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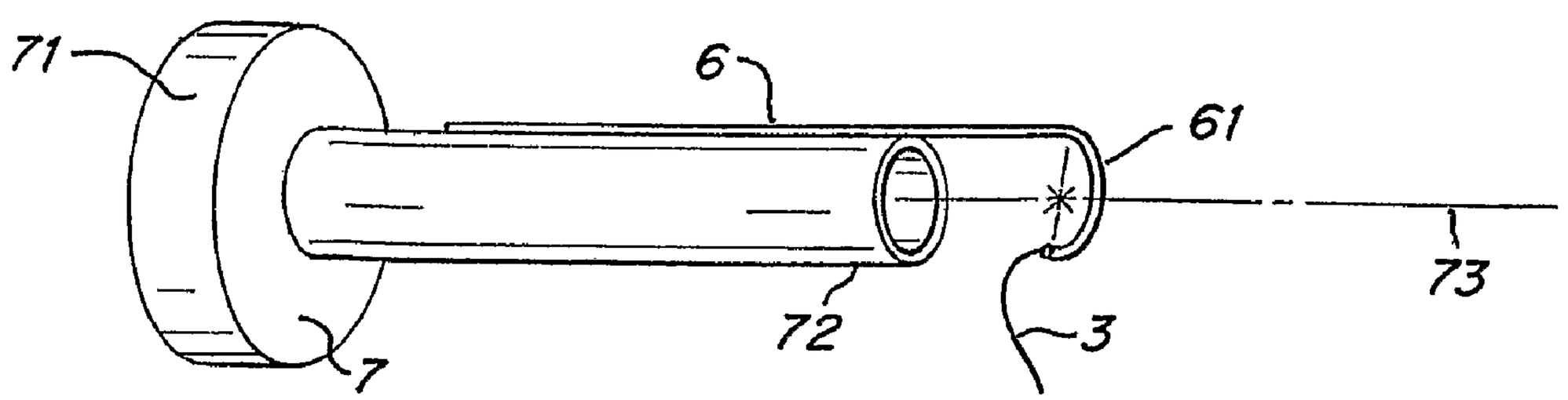

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An apparatus and method for placing a suture by manipulating a cannula and attached needle. The cannula may be usable in a minimally invasive surgical procedure, and the needle may be selectively attached to and/or separated from the cannula. The cannula and needle may include complementary locking members that engage with each other and allow the needle to be used to place a suture by manipulation of the cannula.

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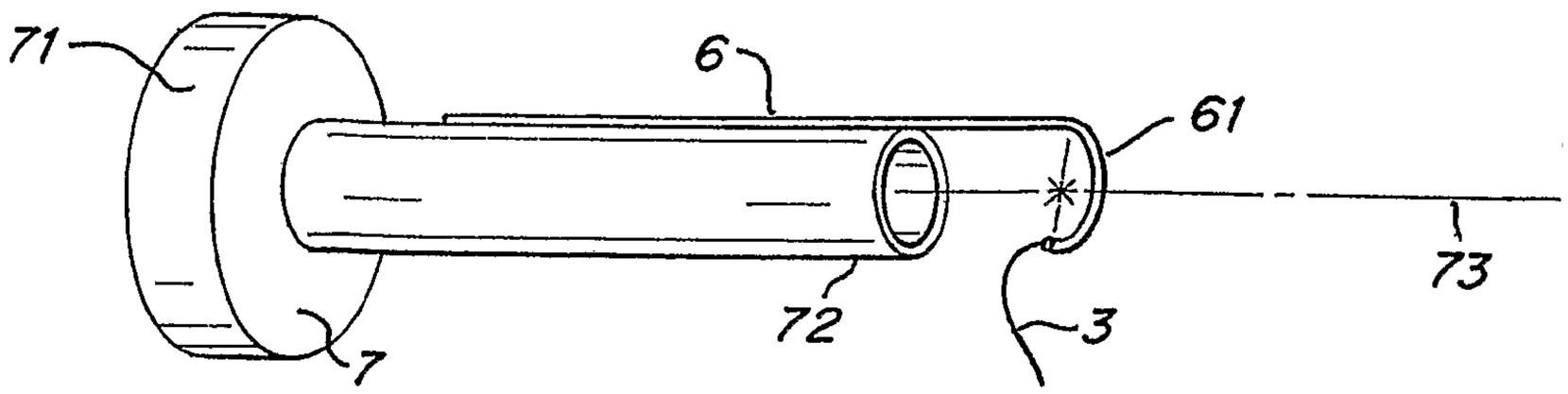

(57) Abstract: An apparatus and method for placing a suture by manipulating a cannula and attached needle. The cannula may be usable in a minimally invasive surgical procedure, and the needle may be selectively attached to and/or separated from the cannula. The cannula and needle may include complementary locking members that engage with each other and allow the needle to be used to place a suture by manipulation of the cannula.

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METHOD AND APPARATUS FOR SUTURE PLACEMENT

BACKGROUND OF INVENTION

1. Field of Invention

This invention relates to methods and apparatus for suture placement.

2. Discussion of Related Art

Surgical procedures frequently involve the placement of suture in a material, such as body tissue, a prosthetic or other medical implant or device, or combinations thereof. Many different approaches and devices have been developed for suture placement. For example, suturing instruments exist for placing sutures in body tissues or other materials. One such device is the SMARTSTITCH suturing device sold by Opus Medical of San Juan Capistrano, CA. This device may be used in an arthroscopic technique to place a mattress stitch in a rotator cuff tendon when reattaching the tendon to the humerus. The device has a set of jaws that are used to clamp the tendon, and then fire a pair of retractable needles that extend through the tendon, engage suture, and draw the suture through the tendon as the needles retract.

Fig. 1 shows a schematic diagram of a humerus 1 and a portion of a rotator cuff tendon 2 that is normally attached to the head of the humerus. In one type of damage to the rotator cuff, the tendon 2 may detach or be partially torn from the humerus 1, such as that shown schematically in Fig. 2. Such damage may be repaired by reattaching the rotator cuff tendon to the humerus 1 by a suture or other fixation so that the body's normal healing processes can naturally effect reattachment of the tendon to the bone. One repair technique for reattaching the rotator cuff 2 to the humerus 1 involves fixing an anchor 101 at a margin between the articulating portion 11 of the humerus 1 and the humerus' greater tuberosity 12. A suture 102 is secured to the rotator cuff 2, e.g., using the suturing device described above, and is secured to the anchor 101. The suture 102 is then tensioned so that the rotator cuff 2 is held in place close to the humerus 1. Thereafter, the body may reestablish the proper attachment of the rotator cuff 2 to the humerus 1.

SUMMARY OF INVENTION

In one aspect of the invention, an apparatus includes a cannula having at least one lumen and that is constructed and arranged to be used in a minimally-invasive surgical procedure. For example, such a cannula may be usable in an arthroscopic procedure when performing surgery on a shoulder or knee. A needle may be attached to the cannula and may have a tissue penetrating portion adapted to carry a suture. The needle may be manipulated by movement of the cannula to place the suture in a material. One feature that may be provided in some embodiments is to allow the cannula to be used for other additional purposes, such as visualization of the surgical site through the same cannula used to place a suture by providing an endoscopic camera in the cannula lumen. In addition, or alternately, another surgical instrument may be provided in the cannula, such as a grasping device that is used to hold a material in place while the needle is used to place a suture in the material.

In one aspect of the invention, the needle may be selectively attached to and/or separated from the cannula. For example, the cannula and needle may include complementary locking members that engage with each other and allow the needle to be used to place a suture by manipulation of the cannula. The cannula may be usable in a minimally-invasive procedure, and then the needle engaged with/disengaged from the cannula as needed.

In one aspect of the invention, there is provided an apparatus comprising: a cannula having at least one lumen and constructed and arranged to be placed in an arthroscopic portal in a minimally-invasive surgical procedure and allow an instrument including an endoscope or grasping device to be passed through the at least one lumen of the cannula and used at a surgical site in the minimally-invasive surgical procedure, the cannula having a wall with an inner surface defining the at least one lumen, a first complementary locking member arranged on an outer surface of the wall, a distal end, a proximal end, and a longitudinal axis that is generally parallel to the lumen; and a needle having a second complementary locking member that is engaged with the first complementary locking member of the cannula so the needle is removably attached to the wall of the cannula and is movable in a direction along the longitudinal axis relative to the cannula, the needle having a proximal

end that is positioned near the proximal end of the cannula and a tissue penetrating portion that is positioned distal of the distal end of the cannula, the tissue penetrating portion including a curved portion positioned in a plane transverse to the longitudinal axis, the needle carrying a suture that extends along a length of the cannula, wherein the needle and cannula are engaged such that the needle is movable to extend the tissue penetrating portion away from the distal end of the cannula and the tissue penetrating portion is manipulable by movement of the cannula to place the suture in a material, and wherein the needle is attached to the wall of the cannula such that an endoscope or grasping device is passable through the at least one lumen of the cannula and usable at a surgical site in the minimally-invasive surgical procedure with the needle attached to the wall.

Aspects of the invention provided a cannula and needle arrangement that may be used to place a stitch in a rotator cuff during a surgical repair. However, not all aspects of the invention are restricted to use in rotator cuff repair.

BRIEF DESCRIPTION OF DRAWINGS

Various aspects of the invention are described with reference to illustrative embodiments, wherein like numerals reference like elements, and wherein:

FIG. 1 is a schematic diagram of a head of a humerus and attached rotator cuff tendon;

FIG. 2 shows a prior art technique for repairing a rotator cuff injury;

FIG. 3 is a schematic diagram of a tissue repair arrangement in accordance with an aspect of the invention;

FIGS. 4 - 6 show the use of a needle for placing a suture in a tissue in accordance with the invention;

FIG. 7 shows a needle in engagement with a cannula in accordance with an aspect of the invention;

FIG. 8 shows an illustrative arrangement for engaging a needle with a cannula in one embodiment;

FIG. 9 shows an illustrative arrangement for engaging a sleeve and needle assembly with a cannula in accordance with another embodiment;

FIG. 10 shows a guide apparatus used in forming a passageway in accordance with the invention;

FIG. 11 shows the use of a guide apparatus for passing a suture or other element through a transosseous passageway in accordance with the invention;

FIG. 12 shows a technique for passing a suture placed in a tissue through a passageway;

FIG. 13 shows the engagement of a suture with a suture fixation device in accordance with the invention;

FIG. 14 shows the placement of a suture fixation device relative to the bone in accordance with the invention;

FIG. 15 shows a suture fixation device engagement tool in engagement with a suture fixation device in accordance with the invention; and

FIGS. 16A-B and 17A-B show side and rear views, respectively, of illustrative embodiments of suture fixation devices in accordance with the invention.

