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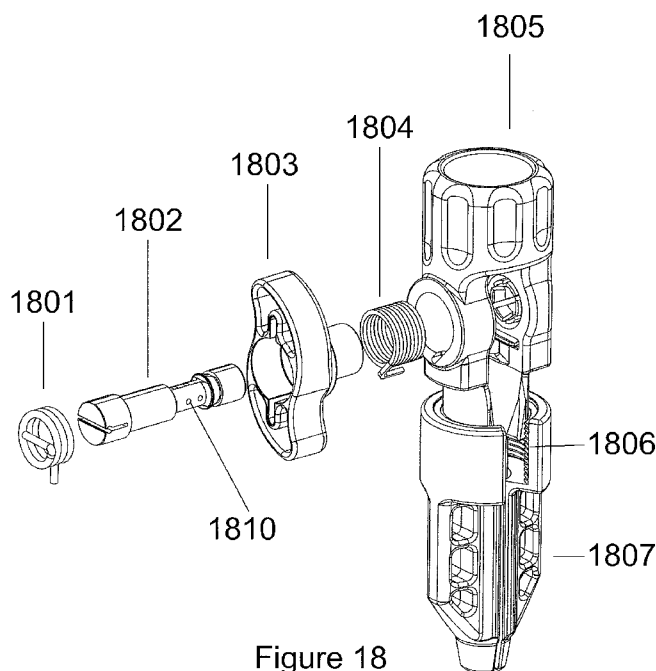


Figure 18

(57) Abstract: A surgical instrument may be used to apply tension to a flexible suture to close and secure a broken or cut bone (e.g. a sternum following a sternotomy). The device preferably applies an adjustable tension to the flexible suture in order to secure the bone together. Multiple instruments may be used together to ensure the desired tension is applied to the entire bone structure being secured with the flexible sutures. Once the desired tension is achieved, the device preferably provides a mechanism to apply a uniform twist to the flexible suture to lock the flexible suture in place. The instrument preferably decreases the upward tension applied to the flexible sutures over the duration of the application of twisting. The device may automatically cut the flexible suture, or the flexible suture may be cut by the surgeon once the twisting action has been performed.

WO 2010/129076 A1



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SURGICAL INSTRUMENT AND METHOD FOR TENSIONING AND SECURING A FLEXIBLE SUTURE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Patent Application No.
5 12/436,926 filed May 7, 2009, where this application is incorporated herein by
reference in its entirety.

BACKGROUND

Field

This disclosure is generally related to securing bones using a
10 flexible suture and more particularly to surgical instruments suitable for securing
the sternum with flexible sutures following a sternotomy

Description of the Related Art

During an open heart procedure, the patient's sternum is cut in
half lengthwise in a procedure called a median sternotomy. At the end of the
15 surgery, the two halves are brought together and secured with standard
surgical wire sutures. The wire sutures may be placed around or through the
sternum, and tension may be applied to the wire sutures to bring the two
separated parts of the sternum together. Once in place, with the desired
tension, the wire suture is then twisted together on itself in a helical pattern to
20 lock the wire suture in place and prevent separation, or dehiscence of the
sternum. This is typically done using surgical pliers to tension and twist the
wire sutures together, but other methods may be used.

Dehiscence of the sternum is a serious concern for patients,
hospitals and surgeons, occurring in an estimated 2.5% of all sternotomies.
25 The dehiscence delays healing, may be uncomfortable for the patient, and
increases the likelihood of infection which typically requires additional surgery
to treat.

While securing the sternum together with the wire sutures, the surgeon attempts to apply sufficient tension so that the sternum is held together and does not dehisce following surgery. The surgeon also attempts to twist the wire sutures uniformly so that the wire sutures do not become unlocked and
5 loosen following surgery, which may allow the sternum to dehisce. The surgeon would also like to ensure that the wire sutures do not break while being tensioned and twisted. Should a wire suture break, it may require the surgeon to replace all the wire sutures that have previously been tensioned and twisted, and the sternum closure be started again.

10 Instruments and methods for attaching a wire suture to two parts of a bone to hold the bone together and apply a tension to the wire suture are well known in the prior art. Various methods for locking the tensioned wire suture are also described in the prior art, including ferrules, crimps or twisting. Various methods of threading the wire suture through, or around the sternum
15 have also been described in the literature, and methods such as single loops, double loops, or figure of eight loops may be used by surgeons to secure the sternum.

BRIEF SUMMARY

Various embodiments of surgical instruments and methods for
20 providing a desired tension to a flexible suture, and providing a twist to said flexible suture while under the desired tension, are described herein. One example of a flexible suture is a stainless steel wire suture as used in a sternal closure after a median sternotomy.

At least one embodiment of a surgical instrument may be
25 summarized as comprising a mechanism for tensioning a flexible suture encircling a bone, a second mechanism for applying a plurality of twists to a flexible suture used to secure a flexible suture to a bone while maintaining tension in said suture, and a base that supports the surgical instrument on a bone during tensioning of a flexible suture. The flexible suture may be a
30 stainless steel wire suture.

The surgical instrument may further include a base that comprises an open slot and at least one moveable member to constrain a flexible suture in the slot. The base preferably does not rotate relative to the bone. The surgical instrument may additionally comprise a slot to allow cutting of a flexible suture by a tool or comprise a mechanism for cutting a flexible suture. The surgical instrument may restrict a second flexible suture from being tensioned with the same surgical instrument. The surgical instrument may remain in a locked position after tensioning a flexible suture and restrict a second flexible suture from being tensioned with the same surgical instrument. The surgical instrument may be attached to a flexible suture before the suture is moved proximate to or encircles the bone. The surgical instrument preferably tensions the flexible suture before securing the suture by twisting.

At least one embodiment of a surgical instrument may be summarized as comprising a mechanism for tensioning a flexible suture encircling a bone, a second mechanism for applying a plurality of twists to a flexible suture used to secure a flexible suture to a bone while maintaining tension in said suture, and a removable handle used to drive at least one of the mechanisms. The flexible suture may be a stainless steel wire suture.

The surgical instrument may further include a mechanism for tensioning which comprises a one way clutch that restricts the release of tension from a flexible suture after tension has been applied to the flexible suture.

The surgical instrument may further include a mechanism for tensioning comprising one or more springs which are compressed as a flexible suture is tensioned. The instrument may further provide an indication of the tension applied to the flexible suture. The surgical instrument may restrict a second flexible suture from being tensioned with the same surgical instrument. The surgical instrument may remain in a locked position after tensioning a first flexible suture and restrict a second flexible suture from being tensioned with the same tool.

At least one embodiment of a surgical instrument may be summarized as comprising a mechanism for tensioning a flexible suture encircling a bone where the mechanism for tensioning comprises at least one member for securing at least one end of a flexible suture, a second mechanism for applying a plurality of twists to a flexible suture, and an open slot extending from the base of the surgical instrument to the member for securing at least one flexible suture, in which at least one end of said flexible suture is carried. The flexible suture may be a stainless steel wire suture.

The surgical instrument may further include a mechanism for tensioning that comprises a one way clutch that restricts the mechanism from returning to the initial configuration of the mechanism after the surgical instrument is released from a flexible suture encircling a bone.

The surgical instrument may further include a mechanism for applying a plurality of twists that comprises at least two members which are drawn together as tension is applied to a flexible suture and rotate inside a shaft as said plurality of twists are applied. The instrument may also provide an indication of the tension applied to a flexible suture.

The surgical instrument may further include a member for securing at least one end of a flexible suture that is a hole in a rotating shaft. The surgical instrument may restrict a second flexible suture from being tensioned with the same surgical instrument. The surgical instrument may remain in a locked position after tensioning a flexible suture and restrict a second flexible suture from being tensioned with the same surgical instrument.

At least one embodiment of a surgical instrument may be a single-use instrument for securing parts of a bone using a flexible suture, comprising a mechanism for fixing at least one of said sutures to said instrument prior to said suture encircling said bone, and a second mechanism for tensioning said suture prior to securing said suture by twisting.

Yet another embodiment is a system for securing parts of a bone using flexible sutures comprising a plurality of single-use surgical instruments,

each said instrument comprising a mechanism for fixing at least one end of a flexible suture to said instrument prior to said suture encircling said bone.

At least one embodiment of a surgical instrument may be summarized as comprising a member for tensioning a flexible suture encircling a bone, a second member for applying a plurality of twists to the flexible suture, and a base that supports the surgical instrument on the bone during tensioning of the flexible suture. The flexible suture may be a stainless steel wire suture. The surgical instrument may further include a base which comprises an open slot in which the flexible suture is carried. The base preferably rotates less relative to the bone than the number of twists that are applied to the flexible suture. The surgical instrument may comprise a member to cause the flexible suture to break or part at a designated location. The break or part may be set to occur near the end of the plurality of twists that is further away from the bone. The break or part may be set to occur proximate the middle of the plurality of twists.

At least one embodiment of a surgical instrument may be summarized as a surgical instrument comprising a member for tensioning a flexible suture encircling a bone, a second member for applying a plurality of twists to the flexible suture and a third member for decreasing said tension as the plurality of twists are applied. The flexible suture may be a stainless steel wire suture. The surgical instrument may provide an indication of the tension applied to the flexible suture. The member for decreasing tension may decrease the separation between the member for tensioning and the plurality of twists. Also, the member for reducing tension may comprise an elastic member, such as a spring, that is tensioned during tensioning of the flexible suture and released as the plurality of twists are applied. The member for tensioning may comprise one or more elastic members which are deformed as the flexible suture is tensioned.

Another embodiment of a surgical instrument may be summarized as comprising a member for tensioning a flexible suture encircling a bone wherein said mechanism for tensioning comprises at least one member for

securing at least one end of said flexible suture, a second member for applying a plurality of twists to said flexible suture, and an open slot extending from base of surgical instrument to said member in which at least one end of said flexible suture is carried. The flexible suture may be a stainless steel wire suture. The member for applying a plurality of twists may comprise an additional member that restricts the member for applying a plurality of twists from returning to its initial configuration after the surgical instrument is released from the flexible suture encircling the bone. The second mechanism for applying a plurality of twists may comprise at least two members which are drawn together and rotate inside a shaft as the plurality of twists are applied. The surgical instrument may provide an indication of the tension applied to the flexible suture. The member for securing at least one end of the flexible suture may be a hole in a rotating shaft. The surgical instrument may remain in a locked position after tensioning the flexible suture and restrict a second flexible suture from being tensioned.

15 BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, identical reference numbers identify similar elements or acts. The sizes and relative positions of elements in the drawings are not necessarily drawn to scale. For example, the shapes of various elements and angles are not drawn to scale, and some of these elements are arbitrarily enlarged and positioned to improve drawing legibility. Further, the particular shapes of the elements as drawn, are not intended to convey any information regarding the actual shape of the particular elements, and have been solely selected for ease of recognition in the drawings.

Figure 1 are two isometric views of a surgical instrument according to one illustrated embodiment.

Figure 2 is an isometric view a surgical instrument according to another illustrated embodiment.

Figure 3 detailed isometric partial view of a head assembly of a surgical instrument, according to one illustrated embodiment.

Figure 4 is a detailed side elevational view of a tensioning shaft according to one illustrated embodiment.

Figure 5 is an isometric partially exploded view of a surgical instrument according to one illustrated embodiment.

5 Figure 6 is a cross sectional view of a surgical instrument according to one illustrated embodiment.

Figure 7 is a detailed isometric partial view of a base of a surgical instrument according to one illustrated embodiment.

10 Figure 8 is a detailed isometric partial view of a base of a surgical instrument according to another illustrated embodiment.

Figure 9 is a detailed isometric partial view of a base of a surgical instrument according to another illustrated embodiment.

Figure 10 is an isometric view showing a surgical instrument in place on a bone, with flexible sutures, according to one illustrated embodiment.

15 Figure 11 is an isometric view showing multiple surgical instruments in place on a bone, with multiple flexible sutures, according to one illustrated embodiment.

Figure 12 is a detailed side elevational view of a piston assembly with a tension indicator, according to one illustrated embodiment

20 Figure 13 is a cross sectional view of a surgical instrument with flexible sutures, according to one illustrated embodiment

Figure 14 is an isometric view showing cutters being used to cut flexible sutures held within a surgical instrument according to one illustrated embodiment.

25 Figure 15 is a detailed cross sectional view of a piston assembly, according to one illustrated embodiment.

Figure 16 is a diagram showing a detailed view of a piston assembly, according to another illustrated embodiment.

30 Figure 17 is a cross sectional view of a piston assembly, according to another illustrated embodiment.

Figure 18 is an exploded isometric view of a surgical instrument with a mechanism to reduce the upward tension during twisting of flexible sutures according to one illustrated embodiment.

Figure 19 is a cross sectional view of a surgical instrument with a
5 mechanism to reduce the upward tension during twisting of flexible sutures according to one illustrated embodiment.

Figure 20 is a cross sectional view of a surgical instrument with a bending mechanism to cause wires to break at a particular location according to one illustrated embodiment.

10 Figure 21 is a front elevational view of a medical device comprising a mechanism to provide an indication of force being applied to flexible sutures, according to one illustrated embodiment.

Figure 22 is an isometric view of a sternum and a medical device according to another illustrated embodiment that uses spot welding to bond
15 wire sutures together to retain two portions of the sternum together.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various embodiments of the invention. However, one skilled in the art will understand that the invention may
20 be practiced without these details. In other instances, well-known structures have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the various embodiments.

Unless the context requires otherwise, throughout the specification and claims which follow, the word "comprise" and variations
25 thereof, such as, "comprises" and "comprising" are to be construed in an open, inclusive sense that is as "including, but not limited to."

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one
30 embodiment. Thus, the appearances of the phrases "in one embodiment" or "in

an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

5 As used in this specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the content clearly dictates otherwise. It should also be noted that the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

10 The headings provided herein are for convenience only and do not interpret the scope or meaning of the claimed invention.

References in the document are made to a stainless steel wire sutures, which could also refer to any other type of flexible suture.

Figure 1 shows an assembled view of a surgical instrument
15 according to one illustrated embodiment. Surgical instrument 100 comprises base column 101, rotating head 102, tensioning handle 103, central twisting shaft 104 and pistons 105. Surgical instrument 100 may also have cutting slot 106. Surgical instrument 100 comprises open slot 107 that runs vertically through surgical instrument 100. Surgical instrument 100 is so designed, such
20 that a flexible suture or multiple flexible sutures may be loaded into slot 107 and easily drawn into the centre of surgical instrument 100 without being threaded or fed through a lumen or hole. Slot 107 preferably runs through base 108, base column 101, rotating head 102 and central twisting shaft 104. A flexible suture may be secured into tensioning shaft 109 prior to being drawn into open
25 slot 107, or after the flexible suture has been drawn into open slot 107. The surgical instrument may be manufactured in such a way and of such materials that it is to be disposed of after a single use. A single-use instrument may be used to perform a particular action once, or to perform a set of actions, but only on a single patient. An example of performing a particular action once is
30 tensioning and twisting a single flexible suture used to secure a portion of the sternum after a sternotomy. An example of performing a set of actions on a

single patient is tensioning and twisting all, or at least more than one of, the flexible sutures used to secure the sternum after a sternotomy. There are several reasons why it may be preferable for a particular surgical instrument to be "single use" including the ability to ensure proper sterilization and the ability to produce a more cost-effective product. Several examples of apparatus that may restrict the number of actions a particular surgical instrument may perform include a mechanism that locks the device in a position after the first use such that it cannot be used again, components fabricated out of a material such as plastic that becomes deformed after one or several uses and causes the device to fail, or parts that cannot be sterilized after use.

