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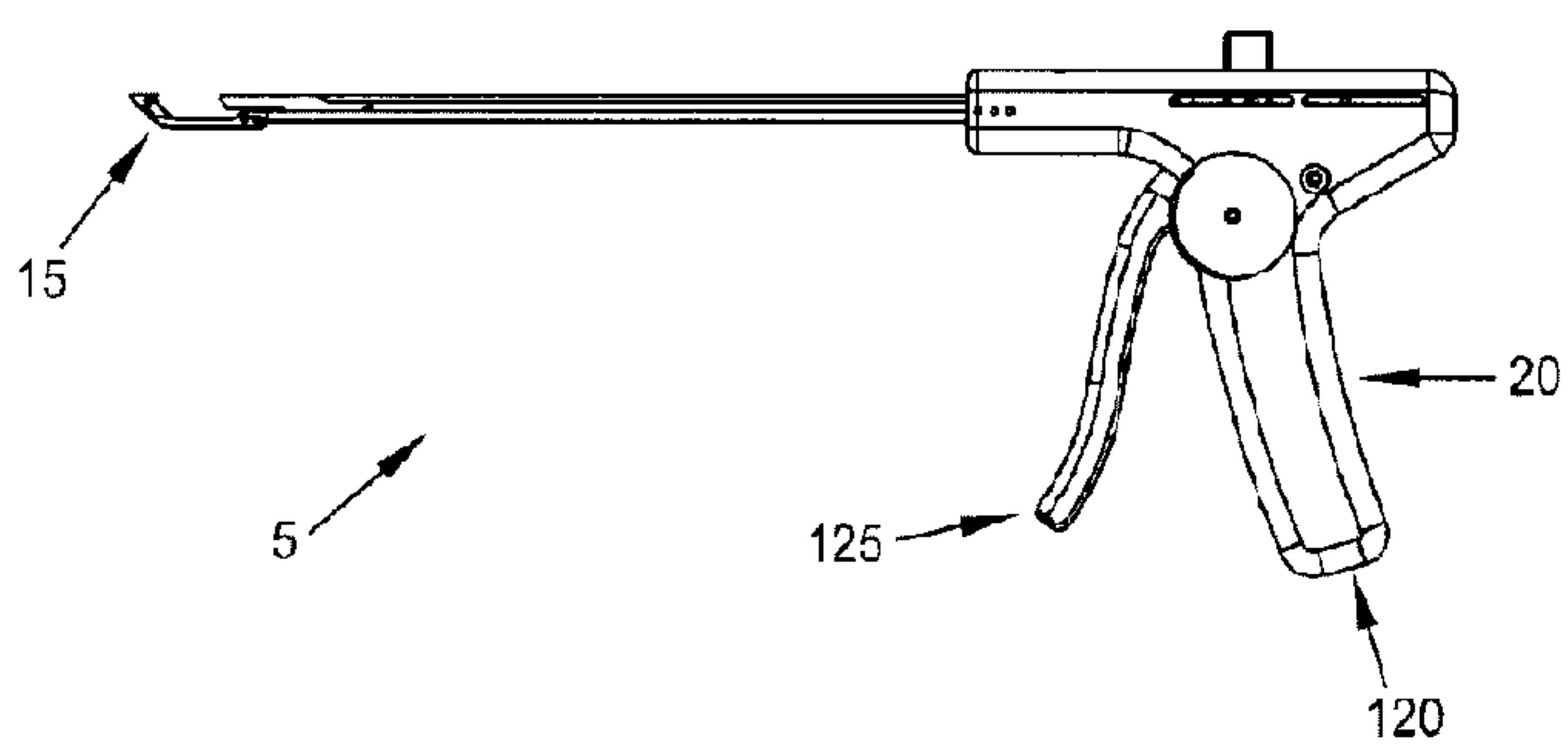


(57) Abrégé/Abstract:
A suture passer including: a shaft having an axis; a first jaw mounted to the shaft in alignment with the axis, the first jaw being configured to releasably support a length of suture thereon; a second jaw movably mounted to the shaft; and a needle movably mounted to the shaft, the needle having a hook and being configured to reciprocate in alignment with the axis so that the hook can selectively pass by the second jaw and engage suture releasably supported on the first jaw; wherein the first jaw has a spring for selectively binding the suture to the first jaw.

Abstract

A suture passer including: a shaft having an axis; a first jaw mounted to the shaft in alignment with the axis, the first jaw being configured to releasably support a length of suture thereon; a second jaw movably mounted to the shaft; and a needle movably mounted to the shaft, the needle having a hook and being configured to reciprocate in alignment with the axis so that the hook can selectively pass by the second jaw and engage suture releasably supported on the first jaw; wherein the first jaw has a spring for selectively binding the suture to the first jaw.

METHOD AND APPARATUS FOR TREATING A HIP JOINT, INCLUDING THE PROVISION AND USE OF A NOVEL SUTURE PASSER

Field Of The Invention

This invention relates to surgical methods and apparatus in general, and more particularly to surgical methods and apparatus for treating a hip joint.

Background Of The Invention

The Hip Joint In General

The hip joint is a ball-and-socket joint which movably connects the leg to the torso. The hip joint is capable of a wide range of different motions, e.g., flexion 490 and extension 492, abduction 494 and adduction 496, medial 498 and lateral rotation 499, etc. See Figs. 1A, 1B, 1C and 1D.

With the possible exception of the shoulder joint, the hip joint is perhaps the most mobile joint in the body. Significantly, and unlike the shoulder joint, the hip joint carries substantial weight loads during most of the day, in both static (e.g., standing and sitting) and dynamic (e.g., walking and running) conditions.

The hip joint is susceptible to a number of different pathologies. These pathologies can have both congenital and injury-related origins. In some cases, the pathology can be substantial at the outset. In other cases, the pathology may be minor at the outset but, if left untreated, may worsen over time. More particularly, in many cases, an existing pathology may be exacerbated by the dynamic nature of the hip joint and the substantial weight loads imposed on the hip joint.

The pathology may, either initially or thereafter, significantly interfere with patient comfort and lifestyle. In some cases, the pathology can be so severe as to require partial or total hip replacement. A number of procedures have been developed for treating hip pathologies short of partial or total hip replacement, but these procedures are generally limited in scope due to the significant difficulties associated with treating the hip joint.

A better understanding of various hip joint pathologies, and also the current limitations associated with their treatment, can be gained from a more thorough understanding of the anatomy of the hip joint.

Anatomy Of The Hip Joint

The hip joint is formed at the junction of the leg and the torso. More particularly, and looking now at Fig. 2, the head of the femur 500 is received in the acetabular cup 502 of the hip, with a plurality of ligaments and other soft tissue serving to hold the bones in articulating condition.

More particularly, and looking now at Fig. 3, the femur 504 is generally characterized by an elongated body terminating, at its top end, in an angled neck which supports a hemispherical head 500 (also sometimes referred to as "the ball"). As seen in Figs. 3 and 4, a large projection known as the greater trochanter 508 protrudes laterally and posteriorly from the elongated body adjacent to the neck of the femur. A second, somewhat smaller projection known as the lesser trochanter 510 protrudes medially and posteriorly from the elongated body adjacent to the neck. An intertrochanteric crest 512 (Figs. 3 and 4) extends along the periphery of the femur 502, between the greater trochanter 508 and the lesser trochanter 510.

Looking next at Fig. 5, the hip socket is made up of three constituent bones: the ilium 514, the ischium 156 and the pubis 518. These three bones cooperate with one another (they typically ossify into a single "hip bone" structure by the age of 25 or so) in order to collectively form the acetabular cup 502. The acetabular cup 502 receives the head of the femur 500.

Both the head of the femur 500 and the acetabular cup 502 are covered with a layer of articular cartilage 520 which protects the underlying bone and facilitates motion. See Fig. 6.

Various ligaments and soft tissue serve 522 to hold the ball of the femur 500 in place within the acetabular cup 502. More particularly, and looking now at Figs. 7 and 8, the ligamentum teres 524 extends between the ball of the femur 500 and the base of the acetabular cup 502. As seen in Figs. 8 and 9, a labrum 526 is disposed about the perimeter of the acetabular cup 502. The labrum 526 serves to increase the depth of the acetabular cup 502 and effectively establishes a suction seal between the ball of the femur 500 and the rim of the acetabular cup 502, thereby helping to hold the head of the femur 500 in the acetabular cup 502. In addition to the foregoing, and looking now at Fig. 10, a fibrous capsule extends between the neck of the femur 528 and the rim of the acetabular cup 502, effectively sealing off the ball-and-socket members of the hip joint from the remainder of the body. The foregoing structures (i.e., the ligamentum teres 524, the labrum 526 and the fibrous capsule 530) are encompassed and reinforced by a set of three main ligaments (i.e., the iliofemoral ligament 532, the ischiofemoral ligament and the pubofemoral ligament) which extend between the femur 504 and the perimeter of the hip socket. See, for example, Figs. 11 and 12, which show the iliofemoral ligament 532, with Fig. 11 being an anterior view and Fig. 12 being a posterior view.

Pathologies Of The Hip Joint

As noted above, the hip joint is susceptible to a number of different pathologies. These pathologies can have both congenital and injury-related origins.

By way of example but not limitation, one important type of congenital pathology of the hip joint involves impingement between the neck of the femur and the rim of the acetabular cup. In some cases, and looking now at Figs. 13A and 13B, this impingement can occur due to irregularities in the geometry of the femur 504. This type of impingement is sometimes referred to as cam-type femoroacetabular impingement (i.e., cam-type FAI). In other cases, and looking now at Figs. 14A and 14B, the impingement can occur due to irregularities in the geometry of the acetabular cup. This latter type of impingement is sometimes referred to as pincer-type femoroacetabular impingement (i.e., pincer-type FAI). Impingement can result in a reduced range of motion, substantial pain and, in some cases, significant deterioration of the hip joint.

By way of further example but not limitation, another important type of congenital pathology of the hip joint involves defects in the articular surface of the ball and/or the articular surface of the acetabular cup. Defects of this type sometimes start out fairly small but often increase in size over time, generally due to the dynamic nature of the hip joint and also due to the weight-bearing nature of the hip joint. Articular defects can result in substantial pain, induce and/or exacerbate arthritic conditions and, in some cases, cause significant deterioration of the hip joint.

By way of further example but not limitation, one important type of injury-related pathology of the hip joint involves trauma to the labrum. More particularly, in many cases, an accident or sports-related injury can result in the labrum 526 being torn away from the rim of the acetabular cup 502, typically with a tear running through the body of the labrum, forming acetabular labral tear 534. See Fig. 15. These types of injuries can be very painful for the patient and, if left untreated, can lead to substantial deterioration of the hip joint.

The General Trend Toward Treating Joint Pathologies Using Minimally-Invasive, And Earlier, Interventions

The current trend in orthopedic surgery is to treat joint pathologies using minimally-invasive techniques. Such minimally-invasive, "keyhole" surgeries generally offer numerous advantages over traditional, "open" surgeries, including reduced trauma to tissue, less pain for the patient, faster recuperation times, etc.

By way of example but not limitation, it is common to re-attach ligaments in the shoulder joint using minimally-invasive, "keyhole" techniques which do not require large incisions into the interior of the shoulder joint. By way of further example but not limitation, it is common to repair torn meniscal cartilage in the knee joint, and/or to replace ruptured ACL ligaments in the knee joint, using minimally-invasive techniques.

While such minimally-invasive approaches can require additional training on the part of the surgeon, such procedures generally offer substantial advantages for the patient and have now become the standard of care for many shoulder joint and knee joint pathologies.

In addition to the foregoing, in view of the inherent advantages and widespread availability of minimally-invasive approaches for treating pathologies of the shoulder joint and knee joint, the current trend is to provide such treatment much earlier in the lifecycle of the pathology, so as to address patient pain as soon as possible and so as to minimize any exacerbation of the pathology itself. This is in marked contrast to traditional surgical practices, which have generally dictated postponing surgical procedures as long as possible so as to spare the patient from the substantial trauma generally associated with invasive surgery.

Treatment For Pathologies Of The Hip Joint

Unfortunately, minimally-invasive treatments for pathologies of the hip joint have lagged far behind minimally-invasive treatments for pathologies of the shoulder joint and the knee joint. This is generally due to (i) the constrained geometry of the hip joint itself, and (ii) the nature and location of the pathologies which must typically be addressed in the hip joint.

More particularly, the hip joint is generally considered to be a "tight" joint, in the sense that there is relatively little room to maneuver within the confines of the joint itself. This is in marked contrast to the shoulder joint and the knee joint, which are generally considered to be relatively "spacious" joints (at least when compared to the hip joint). As a result, it is relatively difficult for surgeons to perform minimally-invasive procedures on the hip joint.

Furthermore, the pathways for entering the interior of the hip joint (i.e., the natural pathways which exist between adjacent bones and/or delicate neurovascular structures) are generally much more constraining for the hip joint than for the shoulder joint or the knee joint. This limited access further complicates effectively performing minimally-invasive procedures on the hip joint.

In addition to the foregoing, the nature and location of the pathologies of the hip joint also complicate performing minimally-invasive procedures on the hip joint. By way of example but not limitation, consider a typical detachment of the labrum in the hip joint. In this situation, instruments must generally be introduced into the joint space using an angle of approach which is offset from the angle at which the instrument addresses the tissue. This makes drilling into bone, for example, significantly more complicated than where the angle of approach is effectively aligned with the angle at which the instrument addresses the tissue, such as is frequently the case in the shoulder joint. Furthermore, the working space within the hip joint is typically extremely limited, further complicating repairs where the angle of approach is not aligned with the angle at which the instrument addresses the tissue.

As a result of the foregoing, minimally-invasive hip joint procedures are still relatively difficult to perform and relatively uncommon in practice. Consequently, patients are typically forced to manage their hip pain for as long as possible, until a resurfacing procedure or a partial or total hip replacement procedure can no longer be avoided. These procedures are generally then performed as a highly-invasive, open procedure, with all of the disadvantages associated with highly-invasive, open procedures.

As a result, there is, in general, a pressing need for improved methods and apparatus for treating pathologies of the hip joint.

The Fibrous Capsule

As noted above, a fibrous capsule extends between the neck of the femur and the rim of the acetabular cup, effectively sealing off the ball-and-socket elements of the hip joint from the remainder of the body.

While the fibrous capsule provides an important function in encapsulating the hip joint, it also presents a significant obstacle to arthroscopically treating pathologies of the hip joint. More particularly, the fibrous capsule presents a tough physical barrier which must be penetrated in order to arthroscopically access the interior of the hip joint. However, the penetration of this tough physical barrier must be effected very carefully, since the anatomical structures which are located immediately below the fibrous capsule are frequently delicate and sensitive to damage.

In addition to the foregoing, the fibrous capsule generally sits in close proximity to the underlying bone. As a result, the workspace located between the fibrous capsule and the underlying bone is typically quite limited, thereby presenting significant visualization and operational challenges to the surgeon.

By way of example but not limitation, arthroscopic treatment of cam-type femoroacetabular impingement (i.e., cam-type FAI) is significantly complicated by the limited workspace present within the fibrous capsule. More particularly, cam-type FAI is generally caused by irregular overgrowths in the geometry of the femur. Treatment of cam-type FAI generally calls for debridement of these femoral overgrowths using a burr or other debridement tool. However, the lack of workspace between the overlying fibrous capsule and the underlying femur can make such debridement procedures technically challenging for even the most experienced surgeons, because it can severely limit the field of vision within the workspace and inhibit proper positioning of the burr.

As a result, there is a pressing need for an improved method and apparatus for increasing the workspace around the femur during an arthroscopic hip procedure.

Capsule Release And Subsequent Re-Stitching

It has been recognized that the workspace around the top end of the femur can be significantly increased during an arthroscopic procedure if the fibrous capsule can be laid open at the start of the arthroscopic procedure and then, at the conclusion of the procedure, the fibrous capsule restored, e.g., by suturing.

More particularly, it has been recognized that an arthroscopic procedure can be performed on the hip joint by (i) creating one or more access portals from the surface of the skin down to the fibrous capsule; (ii) opening the fibrous capsule so as to expose the underlying joint; (iii) performing the desired therapeutic procedure on the underlying joint (e.g., debridement of a femoral overgrowth so as to treat a cam-type FAI); and (iv) restoring the fibrous capsule at the conclusion of the procedure by suturing closed the laid-open capsule.

However, heretofore, it has been technically challenging to arthroscopically suture closed the laid-open fibrous capsule at the conclusion of the therapeutic procedure. This is largely because (i) the workspace present at the remote surgical site is quite limited, and (ii) the fibrous capsule is made up of unusually tough tissue, which can make it extremely difficult to arthroscopically pass suture through the fibrous capsule in the suturing operation.

Thus there is a need for a new method and apparatus for passing suture through the fibrous capsule in a suturing operation, thereby making it more practical for a surgeon to arthroscopically operate on the hip joint by first laying open the fibrous capsule, performing the desired procedure on the hip joint, and then closing the fibrous capsule by suturing at the conclusion of the procedure.

Summary Of The Invention

The present invention provides a novel method and apparatus for passing suture through the fibrous capsule in a suturing operation, thereby making it more practical for a surgeon to arthroscopically operate on the hip joint by first laying open the fibrous capsule, performing the desired procedure on the hip joint, and then closing the fibrous capsule by suturing at the conclusion of the procedure.

According to one aspect of the invention, there is provided a suture passer comprising: a shaft having an axis; a distal jaw fixedly mounted to the shaft in alignment with the axis, the distal jaw being configured to releasably support a length of suture thereon; a proximal jaw movably mounted to the shaft, the proximal jaw being configured to reciprocate in alignment with the axis so as to (i) advance toward the distal jaw so as to clamp tissue between the proximal jaw and the distal jaw, and (ii) retract from the distal jaw so as to release tissue previously clamped between the proximal jaw and the distal jaw; an inner needle movably mounted to the shaft, the inner needle having a hook and being configured to reciprocate in alignment with the axis so that the hook can selectively (i) advance through tissue clamped between the proximal jaw and the distal jaw, and engage the suture releasably supported on the distal jaw, and (ii) retract the suture through the tissue; and an outer needle movably mounted to the shaft in coaxial disposition with the inner needle, the outer needle being configured to reciprocate so as to (i) advance through tissue clamped between the proximal jaw and the distal jaw and engage the suture engaged by the hook of the inner needle so as to clamp the suture to the inner needle, and (ii) retract through tissue clamped between the proximal jaw and the distal jaw; wherein the distal jaw comprises a spring for selectively binding the suture to the distal jaw.

In the suture passer described above, the distal jaw spring comprises a cantilever spring.

In the suture passer described above, one portion of the cantilever spring is mounted to the shaft and another portion of the cantilever spring moves relative to the distal jaw.

In the suture passer described above, the inner needle comprises an inclined surface for engaging the distal jaw spring or suture.

In the suture passer described above, the distal jaw spring comprises a pathway for receiving the inner needle.

In the suture passer described above, the distal jaw comprises a suture slot sized to receive the suture therein.

In the suture passer described above, the distal jaw spring selectively binds the suture in the suture slot.

In the suture passer described above, the distal jaw spring selectively binds the suture against a side wall of the suture slot.

In one embodiment of the invention, the suture slot extends substantially parallel to the axis of the shaft.

In another embodiment of the invention, the suture slot extends transverse to the axis of the shaft.

The suture passer as described above comprises a first portion which extends substantially parallel to the axis of the shaft and a second portion which extends transverse to the axis of the shaft.

In the suture passer described above, the distal jaw spring is configured to releasably capture the suture thereto.

In the suture passer described above, the distal jaw spring comprises a groove for releasably capturing the suture to the distal jaw spring.

In the suture passer described above, the outer needle is sized relative to the inner needle so as to provide column strength to the inner needle.

In the suture passer described above, the hook of the inner needle comprises a distally-extending portion, a base connected to the distally-extending portion and extending transverse to the distally-extending portion, and a proximally-extending portion connected to the base and spaced from the distally-extending portion, and further wherein the outer needle advances relative to the inner needle so as to clamp the suture against the base of the hook of the inner needle.

The suture passer described above comprises a self-contained, pre-assembled tool assembly and a self-contained, pre-assembled needle assembly, and further wherein the self-contained, pre-assembled tool assembly comprises the shaft, the distal jaw and the proximal jaw, and the self-contained, pre-assembled needle assembly comprises the inner needle and the outer needle.

In the suture passer described above, the inner needle is spring mounted to the outer needle.

In the suture passer described above, the self-contained tool assembly comprises a handle, wherein the shaft is mounted to the handle, and further wherein the handle comprises a proximal jaw carriage movably mounted to the handle and connected to the proximal jaw, a needle carriage movably mounted to the handle and connected to the inner needle, and a flange seat connected to the outer needle, the flange seat being movably mounted to the needle carriage.

According to another aspect of the invention, there is provided a suture passer comprising: a shaft having an axis; a first jaw fixedly mounted to the shaft in alignment with the axis, the first jaw being configured to releasably support a length of suture thereon; a second jaw movably mounted to the shaft, the second jaw being configured so as to (i) advance toward the first jaw so as to clamp tissue between the second jaw and the first jaw, and (ii) retract from the first jaw so as to release tissue previously clamped between the second jaw and the first jaw; and a needle movably mounted to the shaft, the needle having a hook and being configured to reciprocate in alignment with the axis so that the hook can selectively (i) advance through tissue clamped between the second jaw and the first jaw, and engage suture releasably supported on the first jaw, and (ii) retract the suture through the tissue; wherein the first jaw comprises a spring for selectively binding the suture to the first jaw.

In the suture passer described above, the spring comprises a cantilever spring.

In the suture passer described above, one portion of the cantilever spring is mounted to the shaft and another portion of the cantilever spring moves relative to the first jaw.

In the suture passer described above, the needle comprises an inclined surface for engaging the spring or suture.

In the suture passer described above, the spring comprises a pathway for receiving the needle.

In the suture passer described above, the first jaw comprises a suture slot sized to receive the suture therein.

In the suture passer described above, the spring selectively binds the suture in the suture slot.

In the suture passer described above, the spring selectively binds the suture against a side wall of the suture slot.

In the suture passer described above, the suture slot extends substantially parallel to the axis of the shaft.

In the suture passer described above, the suture slot extends transverse to the axis of the shaft.

In the suture passer described above, the suture slot comprises a first portion which extends substantially parallel to the axis of the shaft and a second portion which extends transverse to the axis of the shaft.

In the suture passer described above, the spring is configured to releasably capture the suture thereto.

In the suture passer described above, the spring comprises a groove for releasably capturing the suture to the spring.

In the suture passer described above, the second jaw is configured to reciprocate in alignment with the axis of the shaft so as to advance toward, and retract from, the first jaw.

In the suture passer described above, the second jaw is configured to move in an angular motion relative to a longitudinal axis of the shaft.

The suture passer described above further comprises a second needle movably mounted to the shaft in coaxial disposition with the needle.

In the suture passer described above, the second needle is sized relative to the needle so as to provide column strength to the needle.

In the suture passer described above, the second needle is configured so as to selectively clamp suture to the hook of the needle.

In the suture passer described above, the hook of the needle comprises a distally-extending portion, a base connected to the distally-extending portion and extending transverse to the distally-extending portion, and a proximally-extending portion connected to the base and spaced from the distally-extending portion, and further wherein the second needle advances relative to the needle so as to clamp the suture against the base of the hook of the needle.

According to yet another aspect of the invention, there is provided a self-contained, pre-assembled needle assembly insertable as a unit into a self-contained, pre-assembled tool assembly so as to together form a complete suture passer, the self-contained, pre-assembled needle assembly comprising an inner needle configured to pierce tissue and having a hook thereon, and an outer needle configured to pierce tissue and concentrically disposed about the inner needle, the inner needle being spring mounted to the outer needle.

In the self-contained, pre-assembled needle assembly described above, the outer needle substantially covers the hook on the inner needle when the self-contained, pre-assembled needle assembly is in its unbiased condition so as to clamp suture to the inner needle.

In the self-contained, pre-assembled needle assembly described above, the inner needle can be moved relative to the outer needle so as to expose the hook on the inner needle.

Brief Description Of The Drawings

These and other objects and features of the present invention will be more fully disclosed or rendered obvious by the following detailed description of the preferred embodiments of the invention, which is to be considered together with the accompanying drawings wherein like numbers refer to like parts, and further wherein:

Figs. 1A-1D are schematic views showing various aspects of hip motion;

Fig. 2 is a schematic view showing bone structures in the region of the hip joint;

Fig. 3 is a schematic anterior view of the femur;

Fig. 4 is a schematic posterior view of the top end of the femur;

Fig. 5 is a schematic view of the pelvis;

Figs. 6-12 are schematic views showing bone and soft tissue structures in the region of the hip joint;

Figs. 13A and 13B show a schematic view showing cam-type femoroacetabular impingement (i.e., cam-type FAI);

Figs. 14A and 14B show a schematic view showing pincer-type femoroacetabular impingement (i.e., pincer-type FAI);

Fig. 15 is a schematic view showing a labral tear;

Figs. 16 and 17 are schematic views showing a novel suture passer formed in accordance with the present invention;

Figs. 18-38 are schematic views showing various details of the construction and operation of the distal end of the novel suture passer of Figs. 16 and 17;

Figs. 39 and 40 are schematic views showing how the novel suture passer of Figs. 16 and 17 can comprise a reusable tool assembly and a disposable needle assembly;

Figs. 41-50 are schematic views showing various details of the construction and operation of the reusable tool assembly and a disposable needle assembly of Figs. 39 and 40;

Figs. 50A, 50B and 50C are schematic views showing an alternative form of the distal jaw spring of the novel suture passer of Figs. 16 and 17;

Figs. 50D, 50E and 50F are schematic views showing another alternative form of the distal jaw spring of the novel suture passer of Figs. 16 and 17;

Figs. 51 and 52 are schematic views showing an alternative form of the outer needle of the novel suture passer of the present invention;

Figs. 53 and 54 are schematic views showing an alternative form of the inner needle of the novel suture passer of the present invention;

Figs. 55-68 are schematic views showing various details of the construction and operation of the distal end of an alternative form of the novel suture passer of the present invention;

Figs. 69-84 are schematic views showing various details of the construction and operation of the distal end of another alternative form of the novel suture passer of the present invention;

Figs. 85-89 are schematic views showing an alternative form of the distal jaw spring of the novel suture passer of Figs. 69-84;

Fig. 90 is a schematic view showing another alternative construction for the novel suture passer of the present invention;

Figs. 90A, 90B and 90C are schematic views showing an alternative form of the novel suture passer of the present invention;

Figs. 90D, 90E, 90F, 90G, 90H and 90I are schematic views showing the novel suture passer of Figs. 90A, 90B and 90C being used to pass suture;

Figs. 91-94 are schematic views showing still another alternative construction for the novel suture passer of the present invention; and

Fig. 95 is a schematic view showing another form of the novel suture passer of the present invention.

Detailed Description Of The Invention

Looking first at Figs. 16 and 17, there is shown a novel suture passer 5 formed in accordance with the present invention. Suture passer 5 generally comprises an elongated shaft 10 having a distal jaw 15 disposed at the distal end of elongated shaft 10 and a handle 20 disposed at the proximal end of elongated shaft 10.

Looking next at Figs. 18-25, distal jaw 15 is intended to releasably carry a suture 25 thereon. To this end, and as will hereinafter be discussed in further detail, distal jaw 15 has a suture slot 30

(Fig. 18) formed therein. In one preferred form of the present invention, suture slot 30 is sized so that suture 25 can slide easily therein. And in one preferred form of the present invention, suture slot 30 comprises a proximal longitudinal section 35, an intermediate diagonal section 40, and a distal longitudinal section 45. Distal jaw 15 also includes a slot 50 (Fig. 20) at its distal end. A distal jaw spring 55 (Fig. 19) is movably mounted in slot 50. More particularly, distal jaw spring 55 is mounted to elongated shaft 10 at the proximal end of the distal jaw spring, e.g., via a pair of pins 60 extending through the proximal end of the distal jaw spring, such that the distal end of distal jaw spring 55 can flex downwardly relative to distal jaw 15, in a cantilever fashion. A suture seat 70 (Fig. 25) is disposed at the free end of distal jaw spring 55. Suture seat 70 preferably has an inclined surface 72 thereon to act as a ramp to aid the inner needle 80 (and/or the outer needle 85) (see below) in displacing the distal jaw spring 55 downward during the inner and outer needles' deployment stroke, as will hereinafter be discussed in further detail. Distal jaw spring 55 and suture seat 70 are sized and positioned relative to distal jaw 15 so that suture seat 70 normally protrudes across suture slot 30 under the influence of distal jaw spring 55. However, suture seat 70 can be forced out of suture slot 30 by overcoming the bias of distal jaw spring 55, e.g., by camming, as will hereinafter be discussed. As a result of this construction, a suture 25 disposed in suture slot 30 can be releasably held in the suture slot (and hence releasably held to distal jaw 15) with a light friction fit by distal jaw spring 55 and suture seat 70.

Still looking now at Figs. 18-25, suture passer 5 also comprises three elements which are movable relative to elongated shaft 10 and distal jaw 15, i.e., a proximal jaw 75, an inner needle 80 and an outer needle 85, with outer needle 85 being disposed co-axial with, and intermediate, inner needle 80 and proximal jaw 75. More particularly, proximal jaw 75 includes a lumen 90 for slidably receiving outer needle 85 and inner needle 80 (Fig. 19). Outer needle 85 comprises a lumen 95 for slidably receiving inner needle 80, and includes a beveled tip 100 (Fig. 21) which closely surrounds inner needle 80 (Figs. 21-23). Inner needle 80 preferably comprises a sharp distal tip 105, an inclined surface 107 and a suture slot 110. Suture slot 110 is preferably in the form of a "crochet hook", in the sense that it includes a return 115 extending alongside a portion of the suture slot, whereby to provide a "crochet hook" effect for the distal end of inner needle 80.

Returning now to Figs. 16 and 17, handle 20 preferably includes a grip 120 for seating in the palm of the user's hand, and a trigger 125 for actuation by the user's fingers. Handle 20 is constructed so that, by pulling trigger 125 towards grip 120, and thereafter releasing trigger 125, proximal jaw 75, inner needle 80 and outer needle 85 can be moved in a sequenced manner relative to elongated shaft 10 and distal jaw 15, and in a sequenced manner relative to one another, whereby to pass suture through tissue, as will hereinafter be discussed in further detail. Significantly, due to the construction employed by suture passer 5, suture can be arthroscopically passed through even the tough fibrous capsule of the hip joint, whereby to permit arthroscopic suturing of the fibrous capsule. As a result, the present invention makes it more practical for a surgeon to arthroscopically operate on the hip joint by first laying open the fibrous capsule, performing the desired procedure on the hip joint, and then closing the fibrous capsule by suturing at the conclusion of the procedure.