DETAILED DESCRIPTION

This invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

Various aspects of the invention are described below with reference to specific embodiments. For example, aspects of the invention are described in the context of performing a rotator cuff repair. However, it should be understood that aspects of the

invention are not necessarily restricted to rotator cuff repair techniques, or even to surgical techniques performed on a shoulder. Rather, various aspects of the invention may be used in any suitable surgical procedure. Also, aspects of the invention are described in a procedure involving the formation of a transosseous passageway, securing a suture in the passageway, etc. However, it should be understood that aspects of the invention, such as aspects relating to a cannula and attached needle, may be used in any surgical procedure, such as a rotator cuff repair that involves the use of an anchor like that shown in Fig. 2.

Various aspects of the invention may be used in an open surgical procedure or in a closed or minimally-invasive procedure, such as an arthroscopic procedure. Also, various aspects of the invention may be used in any suitable surgical or other procedure involving any suitable body portions, such as bone, muscle, skin, vascular structures, digestive structures or other tissue, implants, mesh, or other medical devices, etc. Aspects of the invention may be used alone, and/or in combination with any other aspects of the invention.

In another aspect of the invention, a needle used to place a suture in a material, such as a rotator cuff tendon and/or implant, may be engaged with a cannula, such as an arthroscopic cannula. Thus, the needle may be operated to place the suture by manipulating the cannula. The needle and cannula may have complementary locking members or otherwise arranged so that the needle may be selectively engaged with the cannula. Thus, the cannula may be usable as a standard arthroscopic cannula, and if needed, may be engaged with the needle. Thereafter, the needle and cannula may be used to place the suture in the selected tissue.

FIG. 3 shows a schematic diagram of a surgical repair in accordance with aspects of the invention. As discussed above, although aspects of the invention are described with reference to a rotator cuff repair for ease of reference and understanding, aspects of the invention may be used in any surgical or other procedure, and may involve any suitable body portions, such as bone, muscle, other tissue or combinations thereof, the brain, medical implants or other devices, etc. Thus, aspects of the invention are in no way limited to the specific embodiments and examples described herein.

In this illustrative embodiment, a rotator cuff tendon 2 is secured by a suture 3 relative to a humerus 1. The suture 3 is placed in the tendon 2, for example, using a

mattress stitch or other arrangement, and is passed through a passageway 5 formed through the humerus 1. In this embodiment, the passageway 5 is formed by first and second intersecting holes. A first hole 51 is formed vertically as shown in Fig. 3 from a first opening at or near a margin between the articulating surface 11 and the greater tuberosity 12 of the humerus 1. The second hole 52 is formed horizontally as shown in Fig. 3 from a lateral position on the humerus 1. The suture 3 is secured at the second opening of the second hole using a suture fixation device 4 that is positioned adjacent the second opening. Although in this embodiment the first and second holes 51 and 52 are arranged at approximately right angles, the first and second holes may be arranged at any suitable angle and may be colinear (i.e., at a 180 degree angle relative to each other).

A wire, other material or the suture 3 may be manipulated in the passageway 5 so as to cut through or crush the relatively soft cancellous bone of the humerus in the passageway 5 so that the suture follows a relatively straight path between the first and second openings into the first and second holes 51 and 52. The relatively straight pathway may be formed by a "flossing" operation, such as by using a wire that is passed through the passageway 5 and is manipulated, e.g., tensioned and reciprocally drawn between the first and second openings, so as to cut through or crush the cancellous bone, thereby forming a relatively straight path for the suture 3.

When deciding where to locate the first hole 51 for the passageway 5, a surgeon often will wish to first determine the final position for the tissue relative to the bone. To do so, the surgeon may wish to place a suture in the tendon 2 and tension the suture 3 (and thus the tendon 2) so that a desired position for the first hole 51 may be determined, e.g., based on the position of the tendon 2 relative to the bone when under tension.

In one aspect of the invention, use of a needle having a hook-shaped or curved end portion may be preferred. Figs. 4-6 show an embodiment of a needle 6 having a hook-shaped tissue penetrating portion 61 at a distal end in accordance with the invention. In the illustrated embodiment, the tissue penetrating portion 61 of the needle 6 has a semi-circular shape and is arranged at an angle, such as 90 degrees to a longitudinal axis of a straight portion 62 of the needle 6. The needle 6 may be formed as a hollow tube so that the suture 3 may pass through the needle 6. Suture may be loaded in the hollow portion of the needle 6 before the surgical procedure is begun, e.g., at the time of manufacture of the needle, or at any suitable time, such as during the surgical

procedure. In some cases, the suture may be fed into the hollow portion of the needle 6 before the tissue penetrating portion 61 is formed, e.g., by bending a tube to form a curved end shape.

The arrangement of the needle 6 may allow placement of a mattress stitch in the tissue 2 by rotating the needle as shown in Figs. 4-6 so that a tip of the tissue penetrating portion 61 passes through a top side of the tissue 2 and exits from a bottom side of the tissue 2 as shown in Fig. 5, and then passes upwardly through the tissue 2 to reemerge at a top side of the tissue 2 as shown in Fig. 6. At this point, the suture 3 extending from the tip of the tissue penetrating portion 61 may be grasped, such as by forceps or other gripping device, and the needle 6 may be rotated in reverse so as to again position the needle 6 as shown in Fig. 4, thereby leaving the suture 3 positioned in the tissue 2 to form a mattress stitch. Of course, the needle 6 may be used to place a suture in any material, including a tissue, such as a tendon as shown, a prosthetic or other surgical implant, etc. During the passage of the suture, the tissue or other material may be held in place, or may be manipulated, by a grasper or other device inserted into the lumen of the cannula. The tissue or other material may also be held in place, or manipulated, by another device, such as a grasper or clamp positioned external to the cannula.

The tissue penetrating portion 61 of the needle 6 may have any suitable shape and may be arranged in a plane that is transverse at any angle to an axis of rotation of the tissue penetrating portion 61 when placing a suture in tissue. That is, although in the illustrated embodiment the tissue penetrating portion 61 has a semi-circular form that lies in a plane at 90 degrees to the rotation axis of the tissue penetrating portion 61 when placing a suture, the tissue penetrating portion 61 need not have a semi-circular form and may lie at any desired angle to the rotation axis. For example, the tissue penetrating portion 61 may be arranged so as to place an inclined mattress stitch in a tissue 2. Further, the needle 6 need not be used only to form a mattress stitch, but rather may be used to form any other suitable stitch type. Also, it is not necessary that the tissue penetrating portion 61 of the needle 6 include a portion that lies in a single plane. Instead, the tissue penetrating portion 61 may not lie in a single plane, e.g., may have a corkscrew-type or partially helical configuration.

In one aspect of the invention, all or portions of a tissue repair procedure may be performed arthroscopically. In this case, and as is known in the art, one or more

cannulas may be provided in one or more portals formed in the patient so as to provide access to the operative site. In one aspect of the invention, a needle used to place a suture in a tissue, such as the needle 6 shown in Fig. 4, may be used in an arthroscopic procedure. For example, the needle 6 may be secured to a cannula so that the needle may be operated by manipulation of the cannula.

Fig. 7 shows an illustrative embodiment of a needle 6 that is secured to a cannula 7. The cannula 7 may have any suitable features found in cannulas used for closed or minimally-invasive surgical techniques, such as one or more valves to resist fluid flow through the cannula 7, an opening through which to introduce a fluid pressure or vacuum, spiral threads or other features on the cannula to aid in placement of the cannula in a portal and/or to help prevent inadvertent removal of the cannula from the portal, and so on. The cannula 7 may be arranged for any type of procedure, such as arthroscopic procedures.

The needle 6 may be secured to the cannula 7 in any suitable way. For example, the needle 6 may be molded into the body of the cannula 7, inserted into the wall of the cannula, may be secured by adhesive, welding, clamps, fasteners, interlocking channels, open channels, or any other suitable device. A proximal end of the needle 6 may terminate at any suitable point, such as midway between a proximal end 71 and a distal end 72 of the cannula 7 as shown, or, more preferably at a position proximal to the proximal end 71. By having the proximal end of the needle 6 positioned proximally of the cannula 7, a user may be better able to access the suture 3 entering the proximal end of the needle 6. The needle 6 may also be axially movable relative to the cannula, e.g., so that the tissue penetrating portion 61 may be moved axially so as to extend away from or toward the distal end 72 of the cannula 7. In addition, although the needle 6 is shown as positioned on an outer surface of the cannula 7, the needle 6, or at least a portion thereof, may be molded into the cannula 7, positioned within the cannula lumen, positioned in the cannula wall, may be arranged within a groove on the outer surface of the cannula, and so on. Although the needle 6 is shown as arranged in an approximately straight fashion along the length of the cannula 7, the needle 6 may be bent, curved or arranged in any suitable way, such as following a spiral path around an outer surface of the cannula 7.

In one illustrative embodiment, a semicircular-shaped tissue penetrating portion 61 of the needle 6 may be arranged relative to the cannula 7 so that a centerpoint of the semicircle lies on a central longitudinal axis 73 of the cannula lumen. Thus, when the cannula 7 is rotated about the central longitudinal axis 73, the tissue penetrating portion 61 may travel in a circular or arc-shaped path about the axis 73. However, it should be understood that the tissue penetrating portion 61 may be arranged in any suitable way relative to the axis 73. Further, a plane in which the tissue penetrating portion 61 lies (if present) may be arranged at any angle transverse to the axis 73, and thus need not be arranged at an angle of 90 degrees to the axis 73, as shown in Fig. 7.

In one aspect of the invention, the needle 6 may be removeably engaged with the cannula 7 so that the needle 6 can be selectively engaged or disengaged with the cannula 7. For example, a cannula 7 may be positioned in a portal in use during a surgical procedure without an attached needle 6. At some point during the procedure, the surgeon may wish to attach a needle 6 to the cannula 7 and manipulate the cannula 7 so as to use the needle 6 to place a suture in a material. The needle 6 may be secured to the cannula while the cannula remains in place in the portal (e.g., by inserting the needle 6 into the cannula lumen), or the cannula may be removed from the portal, the needle attached, and the cannula and attached needle inserted into the portal.

By attaching a needle to a cannula like that shown above, the cannula lumen may remain available for use with other instruments, such as an endoscope, grasper or other surgical instrument. However, in some embodiments the cannula lumen may not remain open for other use, such as if the needle is secured to a cylindrical plug that is inserted into, and completely or partially blocks, the cannula lumen when the needle is engaged with the cannula.

Fig. 8 shows one illustrative embodiment in which a needle 6 may be removably secured to a cannula 7. In this embodiment, the cannula 7 includes a dovetail-shaped groove 74 into which a correspondingly shaped portion of the needle 6 is inserted. The complementary locking arrangement used by the cannula 7 and the needle 6 need not necessarily be dovetail-shaped as shown in Fig. 8, but rather may have any suitable arrangement. For example, the cannula 7 may have an oval-shaped groove that extends into the wall of the cannula 7, and the needle 6 may have a complementary oval shape that engages with the groove. Thus, the needle 6 may be selectively secured to the

cannula 7 so that rotation (e.g., about a longitudinal axis of the cannula lumen) or other manipulation of the cannula 7 can cause the needle to be manipulated so as to place a suture in a material. The complementary locking arrangement between the needle 6 and the cannula 7 may also allow for axial movement of the needle 6 relative to the cannula 7, e.g., so the tissue penetrating portion 61 can be moved relative to the distal end 72 of the cannula 7.