Figure 2 shows an assembled view of a surgical instrument according to another illustrated embodiment. Surgical instrument 200 comprises base column 201, rotating head 202, and tensioning handle 203. Also shown are pistons 204 and cutting slot 205. Flexible suture capture lock 206 is also shown.

Figure 3 shows one embodiment of how flexible suture 304 may be secured in tensioning shaft 301. One or more small holes 302 may be made in tensioning shaft 301. The ends of flexible suture 304 may be inserted into holes 302. Rotating tensioning shaft 301 by rotating tensioning handle 303 causes flexible suture 304 to wrap around tensioning shaft 301, and so become secured to tensioning shaft 301. In other embodiments there may be multiple holes 302 at various angles that allow flexible suture 304 to be easily inserted, regardless of the orientation of tensioning shaft 301. Flexible suture 304 may be inserted into small holes 302 either horizontally, from below, or from above. Flexible suture 304 may be secured to tensioning shaft 301 prior to flexible suture 304 being brought proximate to or encircling a bone.

Figure 4 shows an alternate embodiment of a tensioning shaft 400. Opening 401 is large enough that two flexible sutures 405 may easily be pulled into slot 404. One way latch 402 allows flexible sutures 405 to easily enter opening 401 and slot 404, but do not allow flexible sutures 405 to escape from opening 401. Capturing flexible sutures 405 in slot 404 secures flexible

sutures 405 to tensioning shaft 400. Another method of securing flexible suture 407 to tensioning shaft 400 is to use groove 403. Flexible suture 406 may be held in groove 403, and rotated together with tensioning shaft 400. As flexible suture 406 is rotated with shaft 400, it becomes secured to tensioning shaft 400. Flexible sutures 405 may be secured to tensioning shaft 400 prior to flexible sutures 405 being brought proximate to or encircling a bone.

Figure 5 shows an exploded view of a surgical instrument 500 according to one illustrated embodiment. Surgical instrument 500 contains base column 501, lower central twisting shaft 502, upper central twisting shaft 503 and twisting head 504. Open slot 505 may be present which runs through the length of surgical instrument 500. Slot 505 allows flexible sutures to be easily loaded into surgical instrument 500 and into tensioning shaft 506. One or more pistons 507 may sit on top of springs 508, which fit into shafts in base column 501. As flexible sutures are twisted around tensioning shaft 506, by rotating tensioning handle 509, tension is applied to the flexible sutures. This tension is maintained by force from springs 508 on pistons 507. As the tension is increased, by further twisting tensioning shaft 506, pistons 507 move downwards into the base column 501 causing springs 508 to compress. The two part design of central twisting shaft 502, 503 enables central twisting shaft 502, 503 to shorten as pistons 507 move downward into base column 501. Lower central twisting shaft 502 is able to move upwards into upper central twisting shaft 503. One way clutch spring 510 fits over tensioning shaft 506 and restricts tensioning shaft 506 to rotate in one direction only. Thus, as tension is applied to the flexible sutures as tensioning shaft 506 is rotated, this tension is maintained, even if tensioning handle 509 is released, as one way clutch spring 510 does not allow tensioning shaft 506 to counter-rotate, which would release the tension. In this way, increasing tension on the flexible sutures may be maintained, until the desired tension is achieved.

Figure 6 shows a cross section of one embodiment of a surgical instrument, showing in detail the internal mechanisms. Rotating upper twisting shaft 603 causes lower twisting shaft 602 to rotate. Lower twisting shaft 602

and upper twisting shaft 603 fit together in such a way that they are able to rotate within base column 601, and also may compress together, as pistons 604 move downwards into shafts 608 in base column 601. This mechanism allows twisting head 605, tensioning shaft 606, and tensioning handle 607 also to move downwards. In another embodiment, springs 609 may be replaced by a pneumatic seal at the end of pistons 604. The air trapped in shafts 608 by the pneumatic seal provides resistance to the compression motion of pistons 604 in a similar way to the springs. The surgical instrument may comprise of any number of springs 609, pistons 604, and shafts 608 to provide the desired tension to the flexible suture.

Figure 7 shows a base of a surgical instrument in one embodiment, with central opening 701 into which flexible sutures may be drawn through slot 702. The base of the surgical instrument comprises additional flex slots 703, which allow the material surrounding central opening 701 to deform sufficiently to allow the flexible sutures to be drawn easily into central opening 701, where the flexible sutures may be held in place. Once the flexible suture are drawn into central opening 701, the material between central opening 701 and flex slots 703 returns to its relaxed shape and restrains the sutures in central opening 701.

Figure 8 shows a base of a surgical instrument 800 in an alternate embodiment, with central opening 801 into which flexible sutures may be drawn. Central opening 801 is initially open, allowing the flexible sutures to easily be drawn into slot 804 which runs vertically through surgical instrument 800. Once the flexible sutures have been drawn into central opening 801, sliding lock 802 may be pushed closed, by pushing on lock handle 803, and so capturing the flexible sutures in central opening 801 in the base of surgical instrument 800.

Figure 9 shows a base of a surgical instrument in another alternate embodiment, with central opening 901 into which flexible sutures may be drawn. Central opening 901 is initially open, allowing the flexible sutures to easily be drawn into slot 902 which runs vertically through surgical instrument

900. Once the flexible sutures have been drawn into central opening 901, swivel lock 903 may be pushed closed to capture the flexible sutures in central opening 901. Swivel lock 903 may then be held in position by small latch 904 on the base of surgical instrument 900, which locks swivel lock 903 in the closed position.

Figure 10 is a diagram showing an embodiment of a surgical instrument 1000 being used to tighten flexible sutures around a bone. Flexible suture 1001 is placed around or through parts of bone 1002, 1011 to be secured. The flexible suture 1001 may be drawn through base 1003 of surgical instrument 1000 and upwards through slot opening 1006, towards twisting head 1004 of surgical instrument 1000. Flexible suture 1001 may then be secured in tensioning shaft 1005. Alternatively, flexible suture 1001 may be secured into opening 1009 in tensioning shaft 1005, and then drawn downwards into slot 1006, and then secured in base 1003. Once flexible suture 1001 has been secured in base 1003 and to tensioning shaft 1005, base 1003 may be placed on bone 1002 and tensioning handle 1007 may be rotated to apply tension to flexible suture 1001. Tensioning handle 1007 rotates tensioning shaft 1005, which rotates within one-way clutch mechanism 1008. One-way clutch mechanism 1008 allows tensioning handle 1007 and tensioning shaft 1005 to rotate in only one direction. Rotation of tensioning handle 1007 causes flexible suture 1001 to rotate around tensioning shaft 1005 and applies tension to flexible suture 1001. This tension may be progressively increased by continuing to rotate tensioning handle 1007. Flexible suture 1001 is drawn further up into surgical instrument 1000, through a small opening at the base and tension is applied to the flexible suture 1001 surrounding bone 1002, 1011. As tension is applied, the separated parts of bone 1002, 1011 are drawn together. Tensioning handle 1007 is removable from surgical instrument 1000, which allows multiple surgical instruments to be used together in a restricted space, without tensioning handles 1007 becoming entangled, or impacting the operation of other surgical instruments within close proximity.

Figure 11 is a diagram showing an embodiment of multiple surgical instruments being used in parallel to secure a bone. A surgeon may first use surgical instrument 1101 to apply tension to flexible suture 1105. Surgical instrument 1101 may be left in position and second surgical instrument 5 1102 may now be used to apply tension to second flexible suture 1106. Additional surgical instruments 1103 and 1104 may be added in a similar manner to apply tension to flexible sutures 1107 and 1108. Once two or more surgical instruments have been used to apply tension to two or more different flexible sutures, the surgeon may return to any surgical instrument and increase 10 the tension on the corresponding flexible suture. In this way, multiple surgical instruments may be used in a single procedure to accurately adjust the tension on multiple flexible sutures to the preferred tension. This technique gives the surgeon the ability to precisely adjust each flexible suture to the desired tension required to hold the bone together, and gives the surgeon the ability to increase 15 the tension on any one flexible suture.

Surgical instruments 1101, 1102, 1103, and 1104 may each comprise a mechanism for securing at least one end of flexible sutures 1105, 1106, 1107, 1108 to the surgical instrument prior to the sutures 1105, 1106, 1107, 1108 being brought proximate to or encircling a bone.

20 Figure 12 shows a detailed view of one embodiment of a piston assembly and tension indicator. Piston 1201 may include tension indicator 1202, which gives the surgeon an indication of the tension that is being applied to the flexible suture. As more tension is applied to the flexible suture, piston 1201 may move downward into the shaft in base column 1203. This movement 25 may be used to give an indication on piston 1201 of the distance that piston 1201 has moved, and also of the tension that has been applied to the flexible suture.

Once the surgeon is satisfied that all flexible sutures are the desired tension and that the bone is securely held by all the flexible sutures 30 used in the procedure, the surgeon may then begin to secure the flexible sutures in place by twisting each flexible suture together on itself.

Figure 13 shows an embodiment of a surgical instrument that is able to apply a twist to a flexible suture after the suture has been appropriately tensioned. Twisting head 1303 may be twisted in either a clockwise or anticlockwise direction around the central axis of base column 1310. The entire head assembly including tensioning handle 1305, tensioning shaft 1306 and twisting head 1303 rotate in the direction of rotation applied to twisting head 1303. Base column 1310 does not rotate. This twisting motion of twisting head 1303 is translated into a twisting motion of both upper central twisting shaft 1307 and lower central twisting shaft 1308. Lower central twisting shaft 1308 comprises narrow portion 1302 which restricts the two ends of flexible suture 1301 from twisting about each other within the narrow portion 1302. As lower central twisting shaft 1308 is rotated, the two ends of flexible suture 1301 below narrow portion 1302 begin to twist around each other. This action forms twisted part 1304 of flexible suture 1301 between narrow portion 1302 of lower central twisting shaft 1308 and the narrow opening in the base 1309 of the surgical instrument. After a preferred number of complete rotations of twisting head 1303, flexible suture 1301 may now be sufficiently twisted to provide a secure locking mechanism for flexible suture 1301 that has been applied to the bone. The surgeon may repeat this twisting procedure on each of the surgical instruments that may have been used to secure and tension the flexible sutures on the patient's bone.

Figure 14 is a diagram showing an embodiment of how a flexible suture may be cut after being tensioned and twisted. Surgical cutters 1401 may be inserted into cutter opening 1402 and cut the twisted flexible suture. Alternatively, surgical instrument 1400 may include a blade for automatically cutting flexible suture 1403. Cutting flexible suture 1403 will release surgical instrument 1400 from flexible suture 1403 attached to bone 1404 and allow surgical instrument 1400 to be removed. In another embodiment of surgical instrument 1400, the narrow part of the lower central twisting shaft (not shown) will be sufficiently narrow or comprise an edge to weaken the flexible sutures that pass through surgical instrument 1400. When a sufficient number of twists

have been applied to flexible suture 1403, flexible suture 1403 will automatically break at the top of the twisted section, and release surgical instrument 1400 from the twisted flexible suture 1403.

Figure 15 shows a detailed view of an embodiment of a one way
5 mechanism on the piston assembly. Piston 1504 may include a mechanism for preventing the head assembly of a surgical instrument from jumping up after cutting a flexible suture loaded into the surgical instrument. Ball 1501 is held in place by spring 1502 in cavity 1503 within piston 1504. When piston 1504 is pushed into shaft 1505 in base column 1506, spring 1502 is compressed, ball
10 1501 moves into cavity 1503, and piston 1504 is able to move downwards. Piston 1504 is restricted from moving upward and out of shaft 1505 as any upward motion causes ball 1502 to be forced against the wall of shaft 1505 causing sufficient friction such that piston 1504 is unable to move upwards.

Figure 16 shows a detailed view of an embodiment of a one way
15 mechanism on the piston assembly for preventing the head assembly of a surgical instrument from jumping up, after cutting a flexible suture loaded into the surgical instrument. Piston 1601 may have slots 1602 cut into it at regular intervals. Flexible blade 1603 is held with one edge lying at an angle within slots 1602, allowing piston 1601 to move downwards. As piston 1601 moves
20 downwards, blade 1603 may move from one slot 1602 to the one above it. Blade 1603 is able to move easily from one slot to the one above due to the angular orientation of blade 1603 within slot 1602. If piston 1601 attempts to move upwards, the angle of blade 1603 within slot 1602 resists this movement and prevents piston 1601 from moving upwards.

Figure 17 shows a detailed view of an embodiment of a one way
25 mechanism on the piston assembly for preventing the head assembly of a surgical instrument from jumping up, after cutting a flexible suture loaded into the surgical instrument. In a cross sectional view of shaft 1701 in the base column, spring 1703 inside shaft 1701 in the base column may be enclosed in
30 fluid 1704. Piston 1702 fits into shaft 1701 in the base column, with gap 1705 around piston head 1706. As piston 1702 moves downwards into openings

1701 in the base column, spring 1703 slowly compresses, and fluid 1704 is able to move through gap 1705 around piston head 1706. When tension is released by cutting the flexible suture, piston 1702 moves upwards under pressure from spring 1703. This movement is restricted by the flow of fluid
5 1704 around piston head 1706. This provides a slow upward movement of piston 1702, preventing the head assembly of the surgical instrument mechanism from jumping up.

Figure 18 shows an exploded view of an embodiment of a surgical instrument with a mechanism that enables an initial force to be applied to a
10 flexible suture to tighten the suture around a bone and a second mechanism to decrease the force applied to the flexible suture as a twist is applied to the flexible suture. Applying a sufficiently high initial force enables the flexible suture to be adequately tensioned around a bone such as the sternum. Adjusting or controlling the upward force applied to the ends of a flexible suture
15 as they are being twisted together enables control of the number of twists per length of wire, or twist density, that can be achieved before the flexible suture breaks. Preferably, decreasing the upward force applied to the ends of a flexible suture as they are being twisted together increases the number of twists per length of wire, or twist density, that can be achieved before the flexible
20 suture breaks. Higher twist density is preferable as a higher twist density typically increases the amount of force required to separate the pieces of bone being held together by the flexible suture.

One end of torsion spring 1801 may be fixed to tensioning shaft 1802 and the other end may be fixed to tensioning handle 1803. One way
25 clutch spring 1804 fits over tensioning handle 1803 and preferably restricts tensioning handle 1803 to rotate in one direction only. Turning tensioning handle 1803 causes the end of torsion spring 1801 that is fixed to the tensioning handle to rotate and causes torsion spring 1801 to exert a force on tensioning shaft 1802 in accordance with the angular form of Hooke's law.
30 When sufficient force is applied to tensioning shaft 1802, tensioning shaft 1802 will rotate and wind up the flexible sutures that have been inserted into holes

1810. The force that is applied to the flexible sutures by the rotation of tensioning shaft 1802 is proportional to the force that torsion spring 1801 exerts on tensioning shaft 1802, if frictional forces are ignored.

Twisting head 1805 is rotated to cause two ends of a suture to be
5 twisted around each other. Twisting head 1805 is preferably connected to base column 1807 by threaded section 1806. As twisting head 1805 is rotated it moves downward into base column 1807 and the force applied to the flexible sutures wrapped around tensioning shaft 1802 is decreased. As the force applied to the flexible sutures is decreased, torsion spring 1801 causes
10 tensioning shaft 1802 to rotate and wind up the flexible suture preferably causing a reduced, but non-zero force, to continue to be applied to the flexible sutures during twisting. The mechanical action provided by torsion spring 1801 enables the force applied to flexible sutures wrapped around tensioning shaft 1802 to be gradually reduced as twisting head 1805 is rotated relative to base
15 column 1807. As torsion spring 1801 unwinds to its rest position, the upward force on flexible sutures may be reduced to zero.