Suture passer 5 is preferably used as follows.

Looking now at Figs. 18 and 19, proximal jaw 75 is initially retracted proximally relative to distal jaw 15 so as to provide a gap 127 therebetween, inner needle 80 is initially retracted so that its distal end resides within lumen 90 of proximal jaw 75, and outer needle 85 is initially retracted so that its distal end resides proximal to the distal end of inner needle 80. A suture 25 is slipped into suture slot 30 of distal jaw 15 and then pulled distally so that the suture sits at the convergence of proximal longitudinal section 35 and intermediate diagonal section 40 of suture slot 30 - this action causes the suture to engage the inclined surface 72 of suture seat 70 and thereby drive (i.e., cam) suture seat 70 (and the free end of distal jaw spring 55) downwardly far enough for the suture to slip above suture seat 70, whereupon suture seat 70 (and distal jaw spring 55) press upwardly so as to releasably capture suture 25 in suture slot 30 via the spring-biased suture seat 70.

With suture passer 5 in this condition, the distal end of the suture passer is ready to be advanced to the remote site where tissue is to be sutured. By way of example but not limitation, the distal end of suture passer 5 may be arthroscopically advanced to a laid-open fibrous capsule in the hip joint, in order to suture closed the laid-open fibrous capsule at the conclusion of an arthroscopic procedure. Once the distal end of suture passer 5 is disposed at the remote site, the suture passer is maneuvered so that the tissue which is to be sutured is located in the gap 127 between distal jaw 15 and proximal jaw 75. Alternatively, and/or additionally, the tissue which is to be sutured may be maneuvered (e.g., with a supplemental tool) so that the tissue is located in the gap 127 between distal jaw 15 and proximal jaw 75.

Looking next at Figs. 26 and 27, proximal jaw 75 is then advanced longitudinally towards distal jaw 15 so as to securely clamp the tissue which is to be sutured between the two jaw members. Preferably inner needle 80 and outer needle 85 are advanced in conjunction with proximal jaw 75, in the manner shown in Fig. 27.

Once the tissue has been securely clamped between distal jaw 15 and proximal jaw 75, inner needle 80 and outer needle 85 are advanced together, as a unit, out of proximal jaw 75 and through the tissue. See Figs. 28 and 29. As this occurs, outer needle 85 closely supports inner needle 80, and vice-versa, thereby providing increased column strength for the two needles and permitting the two relatively thin needles to pass through tough tissue, e.g., the tough fibrous capsule of the hip. In this respect it should be appreciated that this mutual needle support (for increased column strength) is a very important aspect of the present invention, since it enables the two relatively thin needles to pass through extremely tough tissue (e.g., the fibrous capsule of the hip), tissue which neither needle could easily pass through alone, or which a single needle might pass through alone but not accurately along the desired axis of travel (e.g., the single needle might diverge from a straight path and miss a target zone on the other side of the tissue).

In addition to the foregoing, it should also be appreciated that, significantly, proximal jaw 75 also supports inner needle 80 and outer needle 85 during their passage through tissue, since only short lengths of inner needle 80 and outer needle 85 extend beyond (i.e., out of) proximal jaw 75. Again, this needle-reinforcing construction helps enable the two relatively thin needles to pass through extremely tough tissue (e.g., the fibrous capsule of the hip) which they might not otherwise be able to penetrate on their own, or which they might not otherwise be able to penetrate accurately on their own.

Inner needle 80 and outer needle 85 continue to move distally as a unit until the distal tips of inner needle 80 and outer needle 85 exit the far side of the tissue and the distal tip of inner needle 80 starts to enter distal jaw 15. At or near this point, forward advancement of outer needle 85 is stopped, and inner needle 80 advances alone. As inner needle 80 advances, its inclined surface 107 engages the inclined surface 72 of suture seat 70 and/or suture 25, thereby causing suture seat 70 and distal jaw spring 55 to be cammed downwardly, and thereby releasing suture 25 from the capture previously provided by suture seat 70 and distal jaw spring 55 (Figs. 30-33). As this occurs, suture 25 is urged distally within suture slot 30, with intermediate diagonal section 40 and distal longitudinal section 45 accommodating suture 25. Inner needle 80 continues to move distally until suture slot 110 in inner needle 80 is positioned above suture 25 (Figs. 34 and 35), whereupon distal jaw spring 55 and suture seat 70 deliver suture 25 up into suture slot 110 in inner needle 80 (Figs. 34 and 35). Inner needle 80 is then retracted, carrying suture 25 with it, until suture 25 encounters the bevelled tip 100 of outer needle 85, whereupon suture 25 is locked between the two needles (Fig. 36).

Then inner needle 80 and outer needle 85 are retracted proximally, as a unit, drawing suture 25 through the tissue which is clamped between distal jaw 15 and proximal jaw 75. See Fig. 37.

Once suture 25 has been passed through the tissue which is clamped between distal jaw 15 and proximal jaw 75, proximal jaw 75 is retracted, thereby releasing the tissue (which has suture 25 passing therethrough) from the suture passer. See Fig. 38.

This passed suture may then be used in ways well known in the art, e.g., so as to stitch closed a laid-open fibrous capsule.

In one preferred form of the invention, and looking now at Figs. 39 and 40, shaft 10, distal jaw 15, handle 20 and proximal jaw 75 are formed as one assembly (e.g., such as the tool assembly 130 shown in Figs. 39 and 40), and inner needle 80 and outer needle 85 are formed as another assembly (e.g., such as the needle assembly 135 shown in Figs. 39 and 40). Such a construction can be highly advantageous, since it permits tool assembly 130 to be reusable and needle assembly 135 to be disposable.

In one preferred form of the invention, and looking now at Figs. 41-44, needle assembly 135 comprises (i) the aforementioned outer needle 85 and a hub 140 secured to the proximal end of outer needle 85, and (ii) the aforementioned inner needle 80 and a tab 145 secured to the proximal end of inner needle 80. A spring 150 is disposed between hub 140 and tab 145, so as to yieldably bias hub 140 and tab 145 away from one another. As a result, spring 150 yieldably biases inner needle 80 proximally relative to outer needle 85, as will hereinafter be discussed in further detail.

Looking next at Figs. 45-48, handle 20 preferably has a needle carriage 155 movably mounted therein.

Needle carriage 155 includes a tab slot 160 for receiving tab 145 of needle assembly 135, as will hereinafter be discussed. Trigger 125 is connected to needle carriage 155 so that moving trigger 125 towards grip 120 causes needle carriage 155 to move distally relative to handle 20. Preferably trigger 125 is connected to needle carriage 155 via a pin-and-slot mechanism, i.e., a pin 165 riding in a slot 170. A spring 175 (Fig. 47), engaging a pin 180 extending out of needle carriage 155, biases needle carriage 155 proximally relative to handle 20 (and hence biases trigger 125 away from grip 120). Spring 175 ensures that needle carriage 155 is returned to the full proximal position when trigger 125 is released.

Handle 20 also includes a flange seat 185 (Fig. 45) movably mounted therein. Flange seat 185 is spring-mounted to needle carriage 155 so that flange seat 185 is spring-biased distally from needle carriage 155. In one preferred form of the invention, flange seat 185 is spring-mounted to needle carriage 155 via a pair of posts 190 (Fig. 47) and a pair of springs 195. Flange seat 185 is adapted to receive a locating flange 200 on hub 140 as will hereinafter be discussed.

Handle 20 also includes a proximal jaw carriage 205 (Fig. 46) movably mounted therein. Proximal jaw carriage 205 is connected to the proximal end of proximal jaw 75 so that the two elements move as a unit. An extension 210 of a spring 215 is seated in an opening 220 formed in proximal jaw carriage 205 so that spring 215 biases proximal jaw carriage 205 proximally, and hence biases proximal jaw 75 proximally, as will hereinafter be discussed.

Needle assembly 135 is loaded into tool assembly 130 by fitting locating flange 200 of hub 140 into flange seat 185, and by fitting tab 145 into tab slot 160 of needle carriage 155. See Fig. 48.

On account of the foregoing construction, when trigger 125 is moved towards grip 120, proximal jaw carriage 205 is moved distally by extension 210 of spring 215, thereby causing proximal jaw 75 to move distally so as to engage tissue disposed in the gap 127 between distal jaw 15 and proximal jaw 75. As this occurs, needle carriage 155 also moves distally, which in turn causes tab 145 (and hence inner needle 80) to also move distally. At the same time, due to the relative rigidity of springs 195 (Fig. 47), flange seat 185 also moves distally, causing hub 140 (and hence outer needle 85) to also move distally, thereby causing inner needle 80 and outer needle 85 to move distally as a unit.

This coordinated distal movement of proximal jaw 75, inner needle 80 and outer needle 85 continues until the force applied to the tissue by proximal jaw

75 equates to the maximum force that spring 215 (Fig. 46) can apply. Spring 215 then begins to wind up, whereupon proximal jaw carriage 205 stops moving distally (and hence proximal jaw 75 stops moving distally), while needle carriage 155 keeps moving distally, thereby causing inner needle 80 and outer needle 85 to continue moving distally, whereby to penetrate the tissue in unison.

Continued movement of trigger 125 toward grip 120 causes the elements to move further distally until flange seat 185 engages a stop 225 formed in handle 20 (Fig. 49), thereby preventing further distal movement of flange seat 185, and hence preventing further distal movement of hub 140, and hence preventing further distal movement of outer needle 85. However, continued movement of trigger 125 toward grip 120 causes tab 145 to be moved distally (Fig. 50) so as to overcome the power of spring 150 (Fig. 44), so that inner needle 80 is advanced distally relative to outer needle 85, whereby to permit inner needle 80 to engage suture seat 70, cam it out of the way, and align its suture slot 110 with suture 25.

The amount of relative movement between inner needle 80 and outer needle 85 can be set in a variety of ways, including having flange seat 185 stop forward distal progress of needle carriage 155. Alternatively, further movement of trigger 125 can be stopped by grip 120 at a set position so as to limit longitudinal movement of inner needle 80 relative to outer needle 85.

Releasing trigger 125 causes, sequentially, needle carriage 155 to withdraw proximally so as to permit inner needle 80 to be moved proximally by spring 150 while hub 140 (and hence outer needle 85) remains stationary, thereby picking up suture 25 in suture slot 110 and then capturing suture 25 between inner needle 80 and outer needle 85. Continued release of trigger 125 causes tab 145 and hub 140 (and hence inner needle 80 and outer needle 85) to move proximally as a unit, and hence causes inner needle 80 and outer needle 85 to withdraw back through the tissue as a unit, carrying the suture therewith. Continued release of trigger 125 causes spring extension 210 to move proximal jaw carriage 205 proximally, whereby to withdraw proximal jaw 75 from the tissue, thereby releasing the tissue from suture passer 5, with suture 25 extending through the tissue.

It should be appreciated that the portion of distal jaw spring 55 which aids in holding suture 25 to distal jaw 15 can take many forms other than that shown in Figs. 24 and 25. By way of example but not limitation, the spring surface that comes into contact with the suture can have a single tooth, multiple teeth or a roughened finish so as to promote the spring's ability to hold the suture. This portion of the distal jaw spring can also have a perpendicular surface that acts to keep suture 25 from moving distally as inner needle 80 passes over the suture.

Thus, Figs. 50A, 50B and 50C show one alternative form of distal jaw spring 55. In this form of the invention, suture seat 70 has its inclined surface 72 formed with an arcuate configuration to receive inner needle 80 during its forward stroke, and includes teeth 226 for positively engaging suture 25 and forcing it against the opposing side wall of the suture slot. In addition, the proximal end of distal jaw spring 55 is modified so that only one pin 60 (Fig. 19) is required - this pin 60 acts as a pivot pin, and clockwise motion of distal jaw spring 55 about this pivot pin is limited by a stop surface 227 which engages a corresponding stop surface on shaft 10. In Fig. 50B a groove 538 to accept needle is also shown.

Figs. 50D, 50E and 50F show another alternative form of distal jaw spring 55. In this form of the invention, suture seat 70 has a backstop feature 228 to limit distal migration of suture 25 when inner needle 80 is driving past the suture during the needle's forward stroke.

In addition to the foregoing, distal jaw spring 55 can be made from one or more materials including plastic, metal and, more specifically, superelastic materials such as Nitinol. The cantilevered portion 536 of distal jaw spring 55 may be one material and the suture-capturing portion of the spring may be another material.

Figs. 51 and 52 show an alternative form of outer needle 85. In this form of the invention, outer needle 85 includes a suture slot 230 at its distal end. Suture slot 230 in outer needle 85 is aligned with, and cooperates with, suture slot 110 in inner needle 80 so as to form a positive suture seat between the two needles when inner needle 80 is retracted toward outer needle 85, whereby to securely capture suture 25 to the two needles.

Figs. 53 and 54 show an alternative form of inner needle 80. In this form of the invention, inner needle 80 is hollow, so that objects and/or fluids can be passed through the interior of the inner needle.

Figs. 55-68 show another preferred construction for the present invention, with Figs. 59 and 60 showing initial tissue puncture, and Figs. 61 and 62 showing continued needle passing. Figs. 63 and 64 show full inner needle deployment Figs. 65 and 66 show initial suture capture, and Figs. 67 and 68 show retraction of needle with captured suture. More particularly, the construction shown in Figs. 55-68 is generally similar to the construction shown in Figs.

16-38, except that (i) suture slot 30 comprises a proximal diagonal section 235 (Fig. 55) and a distal substantially vertical section 240, and (ii) suture seat 70 is replaced by a suture capture block 245 (Fig. 56). In this form of the invention, suture 25 follows the diagonal/vertical configuration of suture slot 30, and suture capture block 245 acts to stabilize suture 25 for positive pickup by inner needle 80.

Figs. 69-84 show another preferred construction of the present invention. More particularly, the construction shown in Figs. 69-84 is generally similar to the construction shown in Figs. 55-68, except that (i) distal jaw spring 55 and suture capture block 245 are replaced by a distal jaw spring 250 (Fig. 83) having a suture guide slot 255 formed therein, and (ii) outer needle 85 is replaced by the outer needle 85 with suture slot 230 shown in Figs. 51 and 52. In this form of the invention, suture 25 is spring-held in suture guide slot 255, and follows the path of suture slot 30 as distal jaw spring 250 is displaced by inner needle 80.

Figs. 85-89 show alternative constructions for releasably capturing suture 25 to distal jaw spring 250. Fig. 85 shows post wire, pre shape set form, having flexible arm 540, loading lead in surfaces 542, suture stop tab 544, and stop tab relief 546. Fig. 86

shows post shape set form having suture clamping surface 548. Fig. 87 shows that gap height 550 can vary. Fig. 88 shows added spike 552 for suture capture, and Fig. 89 shows that the spike 552 can vary in size, shape and quantity. Spikes can be on one or both sides.

Fig. 90 shows another preferred construction of the present invention. More particularly, the construction shown in Fig. 90 is generally similar to the construction shown in Figs. 69-84, except that outer needle 85 lacks suture slot 230 and may or may not directly engage suture 25 and may or may not assist in capturing suture 25 to inner needle 80.

Figs. 90A, 90B and 90C show another preferred embodiment of the present invention illustrating needle capture method. More particularly, in this form of the invention, outer needle 85 is formed with an inclined tip 256, however, this inclined tip is offset 180 degrees from the inclined surface 107 of inner needle 80, whereby to enhance suture gripping between suture slot 110 of inner needle 80 and inclined tip 256 of outer needle 85. Furthermore, in this form of the invention, distal jaw spring 55 is omitted and suture 25 is held in suture slot 30 of distal jaw 15 by friction.

Figures 90D, 90E, 90F, 90G and 90I show a suture passing operation using the suture passer of Figs.

90A, 90B and 90C. In particular, Figures 90D, 90E and 90F show load-grasp-deploy steps, with Fig. 90D illustrating loading suture, Fig. 90E illustrating grasping tissue with jaw, and Fig. 90F illustrating deploying conduit tube.

Figures 90G and 90H show deploy capture needle steps. Figure 90I shows how captured suture is retracted, with reference numeral 491 illustrating pinching suture between main needle and capture needle.

It should also be noted that inner needle 80 can be replaced by a wire with a loop on the end that can capture the suture (e.g., in the manner of a suture threader) and pull it into the outer needle. See, for example, Figs. 91-94, where a wire 260, having a hook 265, grapples the suture and pulls it into outer needle 85.

Fig. 95 shows another preferred embodiment of the present invention. More particularly, in this form of the invention, the longitudinally-reciprocating proximal jaw 75 of the suture passer shown in Figs. 16 and 17 is replaced by a pivoting proximal jaw 270. More particularly, proximal jaw 270 is mounted to elongated shaft 10 via a pivot pin 275, such that longitudinal motion of a drive rod 280 (connected at its proximal end to proximal jaw carriage 205) causes proximal jaw 270 to pivot about pivot pin 275, whereby to open and close the jaw relative to distal jaw 15.

Use Of The Present Invention
For Other Applications

It should be appreciated that the present invention may be used to arthoscopically suture the fibrous capsule of the hip joint, so as to facilitate arthroscopic procedures on the hip joint. The present invention can also be used to arthroscopically suture other tissue, both in the hip joint and in locations other than the hip joint.

Modifications Of The Preferred Embodiments

It should be understood that many additional changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the present invention, may be made by those skilled in the art while still remaining within the principles and scope of the invention.

What Is Claimed Is:

1. A suture passer comprising:

a shaft having an axis;

a distal jaw fixedly mounted to the shaft in alignment with the axis, the distal jaw being configured to releasably support a length of suture thereon;

a proximal jaw movably mounted to the shaft, the proximal jaw being configured to reciprocate in alignment with the axis so as to (i) advance toward the distal jaw so as to clamp tissue between the proximal jaw and the distal jaw, and (ii) retract from the distal jaw so as to release tissue previously clamped between the proximal jaw and the distal jaw;

an inner needle movably mounted to the shaft, the inner needle having a hook and being configured to reciprocate in alignment with the axis so that the hook can selectively (i) advance through tissue clamped between the proximal jaw and the distal jaw, and engage the suture releasably supported on the distal jaw, and (ii) retract the suture through the tissue; and

an outer needle movably mounted to the shaft in coaxial disposition with the inner needle, the outer needle being configured to reciprocate so as to (i) advance through tissue clamped between the proximal jaw and the distal jaw and engage the suture engaged by the hook of the inner needle so as to clamp the suture to the inner needle, and (ii) retract through tissue clamped between the proximal jaw and the distal jaw;

wherein the distal jaw comprises a spring for selectively binding the suture to the distal jaw.

2. A suture passer according to claim 1 wherein the distal jaw spring comprises a cantilever spring.

3. A suture passer according to claim 2 wherein one portion of the cantilever spring is mounted to the shaft and another portion of the cantilever spring moves relative to the distal jaw.

4. A suture passer according to claim 1 wherein the inner needle comprises an inclined surface for engaging the distal jaw spring or suture.

5. A suture passer according to claim 1 wherein the distal jaw spring comprises a pathway for receiving the inner needle.

6. A suture passer according to claim 1 wherein the distal jaw comprises a suture slot sized to receive the suture therein.

7. A suture passer according to claim 6 wherein the distal jaw spring selectively binds the suture in the suture slot.

8. A suture passer according to claim 7 wherein the distal jaw spring selectively binds the suture against a side wall of the suture slot.

9. A suture passer according to claim 6 wherein the suture slot extends substantially parallel to the axis of the shaft.

10. A suture passer according to claim 6 wherein the suture slot extends transverse to the axis of the shaft.

11. A suture passer according to claim 6 wherein the suture slot comprises a first portion which extends substantially parallel to the axis of the shaft and a second portion which extends transverse to the axis of the shaft.

12. A suture passer according to claim 1 wherein the distal jaw spring is configured to releasably capture the suture thereto.

13. A suture passer according to claim 12 wherein the distal jaw spring comprises a groove for releasably capturing the suture to the distal jaw spring.

14. A suture passer according to claim 1 wherein the outer needle is sized relative to the inner needle so as to provide column strength to the inner needle.

15. A suture passer according to claim 1 wherein the hook of the inner needle comprises a distally-extending portion, a base connected to the distally-extending portion and extending transverse to the distally-extending portion, and a proximally-extending portion connected to the base and spaced from the distally-extending portion, and further wherein the outer needle advances relative to the inner needle so as to clamp the suture against the base of the hook of the inner needle.

16. A suture passer according to claim 1 wherein the suture passer comprises a self-contained, pre-assembled tool assembly and a self-contained, pre-assembled needle assembly, and further wherein the self-contained, pre-assembled tool assembly comprises the shaft, the distal jaw and the proximal jaw, and

the self-contained, pre-assembled needle assembly comprises the inner needle and the outer needle.

17. A suture passer according to claim 16 wherein the inner needle is spring mounted to the outer needle.

18. A suture passer according to claim 16 wherein the self-contained tool assembly comprises a handle, wherein the shaft is mounted to the handle, and further wherein the handle comprises a proximal jaw carriage movably mounted to the handle and connected to the proximal jaw, a needle carriage movably mounted to the handle and connected to the inner needle, and a flange seat connected to the outer needle, the flange seat being movably mounted to the needle carriage.

19. A suture passer comprising:

a shaft having an axis;

a first jaw fixedly mounted to the shaft in alignment with the axis, the first jaw being configured to releasably support a length of suture thereon;

a second jaw movably mounted to the shaft, the second jaw being configured so as to (i) advance toward the first jaw so as to clamp tissue between the second jaw and the first jaw, and (ii) retract from the first jaw so as to release tissue previously clamped between the second jaw and the first jaw; and

a needle movably mounted to the shaft, the needle having a hook and being configured to reciprocate in alignment with the axis so that the hook can selectively (i) advance through tissue clamped between the second jaw and the first jaw, and engage suture releasably supported on the first jaw, and (ii) retract the suture through the tissue;

wherein the first jaw comprises a spring for selectively binding the suture to the first jaw.

20. A suture passer according to claim 19 wherein the spring comprises a cantilever spring.

21. A suture passer according to claim 20 wherein one portion of the cantilever spring is mounted to the shaft and another portion of the cantilever spring moves relative to the first jaw.

22. A suture passer according to claim 19 wherein the needle comprises an inclined surface for engaging the spring or suture.

23. A suture passer according to claim 19 wherein the spring comprises a pathway for receiving the needle.

24. A suture passer according to claim 19 wherein the first jaw comprises a suture slot sized to receive the suture therein.

25. A suture passer according to claim 24 wherein the spring selectively binds the suture in the suture slot.

26. A suture passer according to claim 25 wherein the spring selectively binds the suture against a side wall of the suture slot.

27. A suture passer according to claim 24 wherein the suture slot extends substantially parallel to the axis of the shaft.

28. A suture passer according to claim 24 wherein the suture slot extends transverse to the axis of the shaft.

29. A suture passer according to claim 24 wherein the suture slot comprises a first portion which extends substantially parallel to the axis of

the shaft and a second portion which extends transverse to the axis of the shaft.

30. A suture passer according to claim 19 wherein the spring is configured to releasably capture the suture thereto.

31. A suture passer according to claim 30 wherein the spring comprises a groove for releasably capturing the suture to the spring.

32. A suture passer according to claim 19 wherein the second jaw is configured to reciprocate in alignment with the axis of the shaft so as to advance toward, and retract from, the first jaw.

33. A suture passer according to claim 19 wherein the second jaw is configured to move in an angular motion relative to a longitudinal axis of the shaft.

34. A suture passer according to claim 19 further comprising a second needle movably mounted to the shaft in coaxial disposition with the needle.

35. A suture passer according to claim 34 wherein the second needle is sized relative to the needle so as to provide column strength to the needle.

36. A suture passer according to claim 34 wherein the second needle is configured so as to selectively clamp suture to the hook of the needle.

37. A suture passer according to claim 36 wherein the hook of the needle comprises a distally-extending portion, a base connected to the distally-extending portion and extending transverse to the distally-extending portion, and a proximally-extending portion connected to the base and spaced from the distally-extending portion, and further wherein the second needle advances relative to the needle so as to clamp the suture against the base of the hook of the needle.

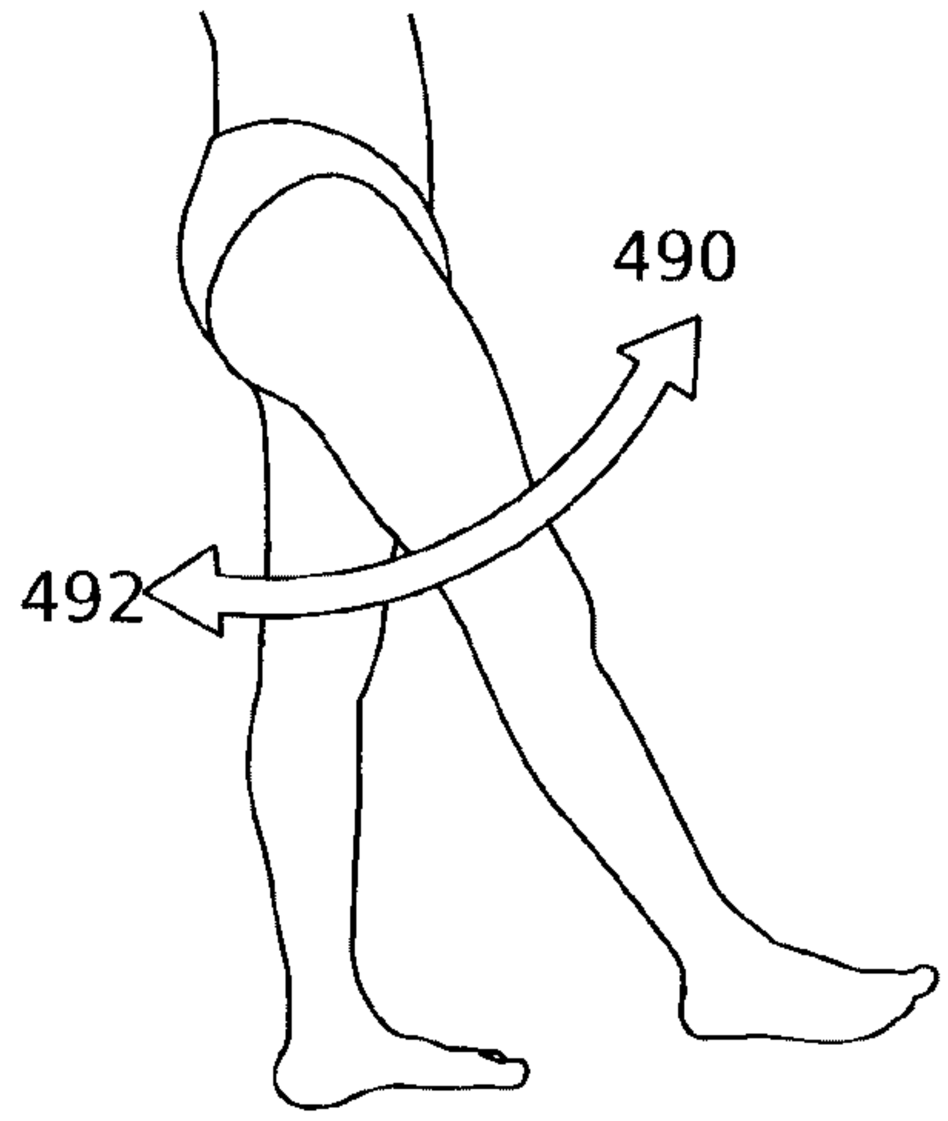


FIG. 1A
(PRIOR ART)

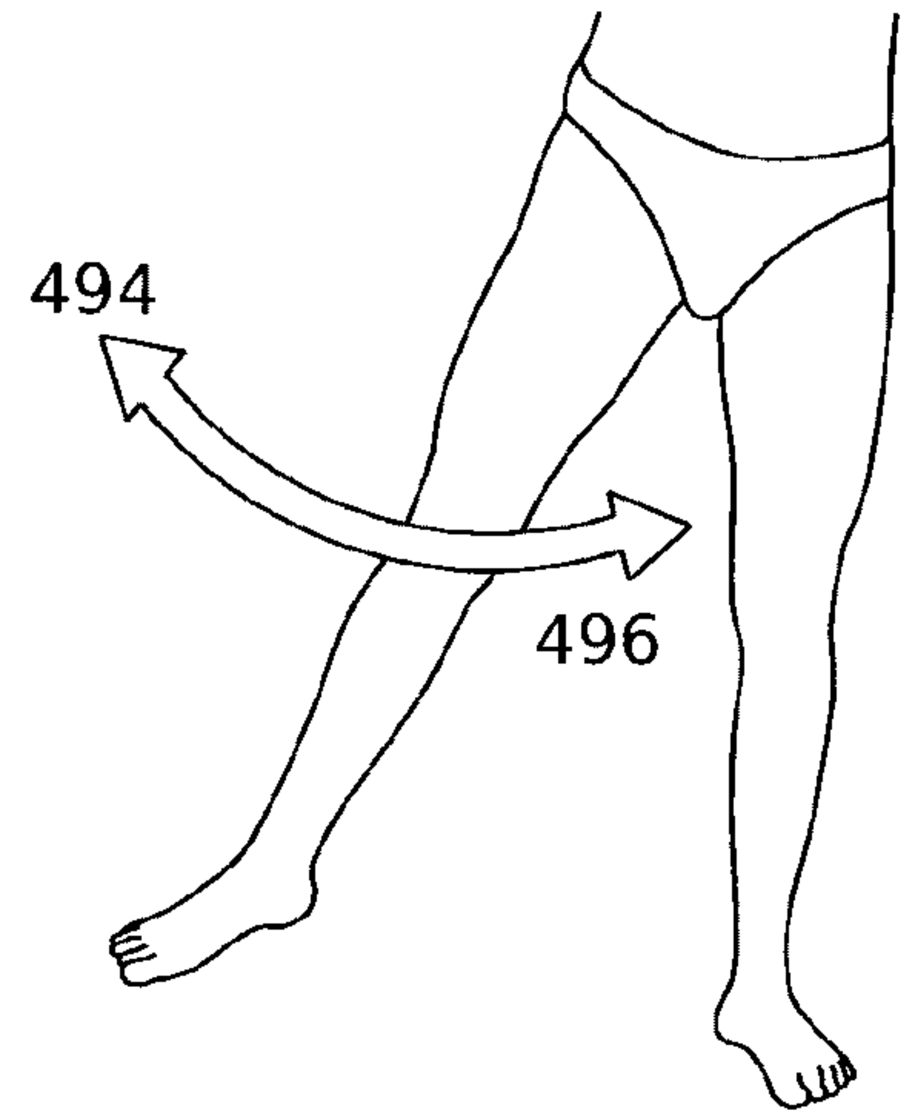


FIG. 1B
(PRIOR ART)