Fig. 9 shows an alternative embodiment in which a needle 6 is fixed to a sleeve member 63 that has one or more complementary locking features that mesh with or otherwise engage with complementary features on the cannula 7. In this embodiment, the complementary locking features have a tooth-like or gear-like form, but the complementary locking features may be arranged in any suitable way. Accordingly, in this embodiment, the needle 6 may be secured to the cannula 7 by sliding the sleeve 63 over the distal end 72 of the cannula 7. It will be understood that rather than having a sleeve 63 that fits over the cannula 7, the sleeve 63 may fit within the internal lumen of the cannula 7, or within a slot in the cannula 7, if desired.

Once a suture is placed in the tissue, such as a rotator cuff tendon, the tissue may be tensioned to determine a location for the opening of the first hole 51 to be formed in the bone. When performing a rotator cuff repair, typically, a first hole 51 of the passageway 5 will be formed vertically from a superolateral position so that the first hole 51 is generally aligned along the length of the humerus 1 and extends into the bone from an opening formed at the margin between the articulating surface 11 and the greater tuberosity 12. This first hole 51 may be formed using a perforator, such as a drill, awl, punch or other suitable device. As with other procedures performed, the first hole 51 may be formed using an arthroscopic portal at a superolateral position, or may be formed in an open surgical procedure.

In accordance with an aspect of the invention, a guide apparatus may be used to form the first and/or second holes of the passageway (e.g., used to locate a starting point or opening for the first and second holes, used to orient a bone perforator when making the holes, or used alone to form the first and/or second holes), or may be used to help feed a suture or suture-like material through the passageway. For example, a first guide member 81 may be secured relative to the first hole 51, as shown in Fig. 10. The first guide member 81 may be part of a guide apparatus 8 used to guide the formation of holes

used to form a passageway in bone and/or to pass a suture or other material through the passageway. In the illustrated embodiment, the first hole 51 has been formed in a vertical direction along the length of the humerus 1, e.g., by drilling the hole in a freehand manner. (Alternately, the first hole 51 may be formed by forcing the first guide member 81 into the bone as with an awl or similar instrument.) The first guide member 81 may include a feature to help secure the first guide member 81 relative to the first hole 51, such as a threaded distal end that allows the first guide member 81 to be screwed into the bone to a desired depth in the first hole 51. It should be understood, however, that the distal end of the first guide member 81 need not be threaded, but instead may unthreaded and inserted into the first hole 51. Alternately, the distal end of the first guide member 81 may be positioned outside of, but adjacent to, the first hole 51 so that a lumen in the first guide member 81 aligns with the first hole 51. The first hole 51 may be formed so as to be deeper than thought to be needed, e.g., 0.5 cm deeper than a hole depth believed to be required. This overdrilling of the first hole 51 may allow for more flexibility in positioning the first guide member 81 to a desired depth in the bone.

The first guide member 81 may be arranged with respect to a reference structure 83 used to position first and second guide members 81 and 82 relative to each other with respect to the passageway 5, as is discussed in more detail below. In this illustrative embodiment, the reference structure 83 is arranged so that the first and second guide members 81 and 82 are positioned at a 90 degree angle relative to each other when engaged with the reference structure 83. However, the reference structure 83 may be arranged in any suitable way so as to orient the first and second guide members 81 and 82 at any desired angle relative to each other, including arranging the first and second guide members 81 and 82 in a co-linear fashion. Further, the reference structure 83 may be made so as to be adjustable, thereby allowing the orientation of the first and second guide members 81 and 82 to be changed. For example, the arc-shaped connecting portion of the reference structure 83 may be made so as to be adjustable in length, e.g., having one arc-shaped portion sliding relative to another arc-shaped portion to allow adjustment of the length of the connecting portion. Alternately, or in addition, engagement portions 84 and 85 of the reference structure 83 that engage with the first and second guide members 81 and 82 may be adjustable in orientation relative to the arc-shaped connecting portion. In short, the reference structure 83 may be arranged in any

suitable way so as to allow adjustment in the orientation of the guide members 81 and 82.

In this illustrative embodiment, the engagement portions 84 and 85 include sleeves that receive at least a portion of the guide members 81 and 82, e.g., the guide members 81 and 82 may be received in bores in the sleeves. The sleeves may be arranged so that the guide members 81 and 82 are movable linearly along their longitudinal axes and rotationally about their longitudinal axes relative to the engagement portions 84 and 85, but otherwise may be relatively restricted in their range of movement. When a stop on the first guide member 81, such as a knob 811 on the proximal end of the guide member 81, contacts an engagement surface on the reference structure, such as a portion of the engagement portion 84, the second guide member 82 may be positioned by the reference structure 83 so that its longitudinal axis passes a point adjacent the extreme distal end of the first guide member 81. Thus, the second guide member 82 may be used to guide the use of a perforator 9 (such as a drill, punch, awl or other bone perforating device) so that the perforator 9 forms a second hole 52 that intersects with the first hole 51 at a location adjacent the distal end of the first guide member 81. As discussed above, the guide member 82 may guide the movement of the perforator 9, e.g., guide the movement of a drill or punch inserted into a lumen of the guide member 82 as shown, or may guide a starting location for forming the second hole, e.g., be used to mark or otherwise determine a starting location for the perforator 9, but otherwise not interact with the perforator 9. By adjusting the depth of the first guide member 81 in the first hole 51, the location where the second hole 52 is formed can be adjusted in position (e.g., in a vertical direction as shown in the figures). For example, by screwing the first guide member 81 into or out of the first hole 51, a surgeon may select a location where the second hole 52 is to be formed in the bone.

In another embodiment, the engagement portion 85 may itself function as a perforator guide with the second guide member 82 being withdrawn from the engagement portion 85. Although in this illustrative embodiment the engagement portions 84 and 85 are shown as relatively short cylindrical sleeves, the engagement portions 84 and 85 may be arranged in any suitable way, e.g., may be elongated so as to more closely approach the humerus 1 and provide improved guidance for a perforator 9 and/or the first and second guide members 81 and 82. Further, the first guide member 81

may be arranged so that is rotationally movable about its longitudinal axis relative to the reference structure 83, but is otherwise held by the engagement portion 84 so that the first guide member 81 is not movable axially. This may aid is appropriately positioning the first guide member 81 and reference structure 83 when forming the second hole 52.

Upon formation of the second hole 52, the second guide member 82 may be screwed into the second hole 52 until a stop on the second guide member 82, such as a knob 821 at a proximal end of the guide member 82, contacts an engagement surface on the engagement portion 85, such as a portion of the sleeve. In this configuration shown in Fig. 11 (stops on the first and second guide members 81 and 82 engaged with respective engagement surfaces on the reference structure 83), the extreme distal ends of the first and second guide members 81 and 82 may be adjacent to each other in the passageway 5 formed by the first and second holes 51 and 52. Accordingly, a surgeon may be assured that if the first and second guide members 81 and 82 are positioned within the bone and stops on the guide members 81 and 82 are respectively in contact with appropriate engagement surfaces on the guide apparatus 8, the extreme distal ends of the guide members 81 and 82 will be positioned adjacent each other. Thus, the surgeon may be assured that a wire 10 or other element may be fed into one of the guide members and retrieved from the other of the guide members, e.g., using a retriever 21 having a hook at a distal end. Such an arrangement may be advantageous when using the guide apparatus 8 in an arthroscopic procedure where the operative site may not be easily visualized.

Although in the above embodiment, stops on the first and second guide members 81 and 82 contact corresponding engagement surfaces on the engagement portions 84 and 85, the guide members 81 and 82 may be positioned relative to the reference structure 83 in any suitable way. For example, the guide members 81 and 82 may have indicator marks on them that may be aligned with a portion of the engagement portions 84 and 85, respectively. The alignment of certain indicator marks on the guide members 81 and 82 may be used to indicate, for example, that the distal ends of the guide members 81 and 82 are adjacent each other. Those of skill in the art will understand that the position of the guide members 81 and 82 relative to the reference structure 83 and relative to each other may be determined in other ways. For example, the first and second guide members 81 and 82 need not necessarily be positioned so that their distal

ends are adjacent in the passageway to assist in feeding a suture from one guide member to the other. Instead, the first and second guide members 81 and 82 may be made to suitably communicate with the passageway in any way so as to facilitate feeding of the suture.

In this illustrative embodiment, the first guide member 81 is shown as having a smaller diameter (at least at the distal end) than the second guide member 82. This may allow the guide apparatus 8 to be used with an arrangement where the first hole 51 is smaller than the second hole 52. A relatively small first hole 51 may allow for more rapid healing and/or provide additional space for other holes in the margin, if needed. However, it should be understood that the guide apparatus 8 and/or the holes that form the passageway 5 may be made in any suitable way, e.g., the first and second holes 51 and 52 may have the same diameter or the first hole 51 may have a larger diameter than the second hole 52.

The guide apparatus 8 may also include additional guide members if desired, e.g., to provide for the formation of a third hole that is formed in the margin and is approximately parallel to the first hole 51, but also intersects with the second hole 52. Similarly, the guide apparatus 8 may include two pairs of guide members like that in the illustrative embodiment that are arranged to form side-by-side passageways 5 in the bone or other body portion.

Although in this illustrative embodiment, the guide apparatus 8 is used to guide the formation of the second hole 52, the guide apparatus 8 need not necessarily be used to guide the formation of the second hole 52. That is, the guide apparatus 8 may be used only to help feed the wire 10, suture or other material through a passageway that is pre-formed in the bone or other body portion. In addition, the first and second guide members 81 and 82 may be arranged so that the members 81 and 82 can be secured in a body portion without requiring holes to be predrilled or otherwise formed. Thus, in one embodiment, the first and second guide members 81 and 82 may be arranged like an awl or other device capable of forming a hole in a body portion, e.g., capable of being forced into bone, forming the passageway 5 by their entry and/or providing a means to help feed a wire, suture or other material through the passageway 5.