Figure 19 shows a cross sectional view of the embodiment of the surgical instrument given in Figure 18. One end 1903 of torsion spring 1904 is fixed to tensioning shaft 1902 and the other end 1905 is fixed to tensioning
20 handle 1901. One way clutch spring 1906 fits over tensioning handle 1901 and preferably restricts tensioning handle 1901 to rotate in one direction only. Turning tensioning handle 1901 causes end 1905 of torsion spring 1904 that is fixed to tensioning handle 1901 to rotate and causes torsion spring 1904 to exert a force on tensioning shaft 1902 in accordance with the angular form of
25 Hooke's law. When sufficient force is applied to tensioning shaft 1902, tensioning shaft 1902 will rotate and wind up ends of flexible sutures 1909 that have been inserted into holes 1908. The force that is applied to the flexible sutures 1909 by the rotation of tensioning shaft 1902 is proportional to the force that torsion spring 1904 exerts on tensioning shaft 1902, if frictional forces are
30 ignored.

Twisting head 1907 is rotated to cause two ends of flexible suture 1909 to form twist 1913 near bone 1914. Twisting head 1907 is preferably attached to base column 1911 by threaded section 1910. As twisting head 1907 is rotated it moves downward into base column 1911, decreasing the distance between tensioning shaft 1902 and the twisted section 1913 of flexible suture 1909. As the distance decreases, torsion spring 1904 preferably causes tensioning shaft 1902 to rotate and wind the ends of flexible suture 1909 around tensioning shaft 1902. Such winding of flexible suture 1909 during rotation of twisting head 1907 decreases the force applied by torsion spring 1904 to tensioning shaft 1902. The decreasing force applied by torsion spring 1904 enables the upward force applied to ends of flexible suture 1909 wrapped around tensioning shaft 1902 to be gradually reduced as twisting head 1907 is rotated relative to base column 1911. Gradually reducing the force applied to ends of flexible suture 1909 enables sufficient tension to remain in the section of the flexible wire 1915 that surrounds the bone 1914 while maximizing the twist density of the twisted section 1913. As torsion spring 1904 unwinds to its rest position, the upward force on ends of flexible sutures 1909 may be reduced to zero. Testing has shown that applying an initial upward force to ends of flexible sutures 1908 of 220 to 450 newtons, and then reducing the upward tension to less than 20 newtons during 6 to 8 revolutions of twisting head 1907 enables a high twist density to form in a twisted section 1913 of length 8 to 12 mm before the suture breaks near the end of the twisted section 1913 that is further away from the bone from the twisting.

Other embodiments of the surgical instrument could use one of many methods of controlling the force to be applied to the ends of the flexible suture that are to be tightened and twisted. For example, an air piston, springs, or lever system could be used. The force applied to the flexible suture may be increased or decreased as the wire is twisted, depending on the desired twist density. The increase or decrease of force may be applied linearly, exponentially, or in any other relationship with respect to the number of twists applied.

Figure 20 shows a cross sectional view of an embodiment of a surgical instrument comprising a mechanism for breaking a wire at a preferred location. The ends of flexible suture 2004 are wrapped around bone 2001 and placed inside a narrow slot 2009 in central twisting shaft 2005. The length 2002
5 of flexible suture that is wrapped around bone 2001 is held in groove 2008. Groove 2008 is offset from the rotational axis of central twisting shaft 2005.

Rotating twisting head 2003 causes central twisting shaft 2005 to rotate. Central twisting shaft 2005 grips two lengths of flexible suture 2004 and causes the lengths of flexible suture 2004 to rotate about each other and form
10 twisted section 2007. Twisted section 2007 forms at an angle to the portion of flexible suture 2004 that is routed within central twisting shaft 2005 because of the position of groove 2008. As central twisting shaft 2005 rotates, the flexible sutures are repeatedly bent in the region between the base of the central twisting shaft 2005 and the top of twisted portion 2007. The repeated bending
15 causes the sutures to work harden, fatigue, weaken and finally break at preferred breaking location 2006. Increasing the distance that groove 2008 is offset from the rotational axis of central twisting shaft 2005 increases the amount of bending the flexible sutures are subjected to at the base of central twisting shaft 2005 and typically reduces the number of rotations of twisting
20 head 2003 required to cause the sutures to part or break at the top of the twisted portion 2007. The preferred location of where the wire will break can be adjusted by controlling the position where the wire is repeatedly bent during rotation. For example, in addition to the previous embodiment, another embodiment of a medical device could preferably part the wire in the middle of
25 a twisted section of wire, and yet another embodiment could part the wire a specified distance above the twisted section of wire.

Figure 21 shows an embodiment of a medical device comprising a mechanism to provide an indication of force being applied to a flexible suture being tensioned by the medical device. Medical device 2100 is shown having
30 no force applied to tensioning handle 2104. Medical device 2106 is shown with force applied to tensioning handle 2110.

Tensioning handle 2104, 2110 is preferably connected to tensioning shaft 2103, 2109 by flexures 2102, 2108. Dial 2101, 2107 may be attached to or marked on tensioning handle 2104, 2110. Dial 2101, 2107 may be a series of grooves, numbers, or other markings. Needle indicator 2105, 2111 is preferably rigidly attached to tensioning shaft 2103, 2109 and points to dial 2101, 2107.

Flexures 2102, 2108 may bend at the middle and the points that they are connected to tensioning handle 2104, 2110 and tensioning shaft 2103, 2109. Increasing the force that is applied to tensioning handle 2104, 2110 increases the amount that flexures 2102, 2108 bend from their rest position. Flexures 2102 are shown with no force being applied to tensioning handle 2104, and flexures 2108 are shown with some force being applied to tensioning handle 2110. As flexures 2102, 2108 are bent, tensioning handle 2104, 2110 rotates about tensioning shaft 2103, 2109, changing the position on dial 2101, 2107 that is pointed to by needle indicator 2105, 2111. The position that needle indicator 2105, 2111 points to on dial 2101, 2107 provides an indication of the force that is being delivered to tension shaft 2103, 2109. Providing an indication of the force that is being delivered to tension shaft 2103, 2109 is useful to inform the medical device user of the quantity of tension being applied to flexible sutures 2112, 2113.

An alternative to securing the wires by twisting is using a form of welding, such as spot welding (also referred to as "resistance welding") to permanently bond flexible sutures made of wire together after tensioning. Figure 22 is a diagram of an embodiment of a medical device that uses spot welding to bond wires. This base 2203 of this tool comprises two tensioning posts 2201 separated sufficiently to allow a welding tool to fit in between the tensioning posts 2201. Ends of wire suture 2202 may be tensioned using an embodiment disclosed previously, such as with a tensioning shaft and tensioning handle, or may be tensioned using one of many other common tensioning methods available. After wire suture 2202 is properly tensioned, spot welder 2205 is used to bond the wires in bonding region 2204. Spot

welder 2205 grips the wires in the bonding region 2204 with electrodes 2206 and applies current to bond the wires. The use of spot welding for securing wires is well known in the art of dentistry and does not require elaboration. One of many dental wire spot welder suppliers is Dentaurem (www.dentaurem.de).

5 Some units are available in the shape of pliers, making it possible to access the limited space under the tensioning tool. Such spot welding pliers are disclosed in US patent 2,267,297 hereby incorporated by reference. It was found that a setting of about 1-2 VAC is sufficient for welding the 0.8mm type 316L stainless steel wire used for sternal closure. A voltage of about 1-2 VAC
10 corresponds to a current of about 1000-2000 A across the wire. Pulse duration is 10-20mS. Shorter pulses are less desirable as higher voltages are required to deliver the same energy. Because of the very low voltage and because an AC voltage is used, the muscles do not respond to the voltage, particularly if a frequency of above 1KHz is chosen. Since most modern inverters operate
15 above 20 KHz, no biological response will occur.

Major advantages of securing wires by welding include the very low profile of the finished joint (after clipping off excess wire) and high tension retention.

CLAIMS:

What is claimed is:

1. A medical instrument to secure flexible sutures to at least one body part, the medical device comprising:
 - means for securing portions of the flexible sutures together; and
 - means for applying a decreasing tension to the flexible sutures during said securing.
2. The medical instrument of claim 1 wherein the means for securing portions of the flexible sutures together comprises a twisting head in which the flexible sutures are retained, the twisting head rotatable in use with respect to the at least one body part while the flexible sutures are retained therein.
3. The medical instrument of claim 2 wherein the means for securing portions of the flexible sutures together further comprises a twisting shaft that extends along a first axis from the twisting head.
4. The medical instrument of claim 3 wherein the means for applying a decreasing tension to the flexible sutures varies a distance between a location where the flexible sutures exit the twisting shaft and a location in the twisting head at which the flexible sutures are retained.
5. The medical instrument of claim 2 wherein the means for securing portions of the flexible sutures together further comprises a base column, the twisting head rotatably mounted to the base column for rotation about a first axis in use.
6. The medical instrument of claim 5 wherein the means for applying a decreasing tension to the flexible sutures varies a distance between a

location where the flexible sutures exit the base column and a location in the twisting head at which the flexible sutures are retained.

7. The medical instrument of claim 5 wherein means for applying a decreasing tension to the flexible sutures comprises a threaded portion of the twisting head and a threaded portion of the base column, the threaded portion on the twisting head threadedly engaging the threaded portion of the base column to vary a distance between a location where the flexible sutures exit the base column and a location in the twisting head where the flexible sutures are retained in response to rotation of the twisting head relative to the base column.

8. The medical instrument of any of claims 1 through 7 wherein the means for applying a decreasing tension to the flexible sutures reduces the tension applied to the flexible sutures as the flexible sutures are twisted together.

9. The medical instrument of claim 7, further comprising:
means for applying an initial tension force to the flexible sutures to tighten the flexible sutures to the at least one body part.

10. The medical instrument of claim 9 wherein the means for applying an initial tension force to the flexible sutures comprises a torsion shaft rotatably mounted in the twisting head to rotate about a second axis, the second axis at least approximately perpendicular to the first axis, the torsion shaft having a flexible suture retaining structure positioned within a portion of the twisting head.

11. The medical instrument of claim 10 wherein means for applying an initial tension force to the flexible sutures further comprises a handle physically coupled to the torsion shaft and a one-way clutch.

12. The medical instrument of claim 11 wherein the one-way clutch comprise a clutch spring physically coupled between the handle and the twisting head to limit rotation of the handle to a single rotational direction.

13. The medical instrument of claim 11 wherein the means for applying a decreasing tension to the flexible sutures further comprises a torsion spring that physically couples the handle to the torsion shaft and which transfers a rotation of the handle into a rotation of the torsion shaft about the second axis.

14. The medical instrument of any of claims 1 through 7 and 9 through 12, further comprising:

means for cutting or breaking the flexible sutures.

15. The medical instrument of claim 14 wherein the means for cutting or breaking the flexible sutures comprises a groove sized to accommodate the flexible sutures and positioned at least proximate an exit of the medical instrument and offset from a central axis of the medical instrument about which central axis the flexible sutures are twisted when in medical instrument is in use.

16. The medical instrument of claim 1 further comprising a slot extending along at least a portion of a length of the medical instrument through which slot the sutures may be inserted without threading through a hole.

17. A medical instrument to secure flexible sutures to at least one body part, the medical device comprising:

a base;

a twisting head, the twisting head rotatably mounted to the base for rotation with respect thereto about a first axis to secure portions of the flexible sutures together;

a torsion shaft having a flexible suture retaining structure, the torsion shaft rotatably mounted to the twisting head to rotate with respect thereto about a

second axis to apply tension to the flexible sutures, the second axis non-parallel to the first axis;

a handle selectively moveable by a user; and

a torsion spring that physically couples the handle to the torsion shaft and which transfers a rotation of the handle into a rotation of the torsion shaft about the second axis.

18. The medical instrument of claim 17, further comprising:

a one-way clutch, the one-way clutch spring physically coupled between the handle and the twisting head to limit rotation of the handle to a single rotational direction.

19. The medical instrument of claim 17 wherein the one-way clutch

comprises a spring.

20. The medical instrument of claim 19, further comprising:

a twisting shaft at least partially received by the base and which extends along the first axis from the twisting head.

21. The medical instrument of claim 17, further comprising:

means for applying a decreasing tension to the flexible sutures while the twisting head is rotated with respect to the base means.

22. The medical instrument of claim 21 wherein the means for

applying a decreasing tension to the flexible sutures comprises a threaded portion on the twisting head and a threaded portion on the base, the threaded portions threadedly engaged to vary a distance between the flexible suture retaining structure of the torsion shaft and a bottom of the base in response to rotation of the twisting head relative to the base.

23. The medical instrument of any of claims 17 through 21, further comprising a slot extending along at least a portion of a length of the medical instrument through which slot the sutures may be inserted without threading through a hole.

24. A medical instrument for connecting metal wires by twisting, said device controlling tension of said wires independent of the twisting operation.

25. A device for sterna closure using metal wires, said device combining the functions of connecting the wires by twisting, controlling the tension in said wires and automatically cutting off the wires.

