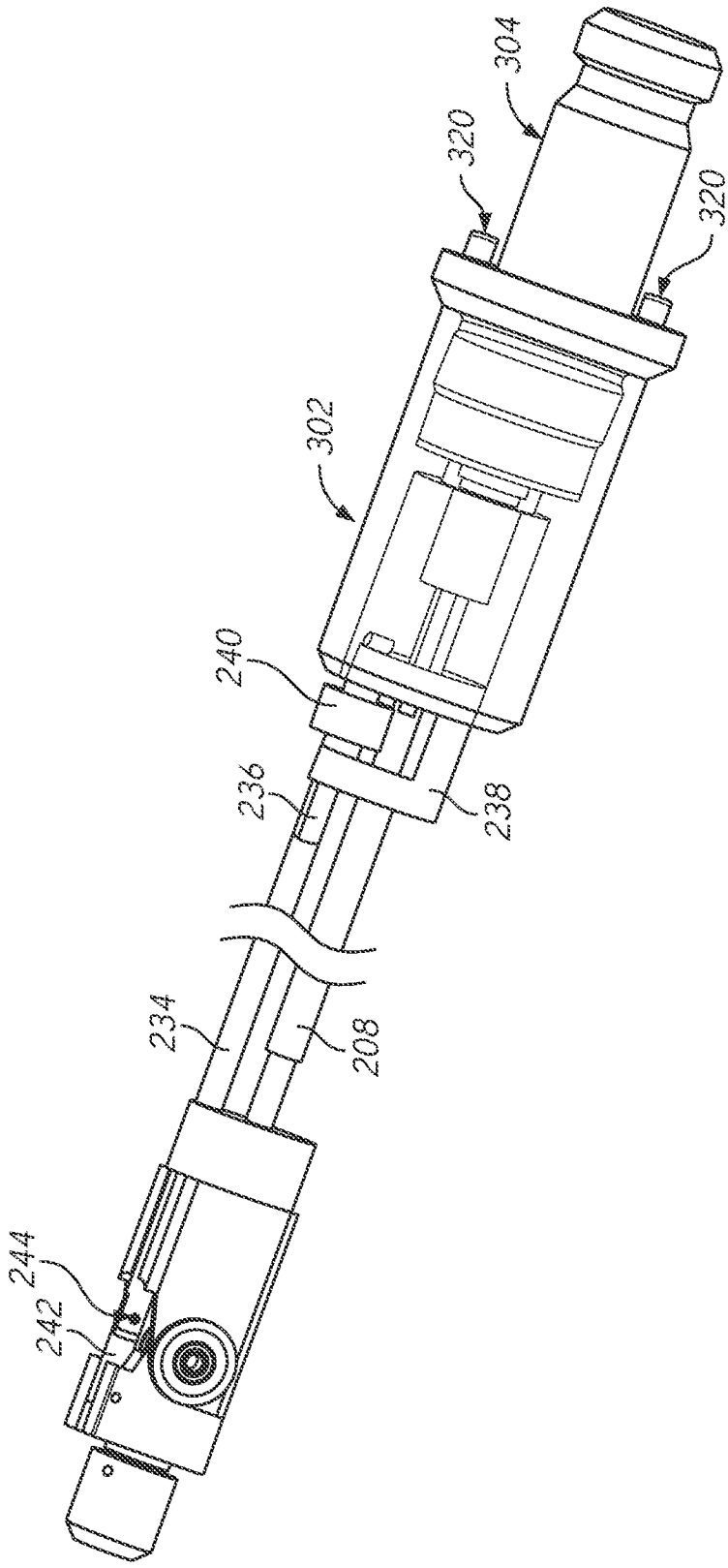


FIG. 6A

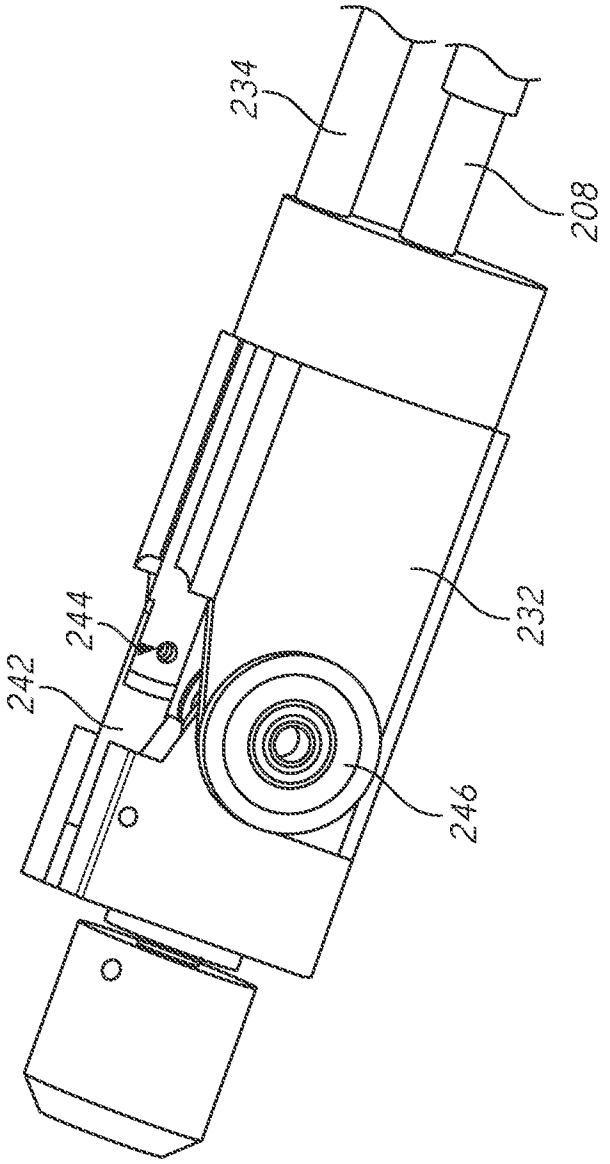


FIG. 6B

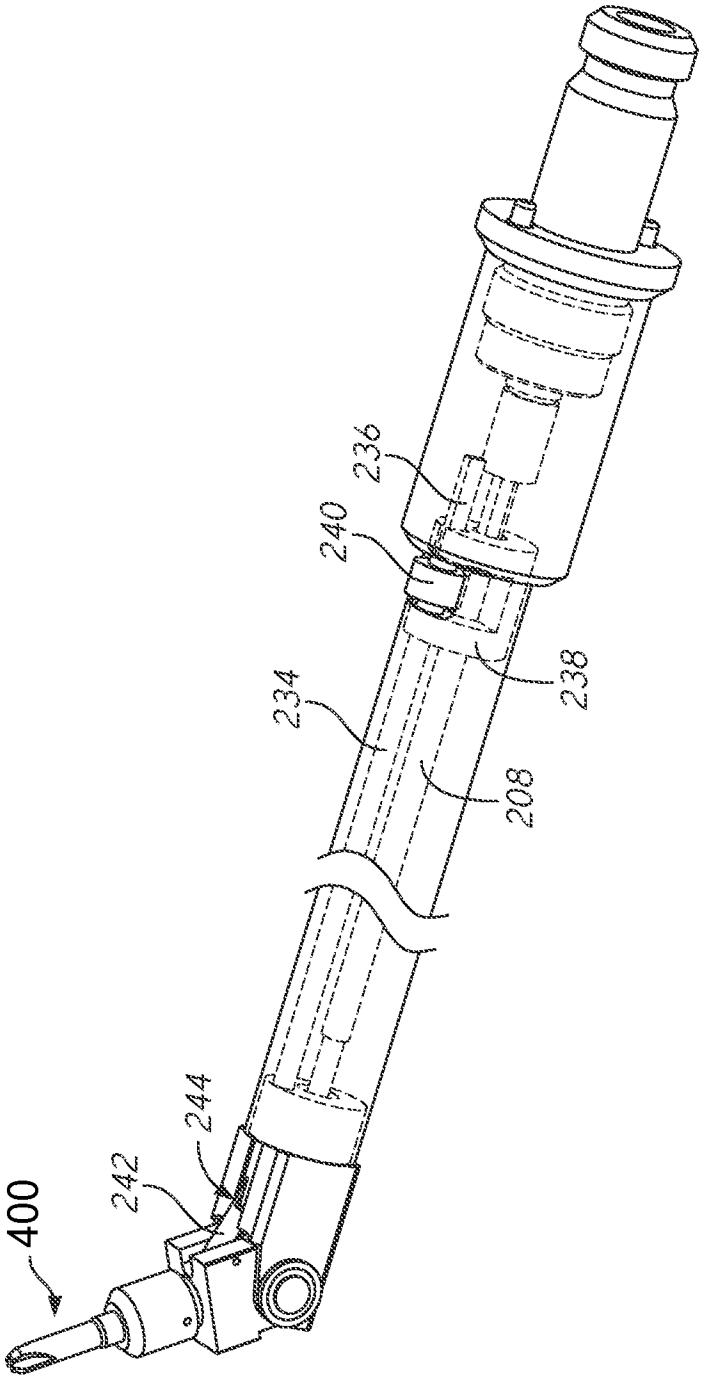


FIG. 7A

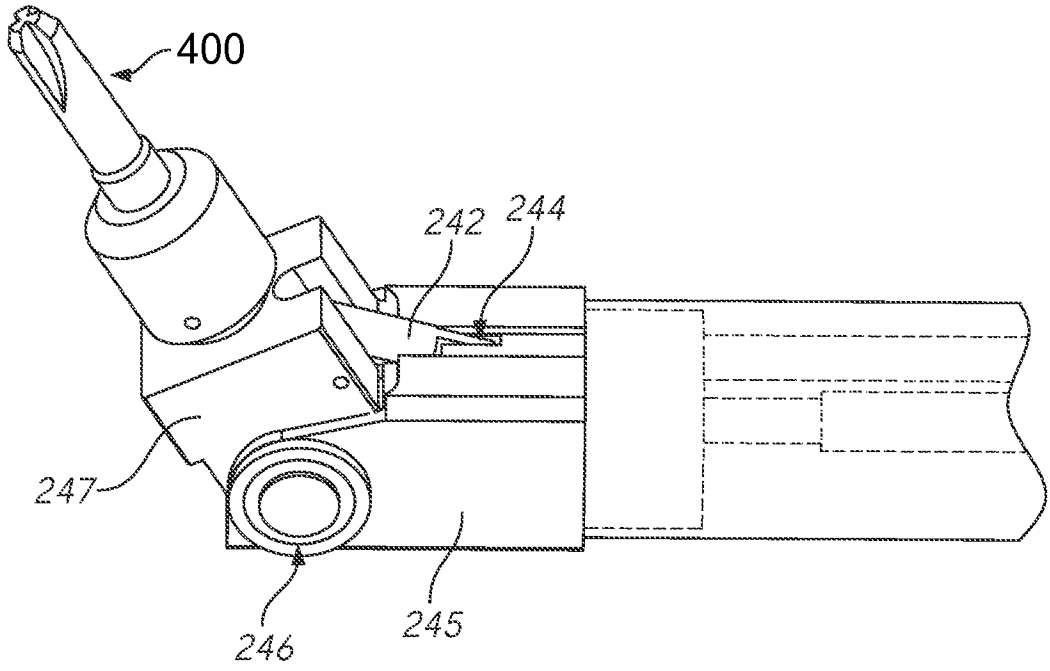


FIG. 7B

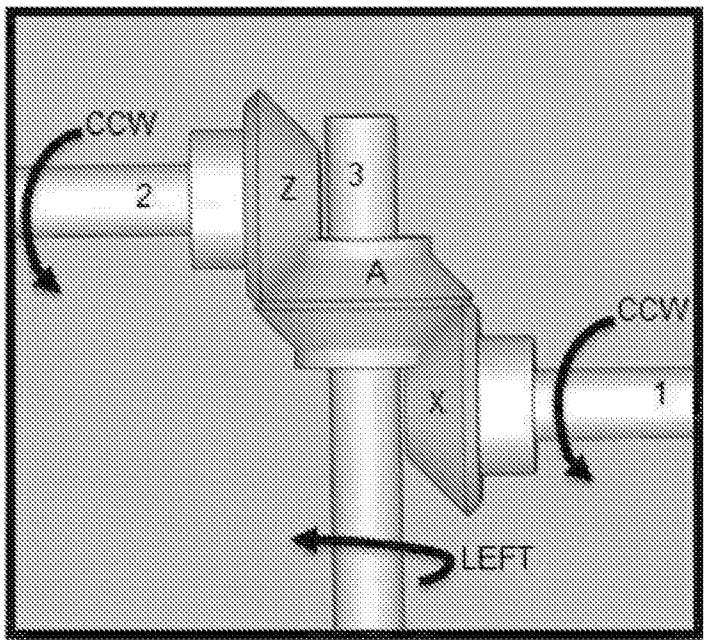


FIG. 8

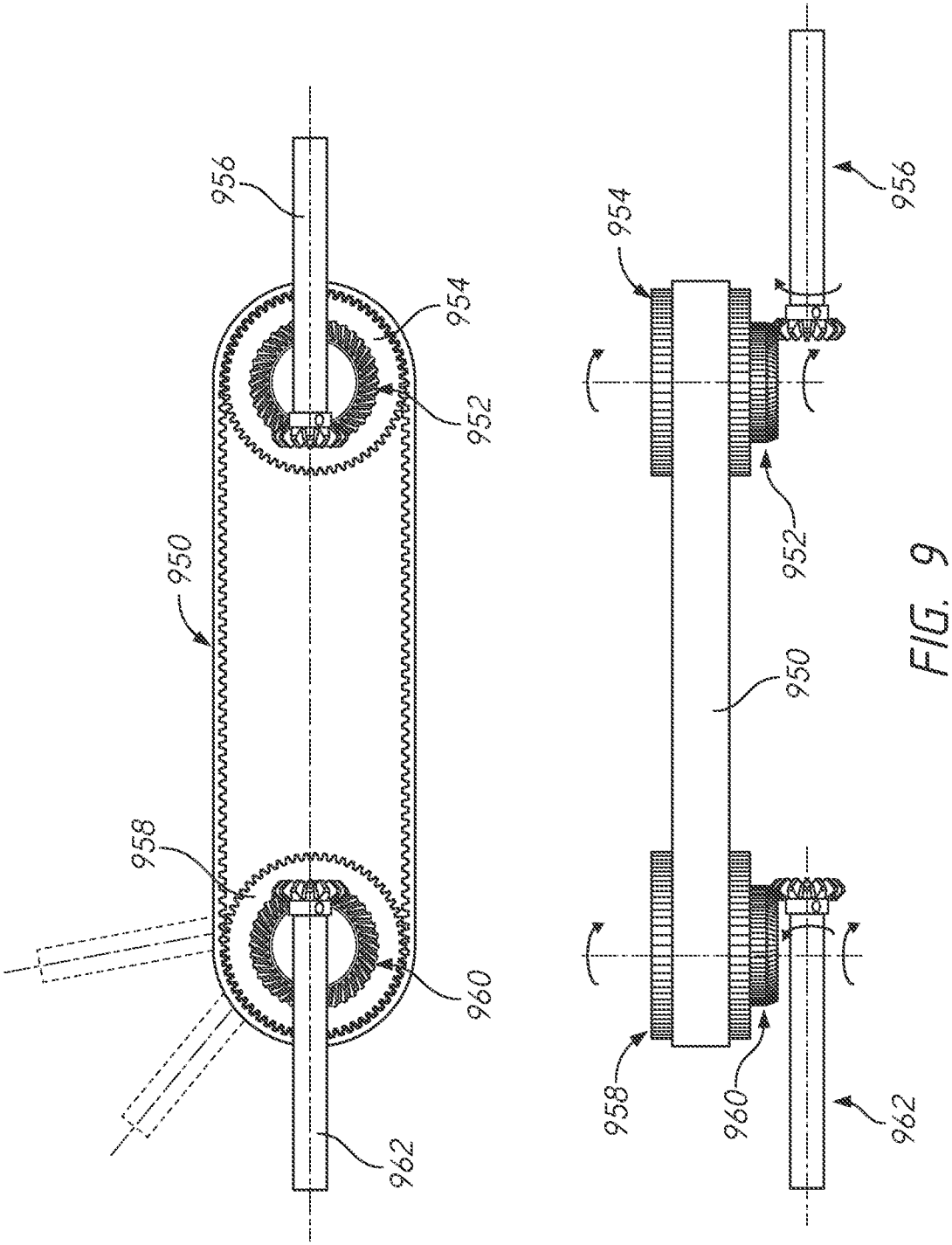


FIG. 9