Once the wire 10, suture or other material has been passed through the passageway 5, as shown in Fig. 12, the wire 10 may be used to pull the suture 3 through

the passageway 5. Prior to being used to pull the suture 3 through the passageway 5, the wire 10 or other material may be used to create a relatively straight pathway for the suture 3 once the suture 3 is tensioned and fixed in place. For example, the wire 10 may be tensioned between the first and second openings 53 and 54 of the first and second holes 51 and 52 or otherwise manipulated so as to cut or crush the body portion, e.g., bone, between the first and second openings 53 and 54. Such manipulation of the wire 10 may perform a kind of "flossing" effect in the bone, allowing the suture 3 to follow a more straight pathway through the passageway 5, reducing the length of suture 3 needed between the rotator cuff 2 and a point of fixation of the suture 3, e.g., near the second opening 54. The wire 10 may have barbs or other saw-like features to aid in cutting bone and forming the pathway. Of course, the more straight pathway could be formed by manipulating the suture 3 itself, e.g., by tensioning the suture 3 when securing the tendon or other material. Reducing the length of suture 3 in the passageway 5 may improve the suture's ability to maintain appropriate tension on the rotator cuff 2, e.g., by reducing the amount of stretch of the suture when under tension.

After the suture 3 has been passed through the passageway 5, the suture 3 may be engaged with a suture fixation device 4 as shown in Fig. 13. Although use of a suture fixation device is not required, the suture fixation device 4 may improve an ability to securely fixate the suture 3 (and the tissue 2) relative to the bone. The suture fixation device 4 may be arranged in any suitable way, but in this illustrative embodiment has an arrangement similar to a button. For example, the suture fixation device 4 may have two through holes formed in a disk-shaped member through which leading ends of the suture 3 are passed. The suture ends 3 may be passed through respective holes in the suture fixation device 4 using one or more feed members 41. The feed members 41 may have an elongated shape that is passed through a respective hole in the suture fixation device 4. A loop at one end of the feed member 41 may receive an end of the suture 3 and thereafter the feed member 41 may be pulled through a respective hole in the suture fixation device 4 so as to pull the suture 3 through the hole. Of course, it should be understood that the suture 3 may be fed through the suture fixation device 4 in any other suitable way. When performing this technique arthroscopically, the suture 3 may be fed through the suture fixation device 4 either inside or outside of the body cavity.

As shown in Fig. 14, after the suture 3 is engaged with the suture fixation device 4, the suture fixation device 4 may be positioned relative to the second opening 54 of the passageway 5 using an applier 42 which removably engages with the suture fixation device 4 and may be selectively disengaged from the suture fixation device when the suture fixation device 4 is positioned as desired. As shown in Fig. 15, the applier 42 may have a pair of tines 421 that engage with recesses or other features on the suture fixation device 4 so as to removably engage with the suture fixation device 4. The tines 421 may be resilient so that the tines are squeezed together when engaged with the suture fixation device 4. Thus, an elastic force biasing the tine ends apart may help maintain engagement of the tines with the grooves 48 in the suture fixation device 4. Alternately, the tine ends may be force-fit into grooves 48 in the suture fixation device so that engagement is maintained based on friction. Of course, it will be understood that the applier 42 may engage with the suture fixation device 4 in any other suitable way, such as a screw-in or snap configurations.

With the suture fixation device 4 in place relative to the second opening 54, the suture 3 may be tensioned so as to appropriately position the rotator cuff 2 relative to the humerus 1. At this point, the suture 3 may be fixed relative to the suture fixation device 4, such as by tying a knot with the suture ends. Thus, the suture fixation device 4 may provide not only a structure to support the suture knot, but also may spread the force of the suture 3 to portions of the relatively hard cortical bone surrounding or otherwise adjacent to the second opening 54. By having the suture fixation device 4 engage with this cortical bone, the suture fixation device 4 may provide a relatively stable and secure fixation point for the suture 3. The suture fixation device 4 may also incorporate a mechanism for knotless fixation of the suture, such as an interference pin, a locking passageway, a locking cap, etc.

Although in the illustrative embodiment described above both ends of the suture 3 are passed through the passageway 5 and secured at or near the second opening 54 of the passageway 5, the suture 3 may be secured in other ways, such as by passing one end of the suture 3 through the passageway 5 and passing another end of the suture 3 around the outside of the bone (e.g., over a portion of the greater tuberosity) where it is secured to the other suture end. In another embodiment, two passageways 5 may be formed through the bone and one end of the suture 3 may be passed through one passageway and

the other end of the suture 3 may be passed through the other passageway. The suture ends may then be secured to each other at or near respective second openings of the passageways 5 on the lateral side of the humerus 1. In yet another embodiment, two or more first holes 51 may be formed so as to intersect with one or more second holes 52. Suture 3 may be passed through the two or more first holes 51 and be secured at the second opening 54 of the one or more second holes 52. Such an arrangement may allow for the use of a single second hole 52 and suture fixation device 4 to secure the rotator cuff at two or more points on the humeral head using two or more sutures that pass through different first holes 51. Other suture fixation techniques may be used as desired.

Figs. 16A-B and 17A-B show illustrative embodiments of suture fixation devices 4 in accordance with the invention. In these embodiments, the suture fixation device 4 includes a restriction in a pathway through the suture fixation device 4 so that suture or other material passing through the suture fixation device is relatively freely moved in one direction through the pathway, but movement of the suture or other material in the other direction in the pathway is resisted. For example, movement of a suture though the suture fixation devices shown in Figs. 16A and 17A in a direction to the left in the side view of the suture fixation devices 4 may be freely allowed, while movement of the suture toward the right may be resisted. This may aid in tensioning the suture 3 because the suture 3 may be pulled from the second hole 52 through the suture fixation device 4 until the rotator cuff or other tissue is appropriately positioned. Thereafter, tension on the suture may be temporarily released, e.g., in preparation for forming a knot, but movement of the suture back through the suture fixation device 4 may be resisted so that the rotator cuff or other tissue is maintained in place until the suture knot is tied or otherwise is secured.

In the Fig. 16A-B embodiment, the suture fixation device includes an outer end having a flange portion 43 that is sized and arranged to contact the cortical bone adjacent the opening in the passageway at which the suture fixation device 4 is positioned, e.g., the second opening 54. One or more pathways 44 may be formed through the suture fixation device 4, such as by a hole or holes formed through the flange 43 (see also Fig. 15). Instead of having multiple holes, the pathway 44 may include a single slot arranged to receive one or more sutures. A recess 49 may be provided in the flange portion 43 to receive one or more knots, if formed with the suture(s) in the pathway 44. A pair of

duck bill members 45 at an inner end of the suture fixation device 4 may extend rearwardly from the flange 43 and may be arranged as to be positionable in the second hole 54. The duck bill members 45 may be separated from each other by a groove that extends across the inner end of the suture fixation device 4 and be resiliently biased toward each other so as to resist the passage of suture or other material through the pathway 44. One or both of the duck bill structures 45 may include serrations 46 or other features that may aid in engaging a suture or other material. In the Fig. 16 embodiment, the groove separating the duck bill structures 45 extends to the flange portion 43 so that the structures 45 are pivotable at a point near the flange portion 43.

The Fig. 17A-B embodiment similarly includes a flange 43 and one or more pathways 44. Duck bill structures 45 are also provided. However, in this embodiment rather than being hinged at a point near respective connection points with the flange 43, the duck bill portions 45 are hinged at a point positioned away from the flange 43. Providing the effective hinge points for the duck bill structures 45 in this manner may provide improved engagement of the duck bill structures 45 with a suture or other material when the suture is urged to move from the outer end toward the inner end through the pathway 44. That is, if the suture is pulled to move toward the inner end, serrations 46 or other features will engage with the suture and increased force on the suture will cause an increased force urging the duck bill structures 45 to move toward each other and further squeeze the suture. The duck bill structures in the Fig. 16 and 17 embodiments or other suitable suture engagement arrangements (such as interference pins, locking caps, etc.) may provide a knotless fixation for the suture. Alternatively, the structures may resist movement of the suture so as to aid the surgeon's ability to maintain tension on the suture while forming a knot.

Although this embodiment depicts the flange of the device resting on the outer cortical surface of the bone, the device may be positioned in a hole which has a counterbore, or countersink, in order to prevent any interference between the flange and other bone or tissues that may come in contact with the site either at rest or during movement. Even in the case where the device is positioned in a counterbore or countersink feature, the device may contact cortical bone. Alternately, the device may only contact the outer, cortical surface of the bone, and not extend into a hole in the bone.

Of course, it should be understood that suture fixation devices may be provided in any suitable form. For example, the duck bill portions 45 extending from the flange 43 in the Figs. 16 and 17 embodiments may be sized to closely fit into a mating hole formed in bone. This close fit may help in maintaining the suture fixation devices 4 in a desired position in the bone. Alternately, the duck bill structures 45 may be formed so as to be tapered on their outer surfaces. Thus, when the suture fixation device 4 is inserted into a hole in the bone, the tapered surfaces of the duck bill structures 45 may contact the sides of the hole and urge the duck bill structures to move toward each other as the suture fixation device 4 is pressed into the hole. In another embodiment, a portion of the suture fixation device 4 that is inserted into a hole may be threaded or otherwise be arranged so as to engage the hole and help prevent the suture fixation device from falling from the hole, e.g., before the suture is secured in place. There are many variations of the mechanism form to retain the suture with respect to the device. Some of these forms may require a knot for final fixation. Other capturing mechanisms may provide sufficient locking of the suture such that a knot is not required. Theses are typically known as "knotless" devices.

Having thus described several aspects of at least one embodiment of this invention, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the scope of the invention. Accordingly, the foregoing description and drawings are by way of example only.

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CLAIMS:

1. An apparatus comprising:

a cannula having at least one lumen and constructed and arranged to be placed in an arthroscopic portal in a minimally-invasive surgical procedure and allow an instrument including an endoscope or grasping device to be passed through the at least one lumen of the cannula and used at a surgical site in the minimally-invasive surgical procedure, the cannula having a wall with an inner surface defining the at least one lumen, a first complementary locking member arranged on an outer surface of the wall, a distal end, a proximal end, and a longitudinal axis that is generally parallel to the lumen; and

a needle having a second complementary locking member that is engaged with the first complementary locking member of the cannula so the needle is removably attached to the wall of the cannula and is movable in a direction along the longitudinal axis relative to the cannula, the needle having a proximal end that is positioned near the proximal end of the cannula and a tissue penetrating portion that is positioned distal of the distal end of the cannula, the tissue penetrating portion including a curved portion positioned in a plane transverse to the longitudinal axis, the needle carrying a suture that extends along a length of the cannula,

wherein the needle and cannula are engaged such that the needle is movable to extend the tissue penetrating portion away from the distal end of the cannula and the tissue penetrating portion is manipulable by movement of the cannula to place the suture in a material, and wherein the needle is attached to the wall of the cannula such that an endoscope or grasping device is passable through the at least one lumen of the cannula and usable at a surgical site in the minimally-invasive surgical procedure with the needle attached to the wall.

2. The apparatus of claim 1, wherein the needle has a hollow portion that accommodates the suture.

3. The apparatus of claim 1, wherein rotation of the cannula about the longitudinal axis causes the curved end portion to travel along an arc-shaped path.

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4. The apparatus of claim 1, wherein the tissue penetrating portion includes a semicircular end portion that lies in a plane perpendicular to the longitudinal axis.