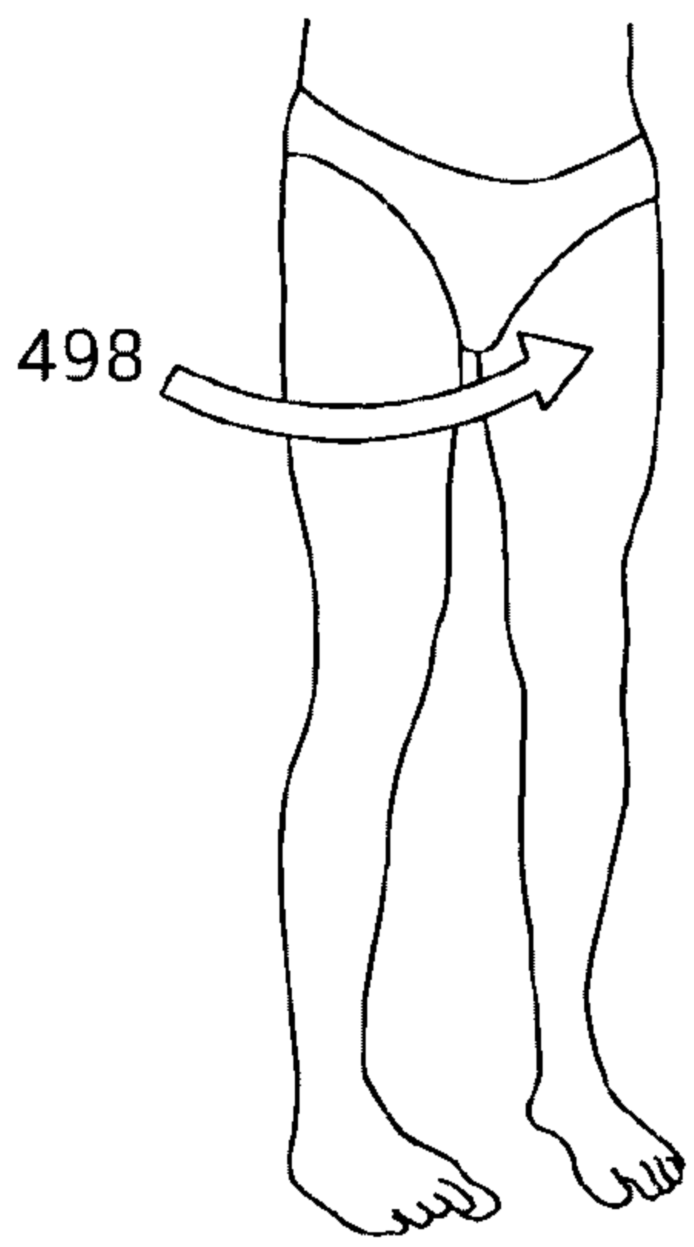


FIG. 1C
(PRIOR ART)

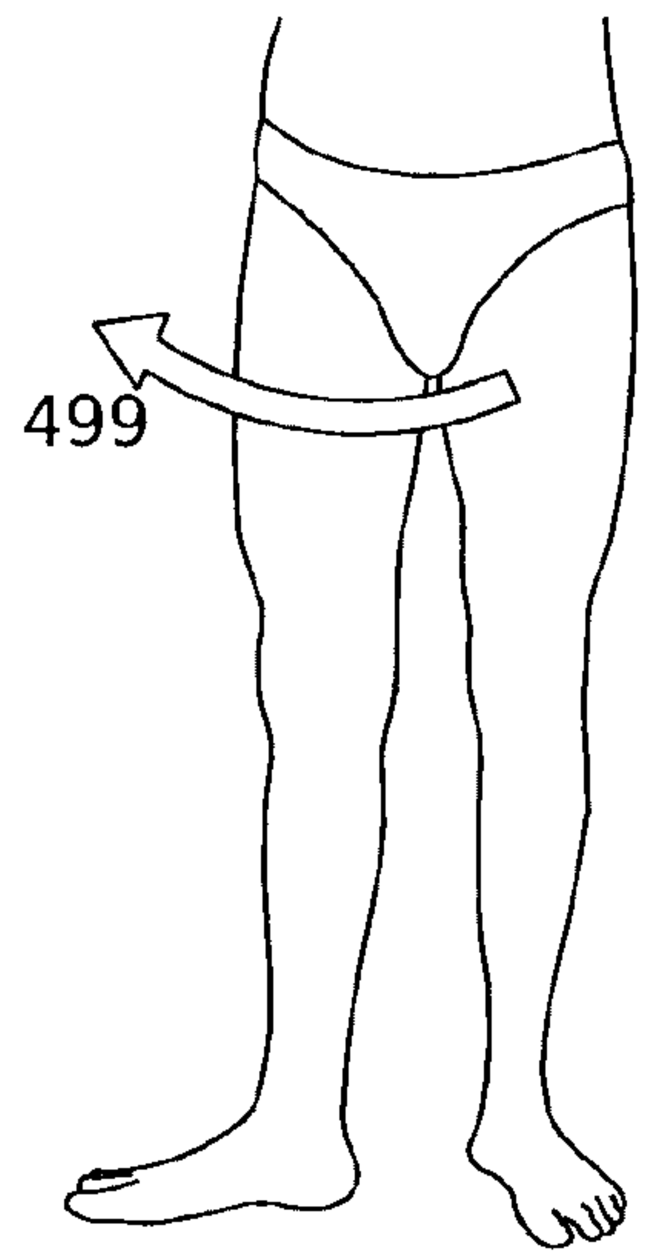


FIG. 1D
(PRIOR ART)

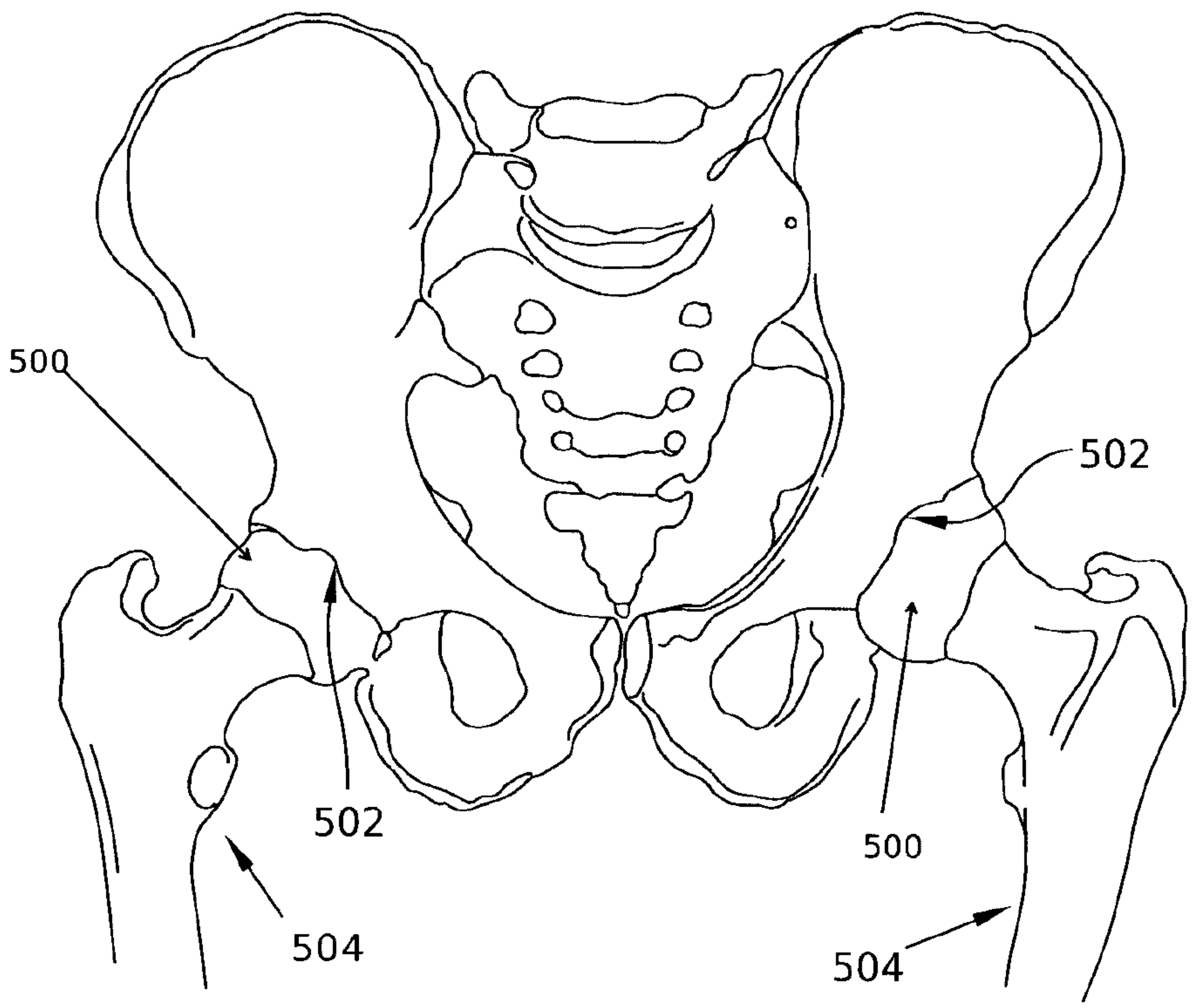


FIG. 2

(PRIOR ART)

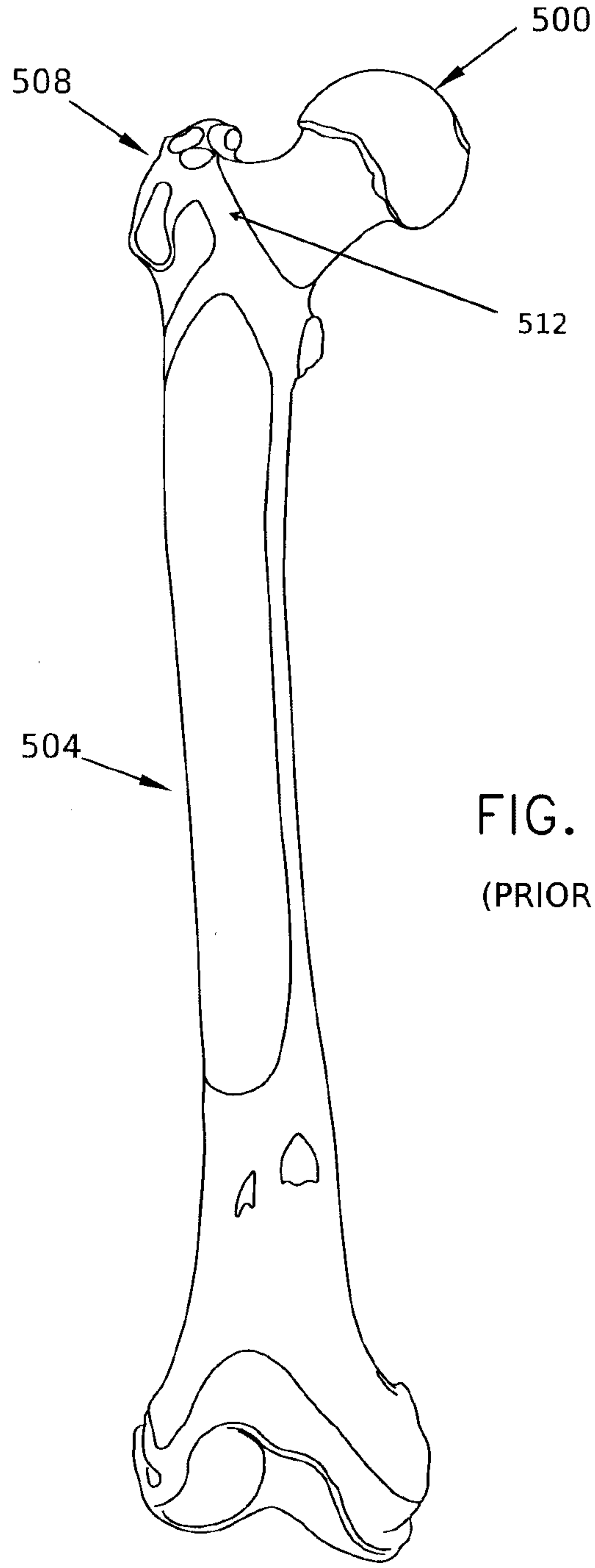


FIG. 3

(PRIOR ART)

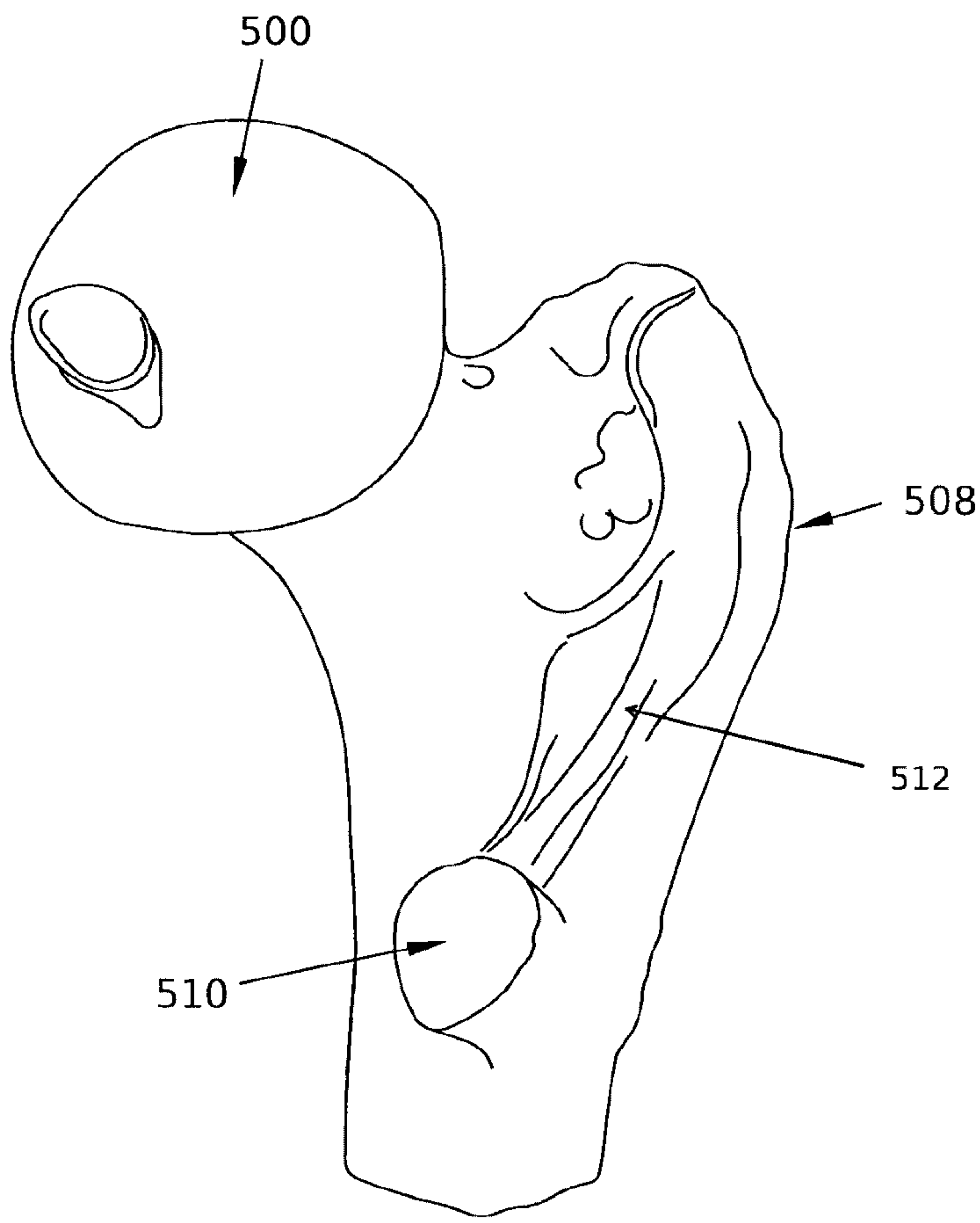


FIG. 4

(PRIOR ART)

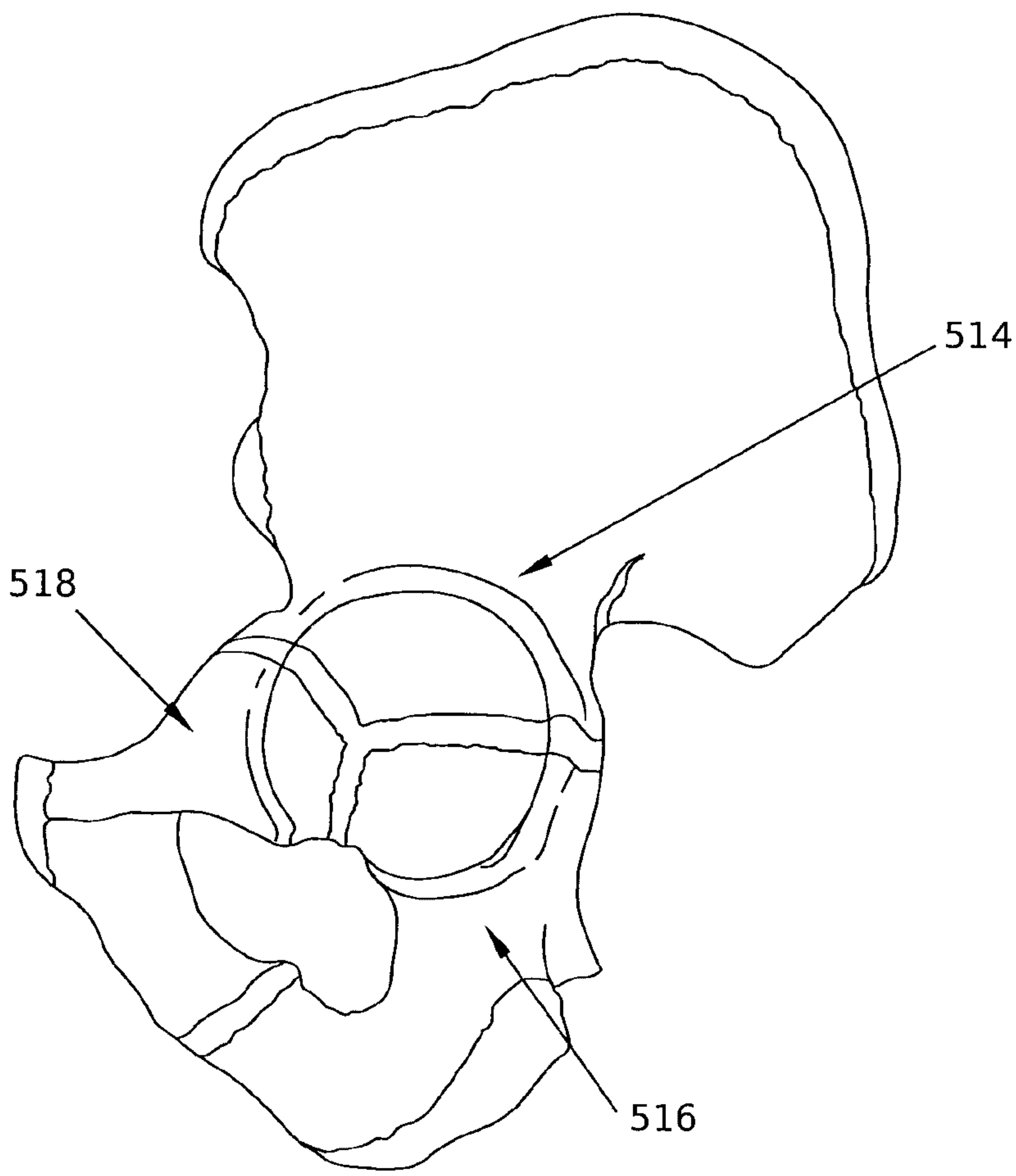


FIG. 5
(PRIOR ART)

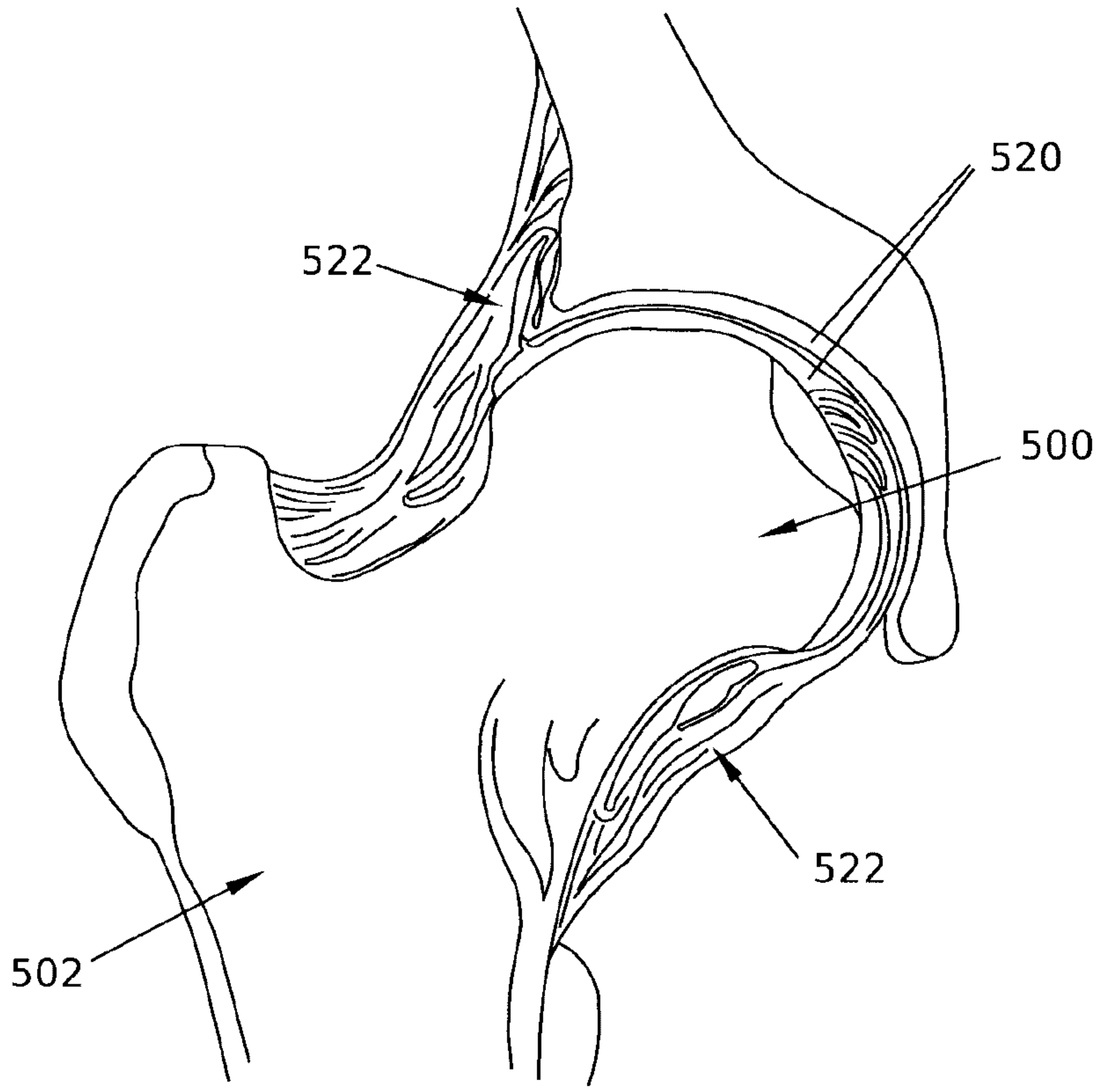


FIG. 6
(PRIOR ART)

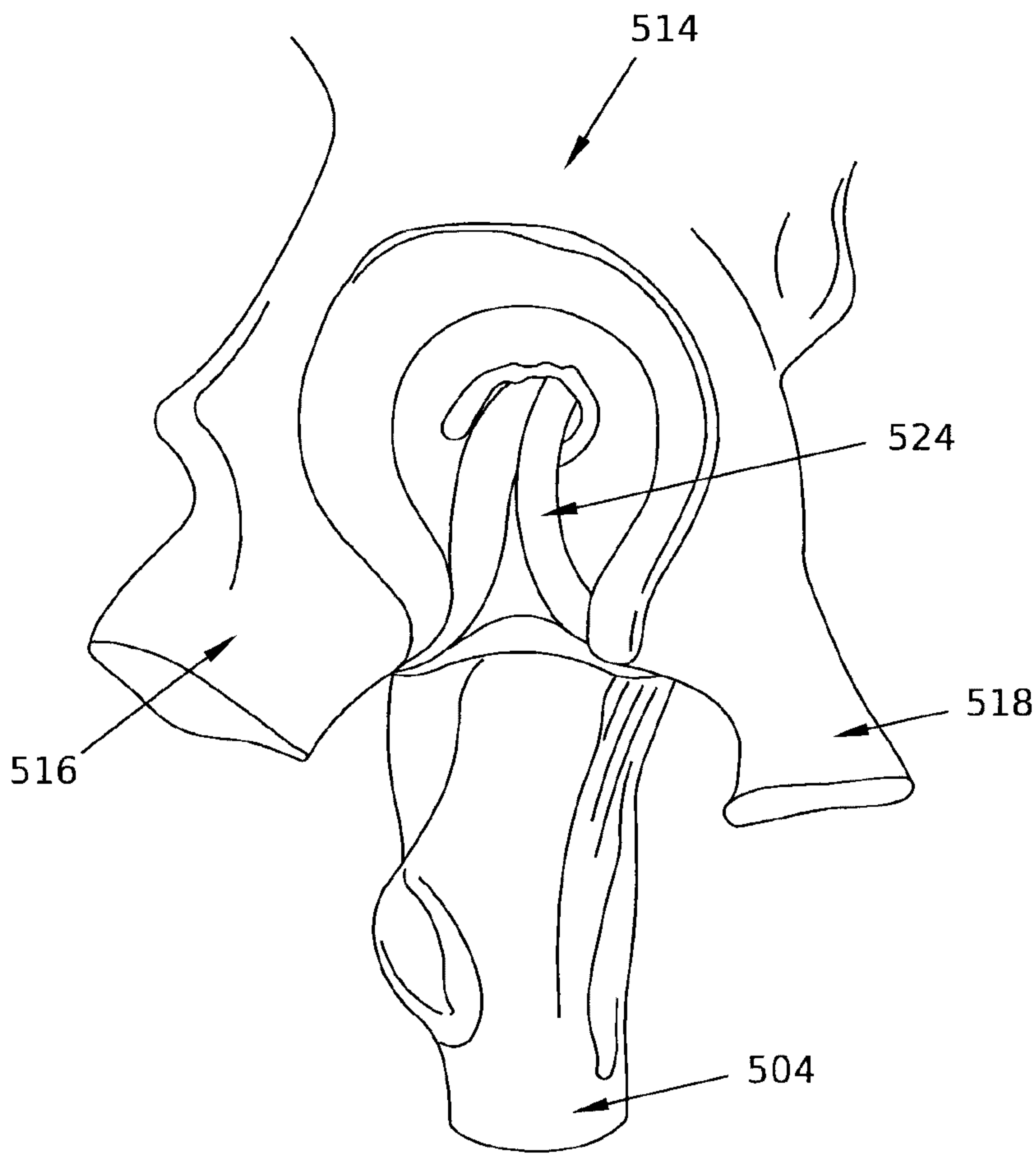


FIG. 7
(PRIOR ART)

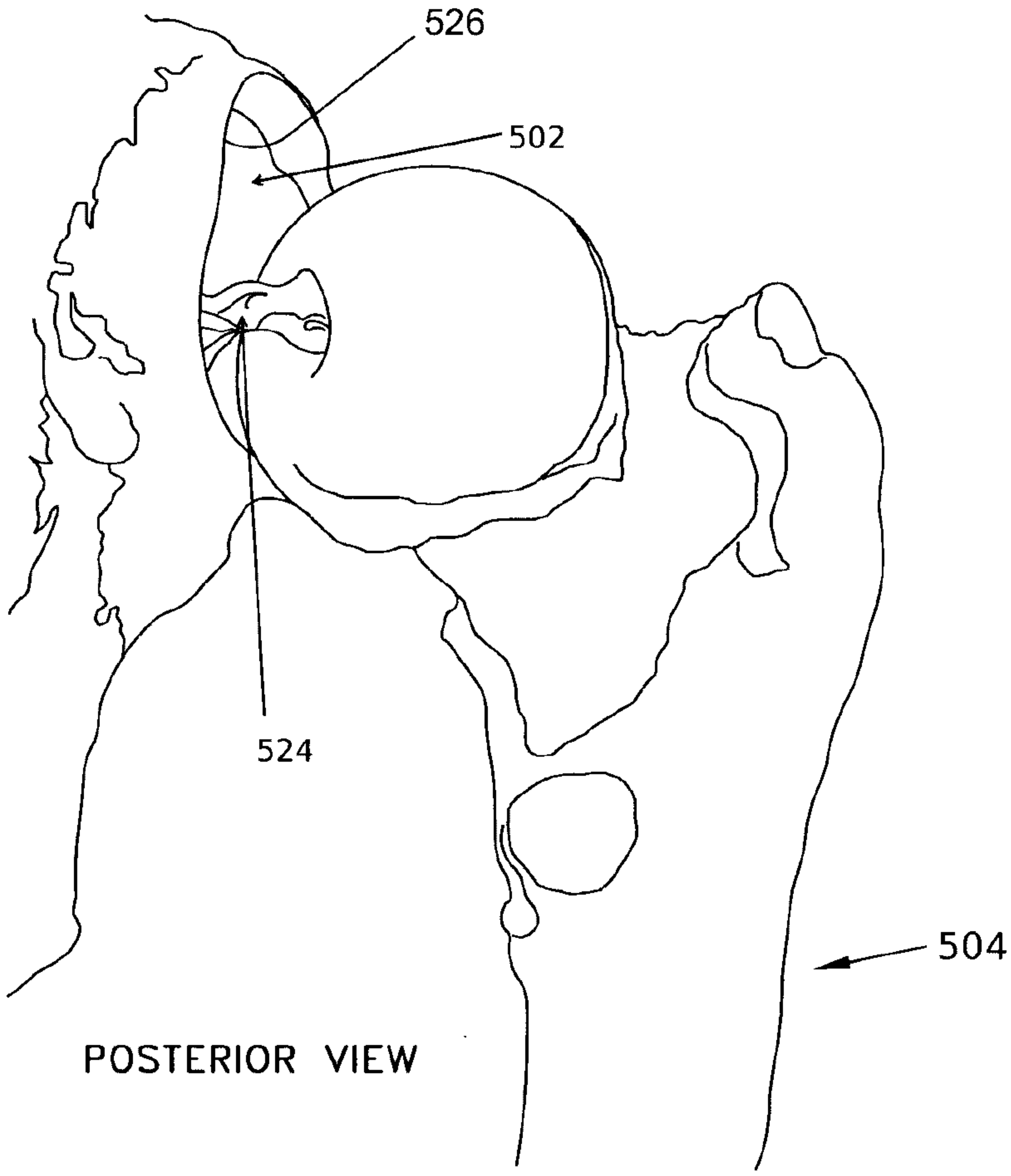


FIG. 8
(PRIOR ART)