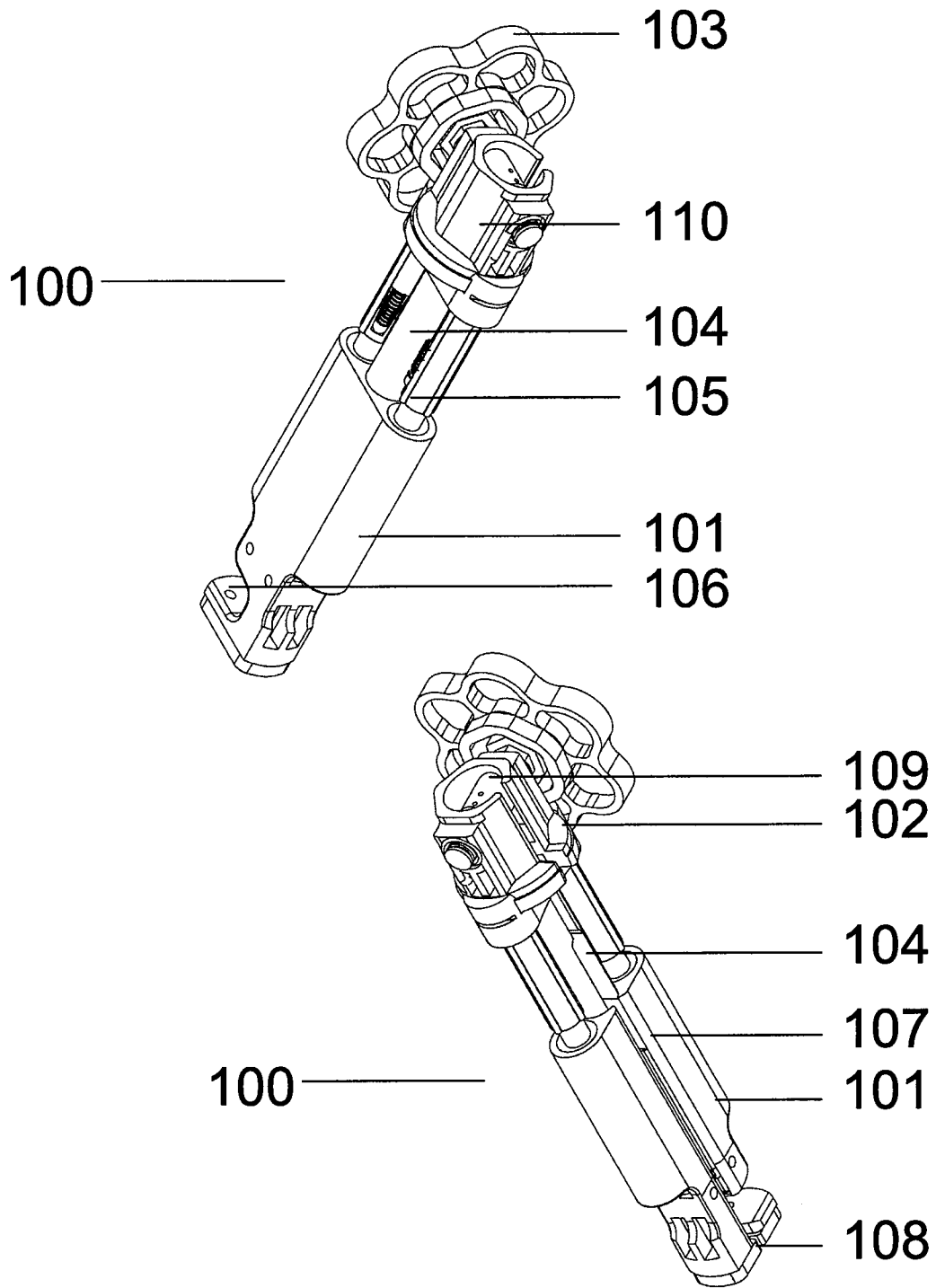


Figure 1

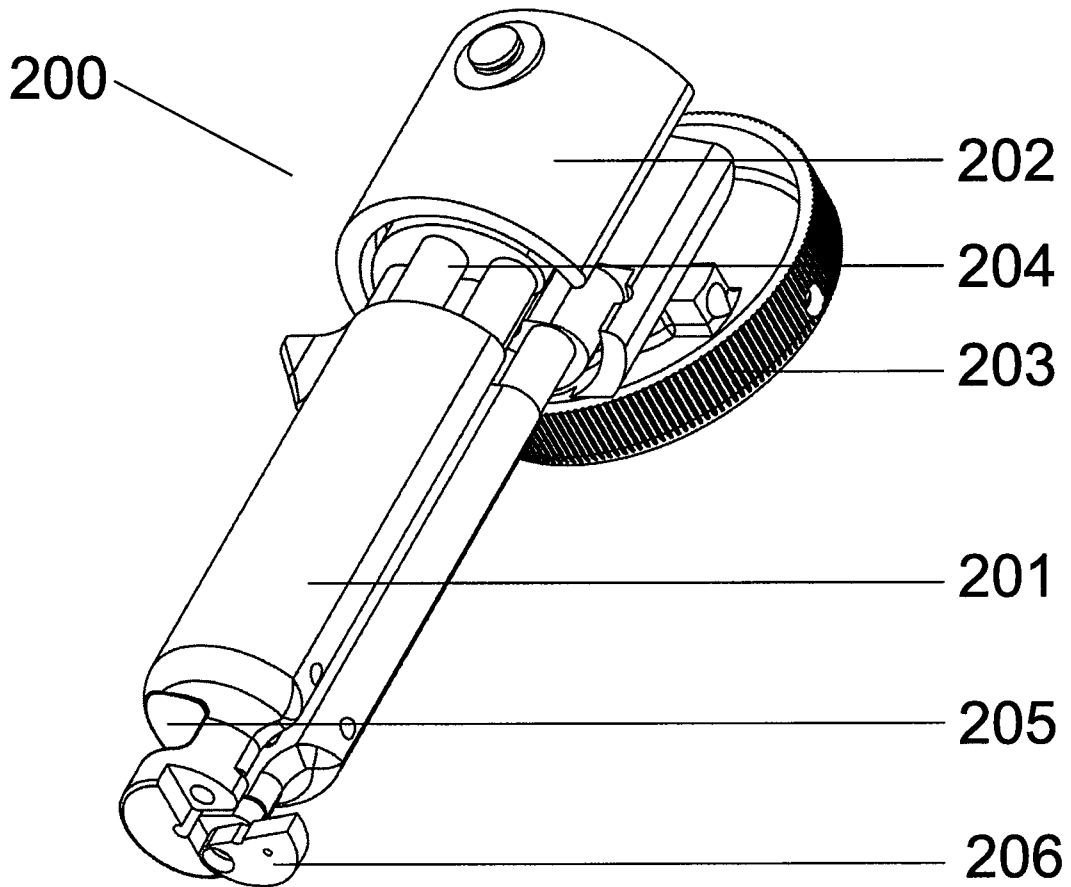


Figure 2

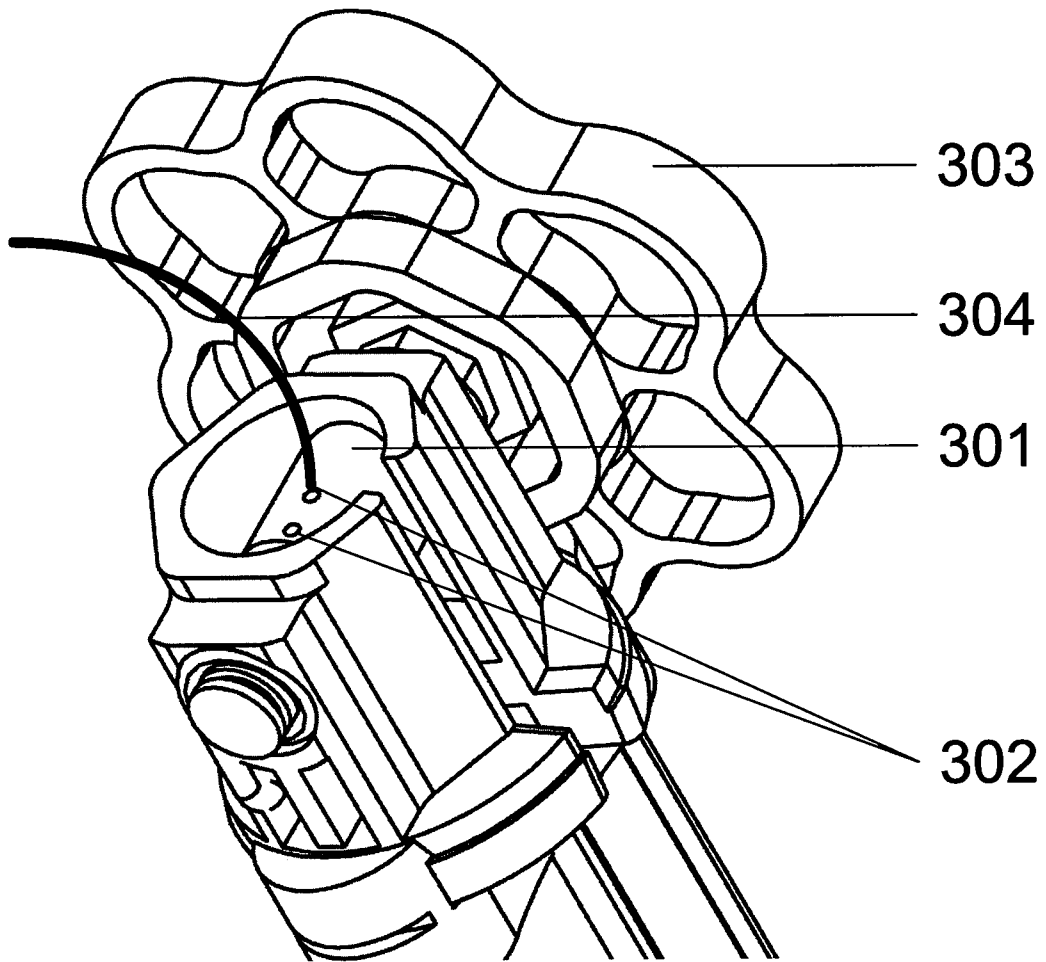


Figure 3

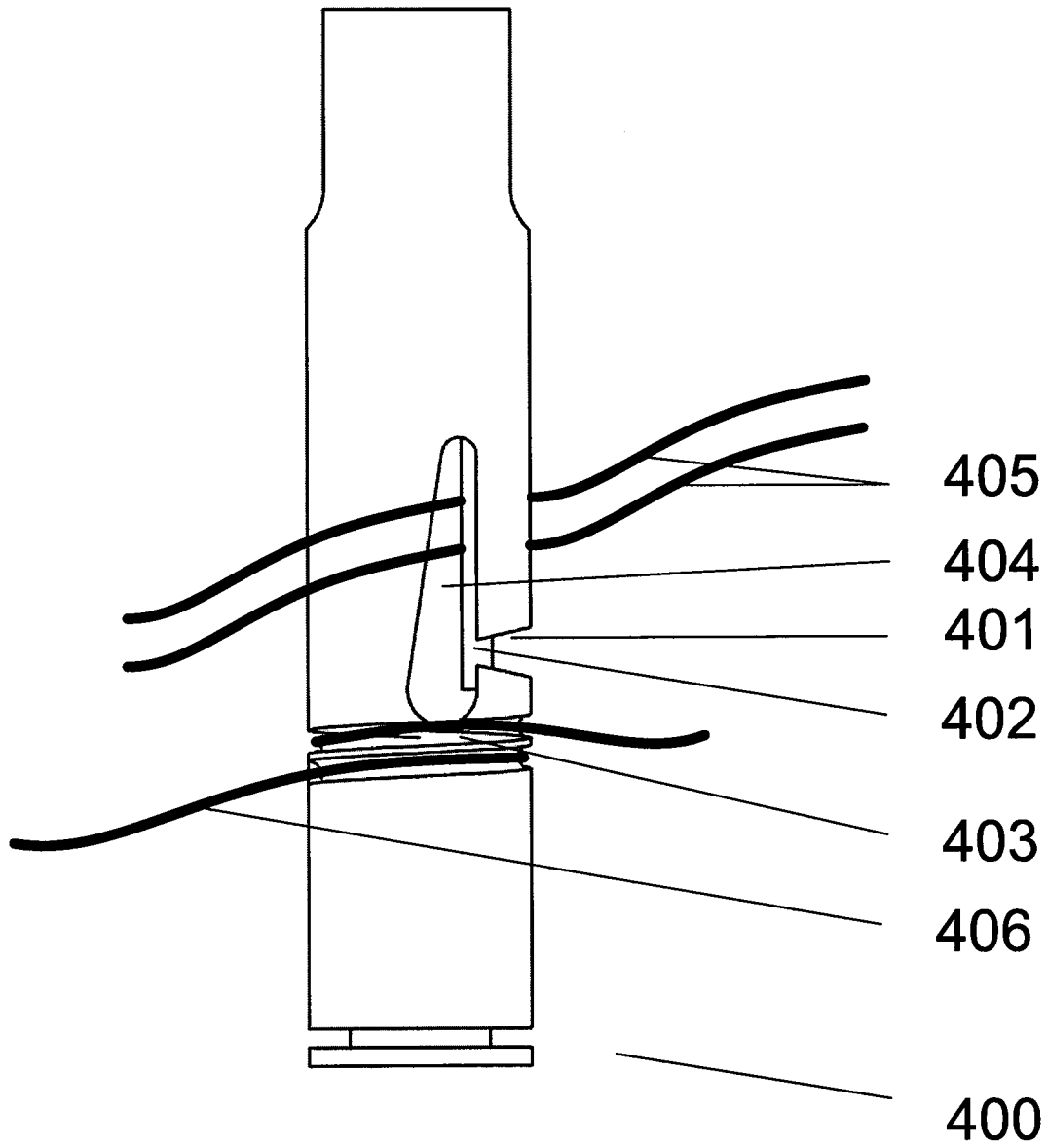


Figure 4

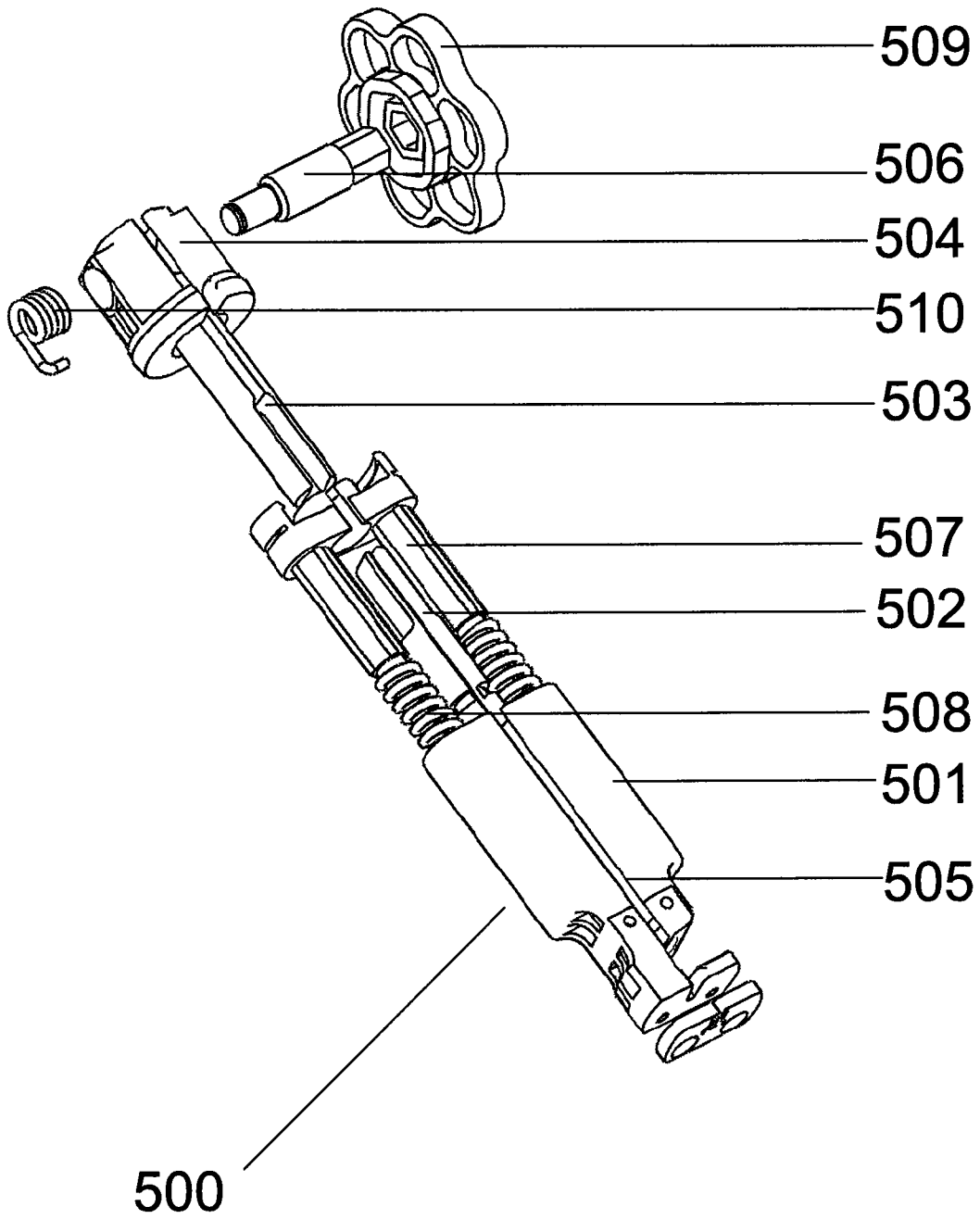


Figure 5

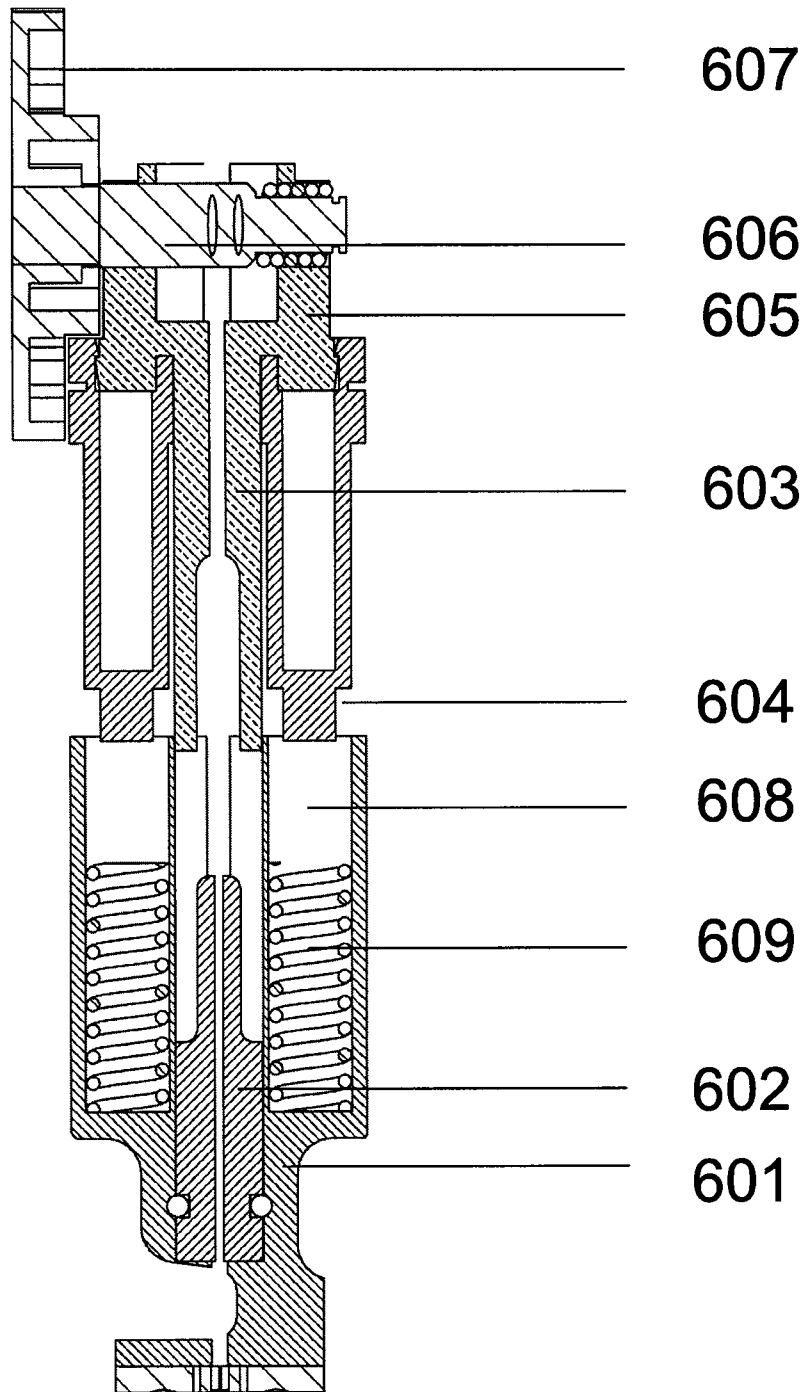


Figure 6

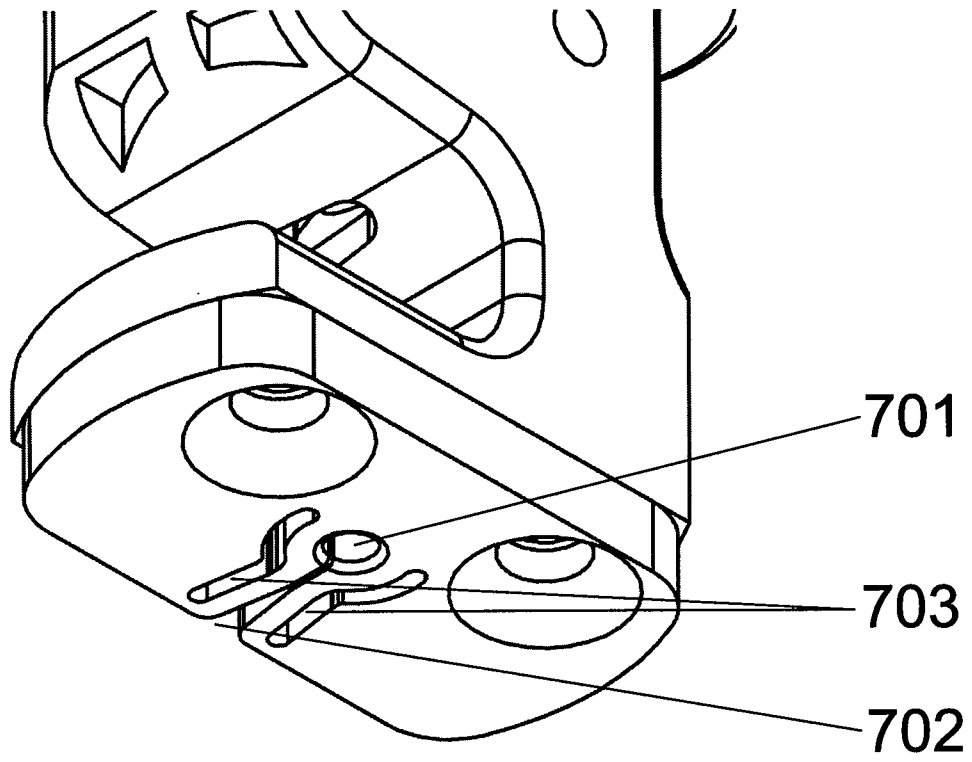


Figure 7

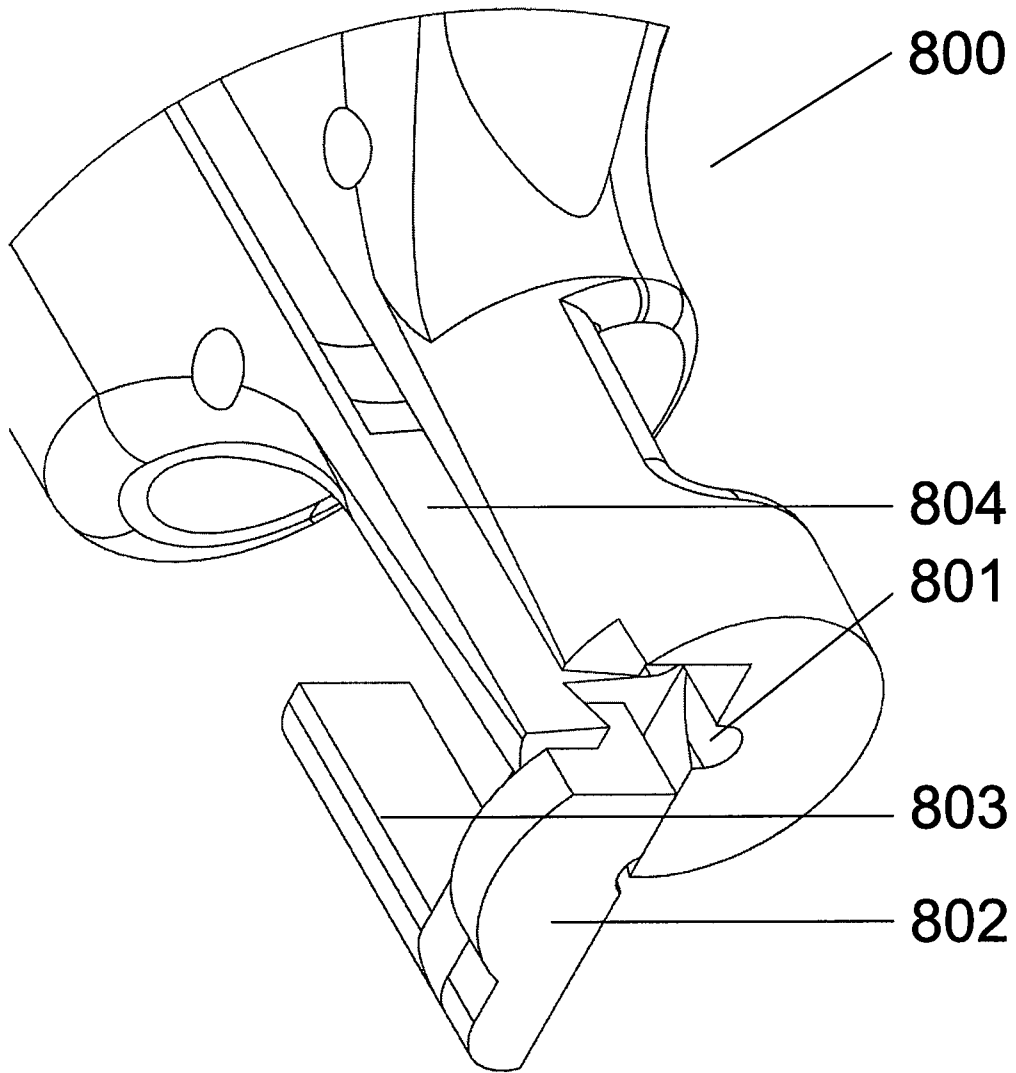


Figure 8

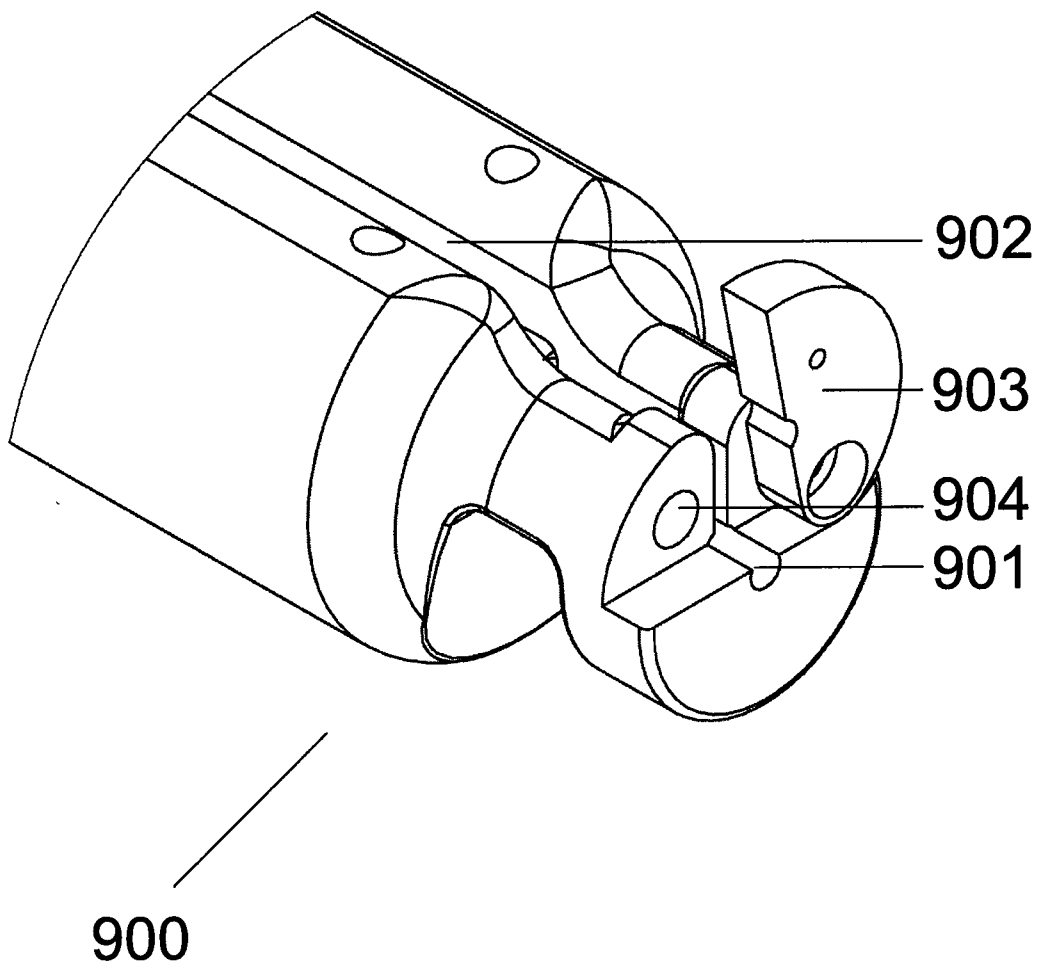


Figure 9

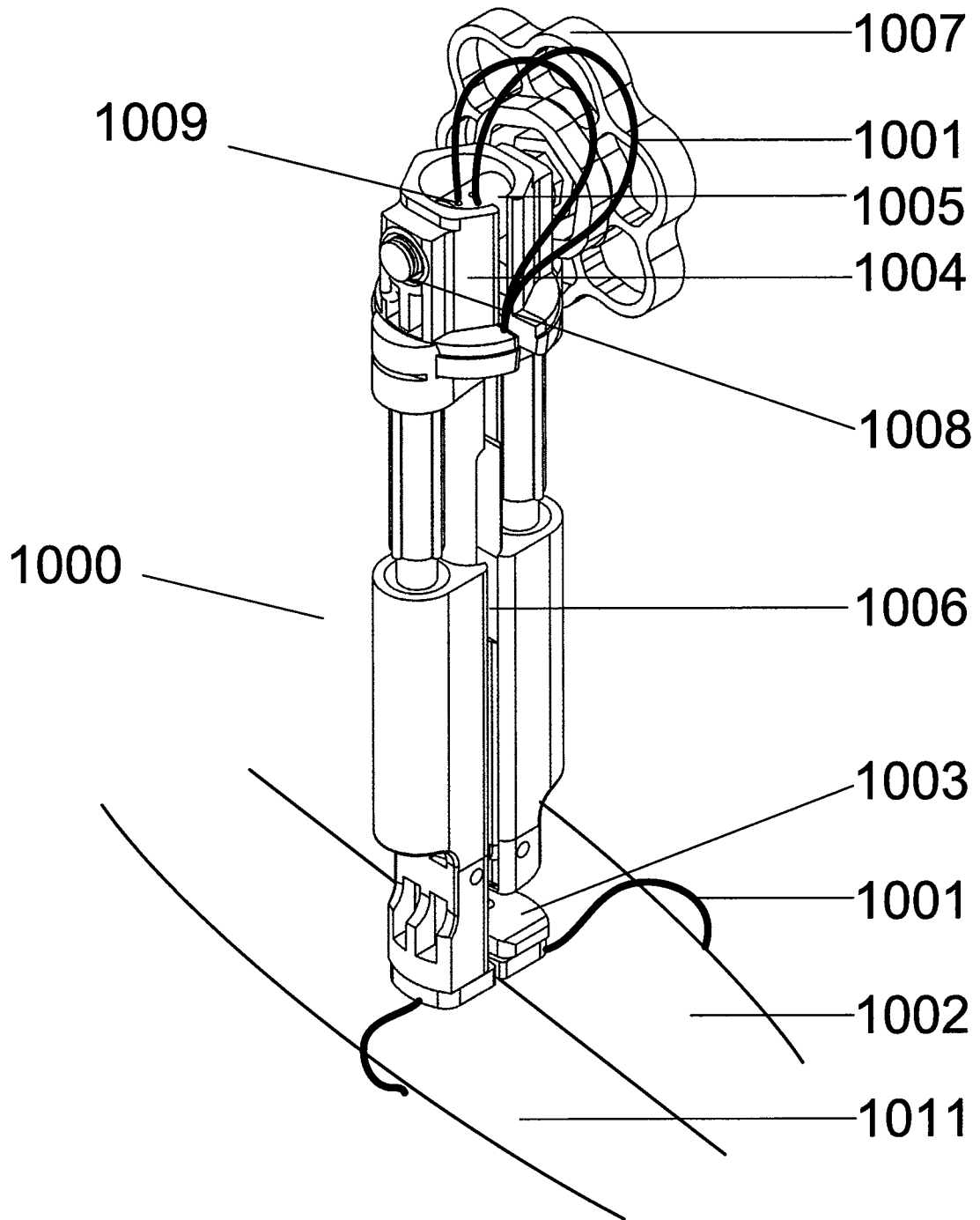


Figure 10

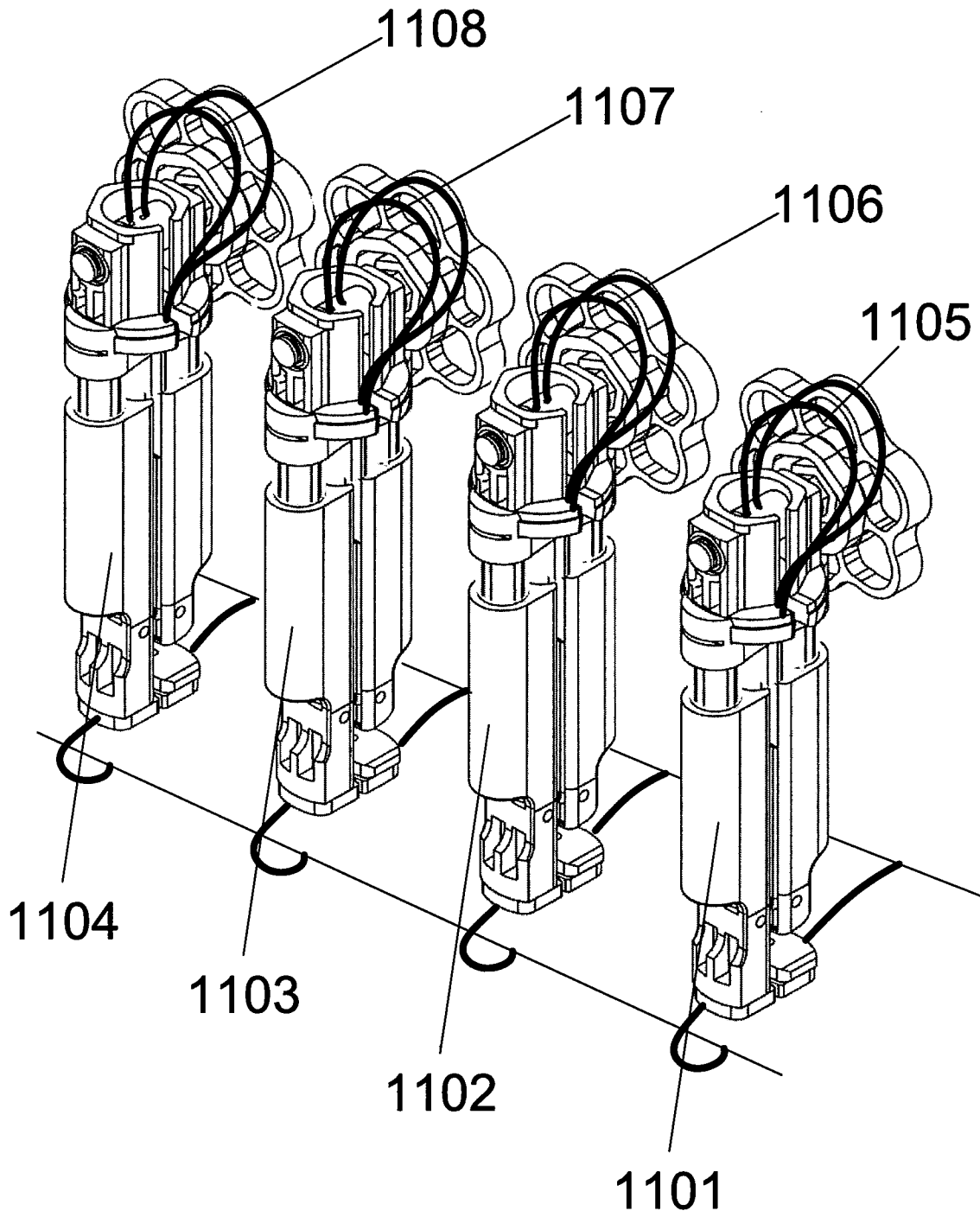


Figure 11

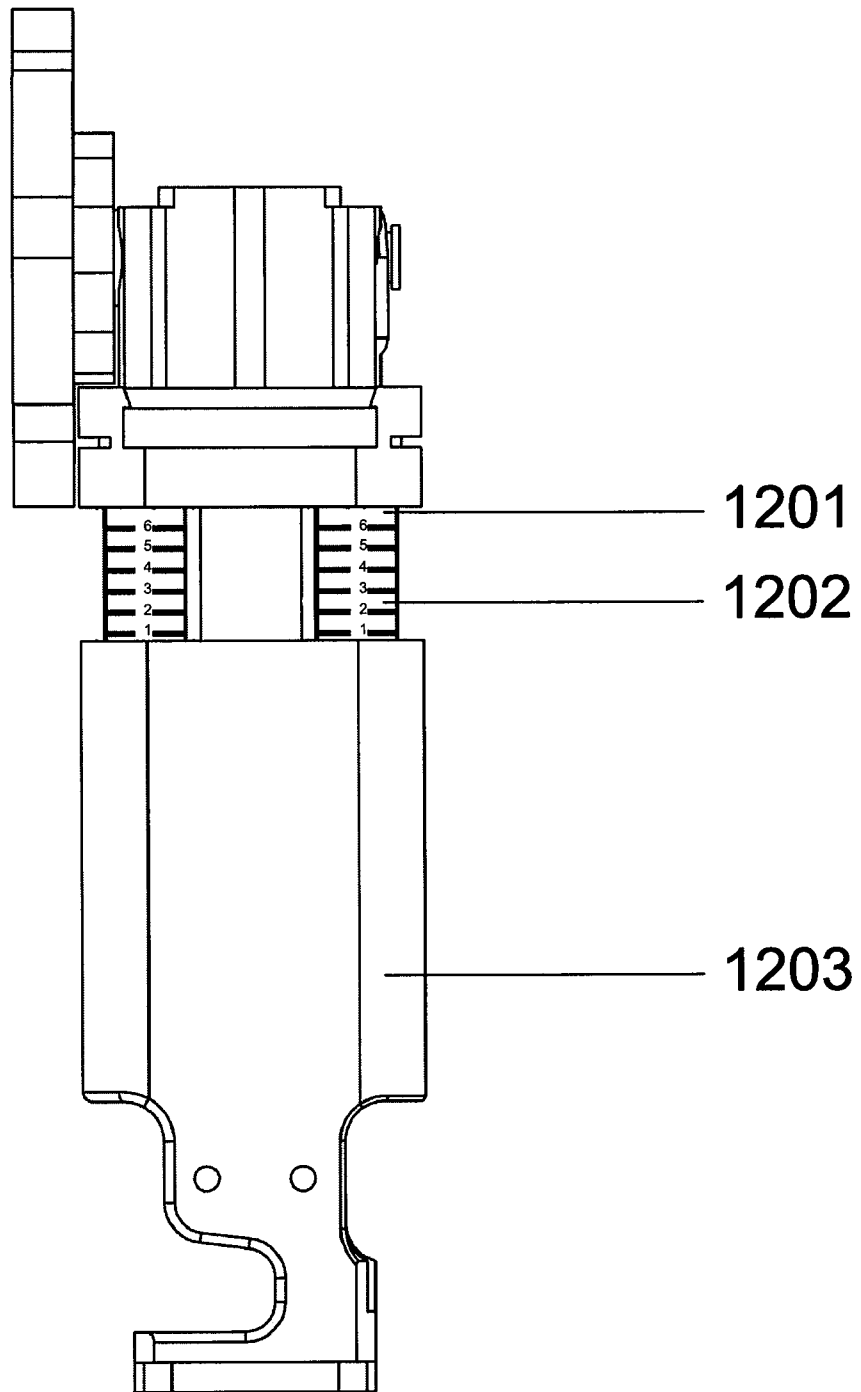


Figure 12

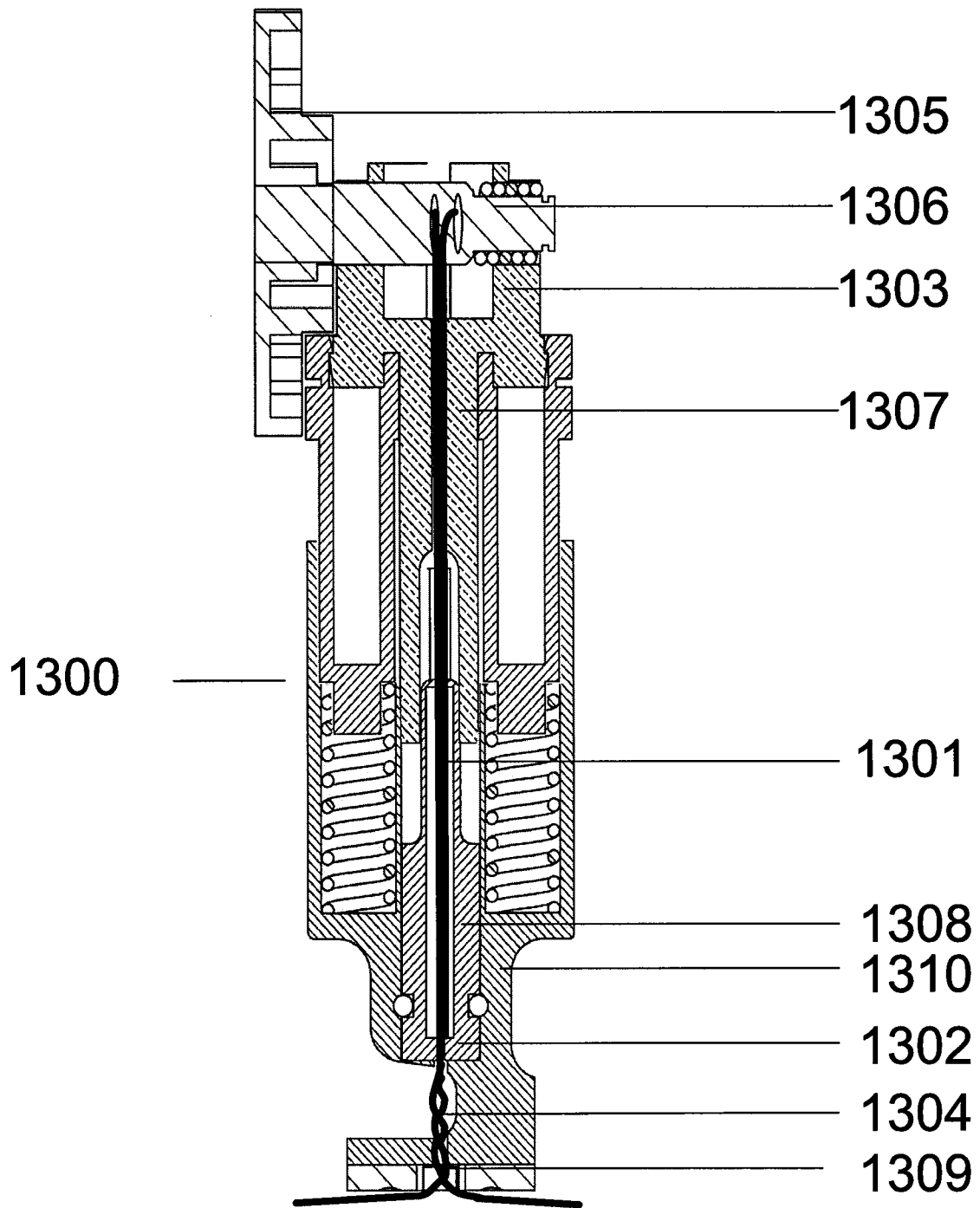


Figure 13

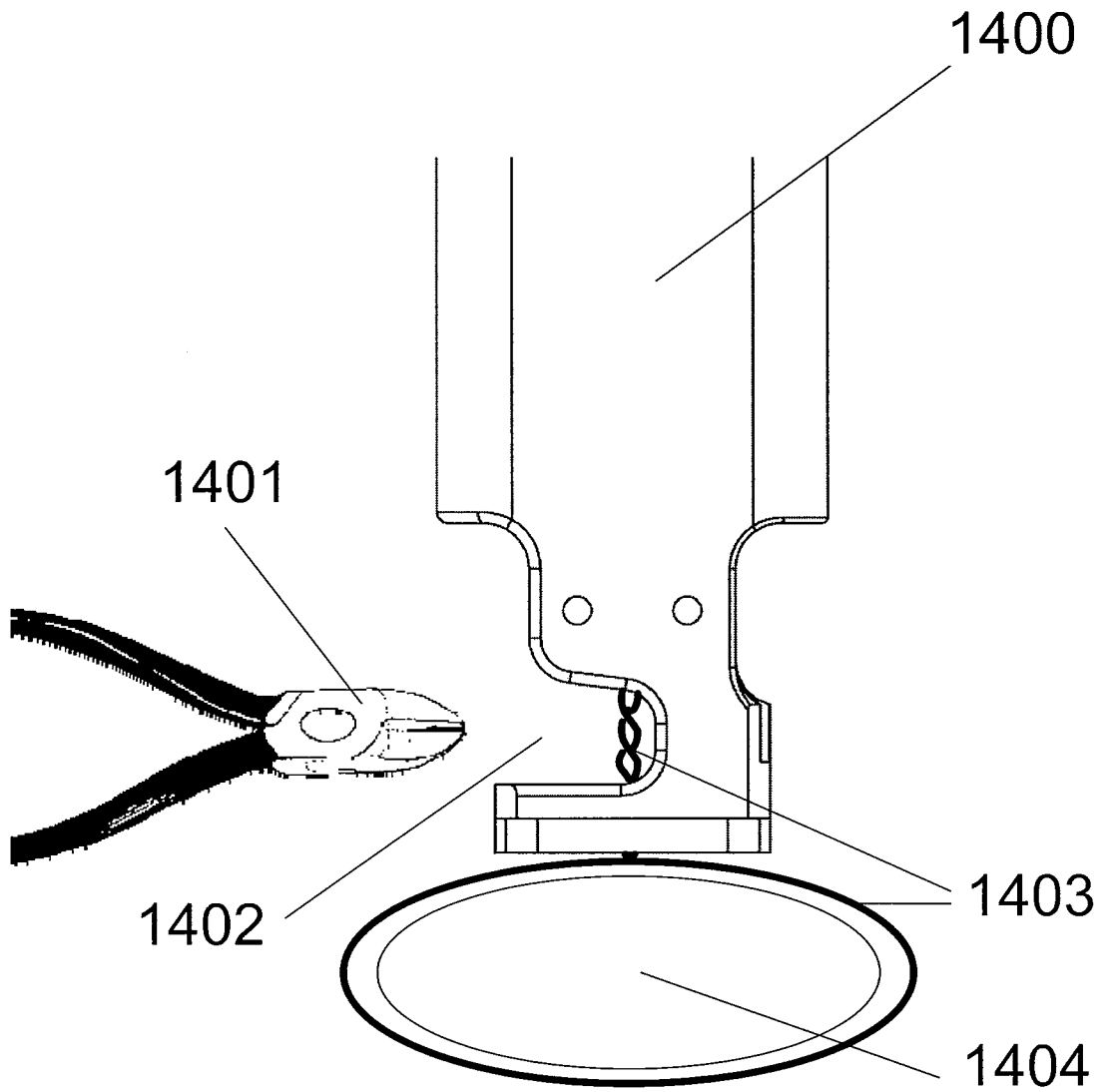


Figure 14

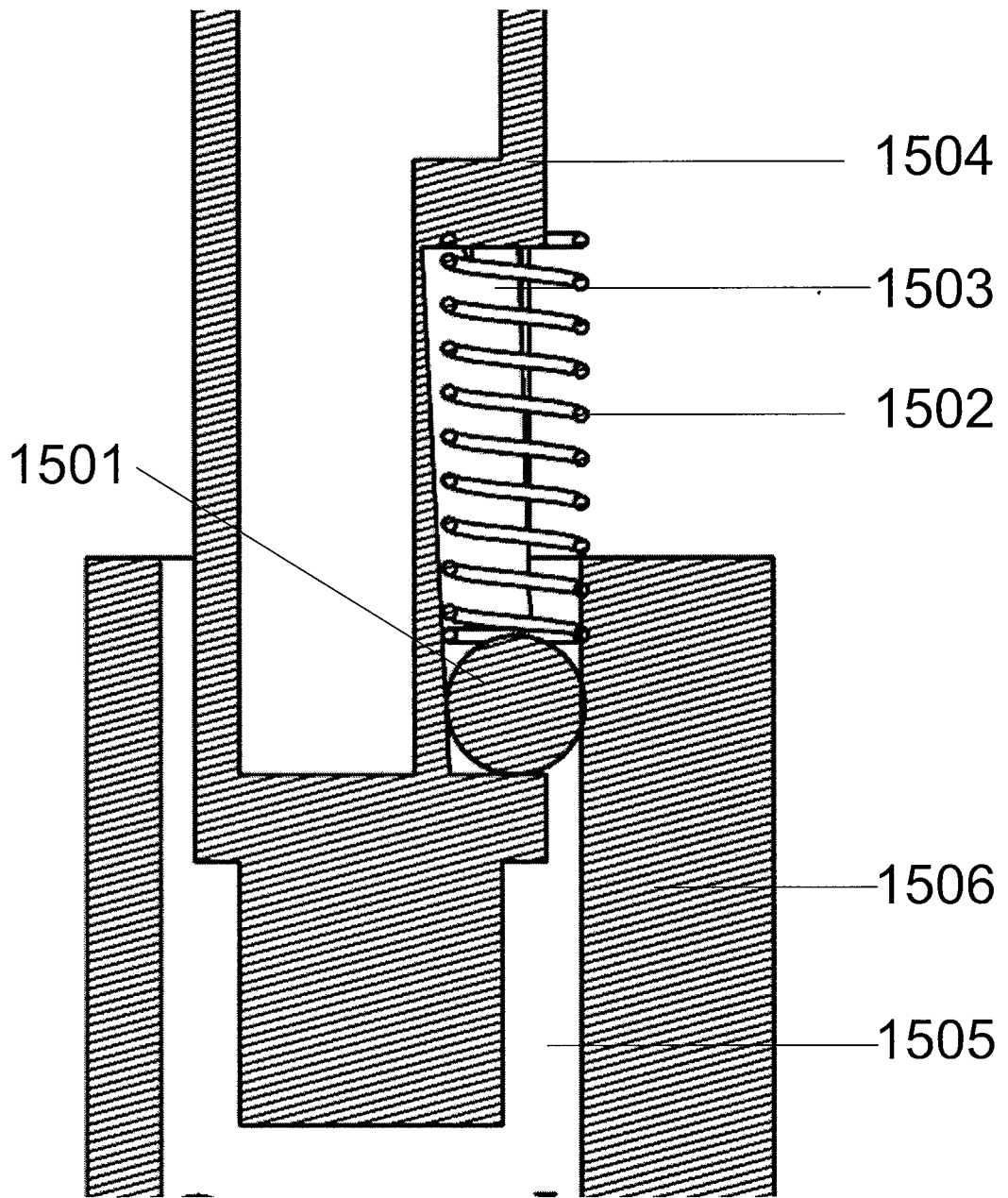


Figure 15

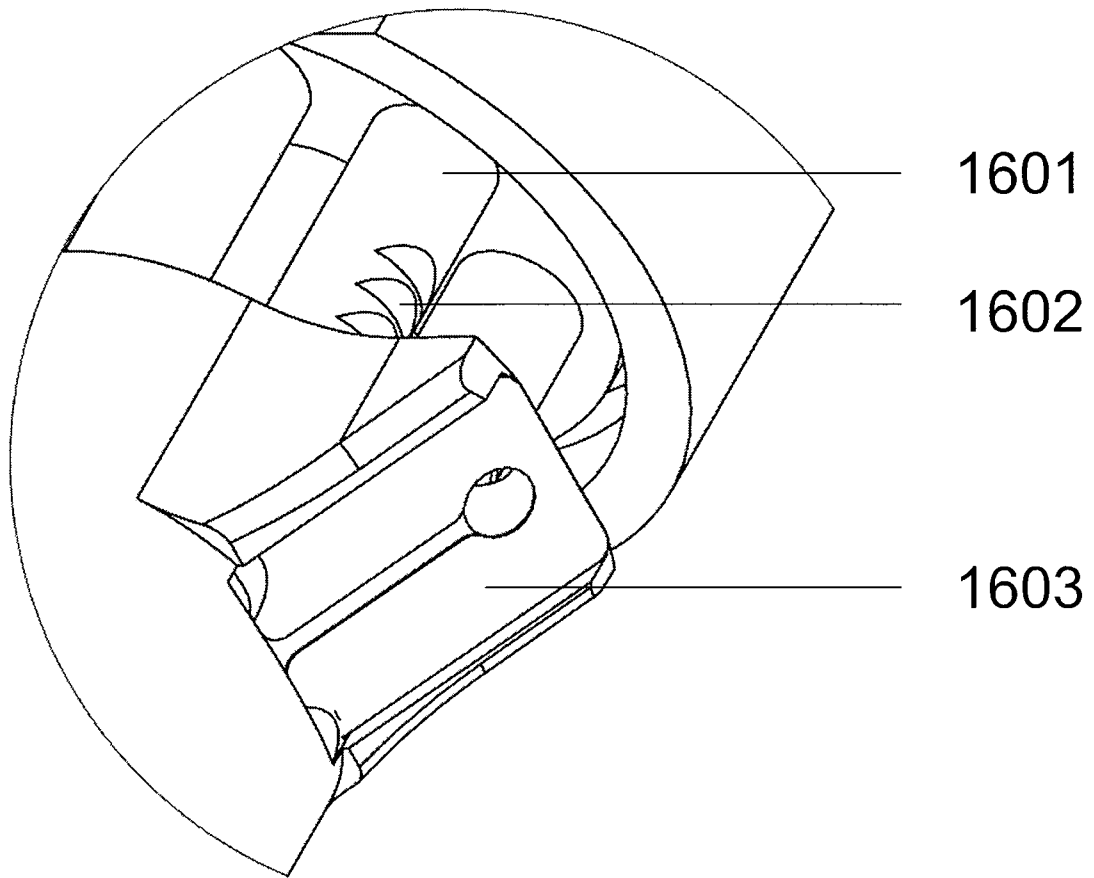