5. The apparatus of claim 4, wherein the longitudinal axis passes through a center of a lumen of the cannula and passes through a center of the semicircular end portion.

6. The apparatus of claim 1, wherein the cannula and needle are constructed and arranged to place a suture in a rotator cuff.

7. The apparatus of claim 6, wherein the cannula and needle are constructed and arranged to form a mattress stitch in a rotator cuff.

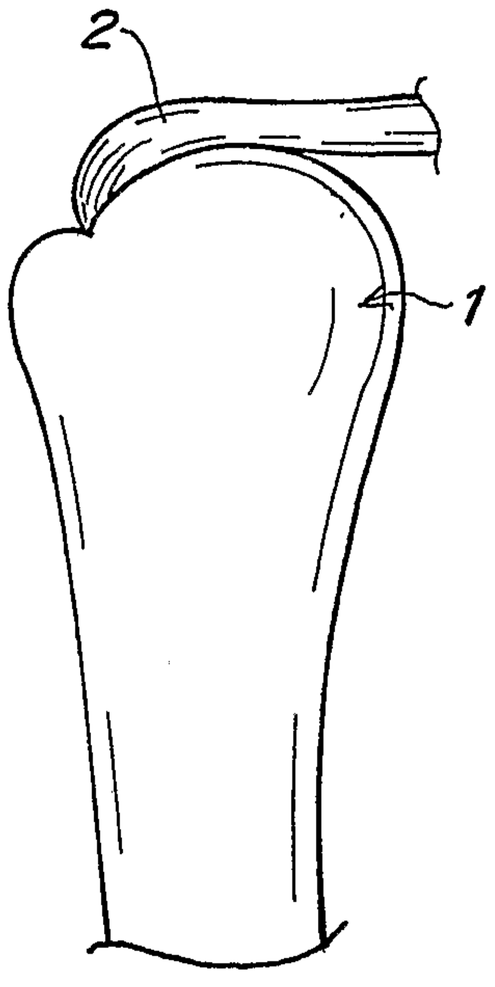

Fig. 1