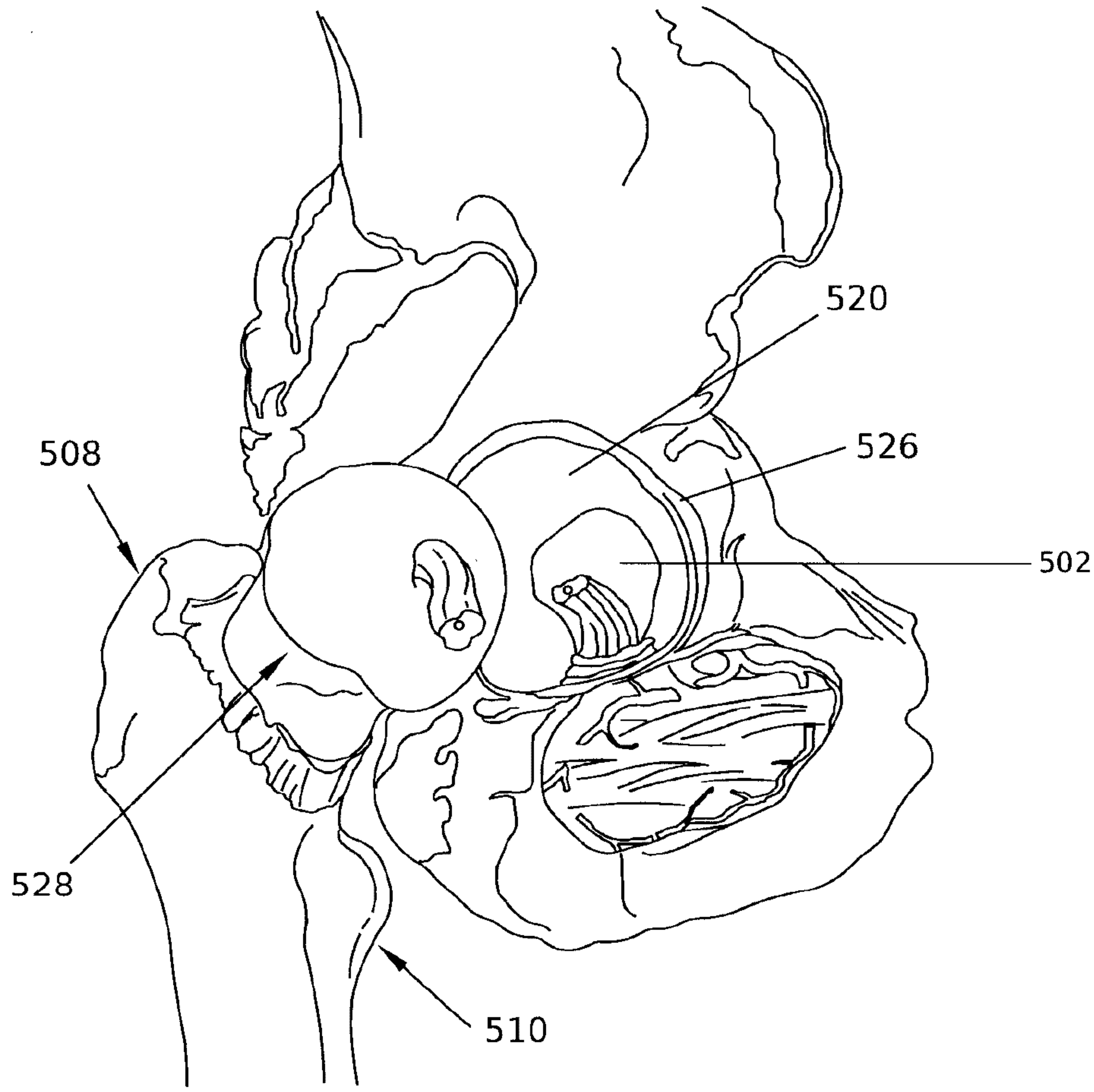


FIG. 9
(PRIOR ART)

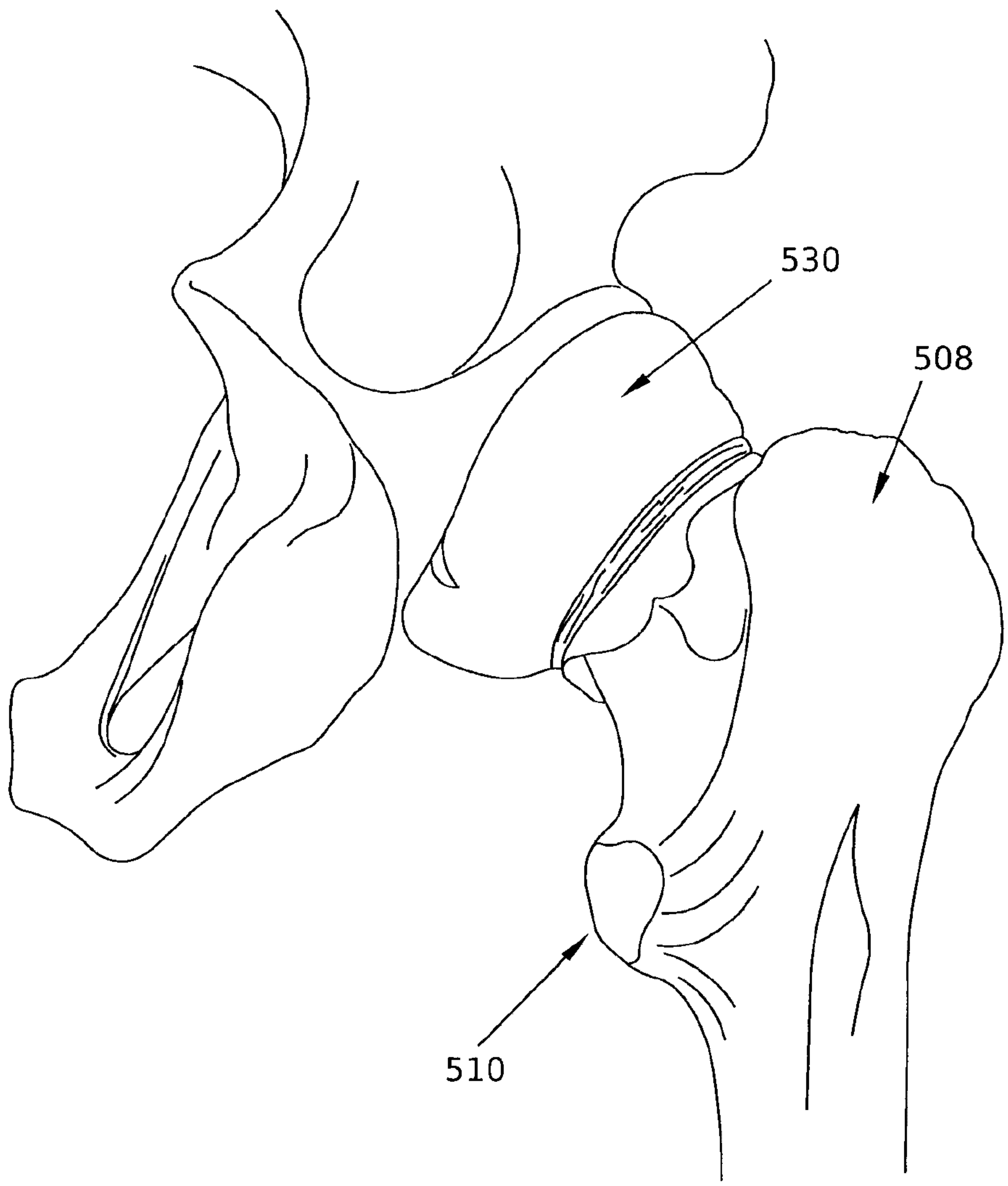


FIG. 10
(PRIOR ART)

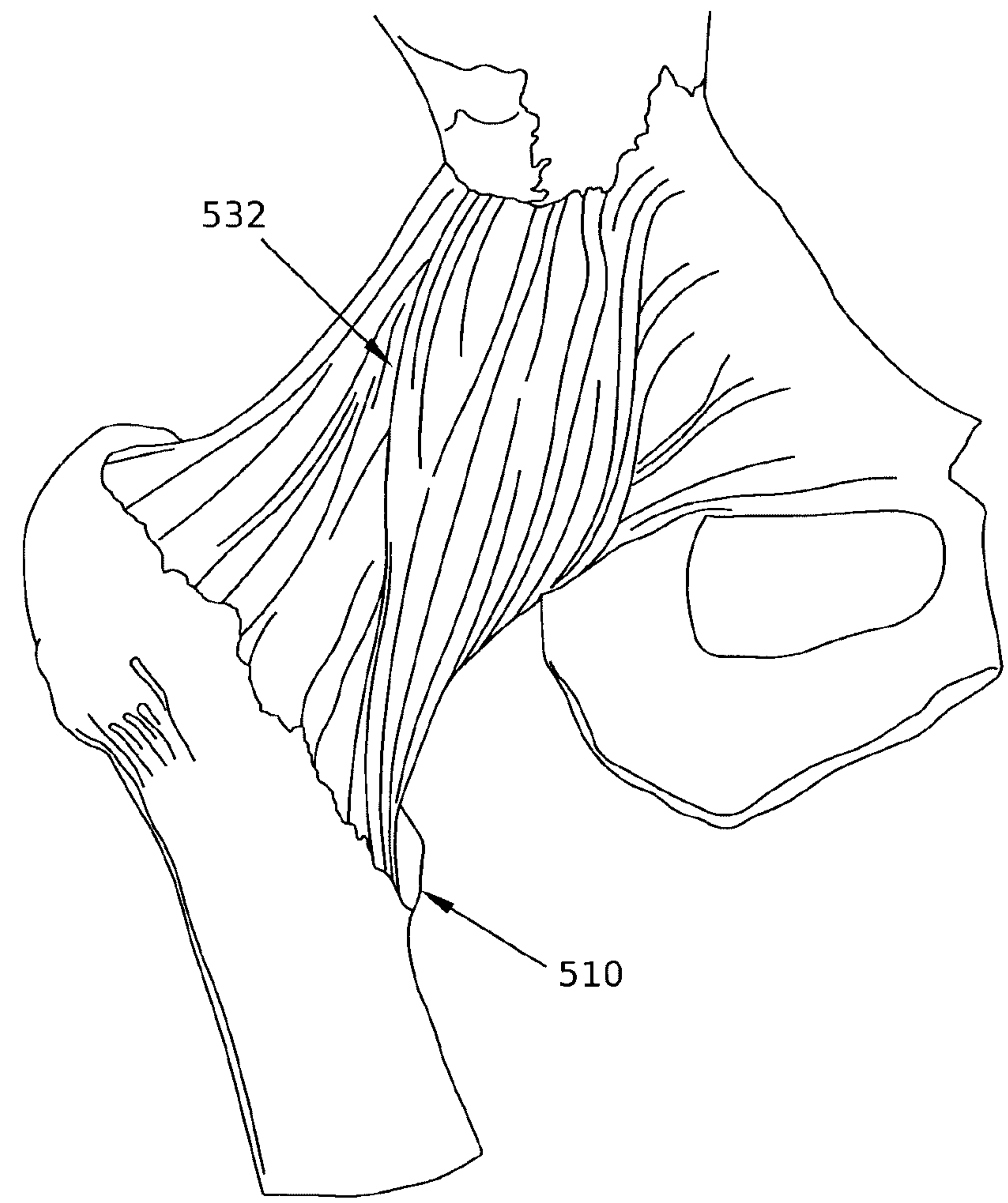


FIG. 11
(PRIOR ART)

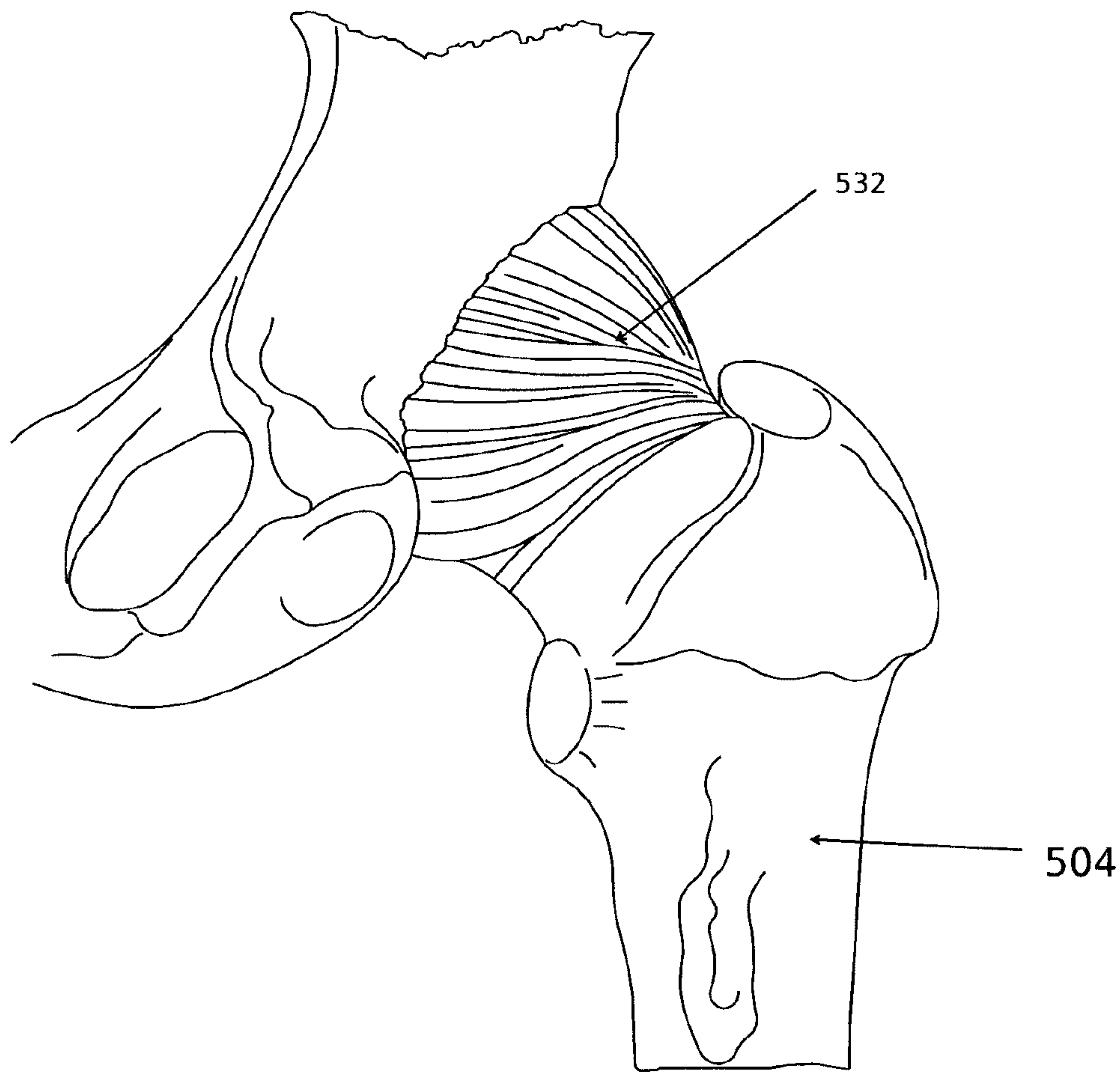


FIG. 12
(PRIOR ART)

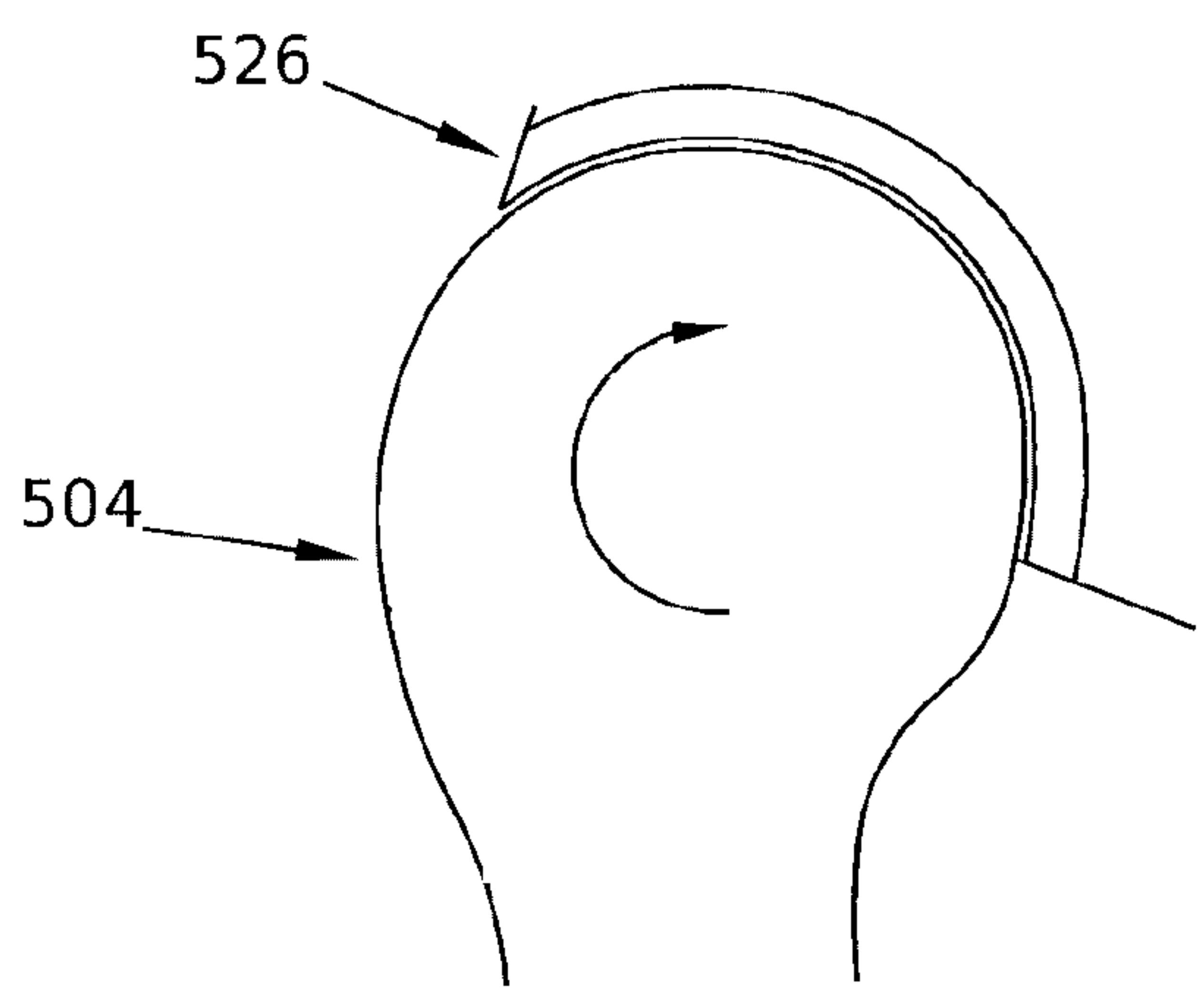


FIG. 13A

(PRIOR ART)

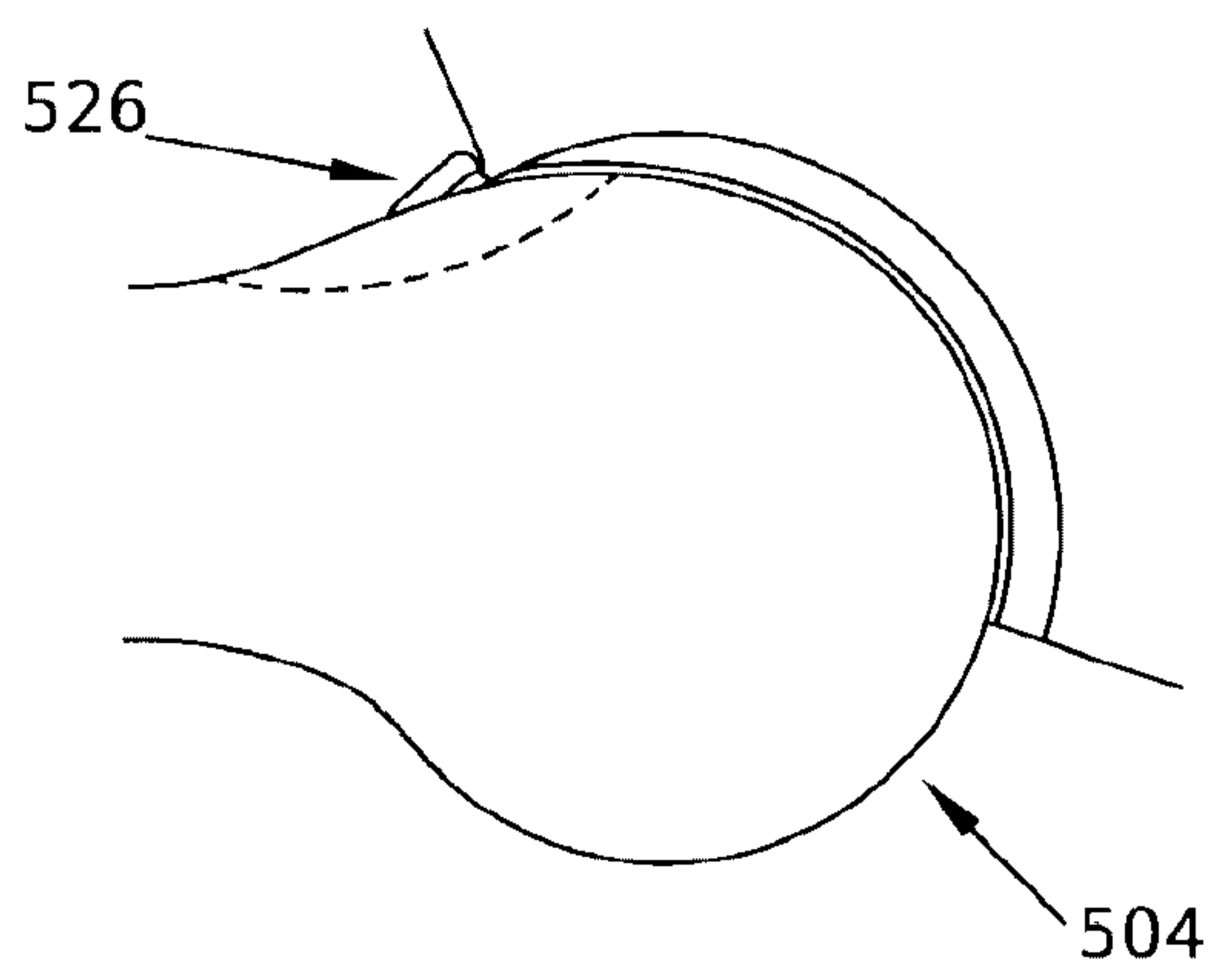


FIG. 13B

(PRIOR ART)

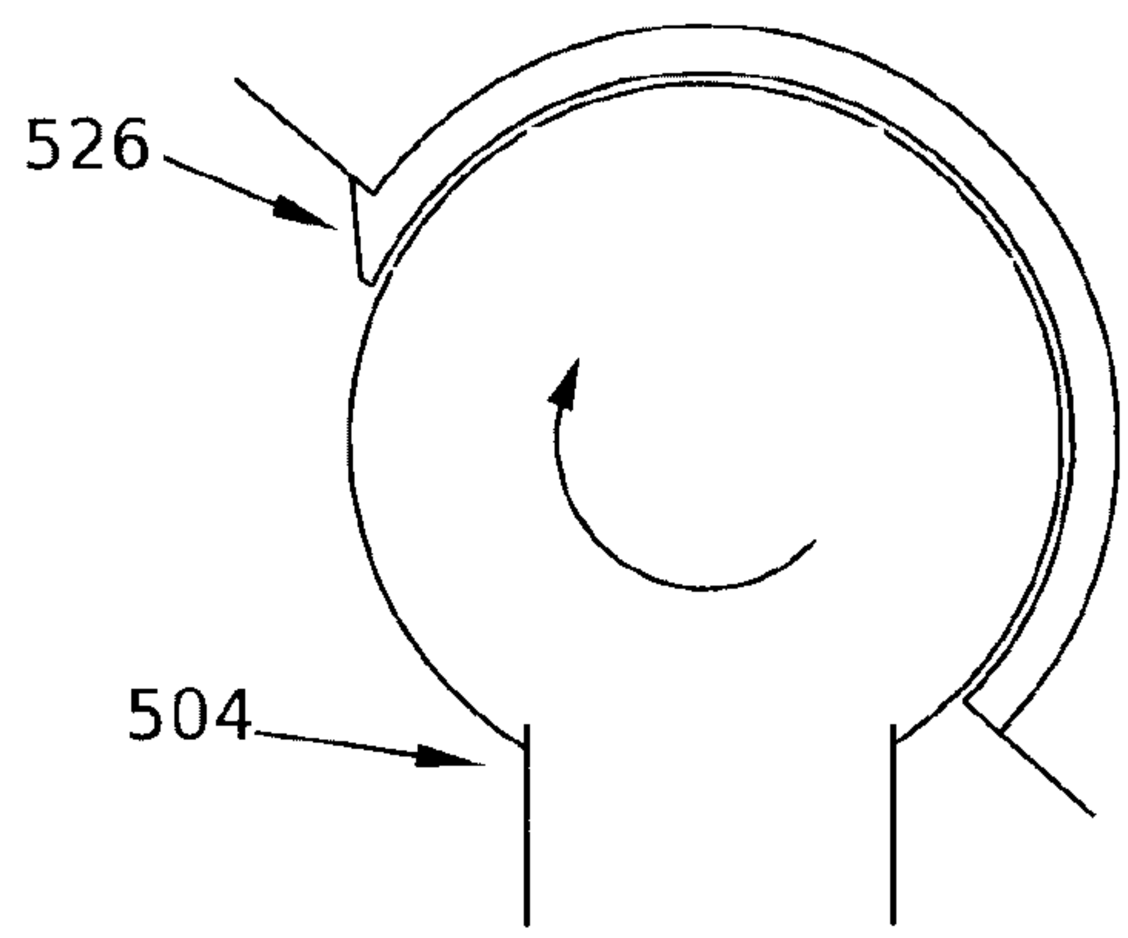


FIG. 14A

(PRIOR ART)

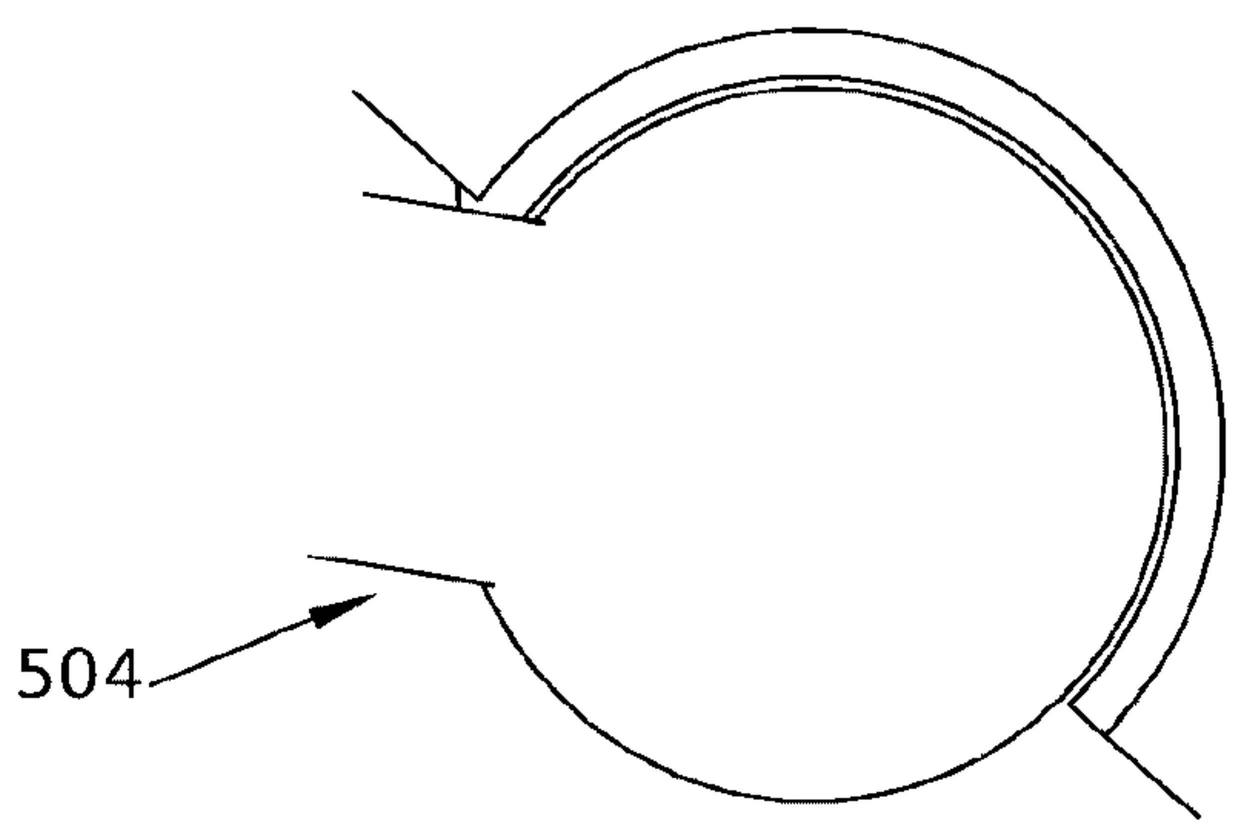


FIG. 14B

(PRIOR ART)