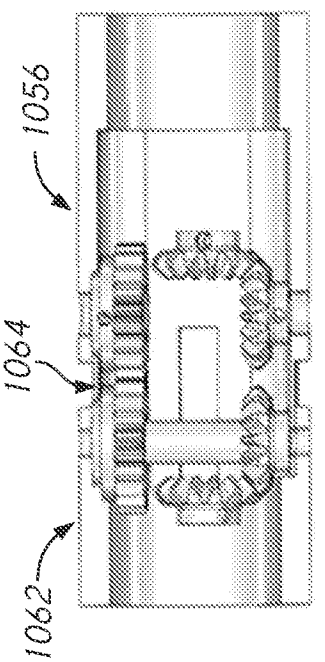


FIG. 10A

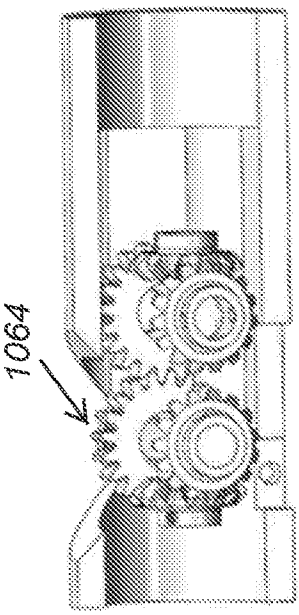


FIG. 10B

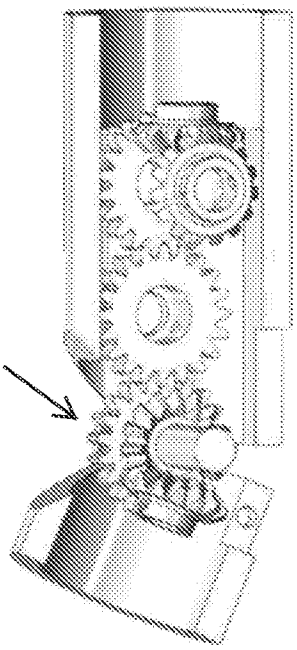


FIG. 10C

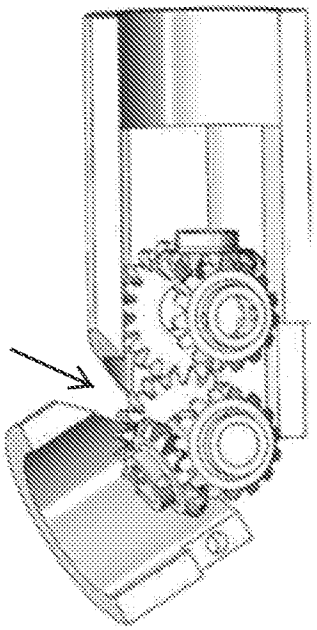


FIG. 10D

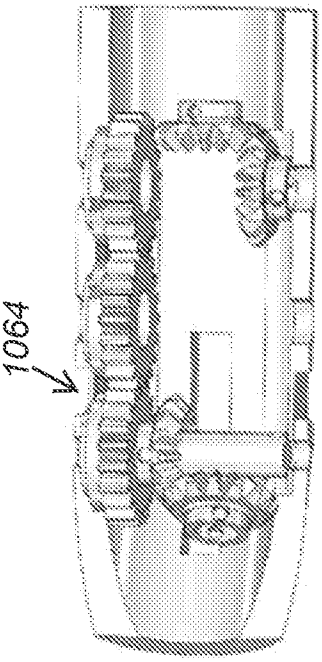


FIG. 10E

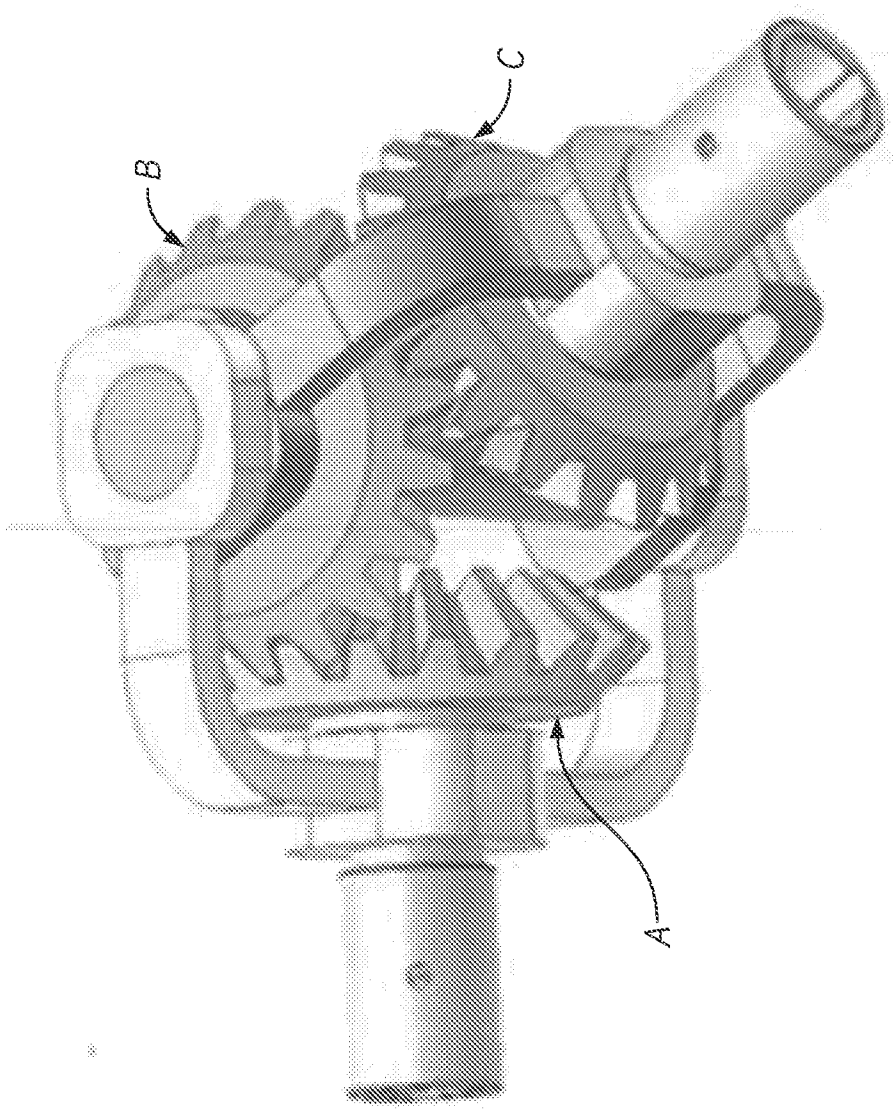