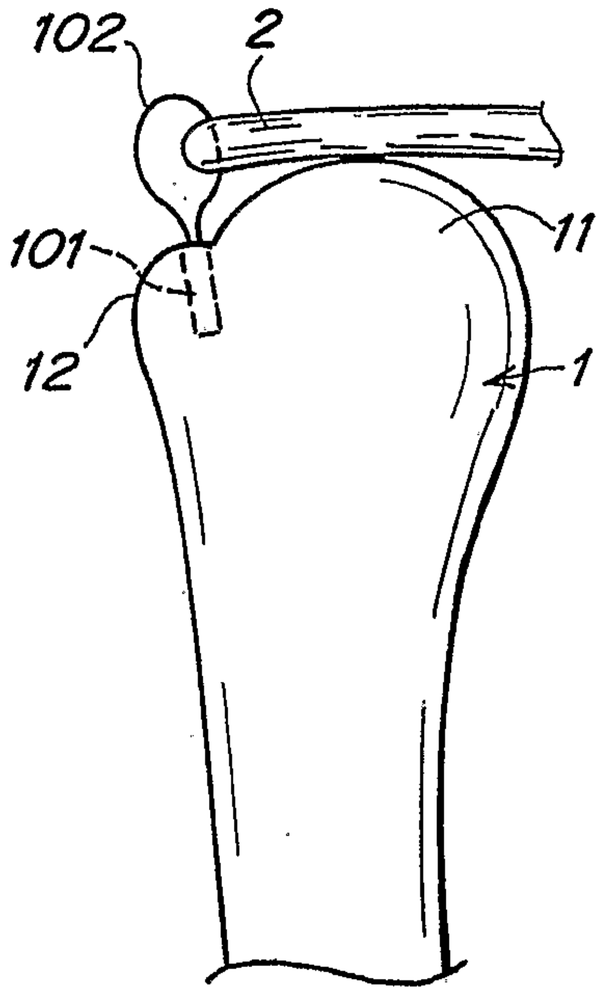

Fig. 2
PRIOR ART

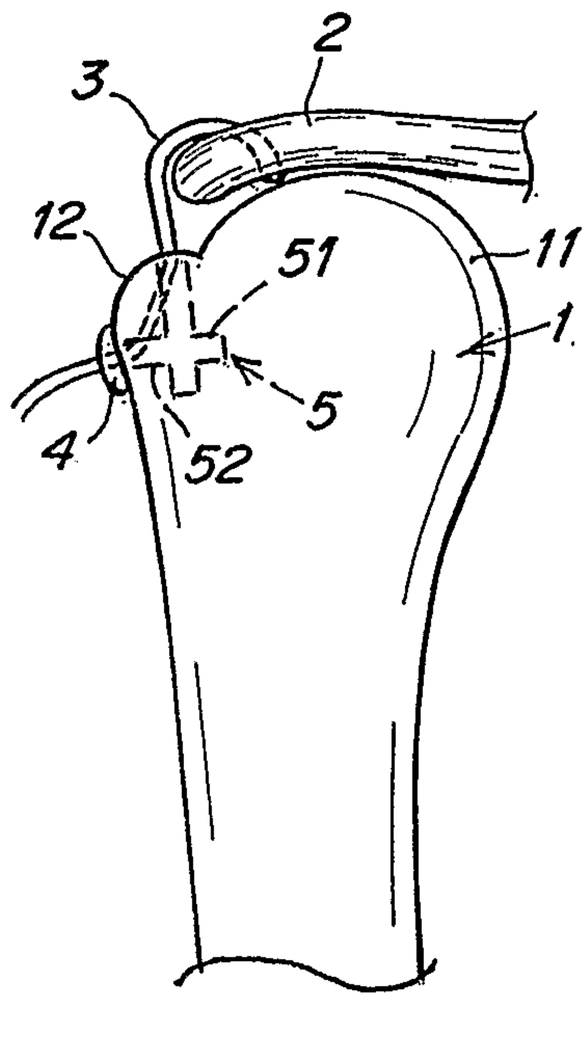

Fig. 3

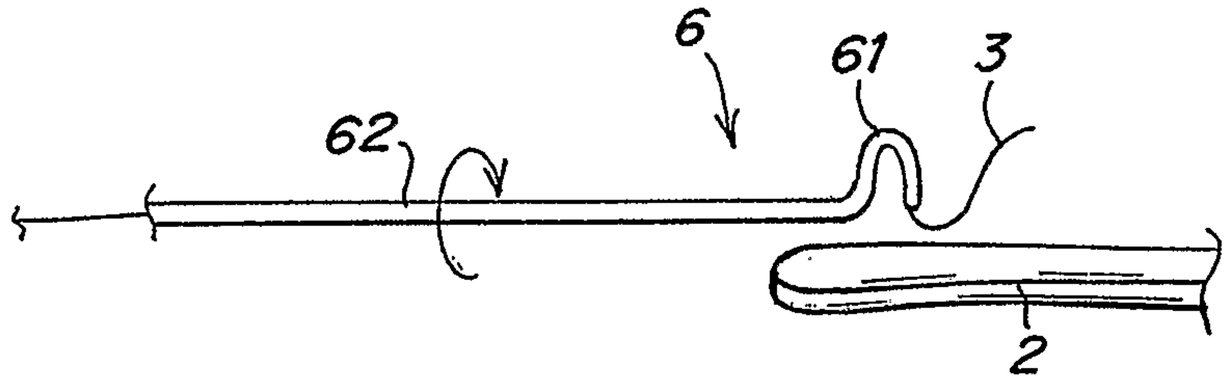

Fig. 4

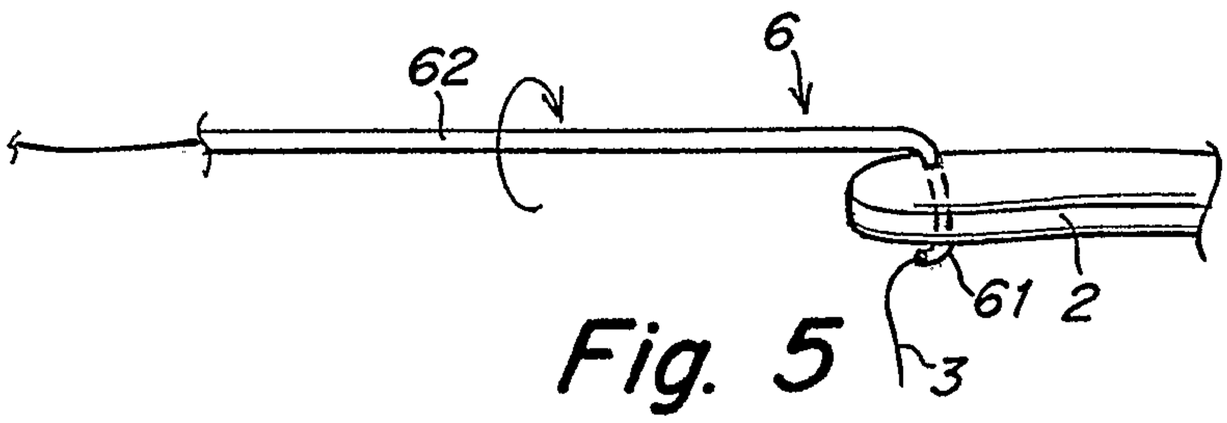

Fig. 5

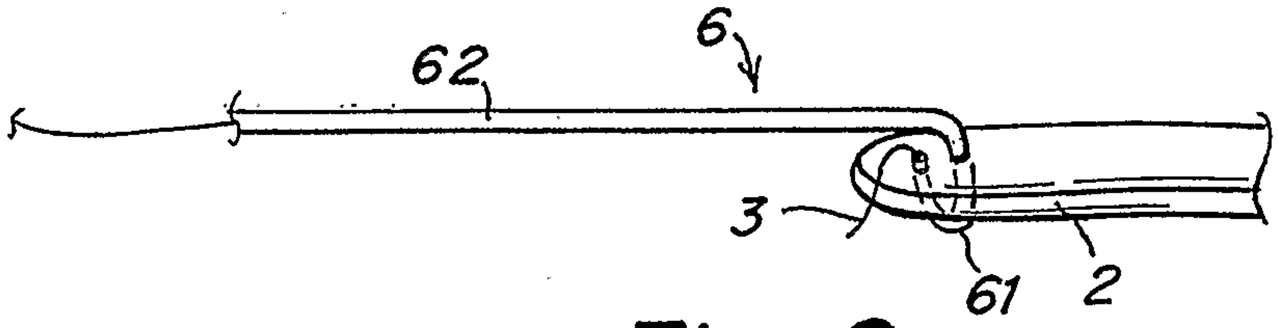

Fig. 6

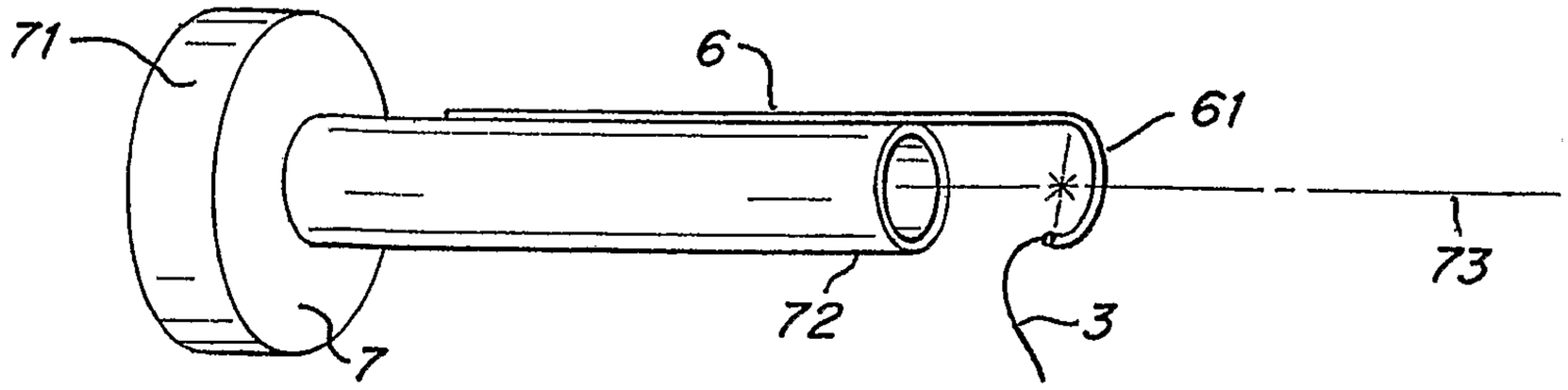

Fig. 7

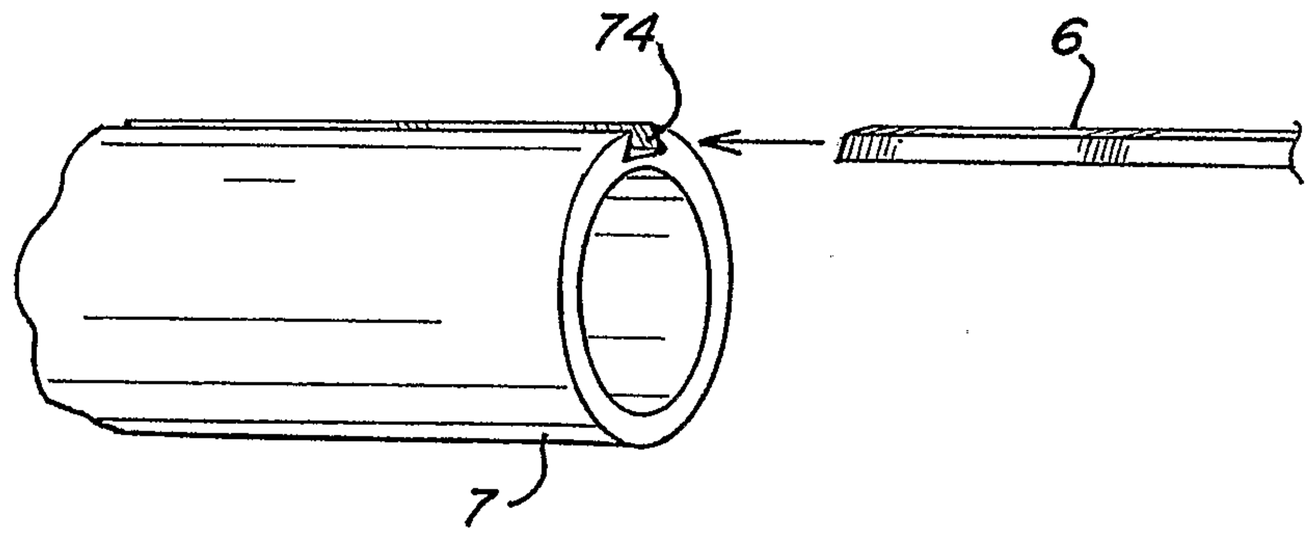

Fig. 8

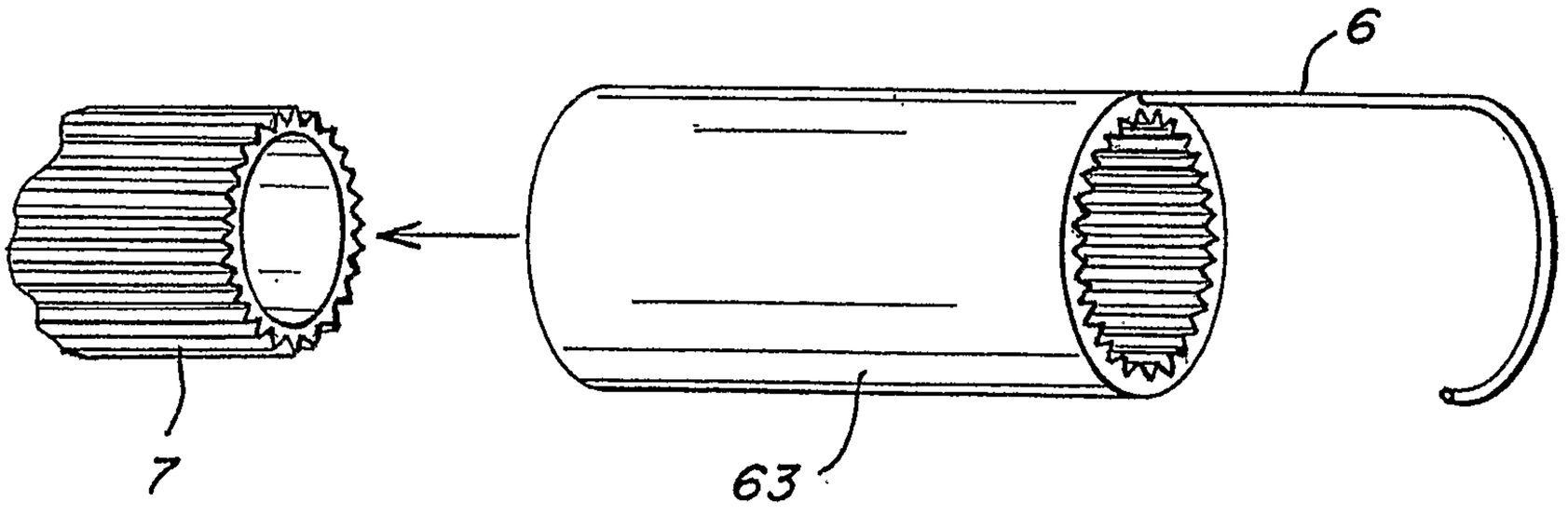

Fig. 9

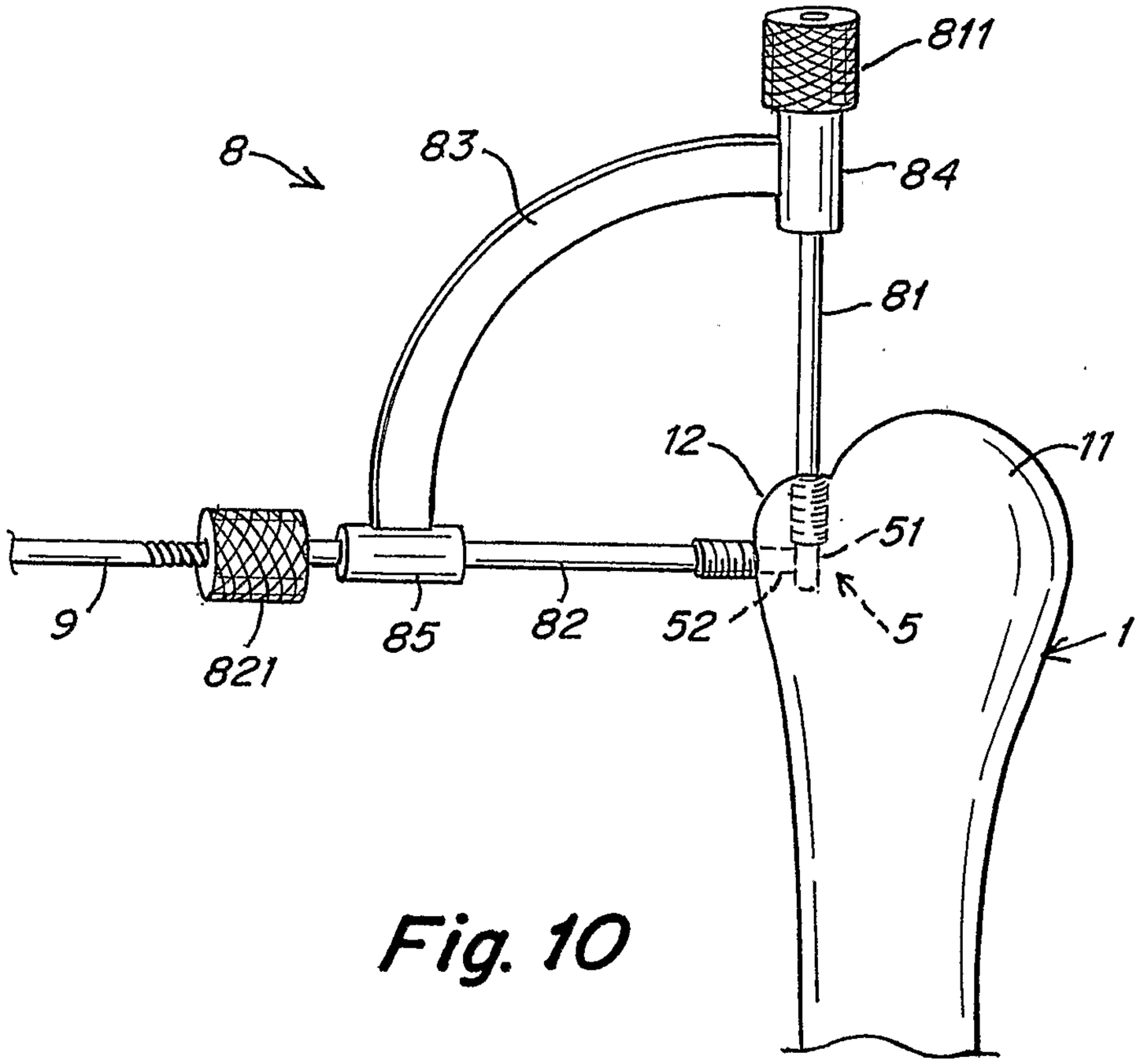
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Fig. 10