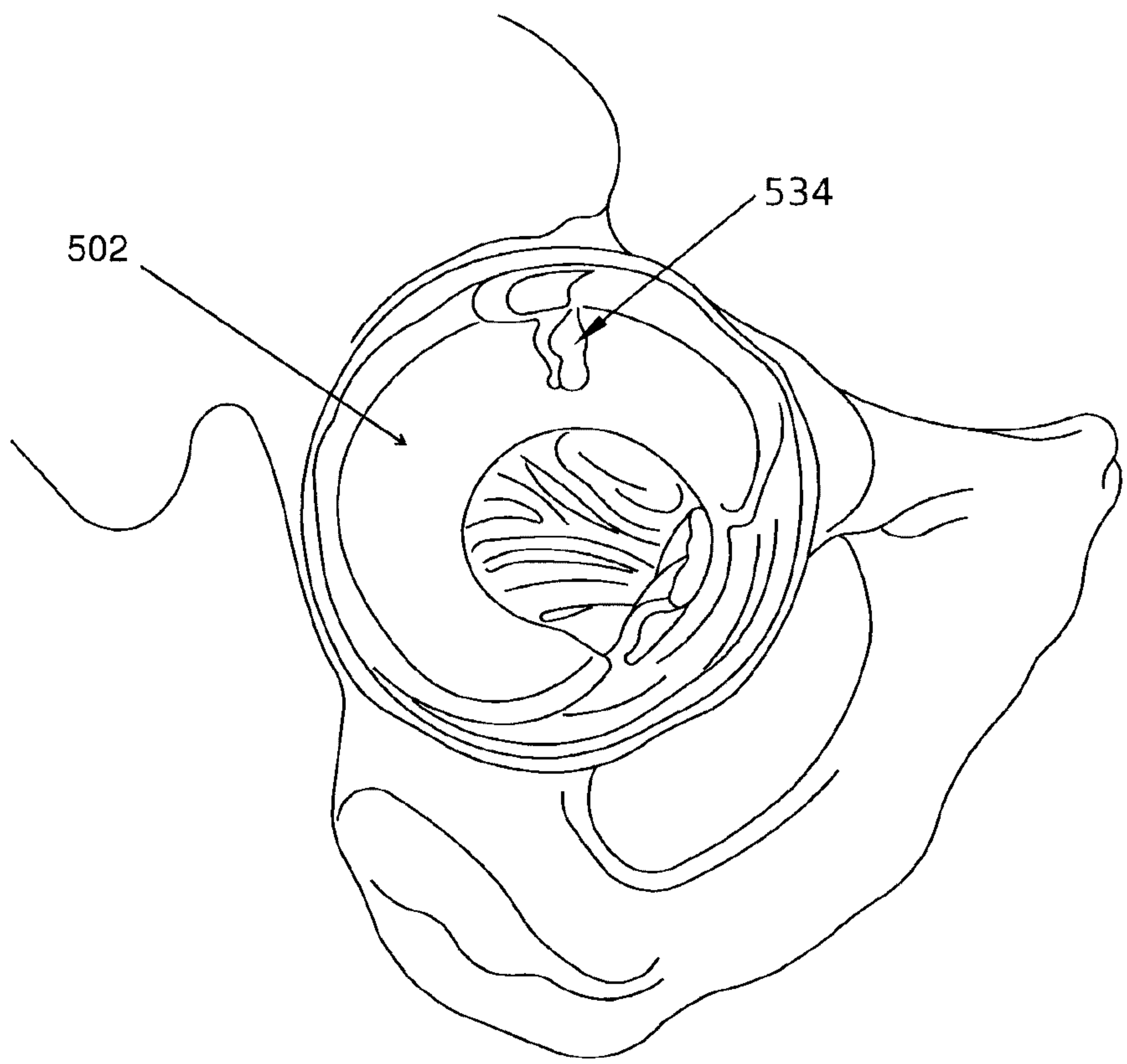


FIG. 15
(PRIOR ART)