Figure 16

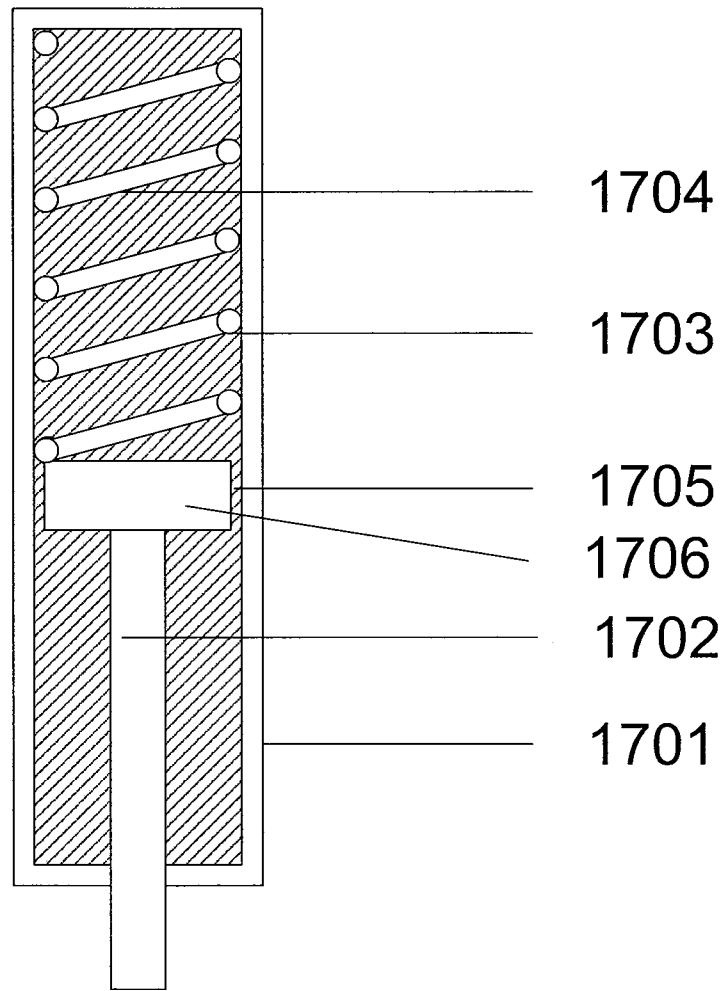


Figure 17

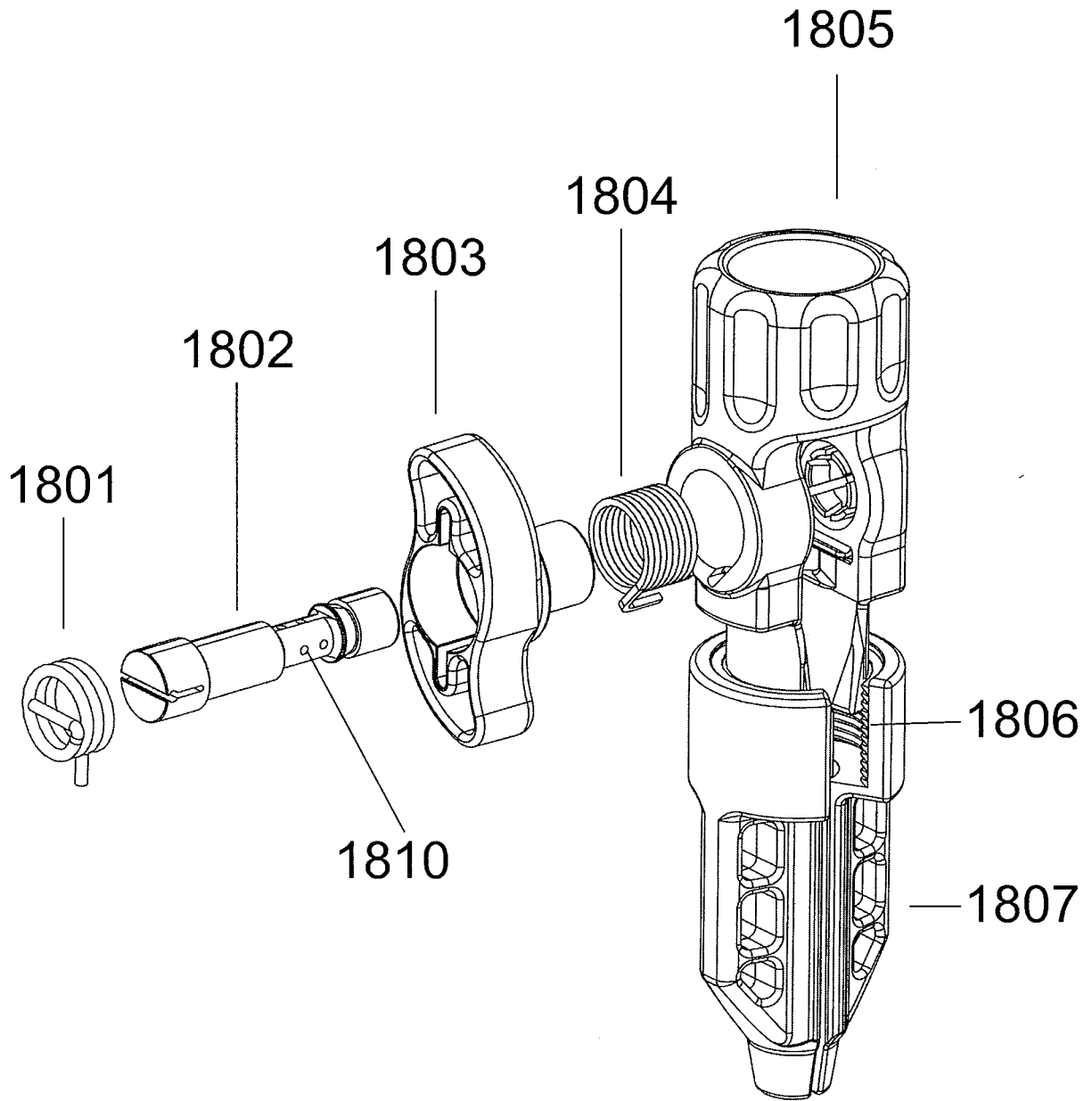


Figure 18

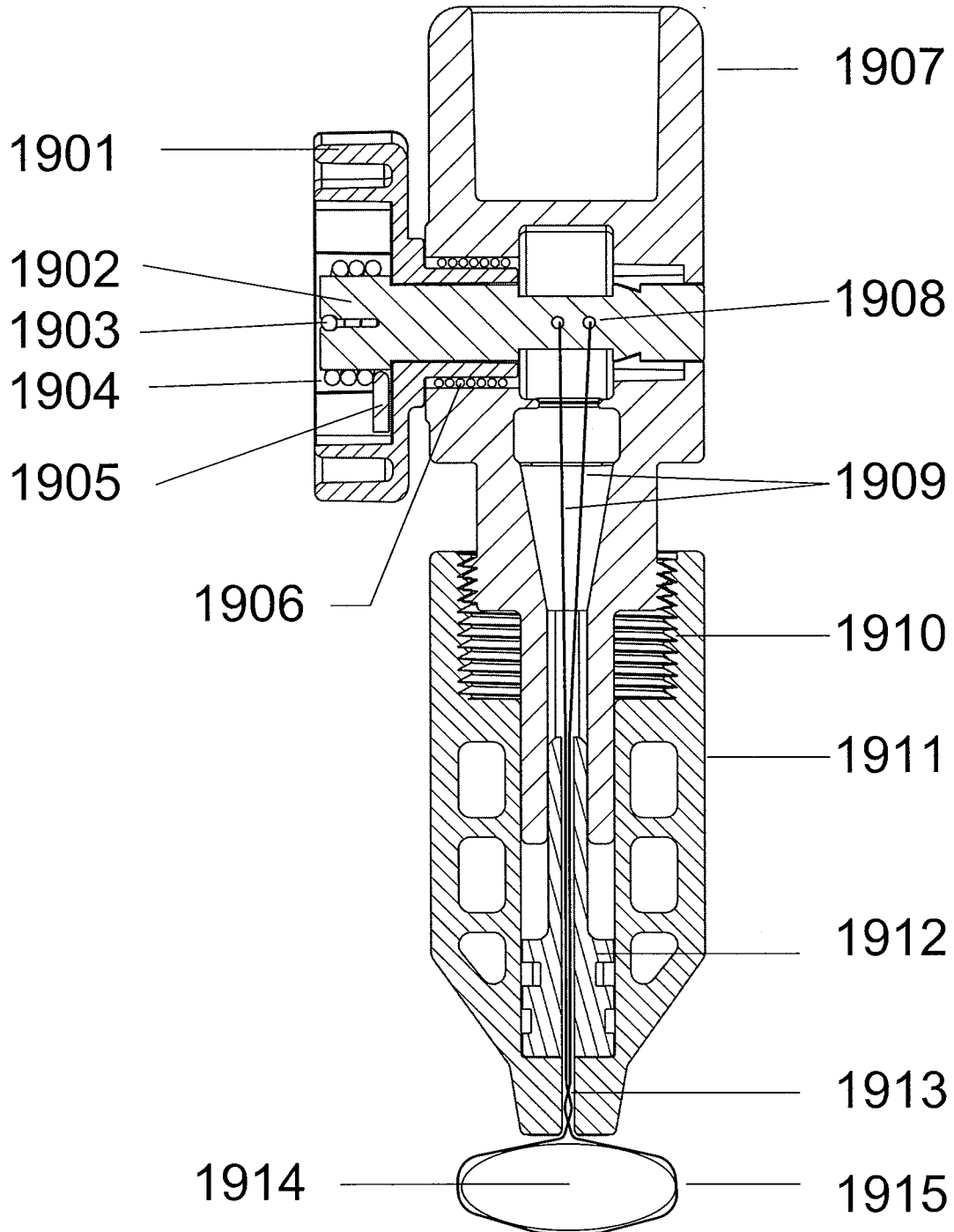


Figure 19

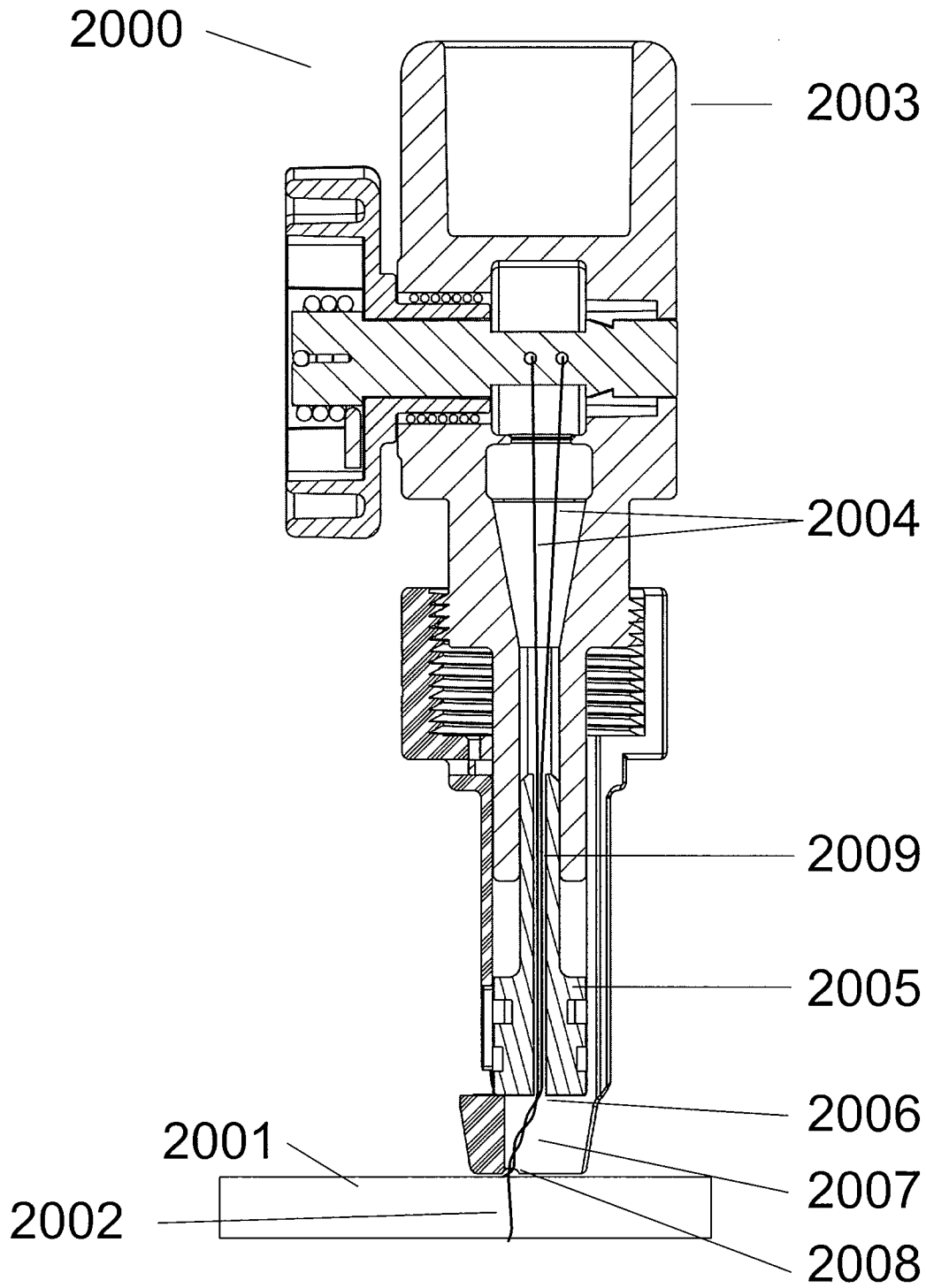


Figure 20

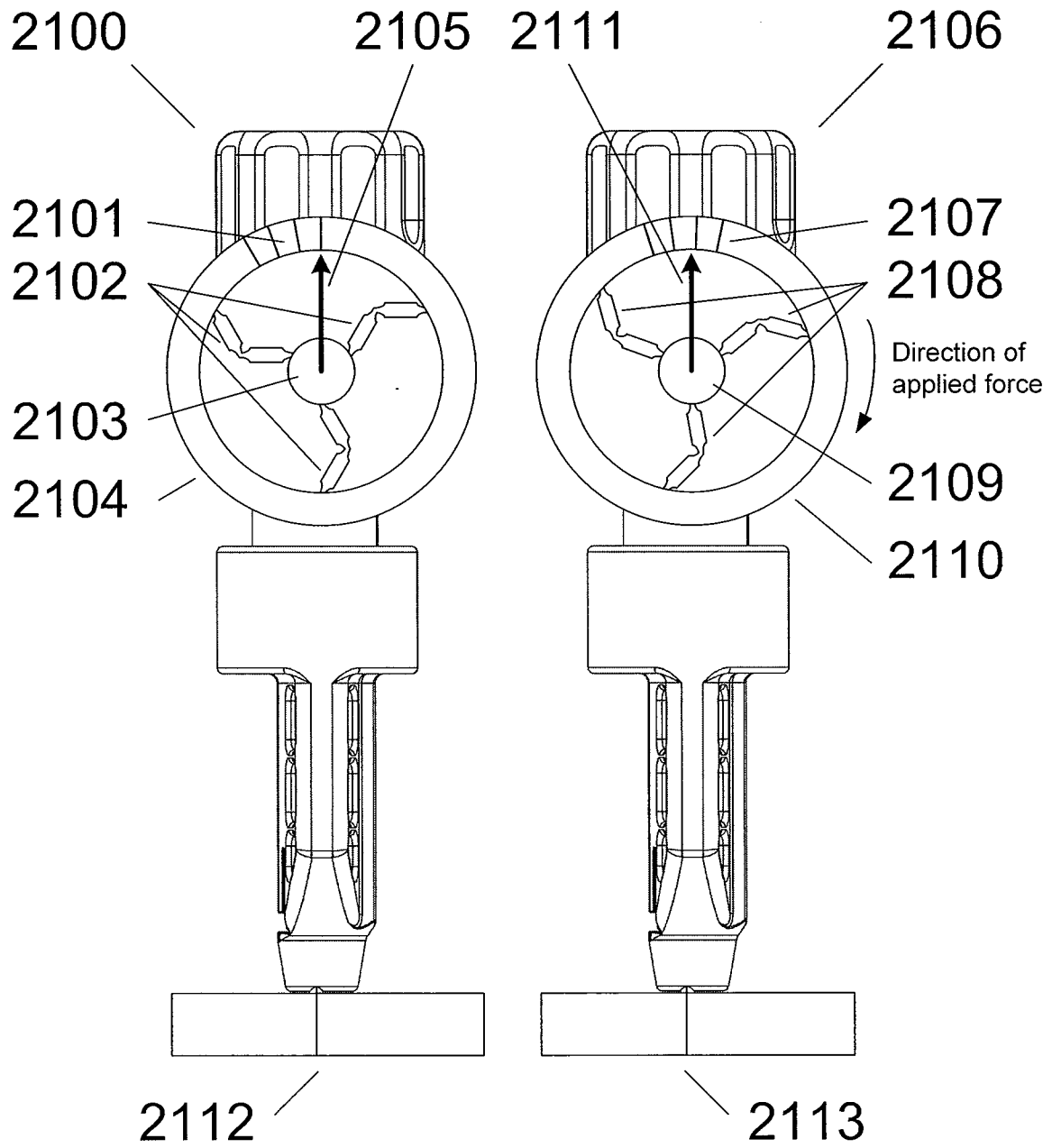


Figure 21

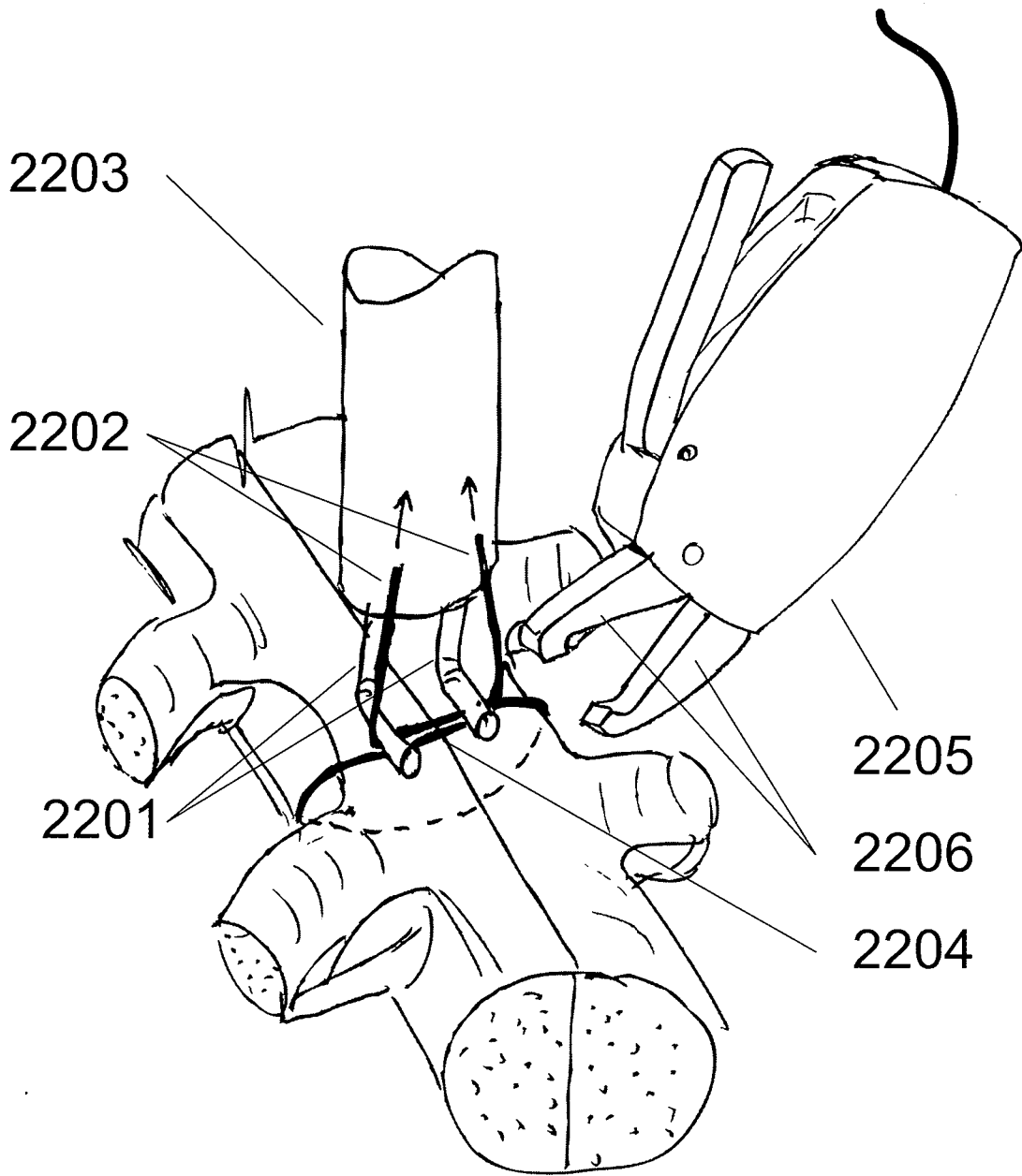


Figure 22

A. CLASSIFICATION OF SUBJECT MATTER

A61B 17/04(2006.01)i, A61B 17/06(2006.01)i, A61B 17/03(2006.01)i, A61B 17/82(2006.01)i, A61B 17/84(2006.01)i, A61B 17/58(2006.01)i, A61B 17/56(2006.01)i

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)

A61B 17/04; A61B 17/06

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: suture, tension, and twist

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008-0275477 A1 (JERRY STERRETT et al.) 06 November 2008 See paragraph 0022 - paragraph 0027; claims 1-17 and figures 1-15b	1,8,9,14