FIG. 11

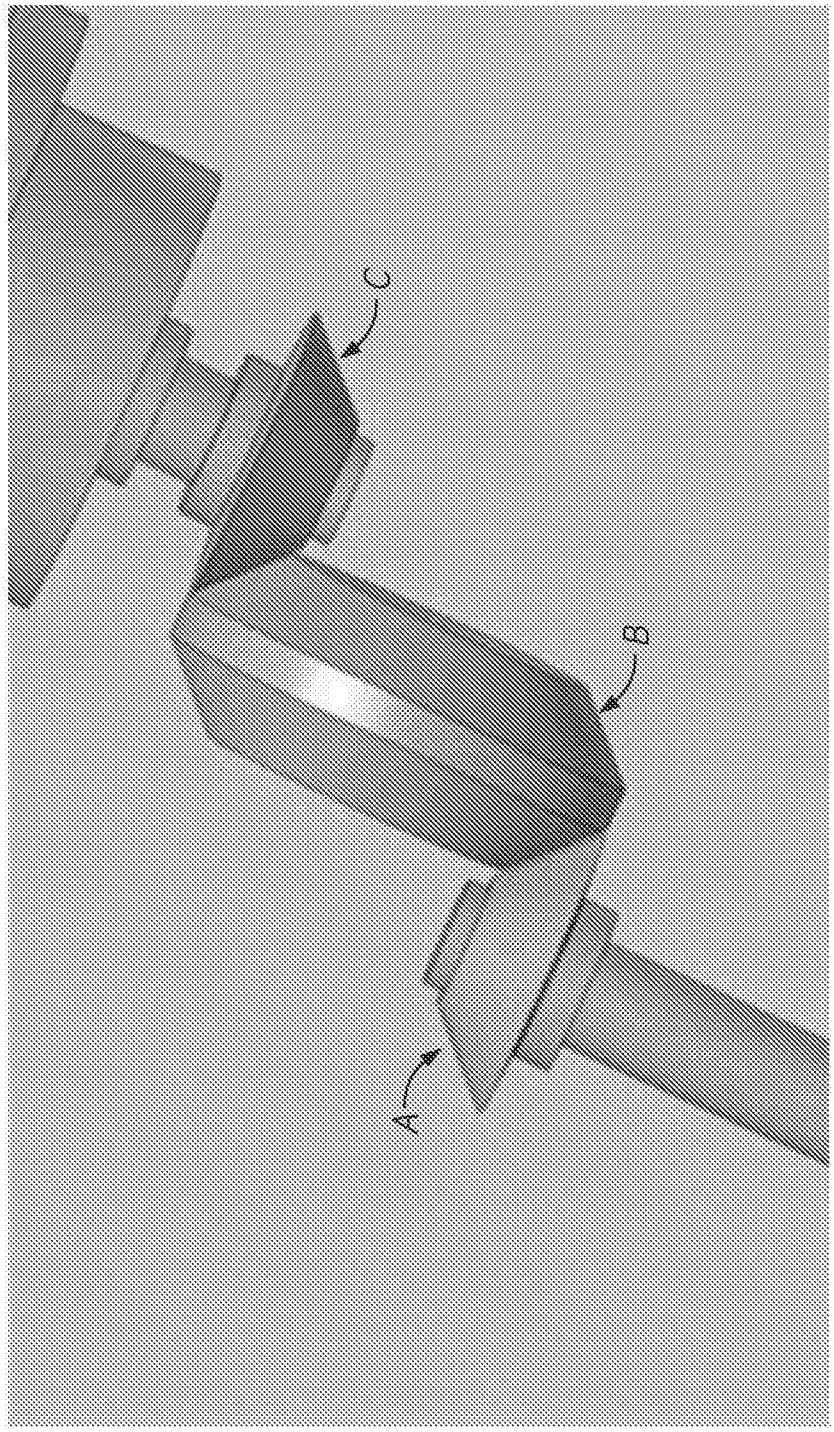


FIG. 12

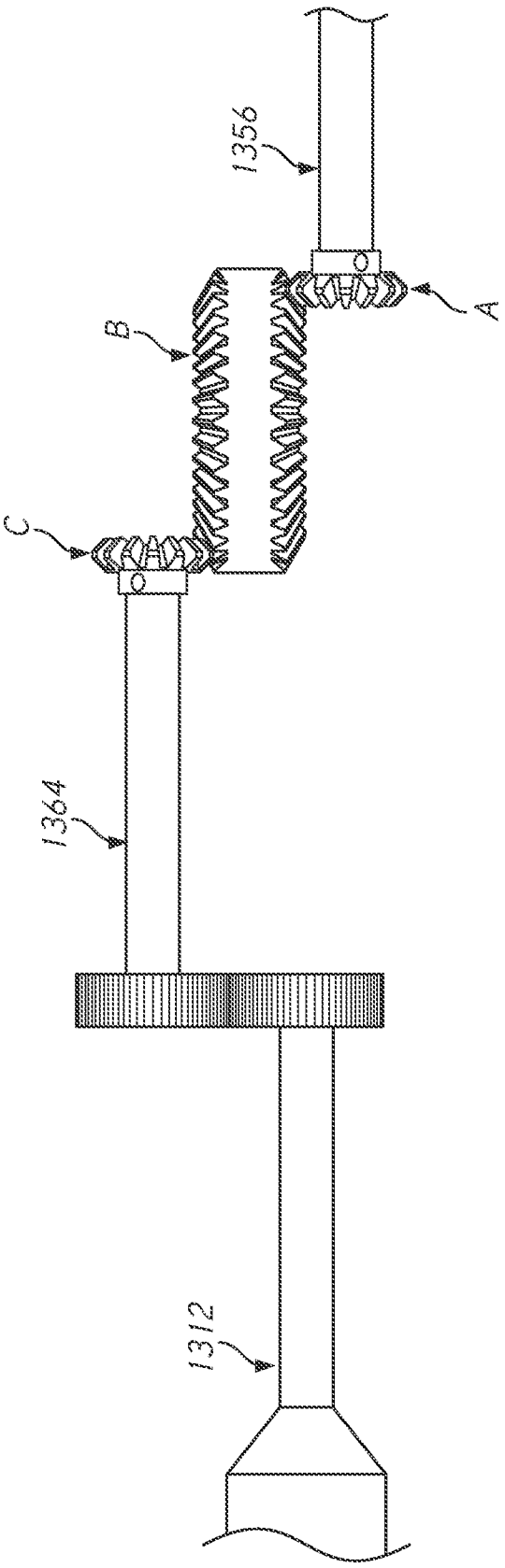


FIG. 13

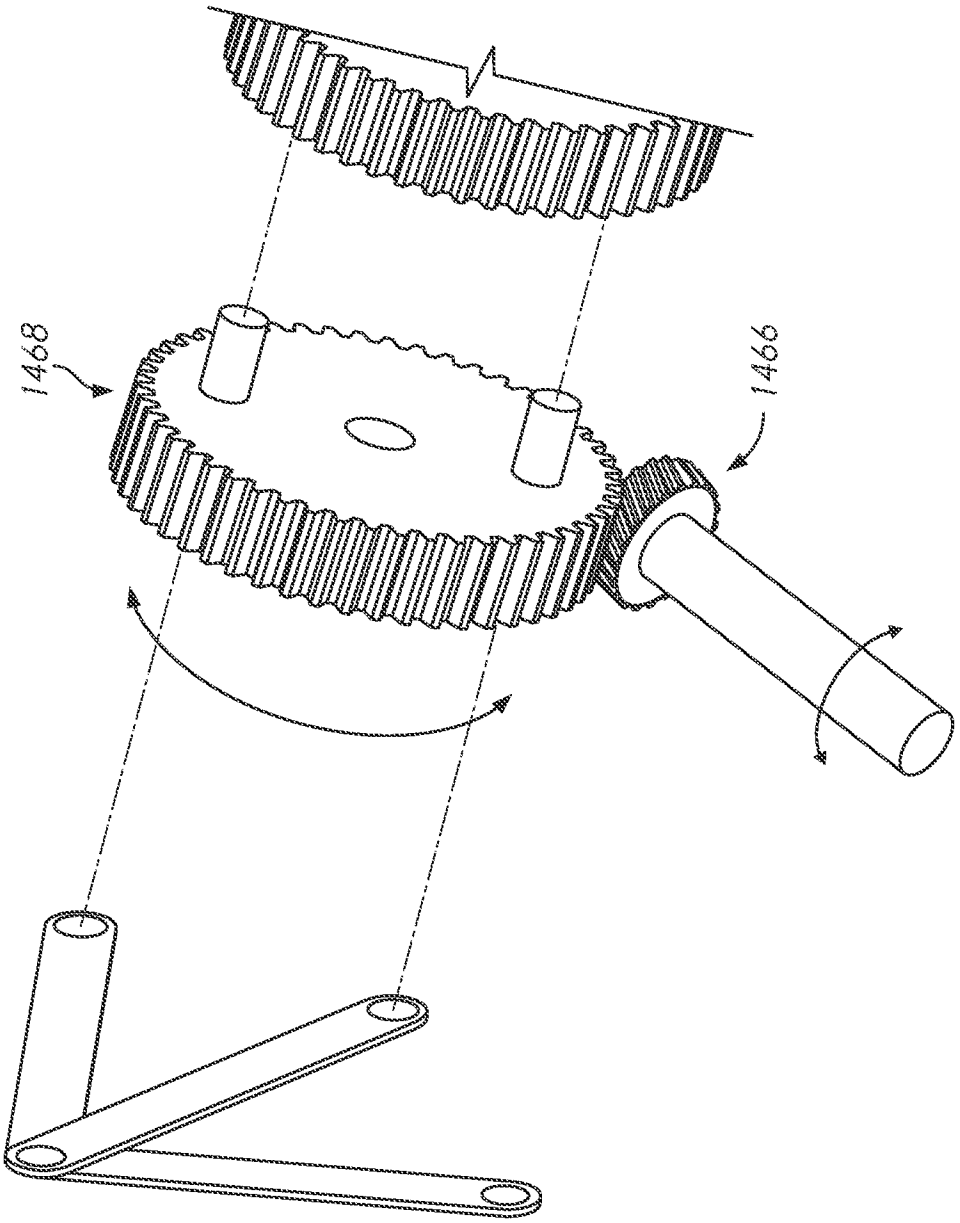


FIG. 14

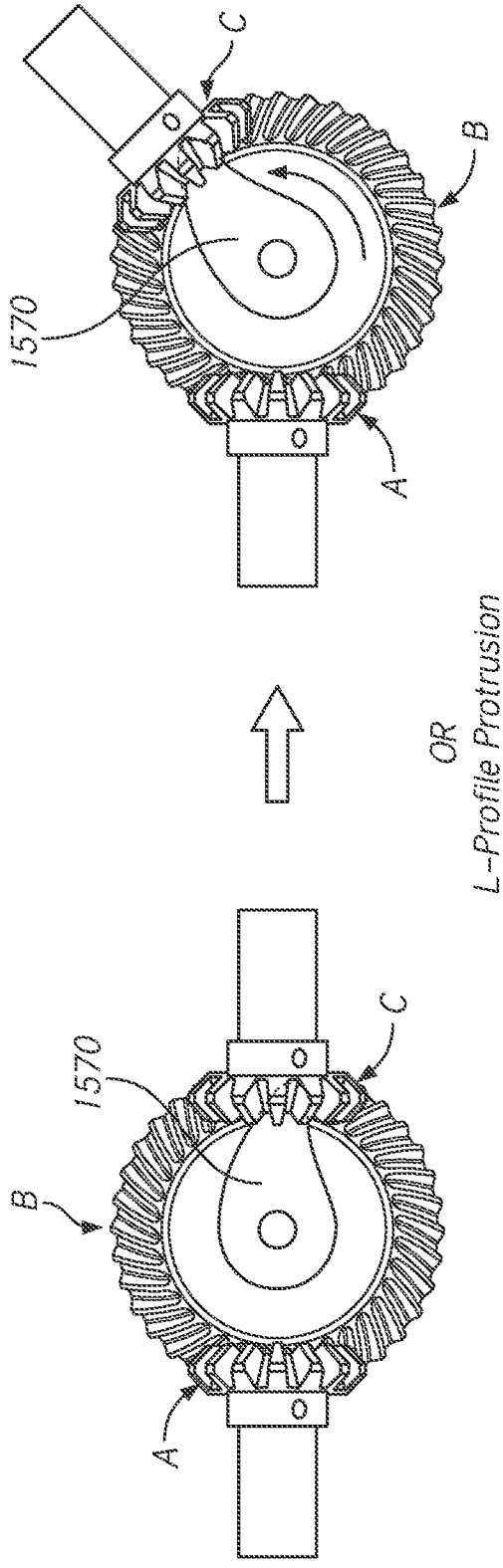


FIG. 15

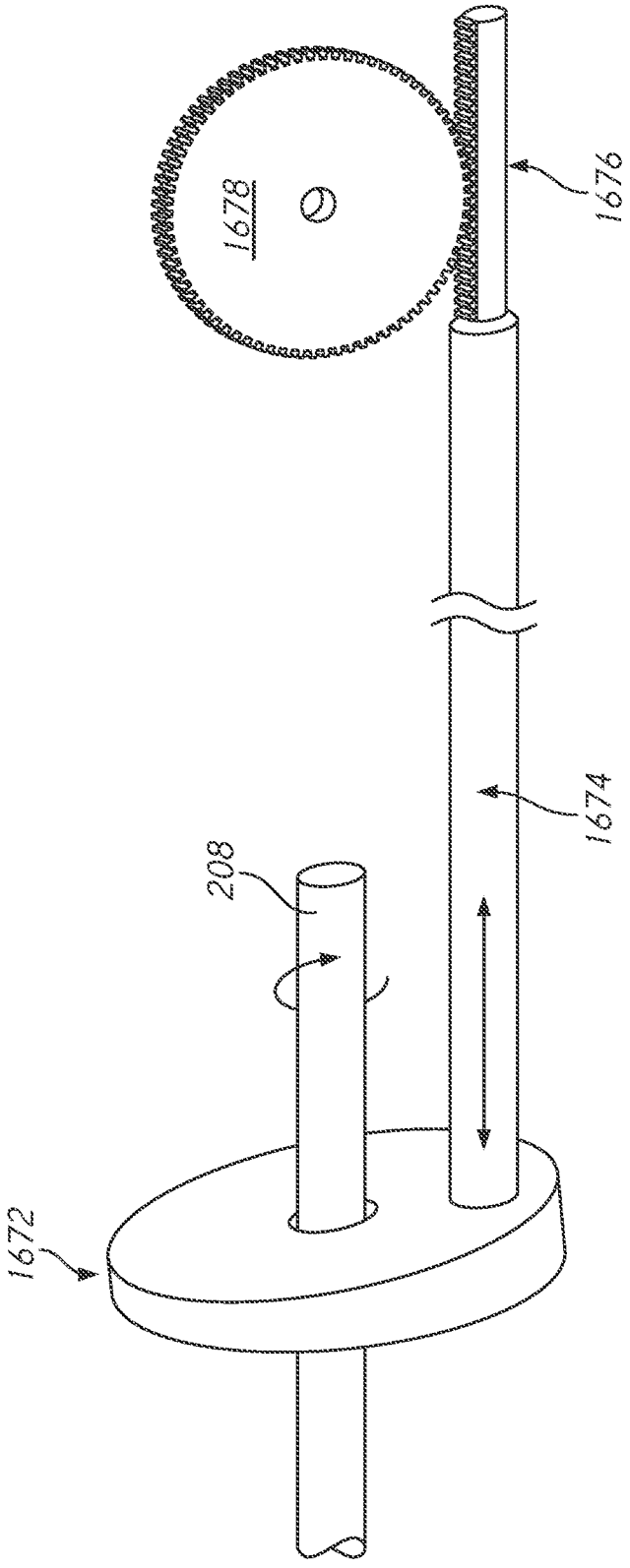
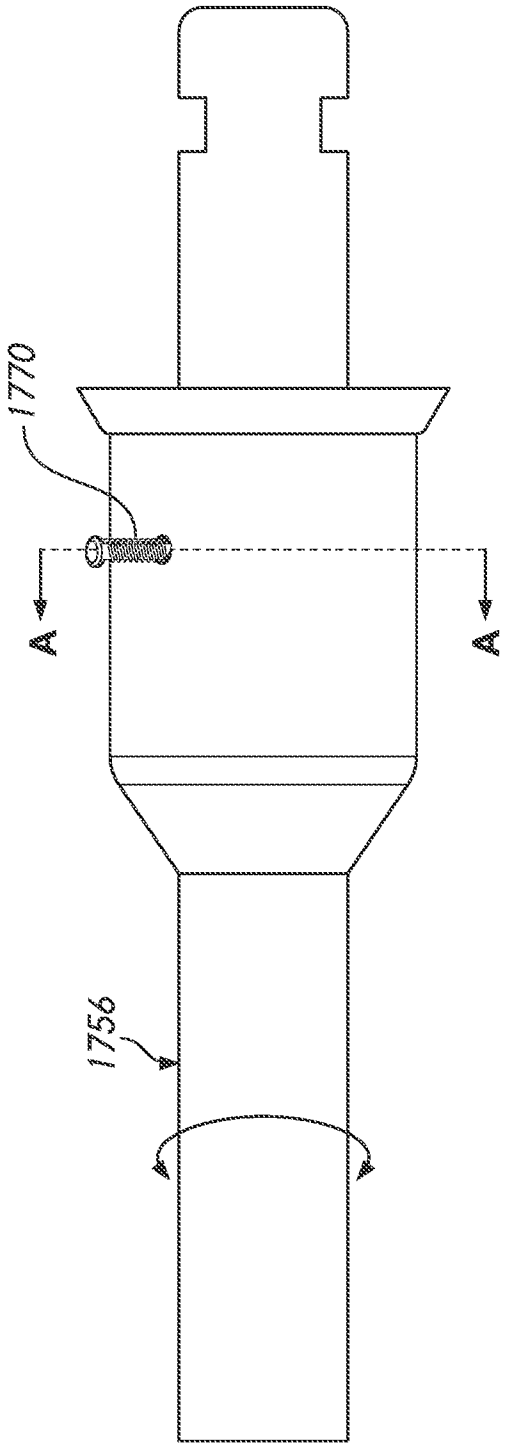