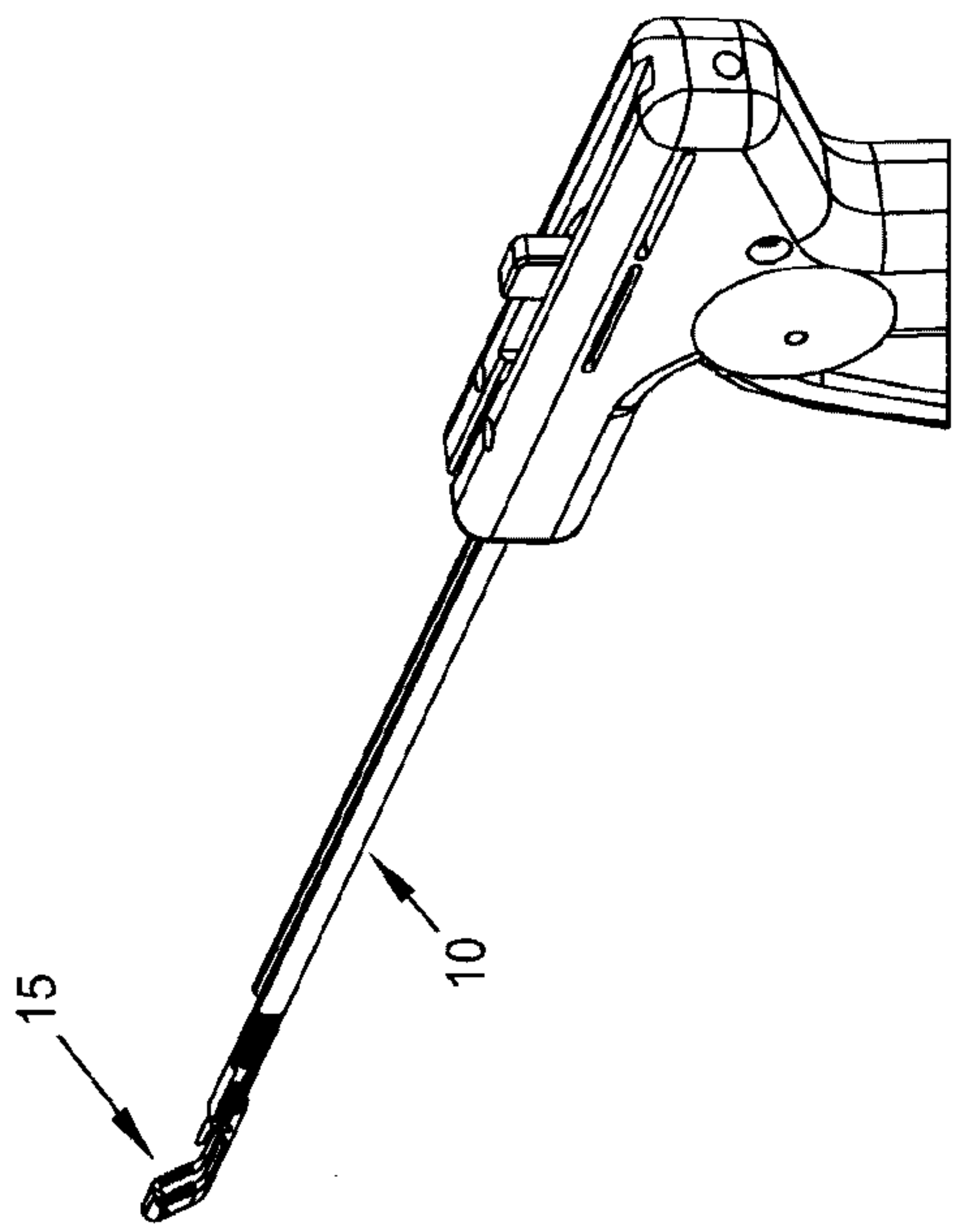


FIG. 17

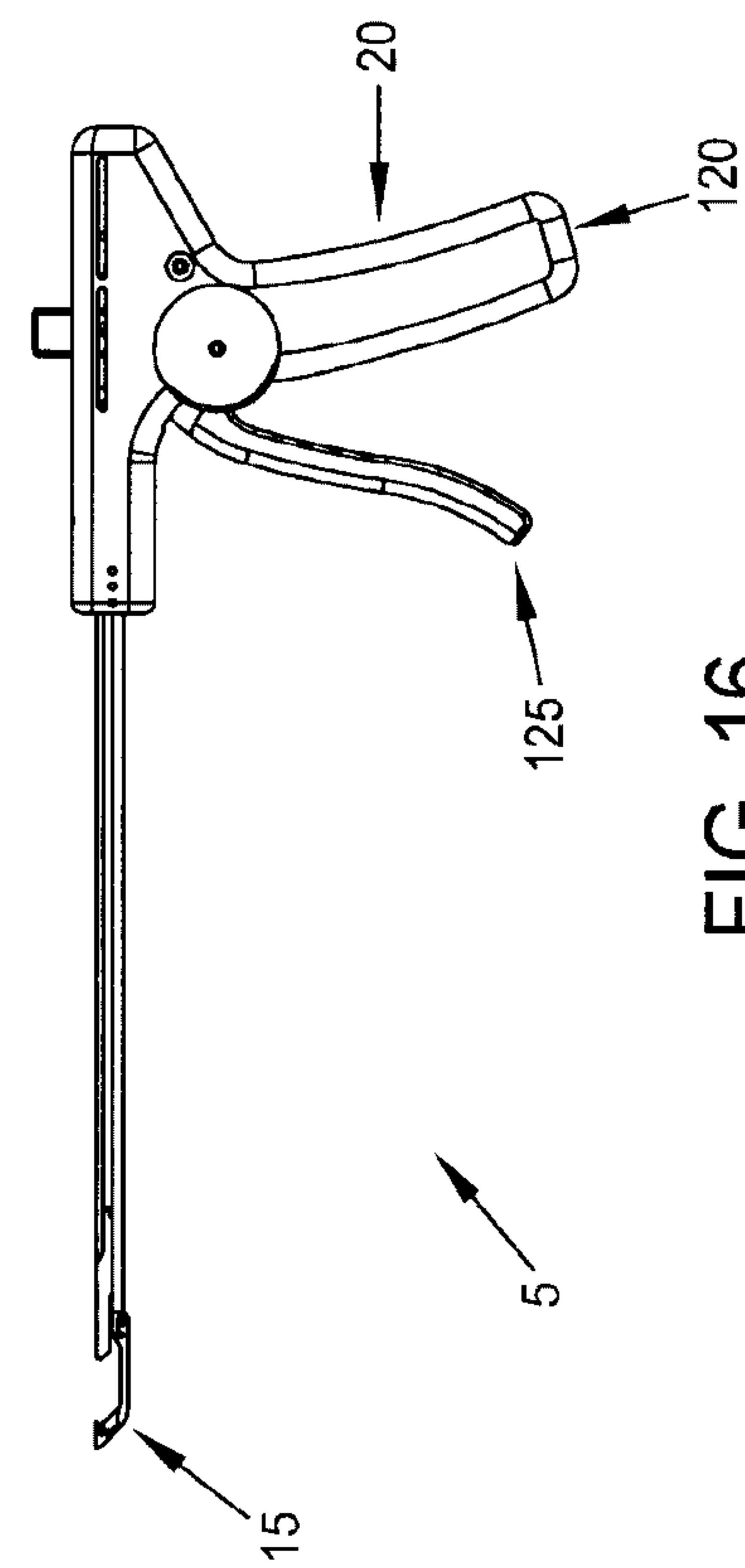


FIG. 16

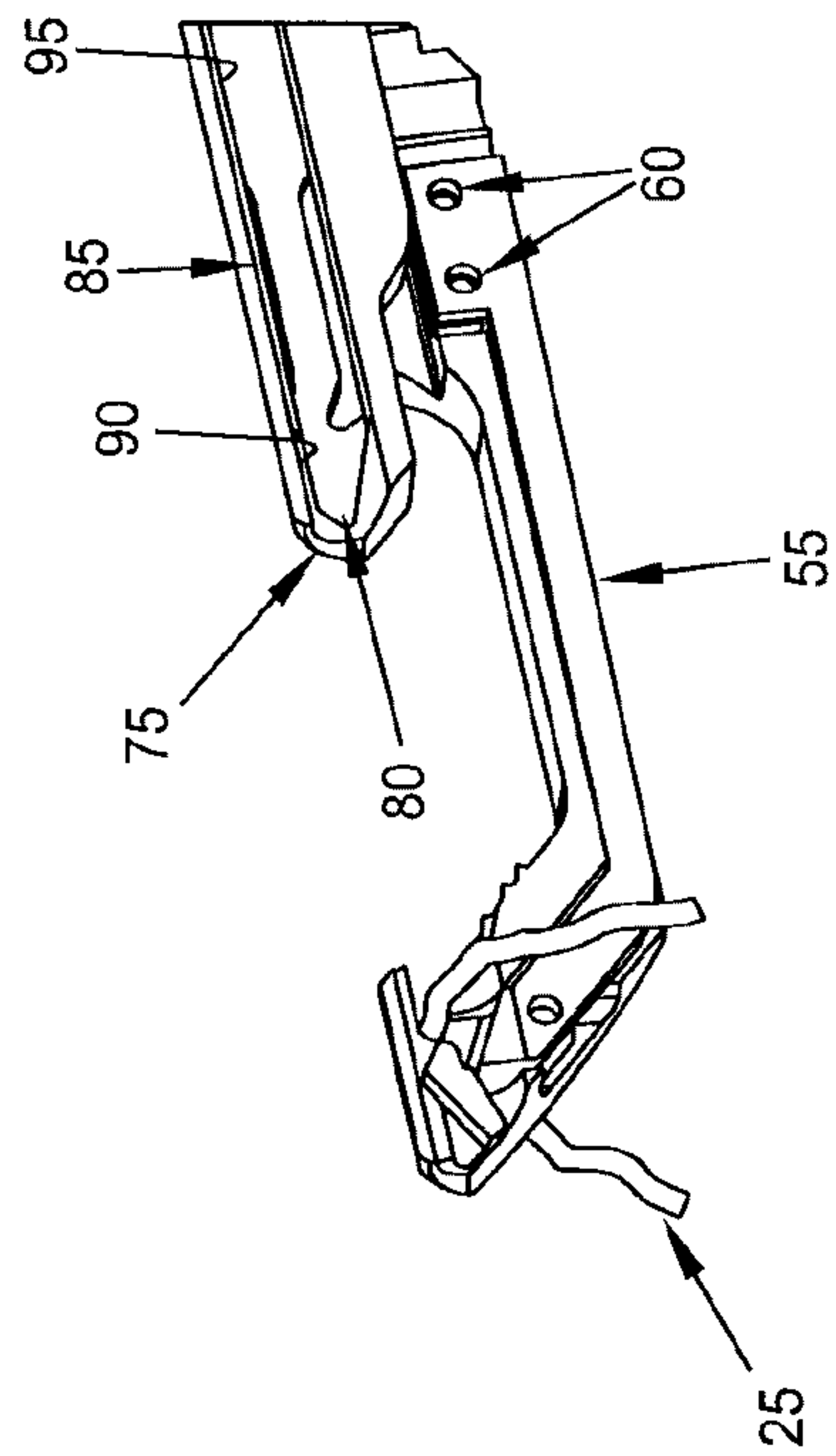


FIG. 19

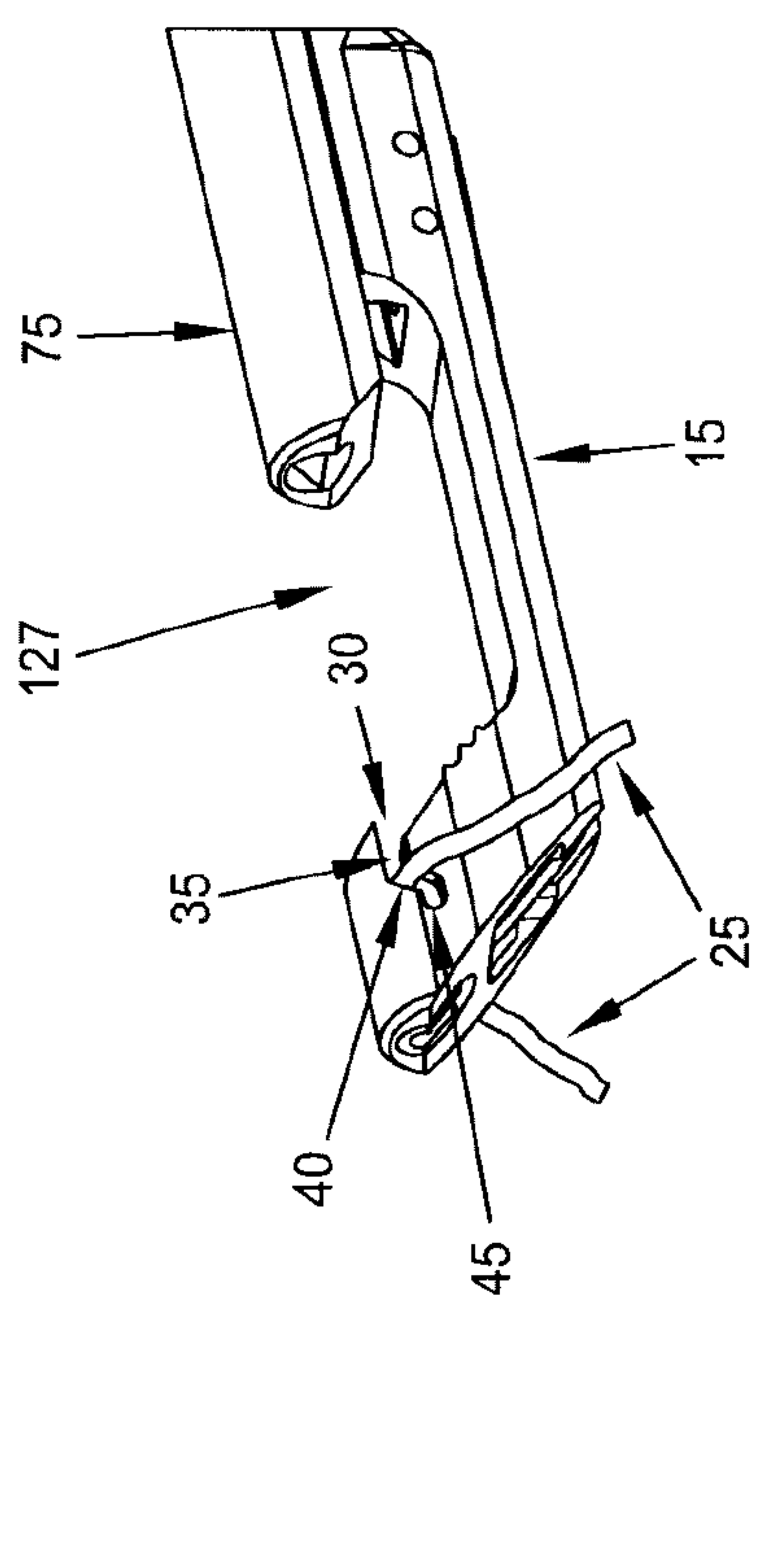


FIG. 18

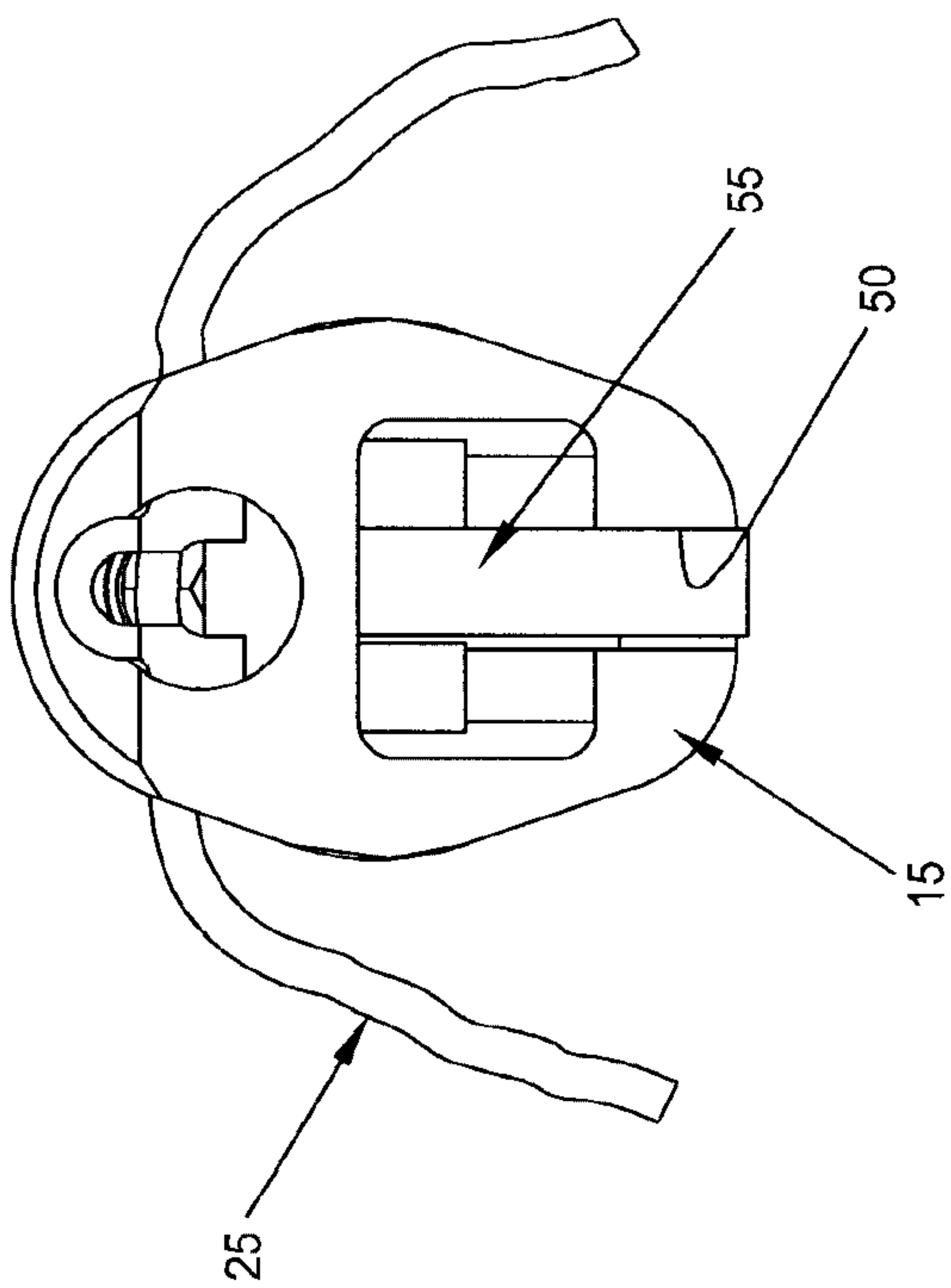


FIG. 20

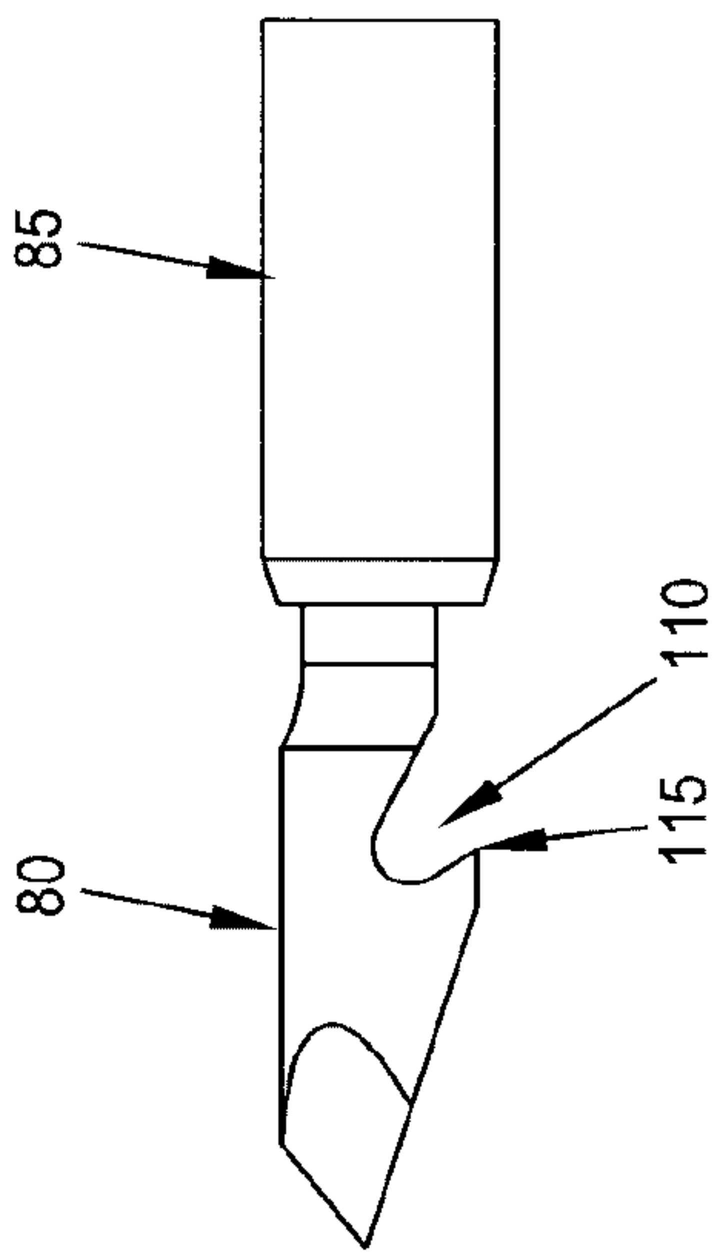


FIG. 22

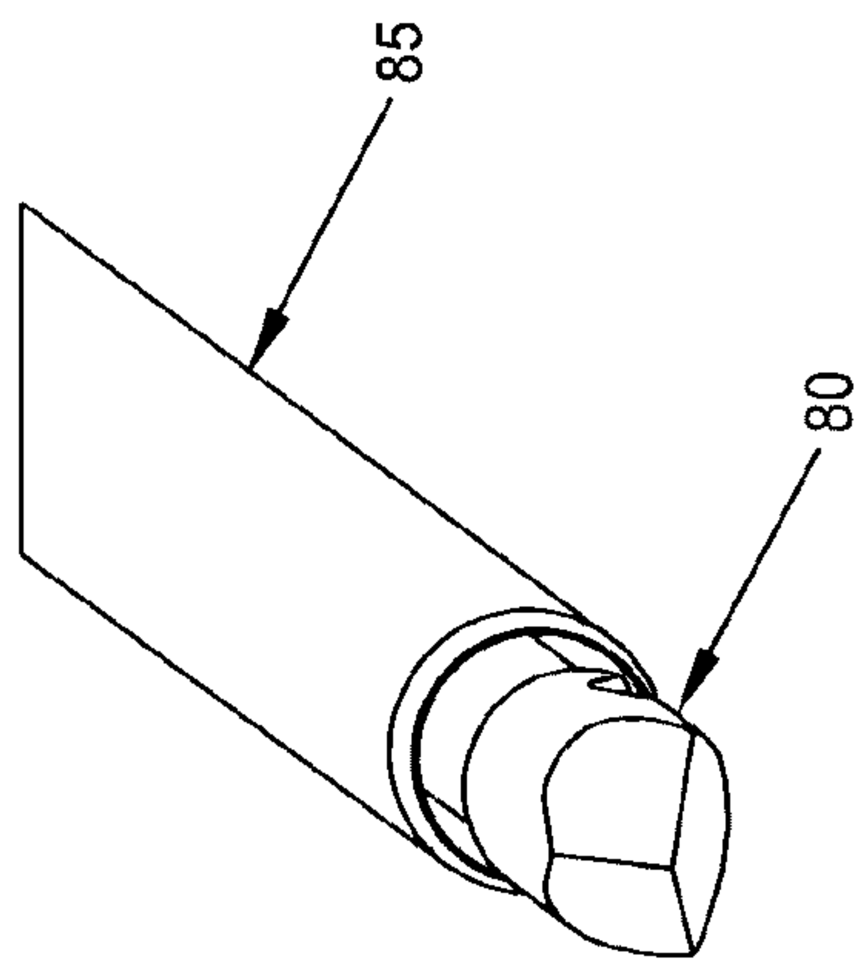


FIG. 23

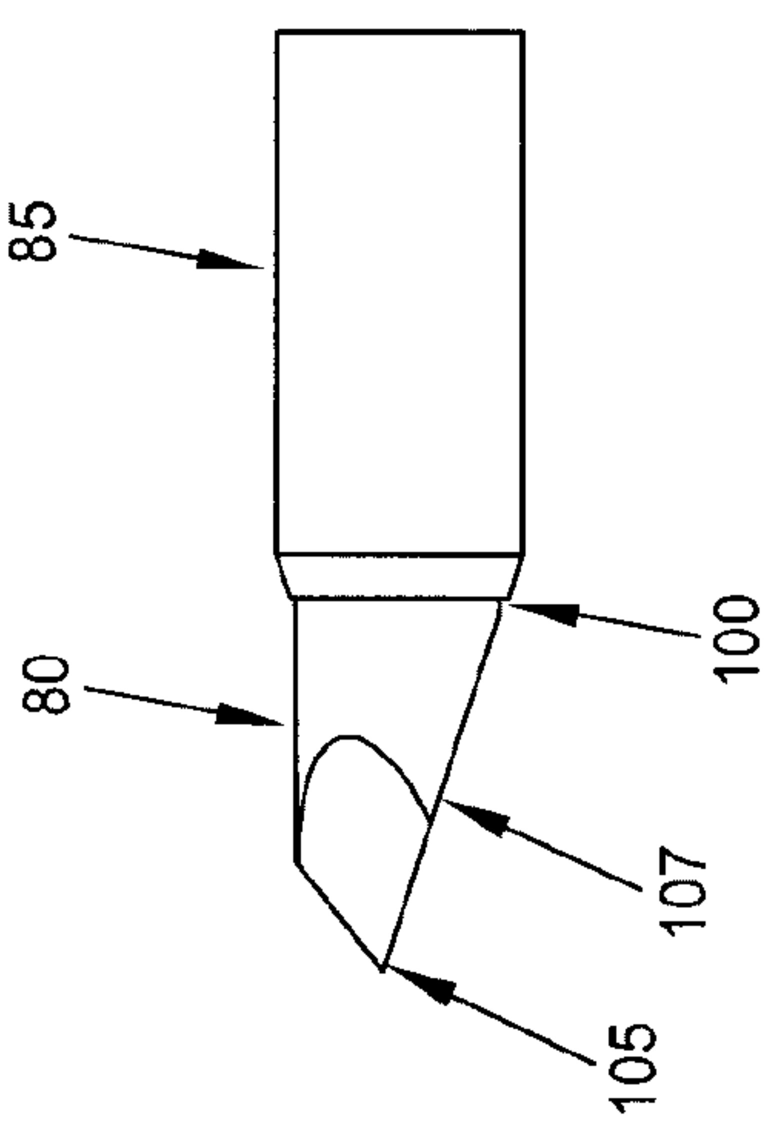


FIG. 21

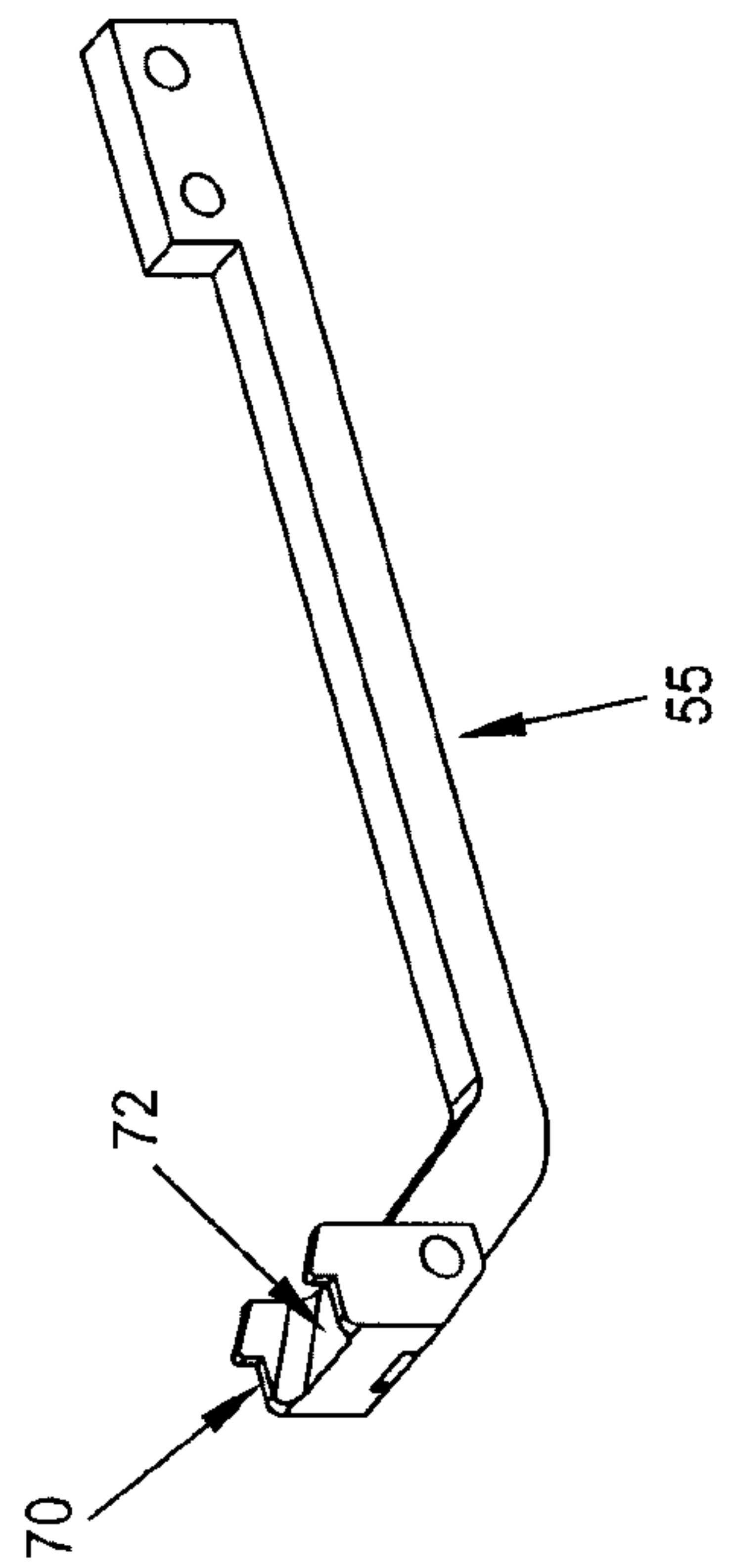


FIG. 25

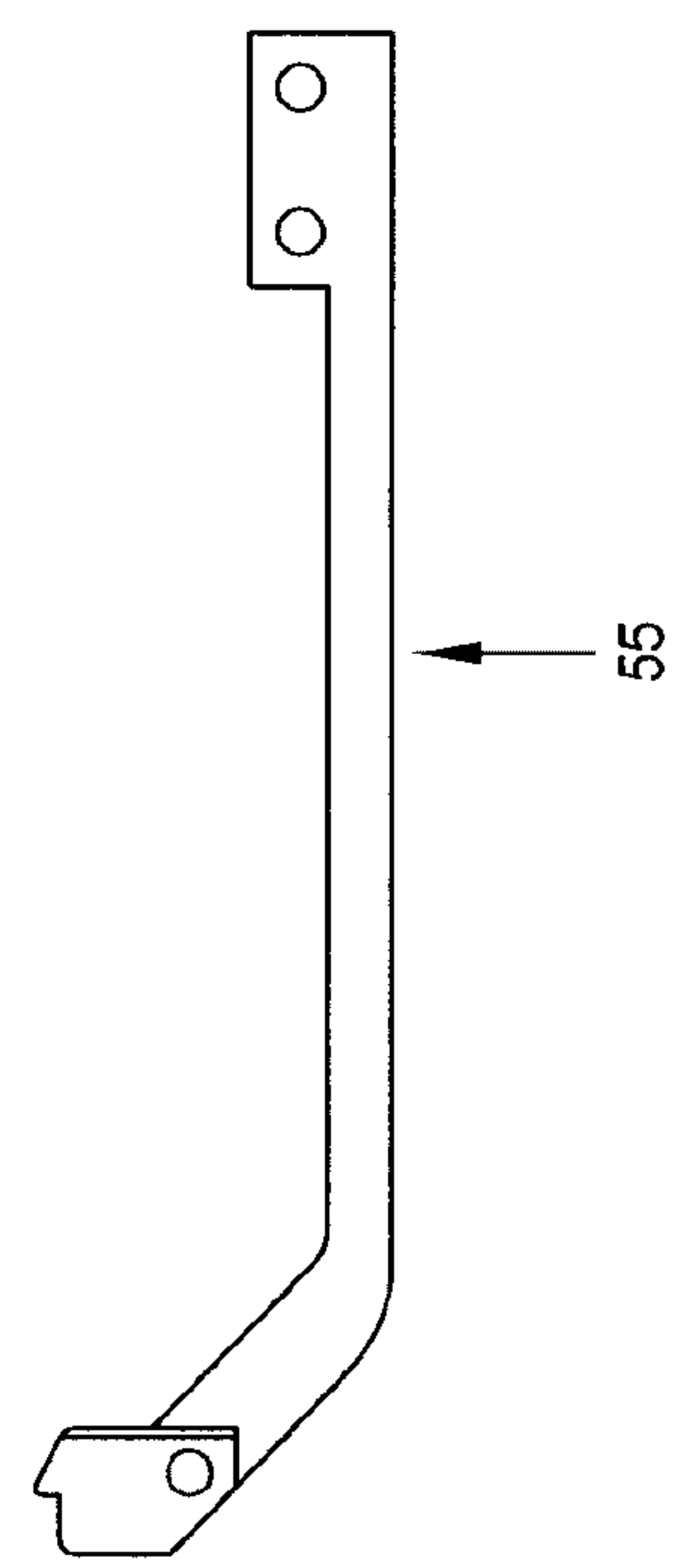


FIG. 24

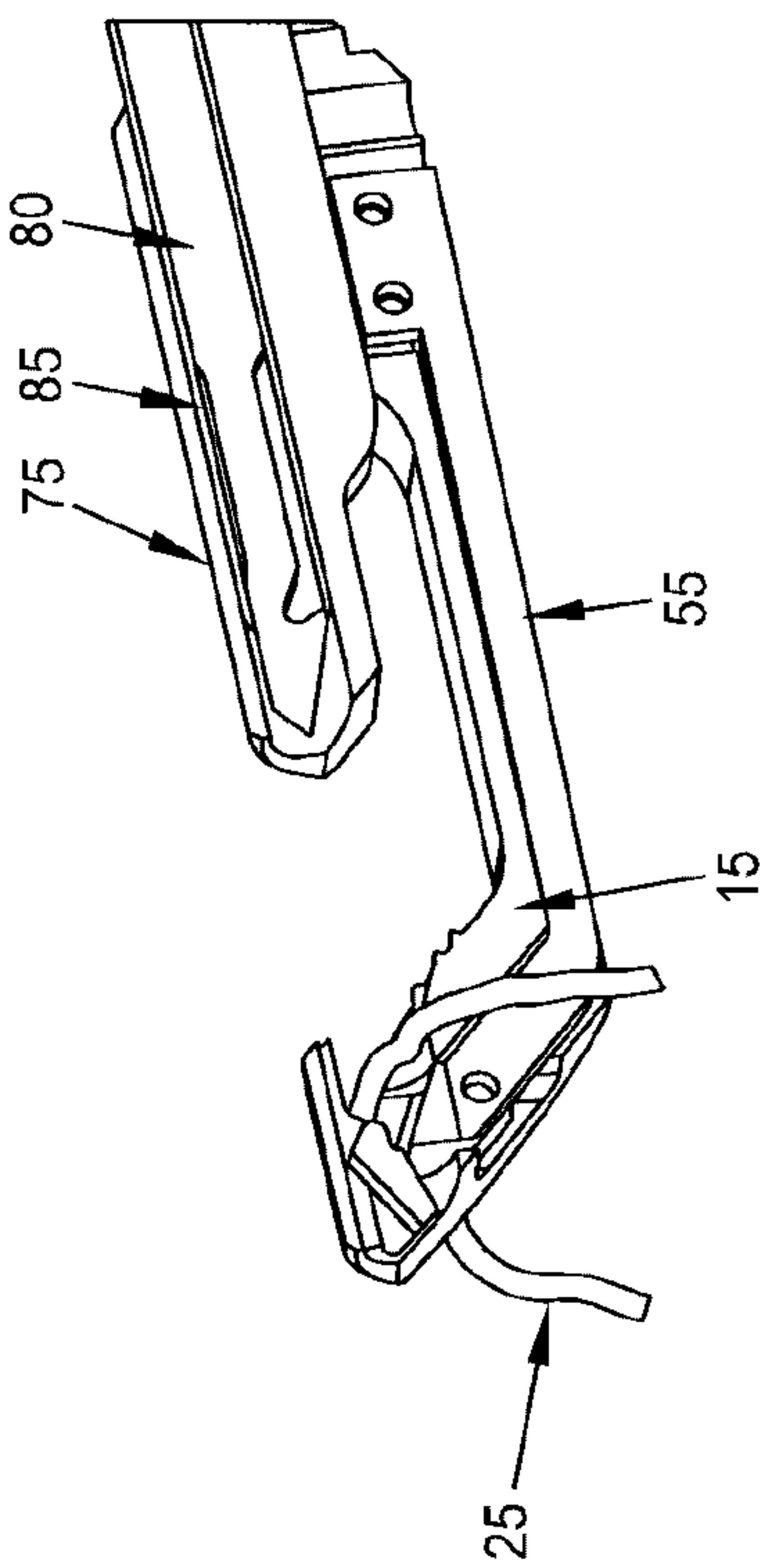


FIG. 27

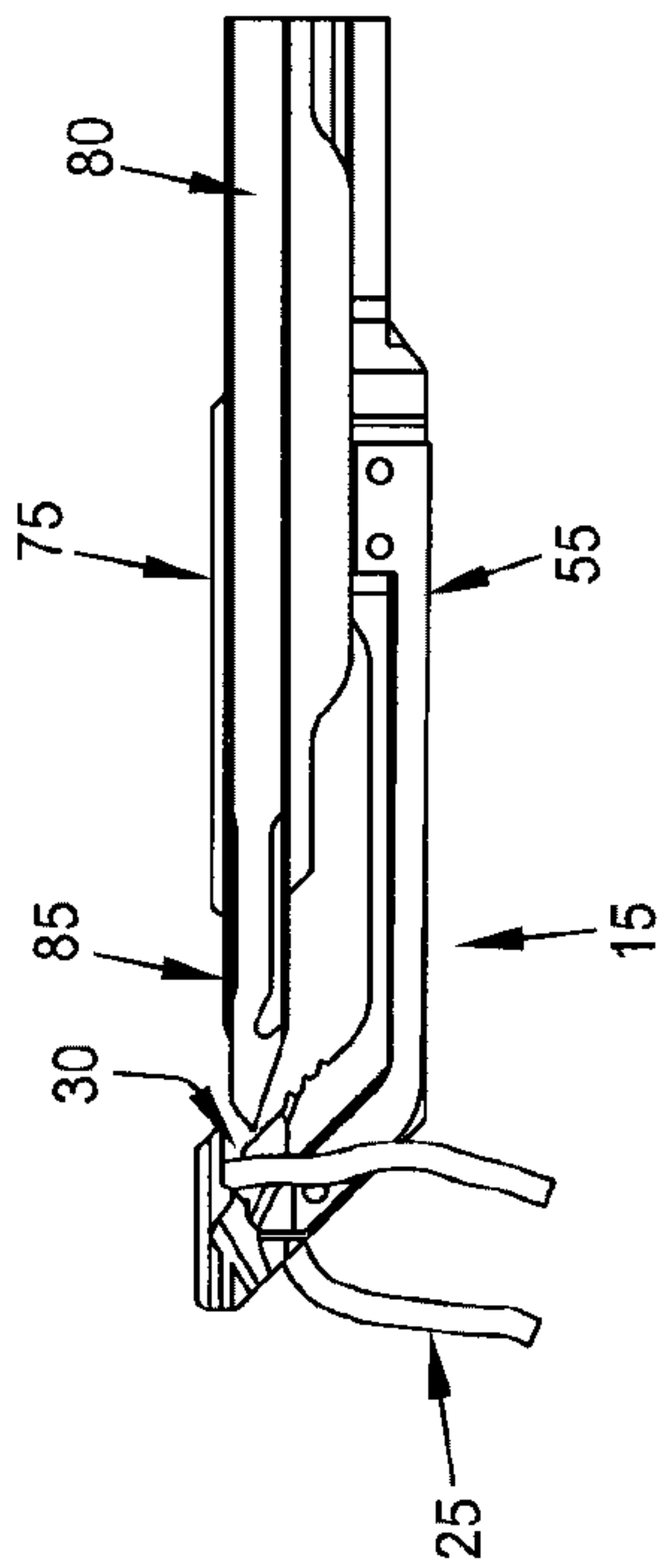


FIG. 29