X	US 2003-0028202 A1 (GREGORY E. SANCOFF et al.) 06 February 2003 See paragraph 0039 - paragraph 0041; claim 4 and figures 1-33	24,25
A	US 2003-0208210 A1 (PETER, J. DREYFUSS et al.) 06 November 2003 See paragraph 0024 - paragraph 0032; claims 1,7 and figures 1-8	1-25
A	US 2007-0225736 A1 (MARK S. ZEINER et al.) 27 September 2007 See paragraph 0029 - paragraph 0034; claim 1 and figures 1A-6D	1-25
A	US 2008-0269785 A1 (FRED P. LAMPROPOULOS et al.) 30 October 2008 See paragraph 0025 - paragraph 0031; claim 1 and figures 1-4	1-25

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"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 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

09 SEPTEMBER 2010 (09.09.2010)

Date of mailing of the international search report

10 SEPTEMBER 2010 (10.09.2010)

Name and mailing address of the ISA/KR



Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

JEONG, Kyu Young

Telephone No. 042 481 8124



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/021835**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

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

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

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

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

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

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

The present application includes multiple groups of inventions as follows:

Group 1: claims 1-23 relating to a medical instrument to secure flexible sutures to one body part.

Group 2: claim 24 relating to a medical instrument for connecting metal wires by twisting.

Group 3: claim 25 relating to a device for for sterna closure using metal wires.

The common technical feature among groups 1-3 is readily derived from document US 2008/0275477 A1 or US 2003/0028202 A1. Therefore, groups 1-3 do not have any common special technical feature over the prior art, thereby resulting in lack of unity of invention. (PCT Rule 13.1, 13.2).

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 an additional fee, this Authority did not invite payment of any additional fee.
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.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2010/021835

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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