FIG. 16



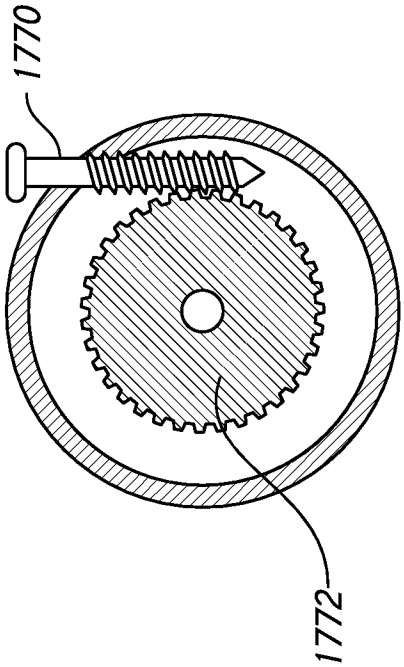


FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/45851

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61B 17/16, A61B 17/88, A61B 17/56, A61B 17/00, A61B 17/58 (2018.01)
CPC - A61B 17/16, A61B 17/88, A61B 17/00, A61B 17/56, A61B 17/58, A61B 17/8875, B25B 23/0035, A61B 17/8886, A61B 17/1615, A61B 17/1624, A61B 17/1631

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/0152867 A1 (Petrzelka et al.) 23 June 2011 (23.06.2011) Entire document especially Fig. 1-4; para [0042], [0044]-[0046], [0049], [0051]	1-7
A	US 2002/0183762 A1 (Anderson et al.) 5 December 2002 (05.12.2002) Entire document especially Fig. 22; para [0079], [0102]	1-7
A	US 2016/0106442 A1 (Guo et al.) 21 April 2016 (21.04.2016) Entire document	1-7
A	US 5,660,491 A (Roberts et al.) 26 August 1997 (26.08.1997) Entire document	1-7
A	US 2009/0023988 A1 (Korner et al.) 22 January 2009 (22.01.2009) Entire document	1-7
A	US 2011/0301416 A1 (Dejima et al.) 8 December 2011 (08.12.2011) Entire document	1-7
A	US 5,484,440 A (Allard) 16 January 1996 (16.01.1996) Entire document	1-7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2018	19 OCT 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/45851

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

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

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

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

3. ☒ Claims Nos.: 8-27
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.