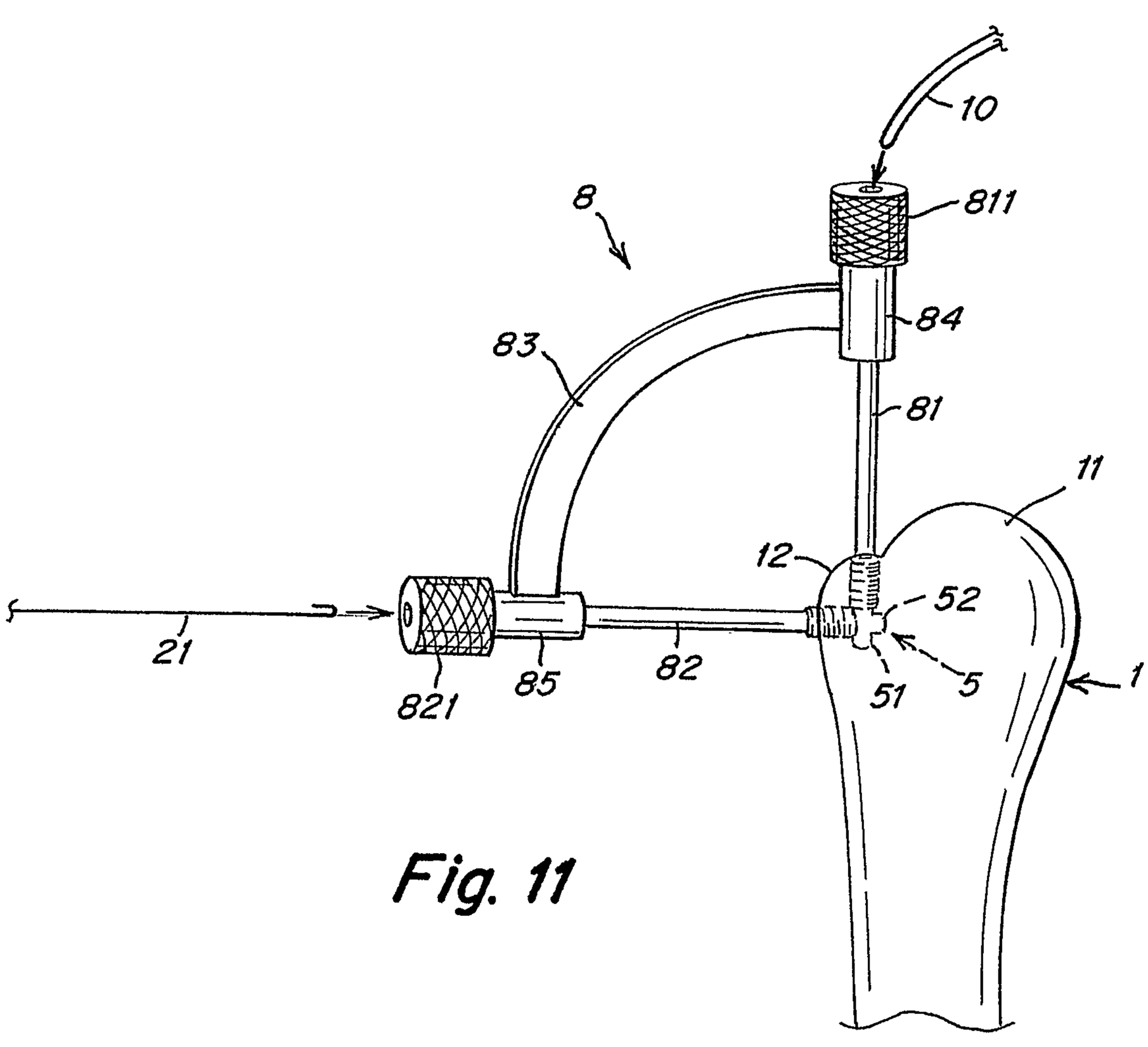
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Fig. 11