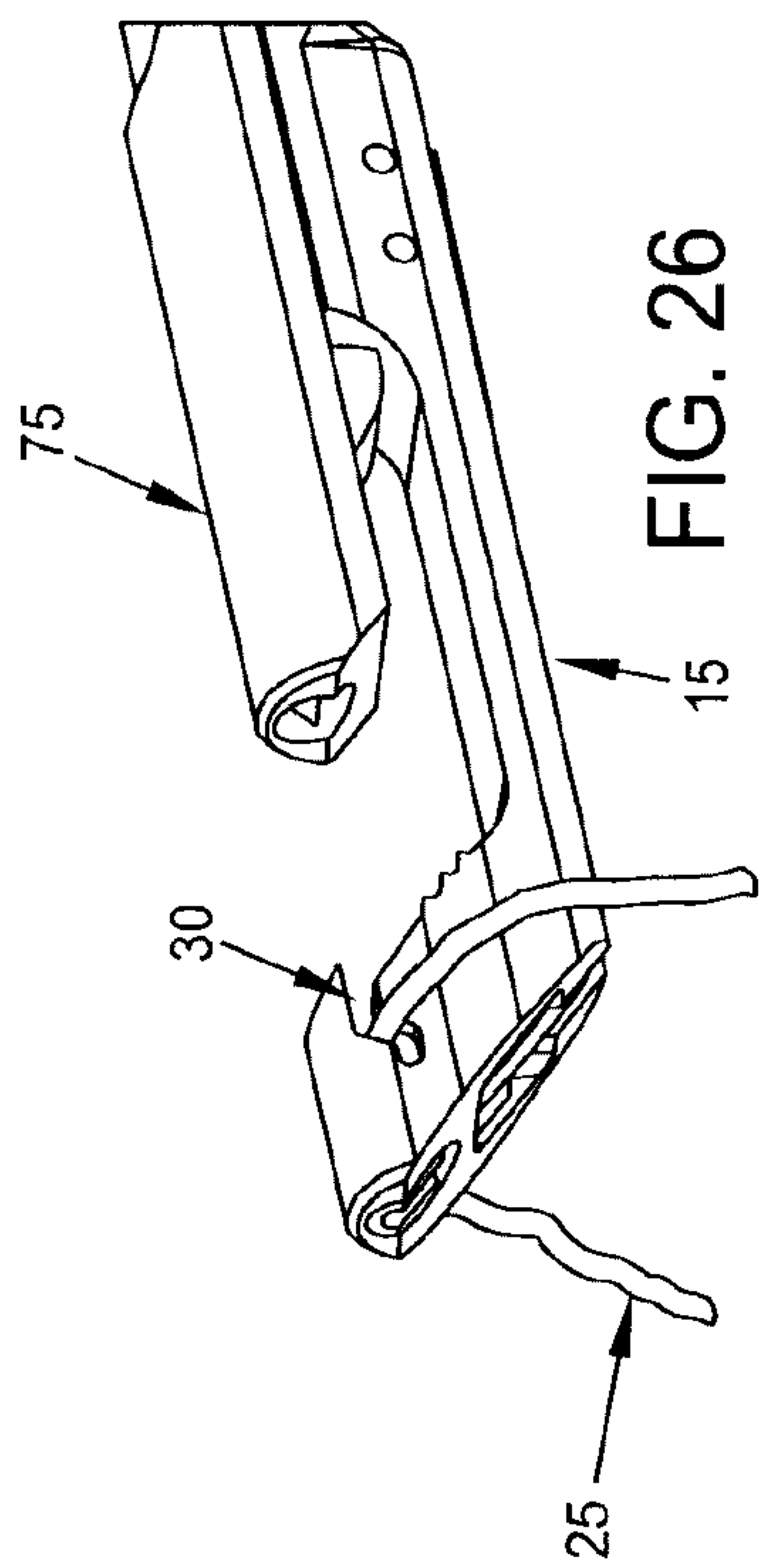


FIG. 26

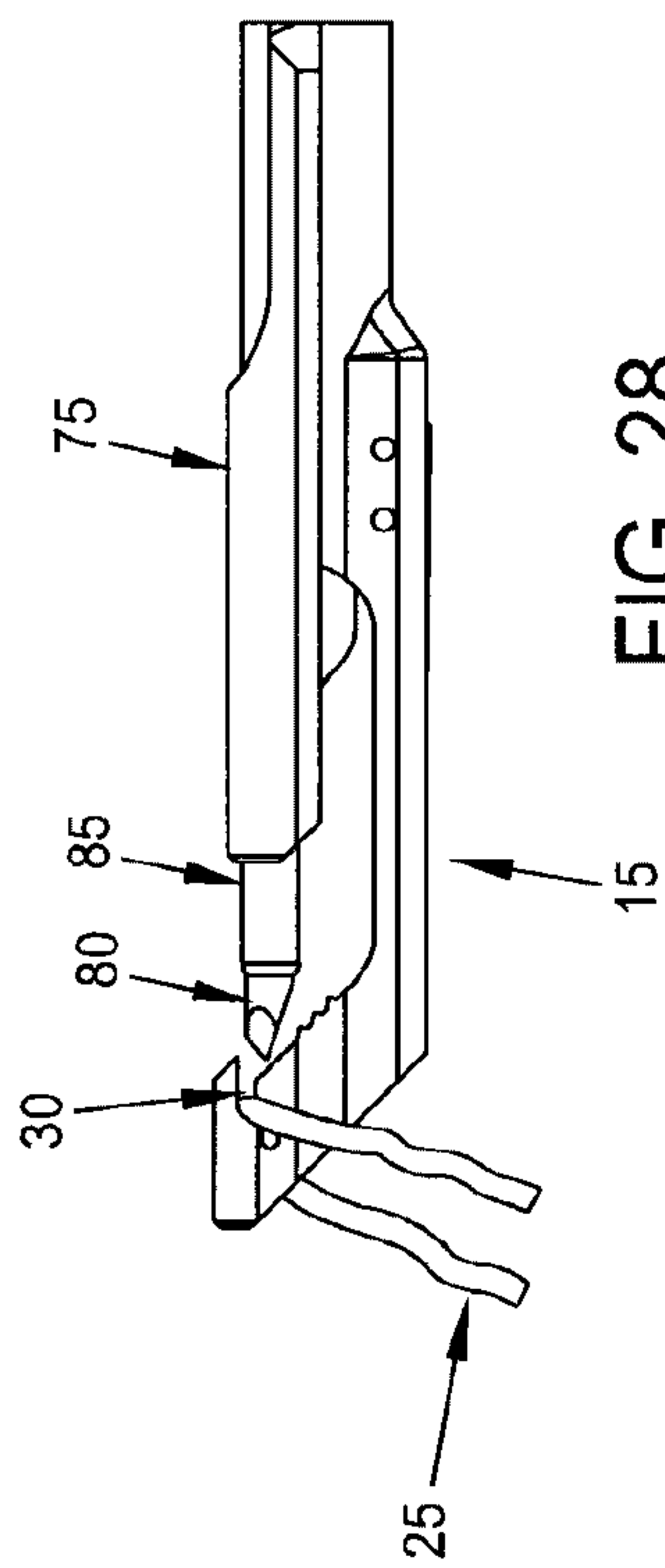


FIG. 28

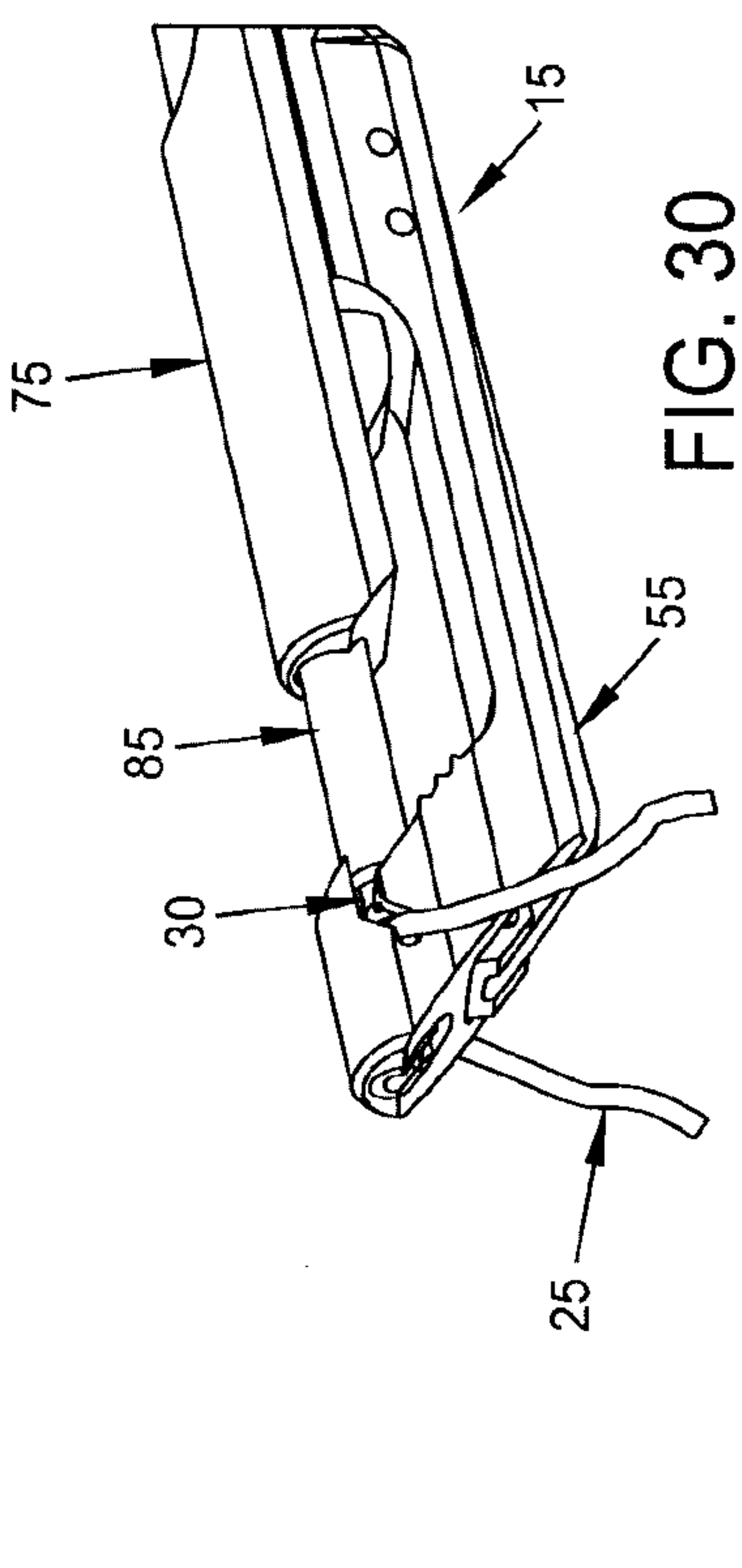


FIG. 30

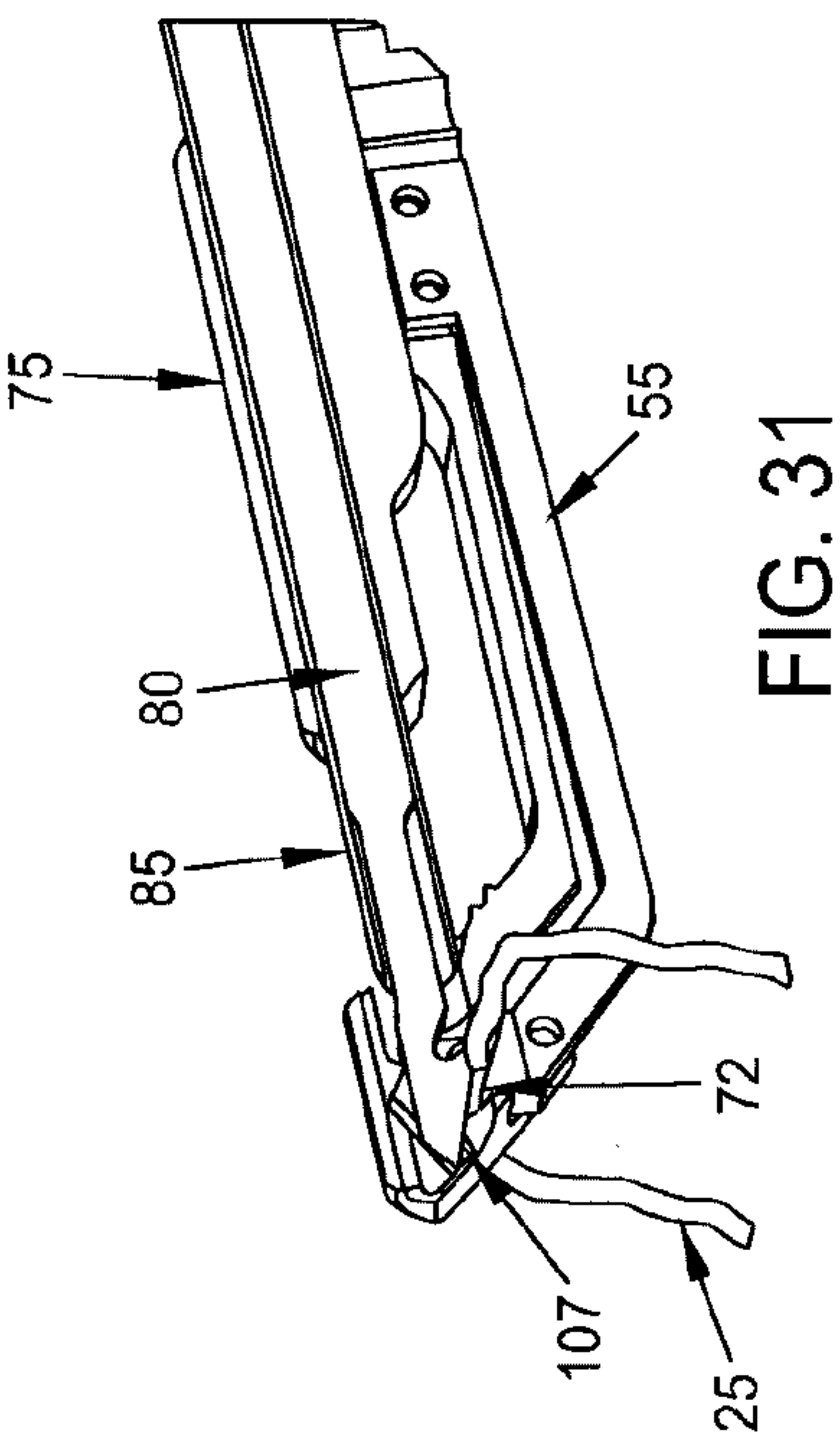


FIG. 31

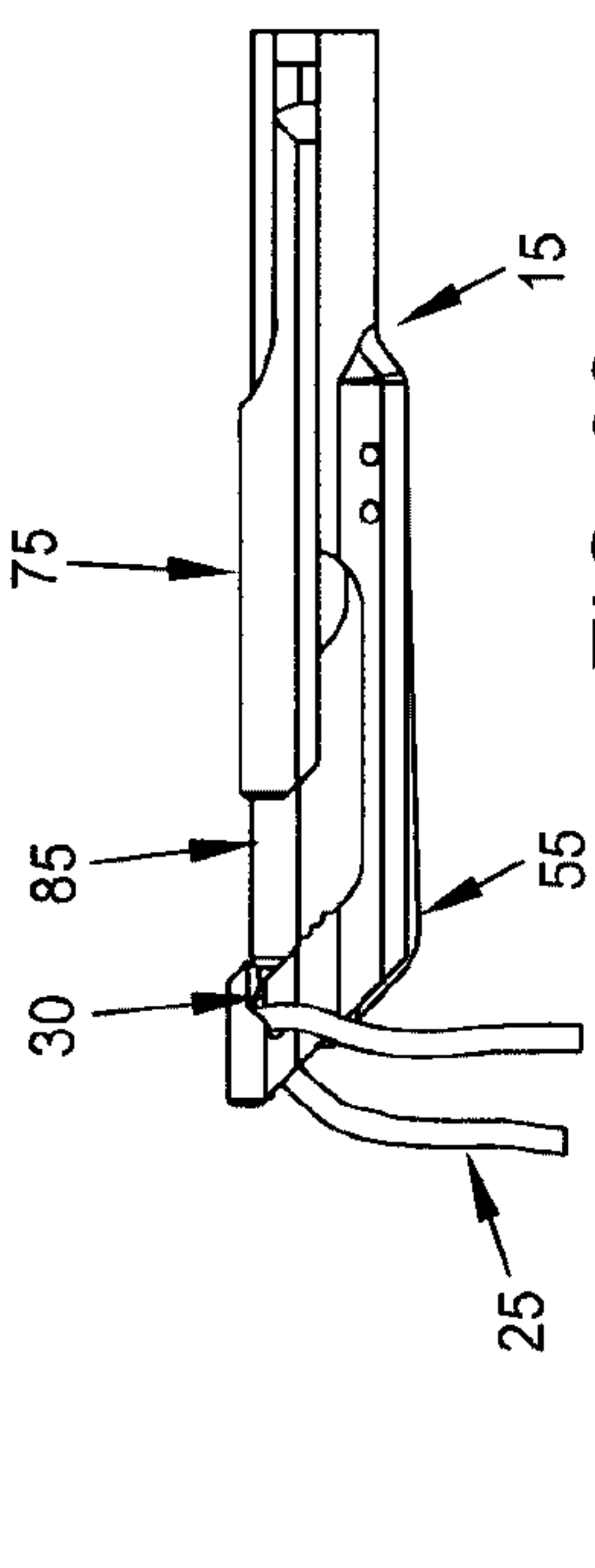


FIG. 32

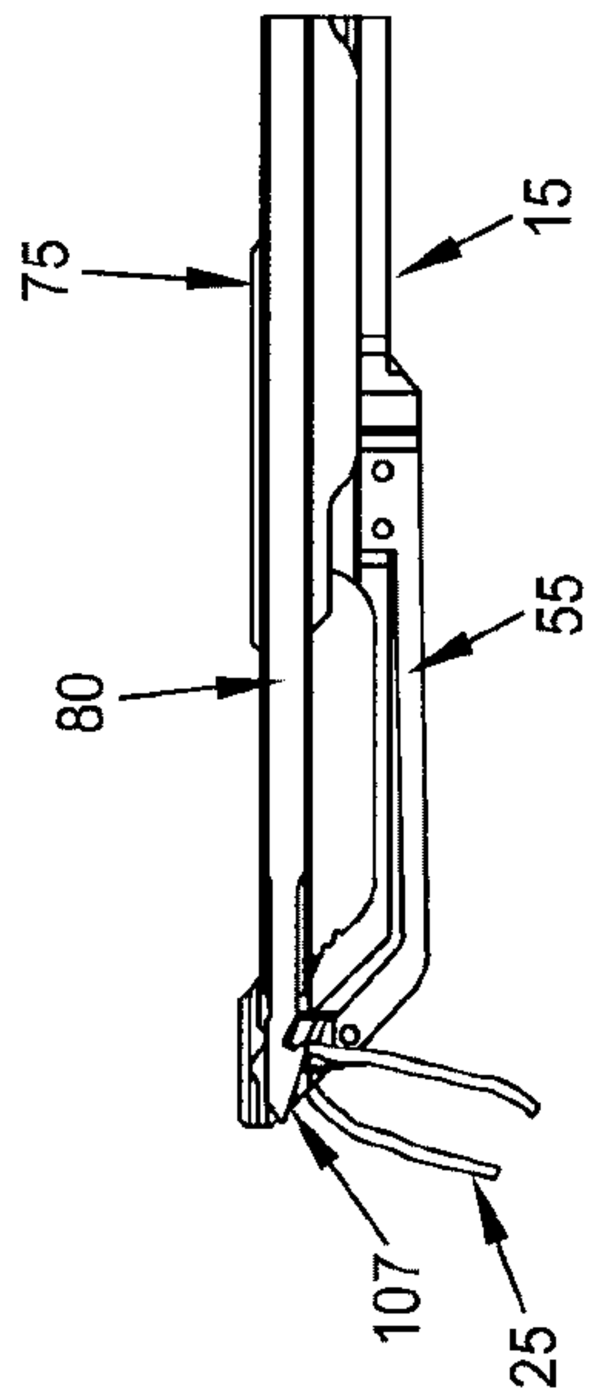


FIG. 33

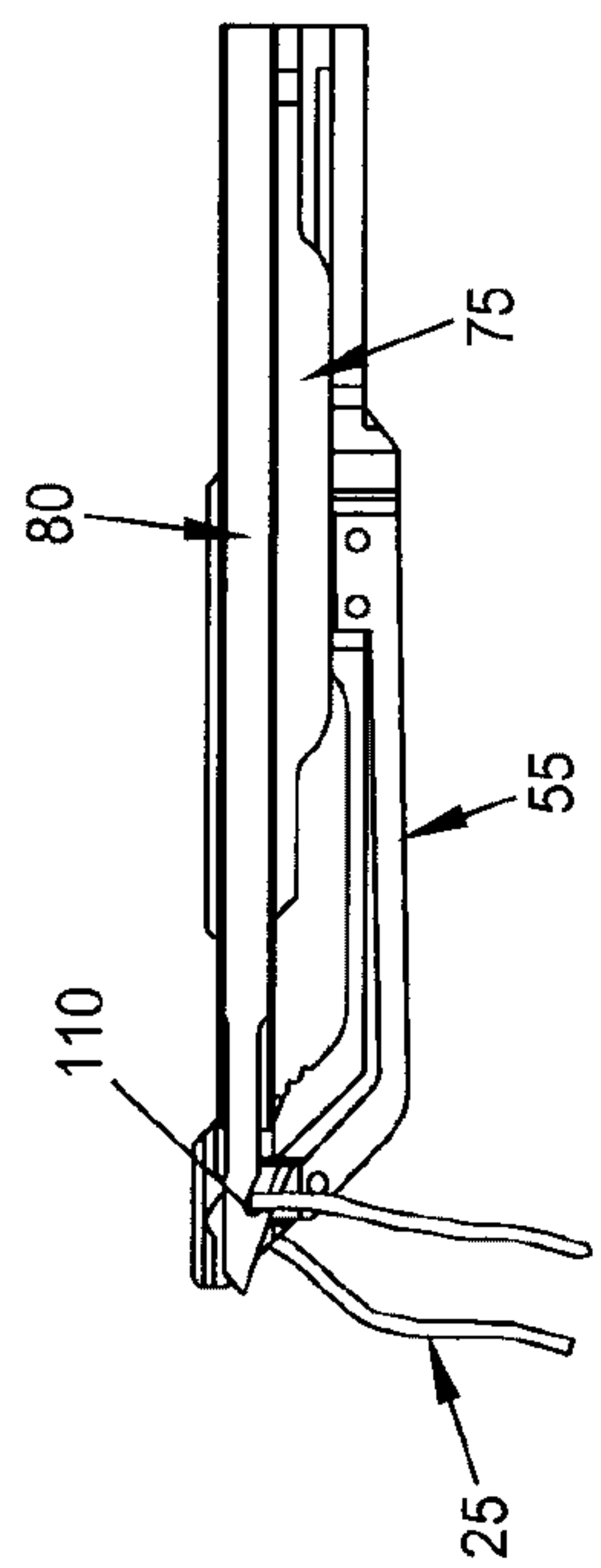


FIG. 35

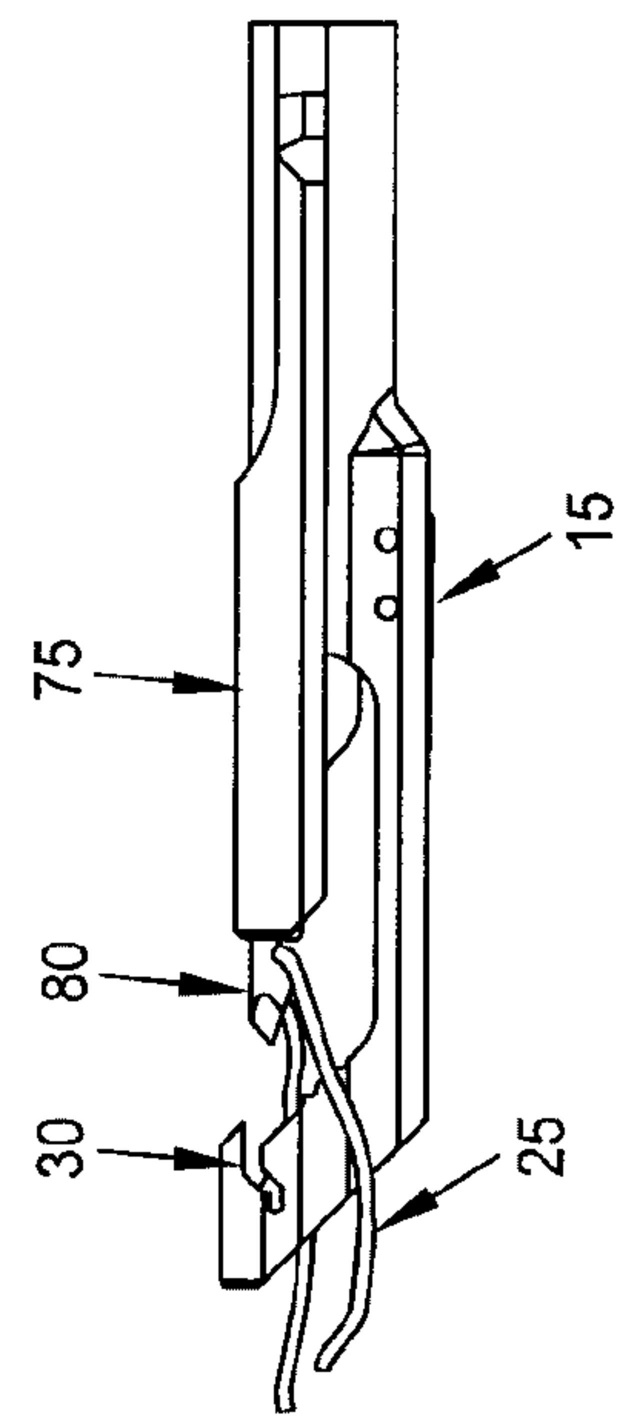


FIG. 37

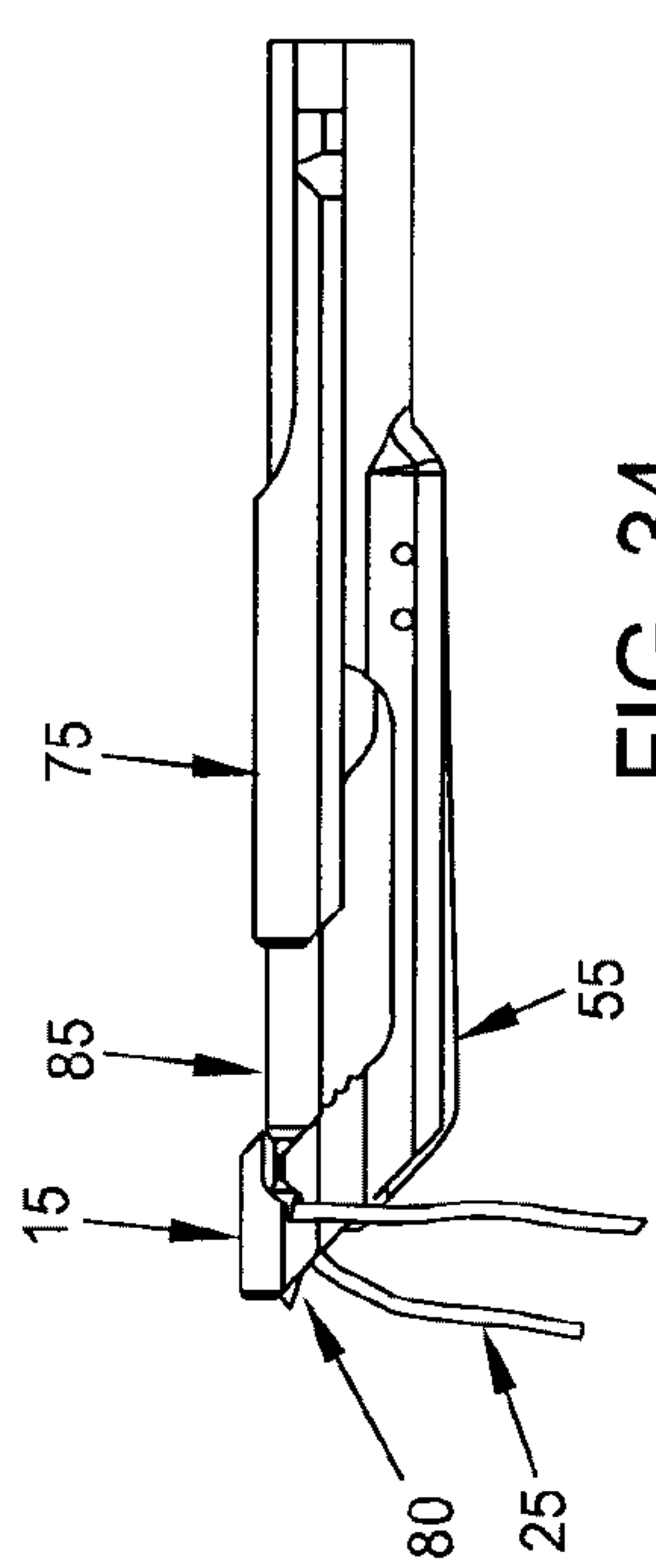


FIG. 34

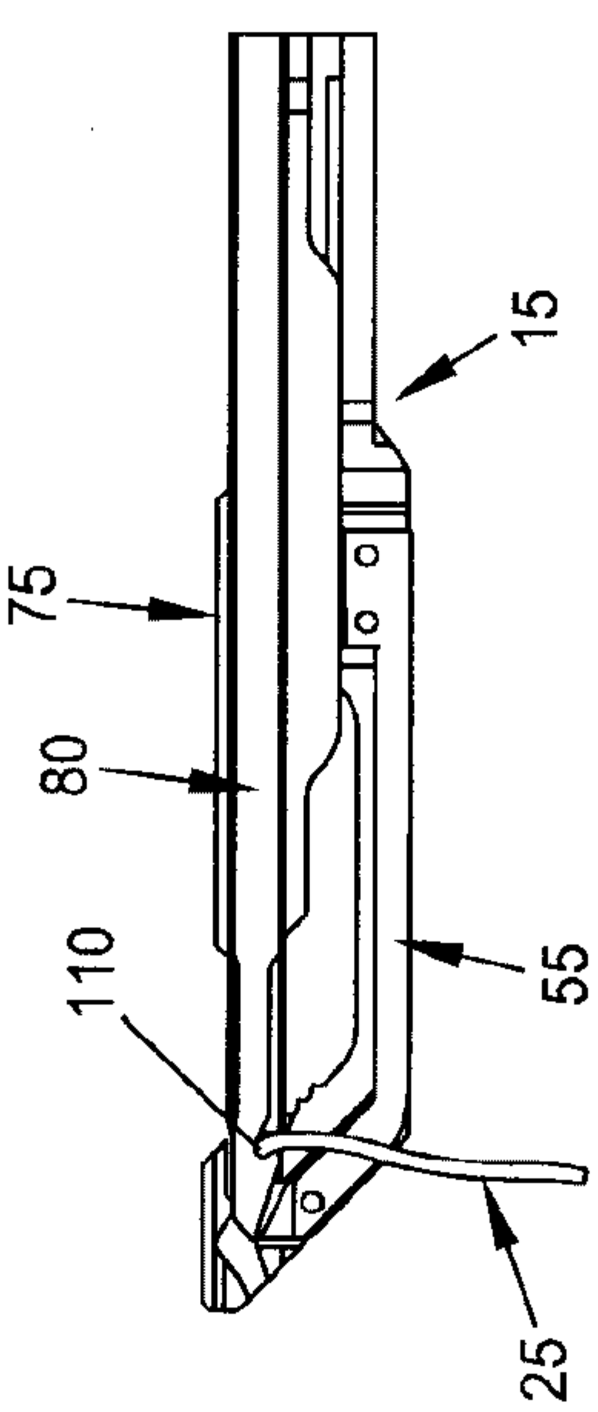


FIG. 36

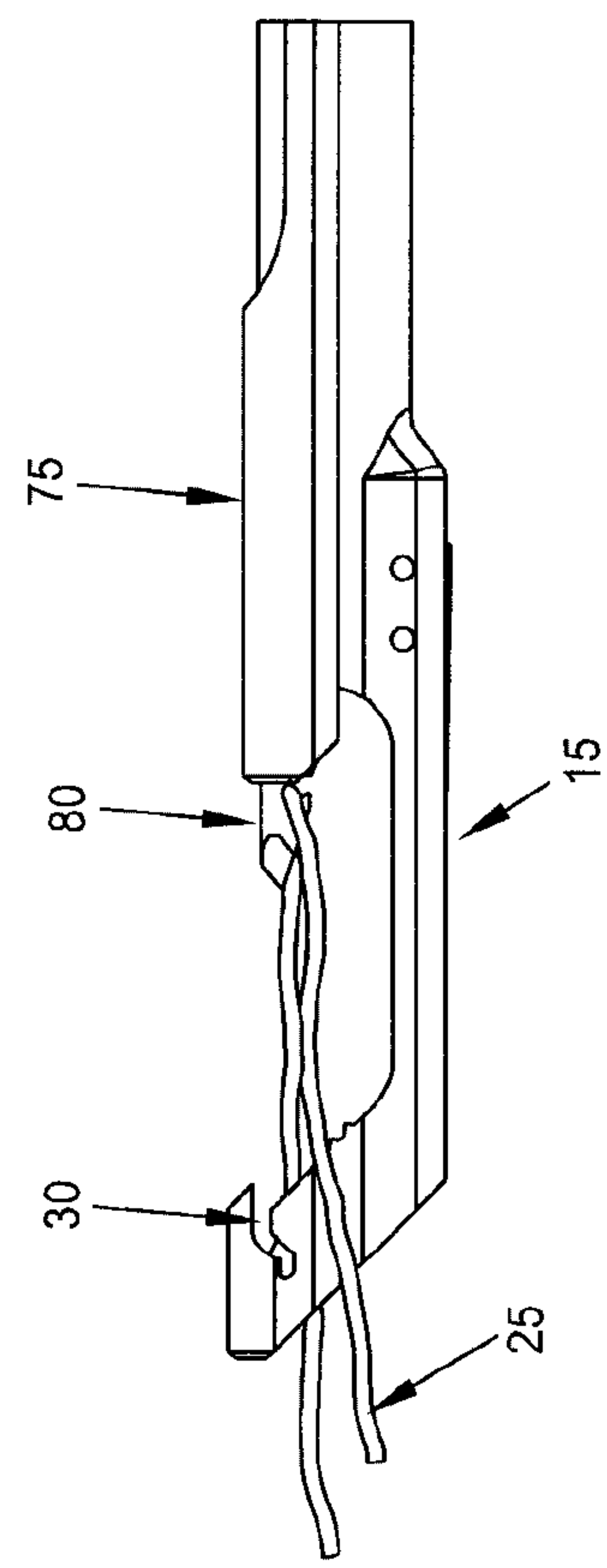


FIG. 38

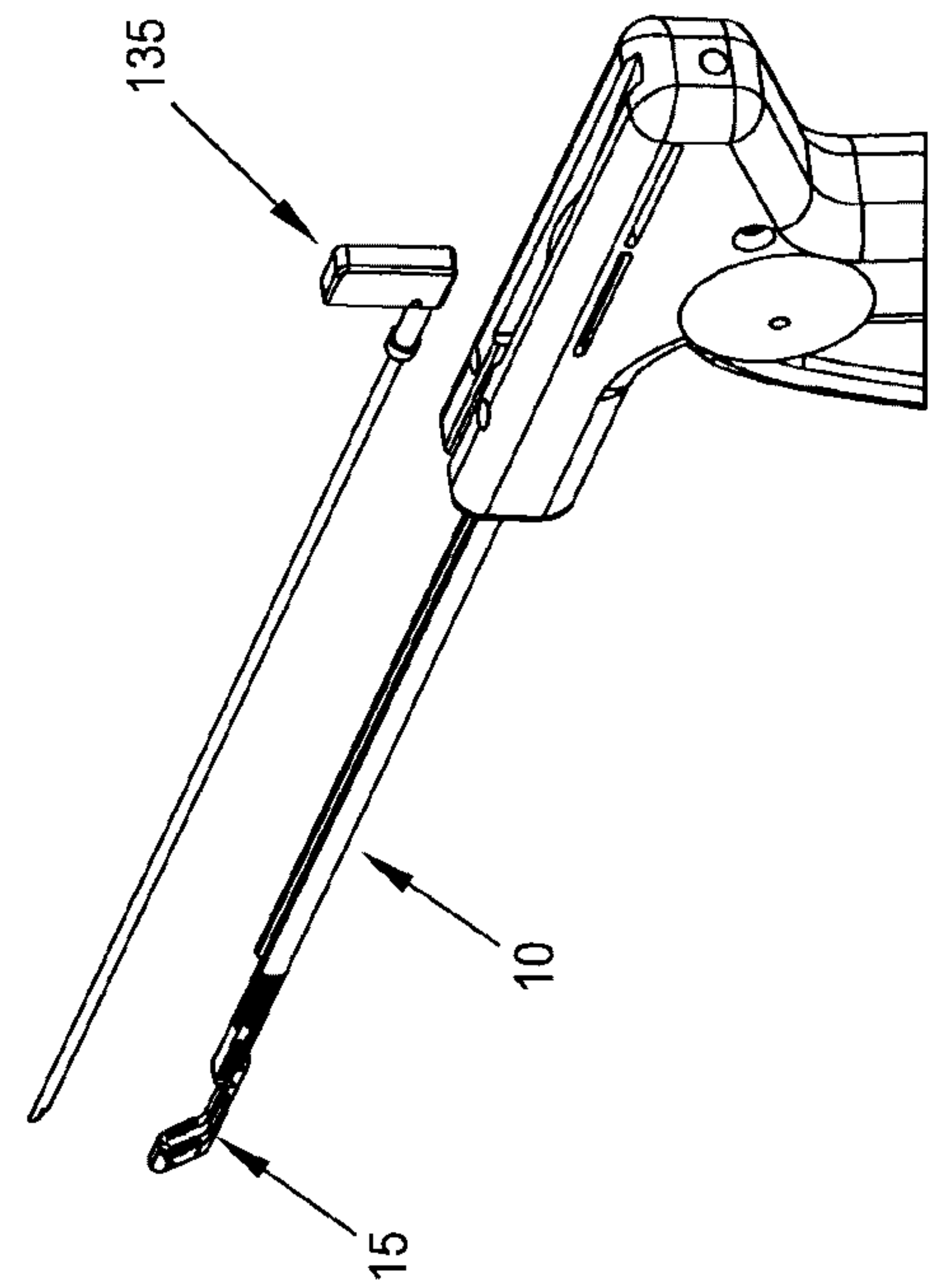


FIG. 40