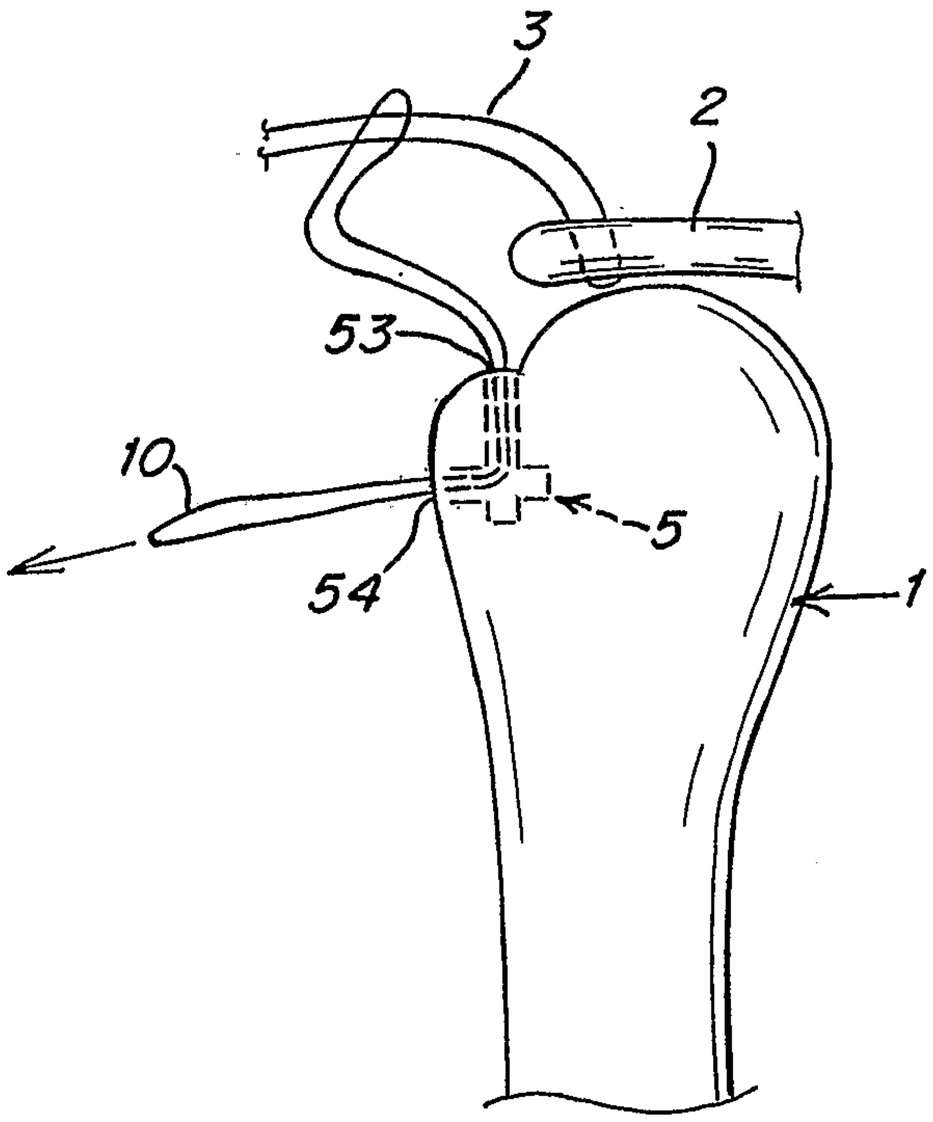


Fig. 12

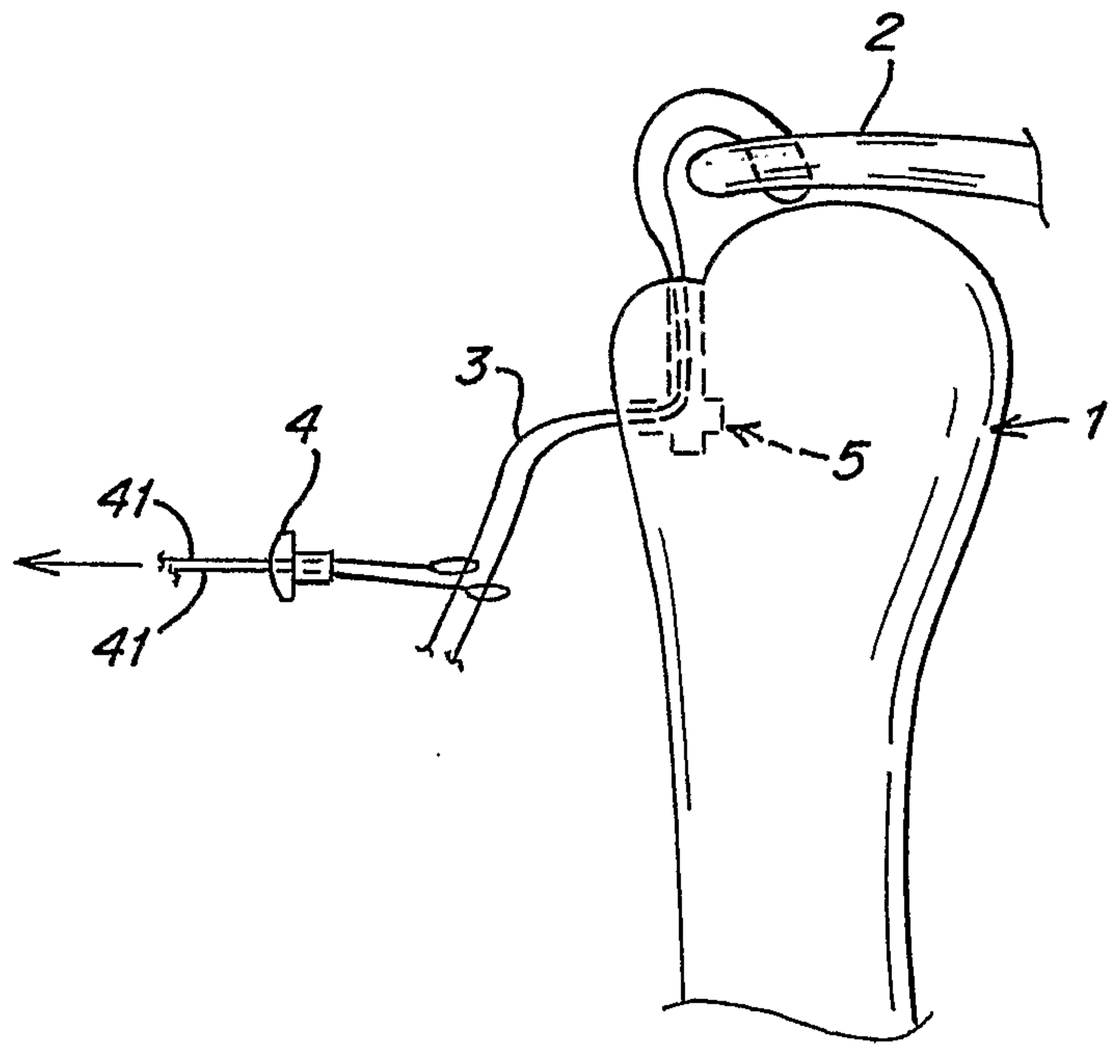


Fig. 13

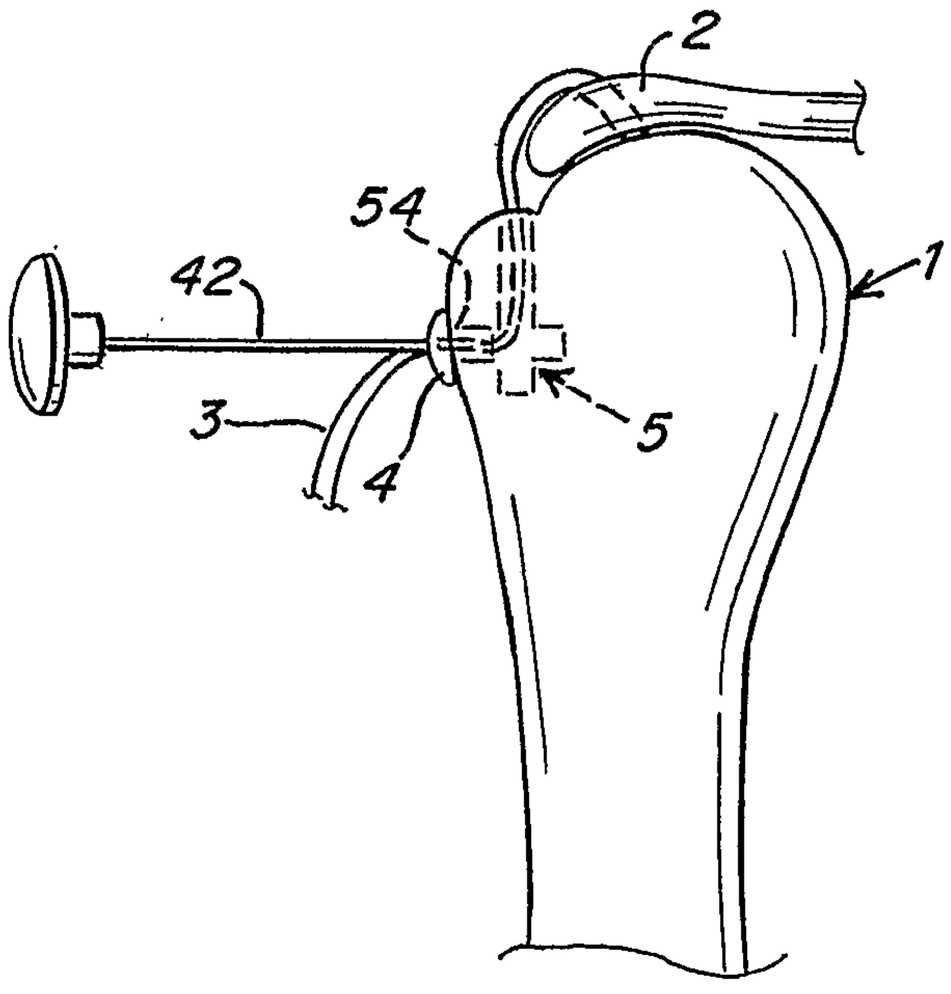


Fig. 14

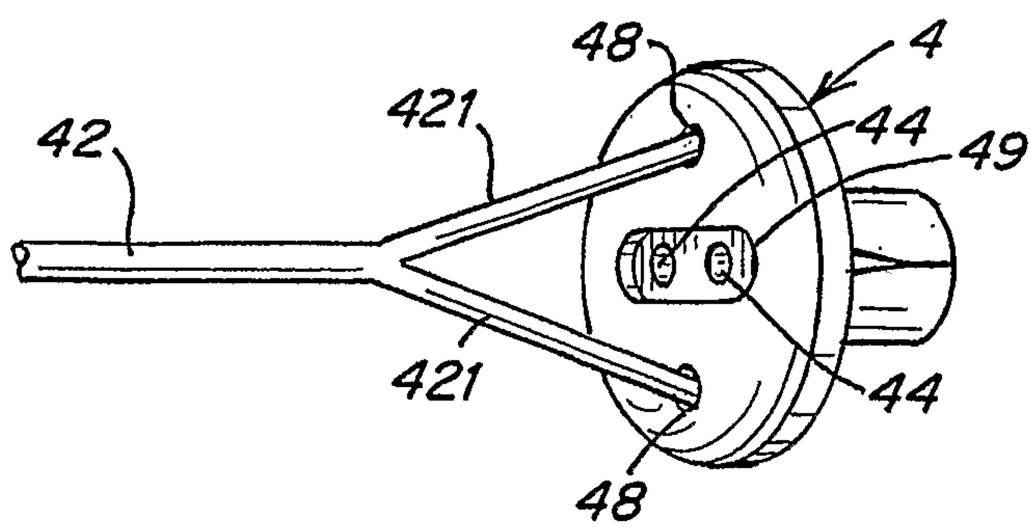


Fig. 15

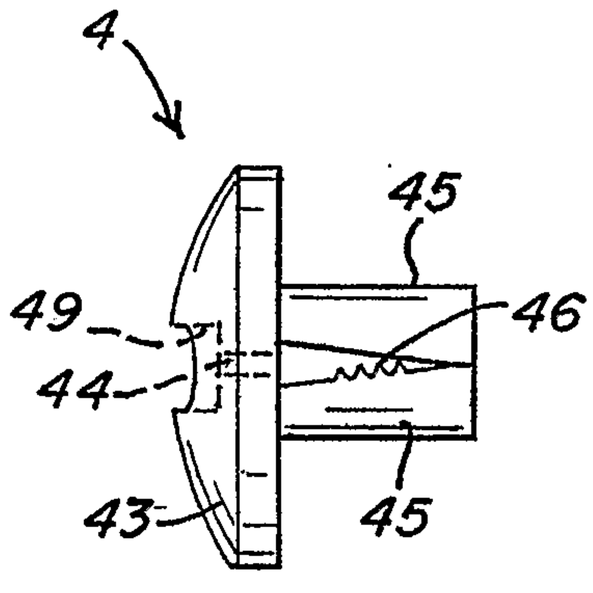


Fig. 16A

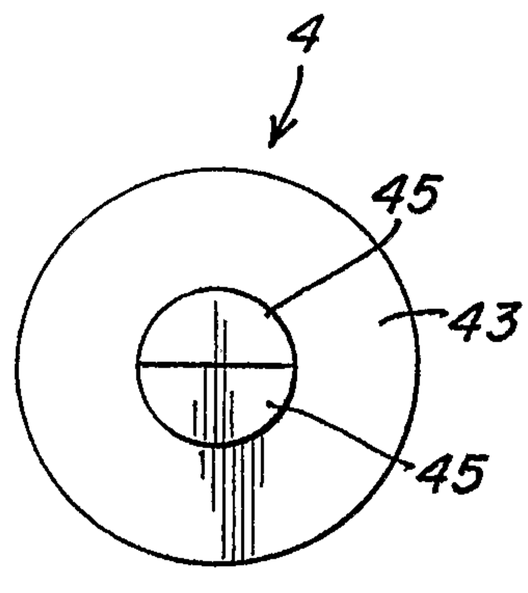


Fig. 16B

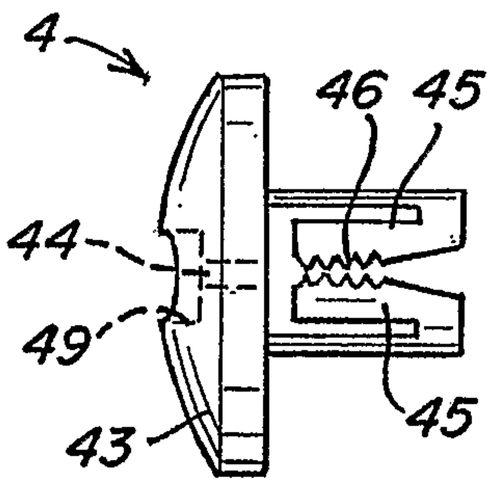


Fig. 17A

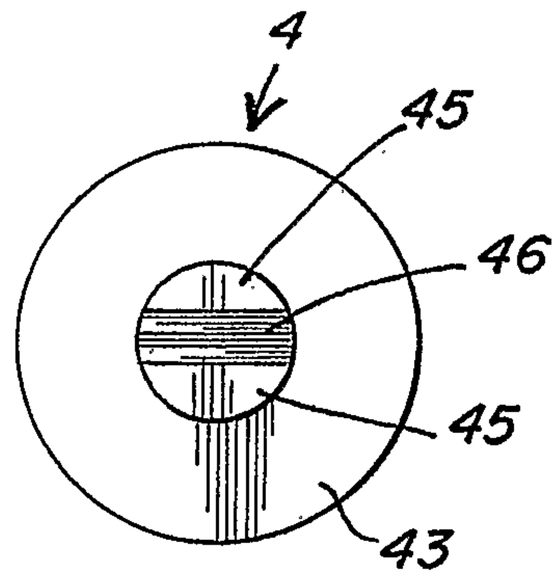
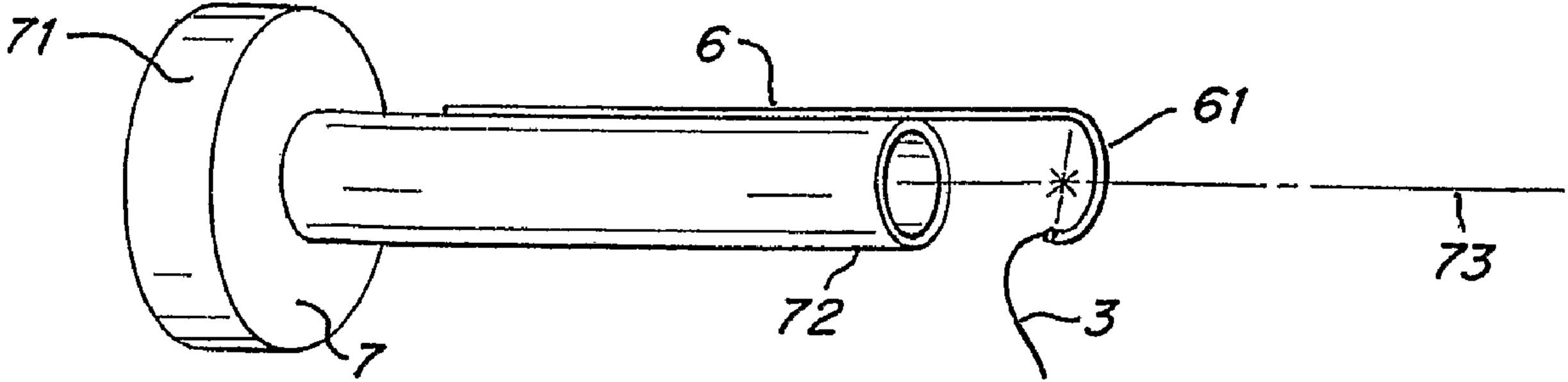


Fig. 17B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