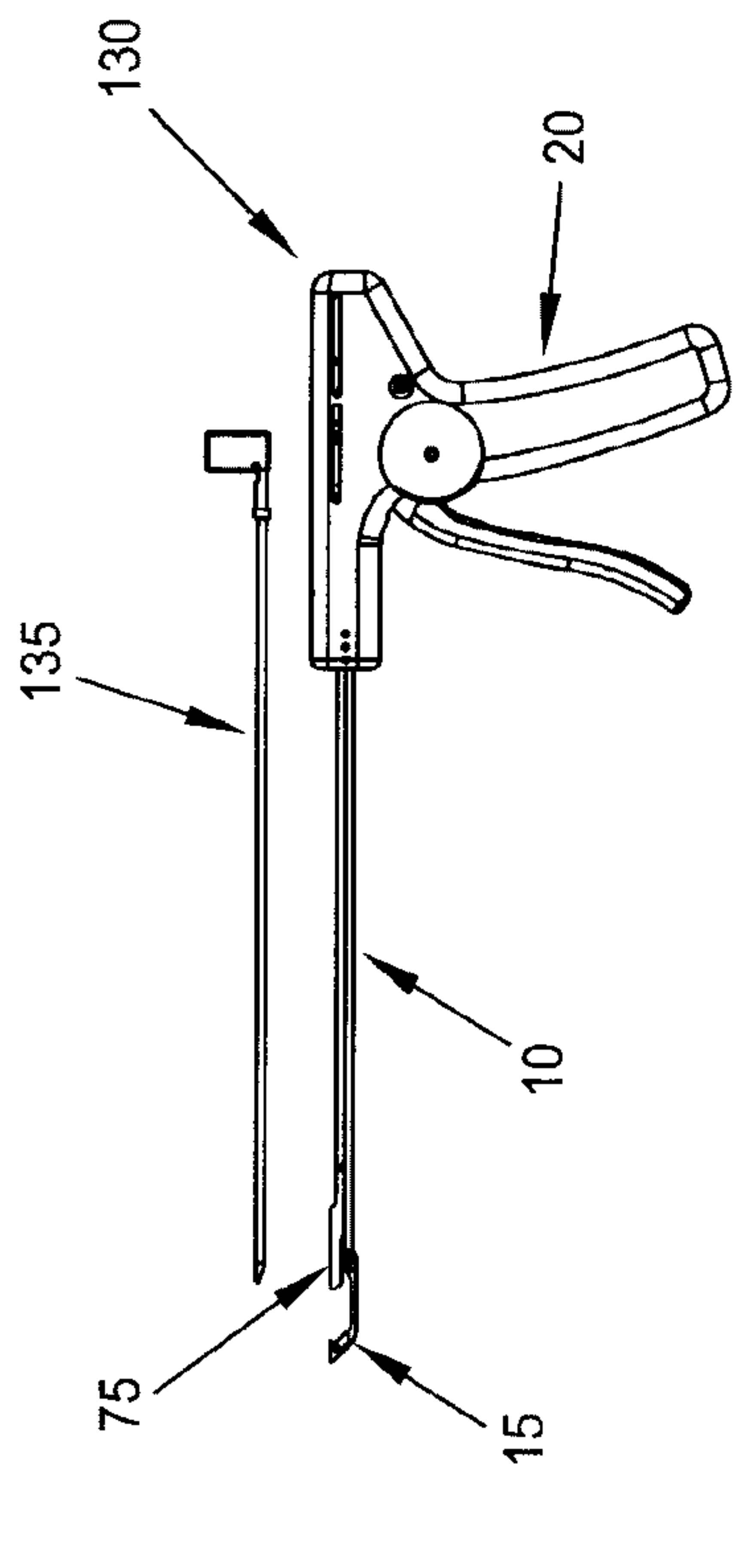


FIG. 39

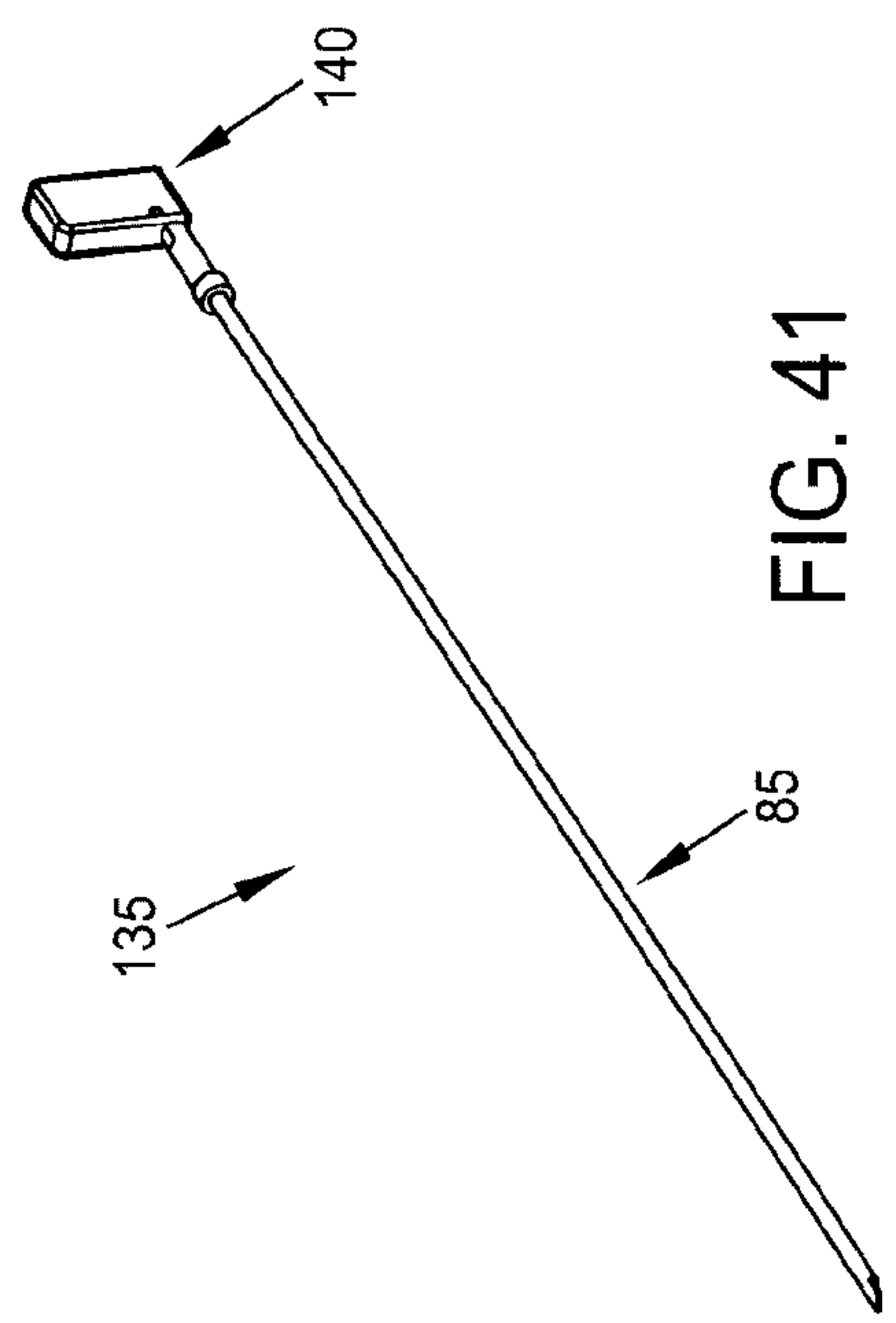


FIG. 41

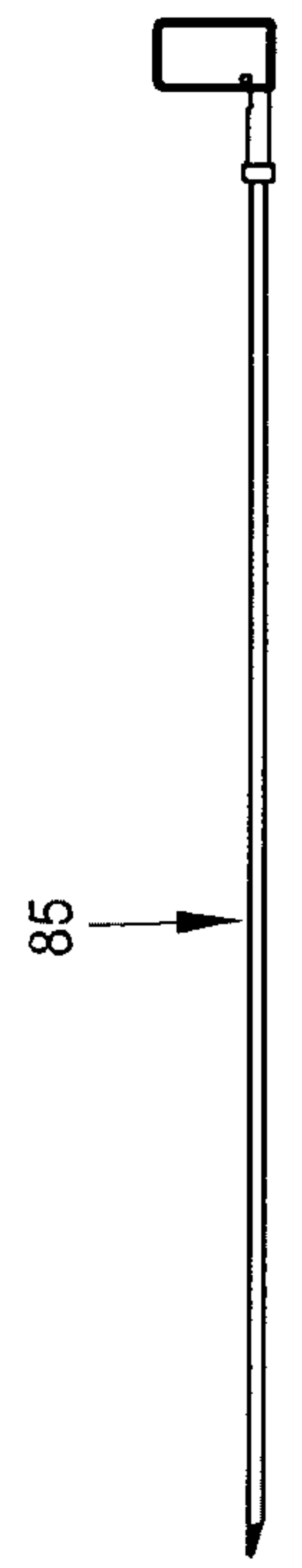


FIG. 42

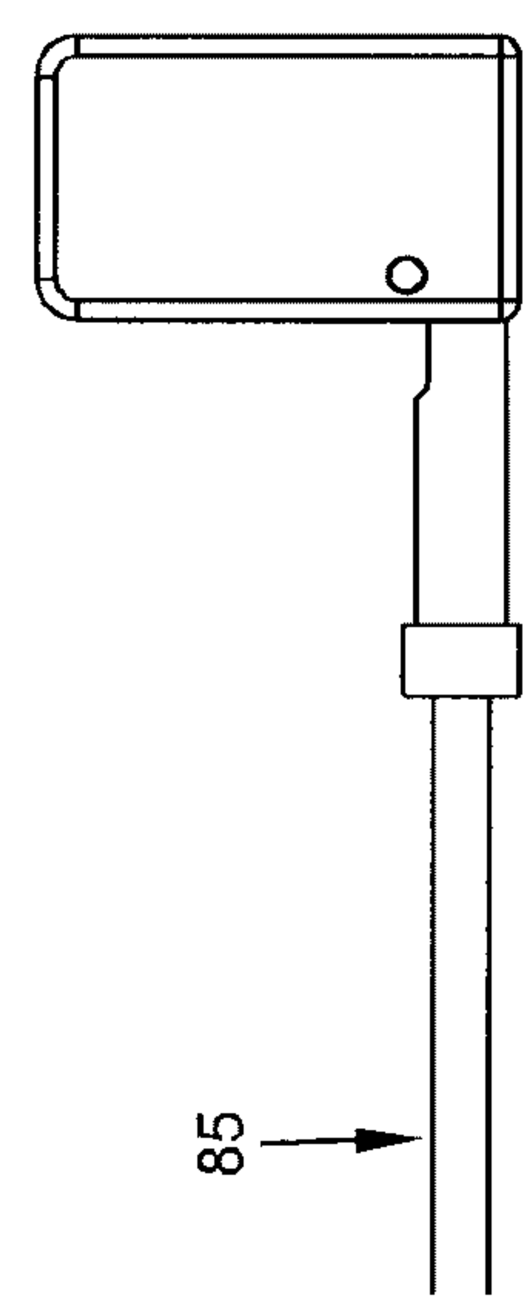


FIG. 43

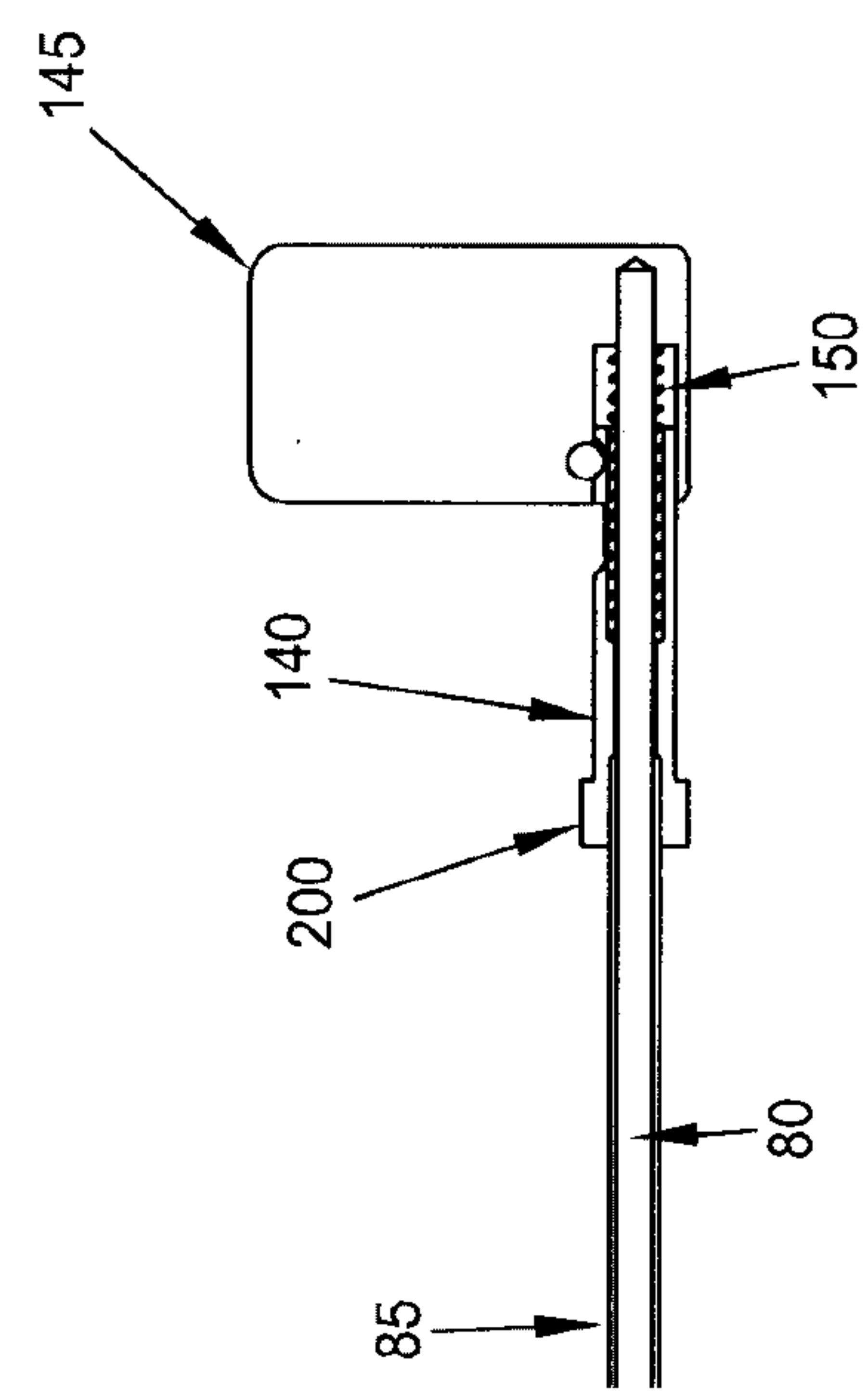


FIG. 44

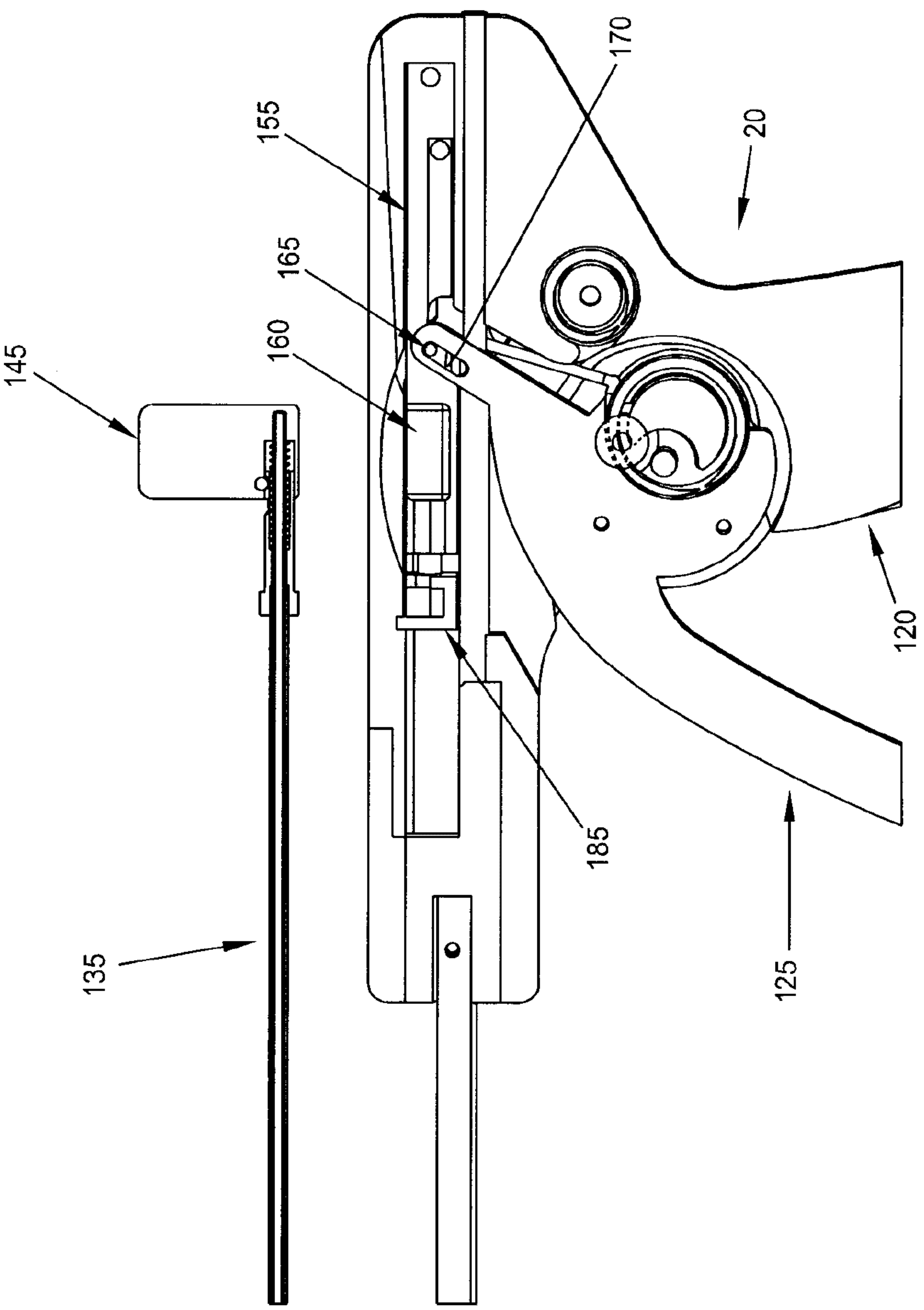


FIG. 45

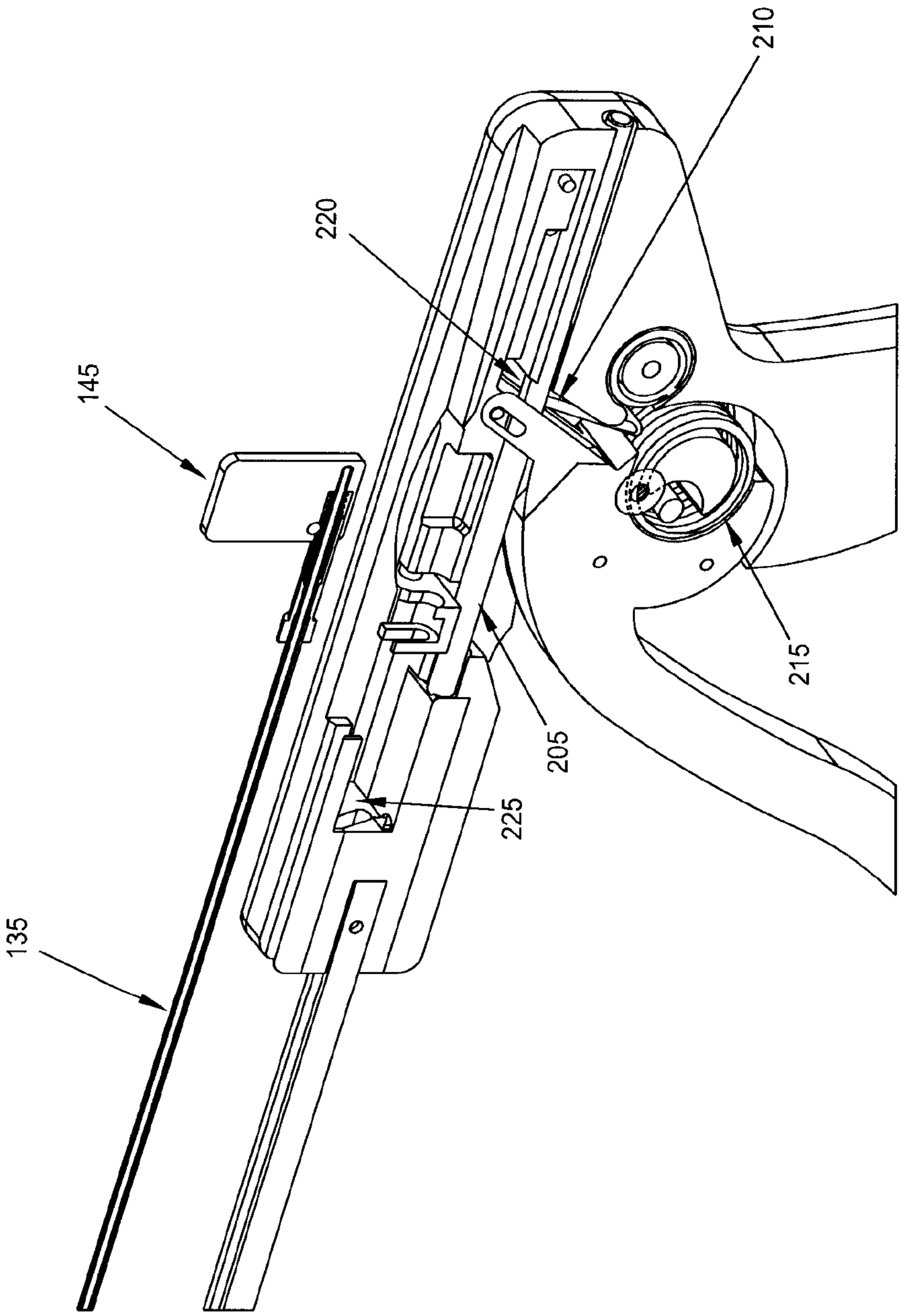


FIG. 46

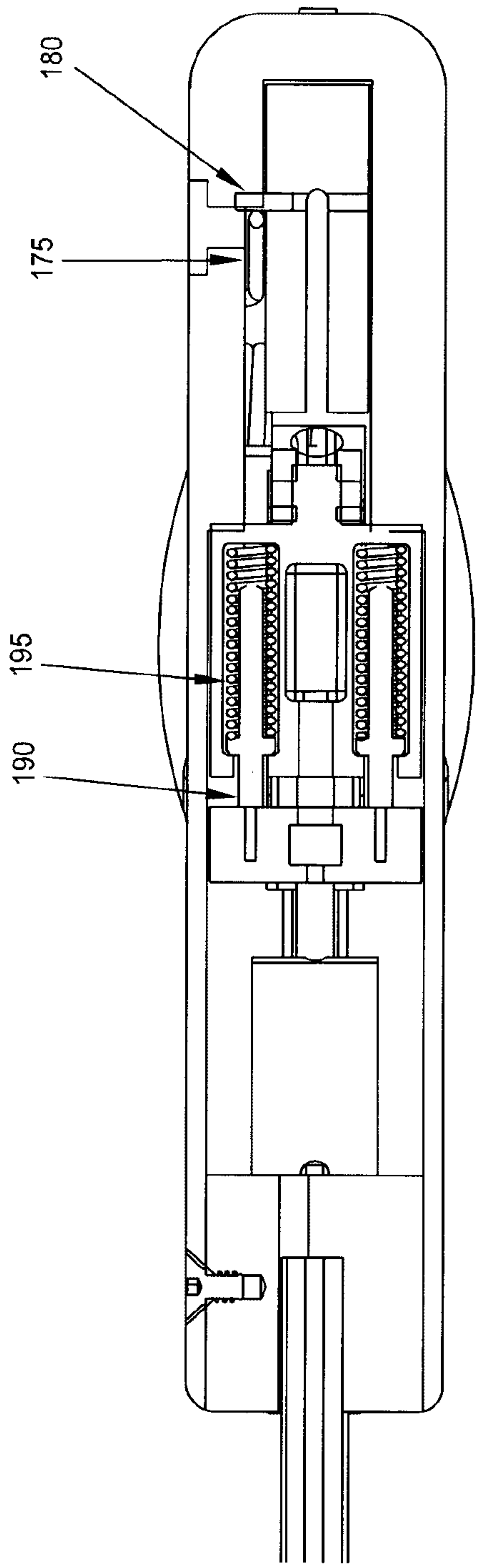


FIG. 47

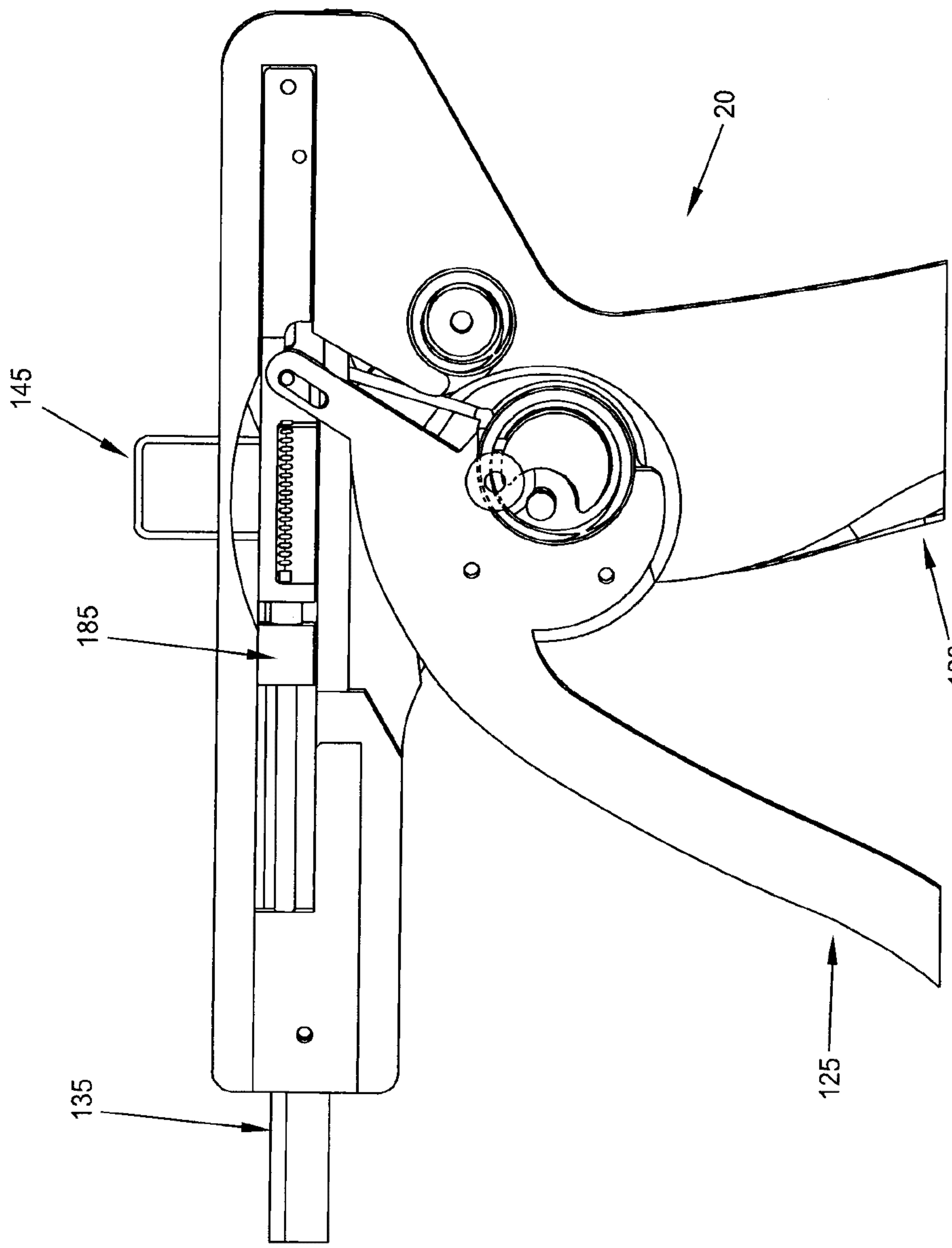


FIG. 48

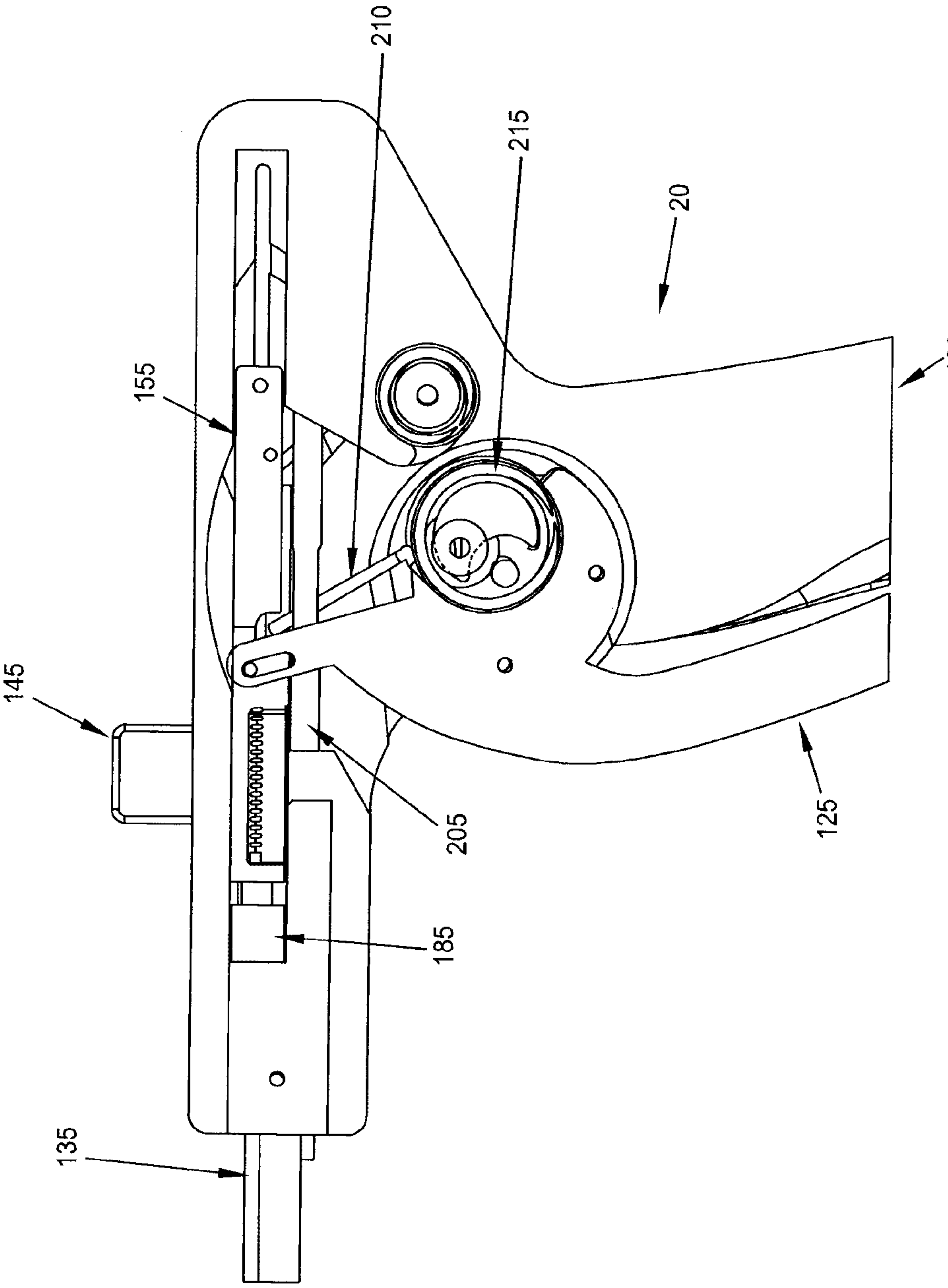


FIG. 49

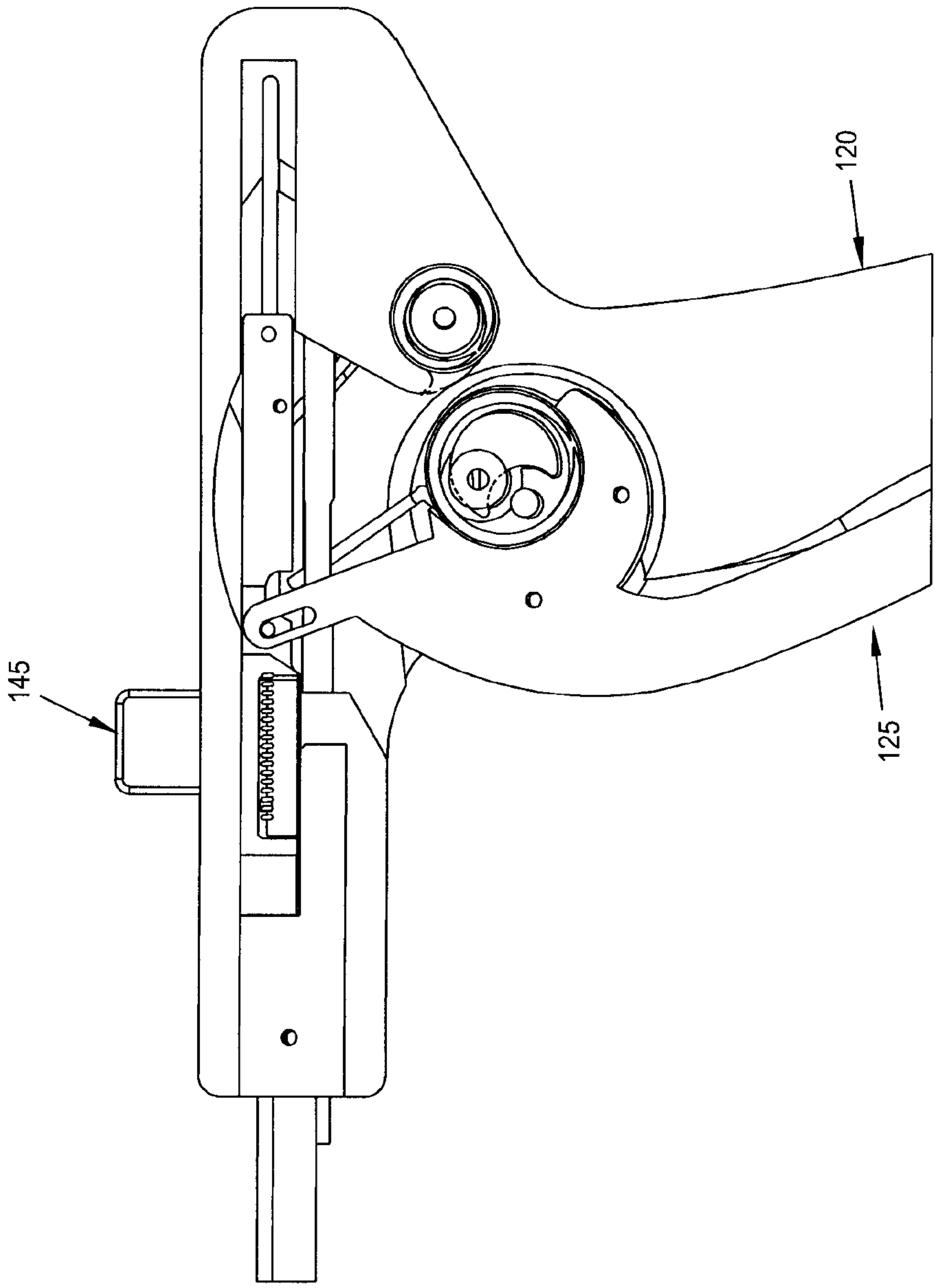


FIG. 50

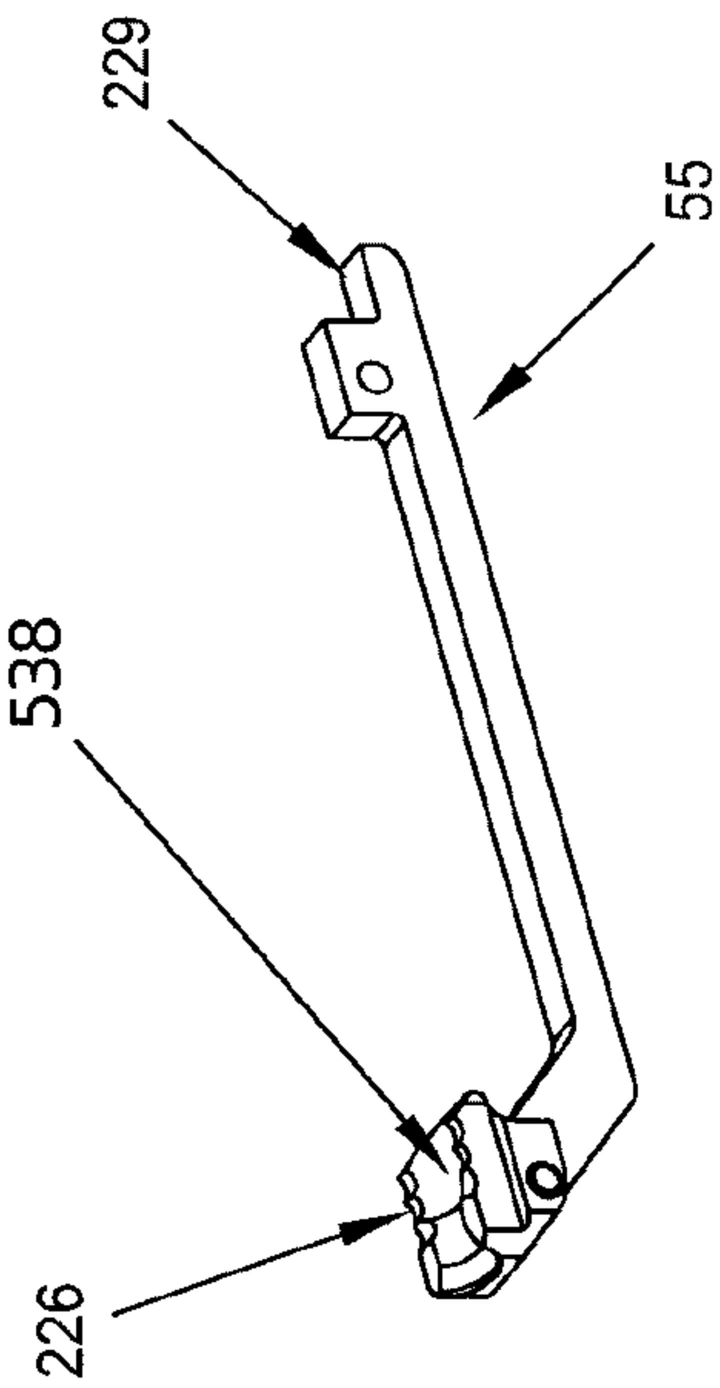


FIG. 50B

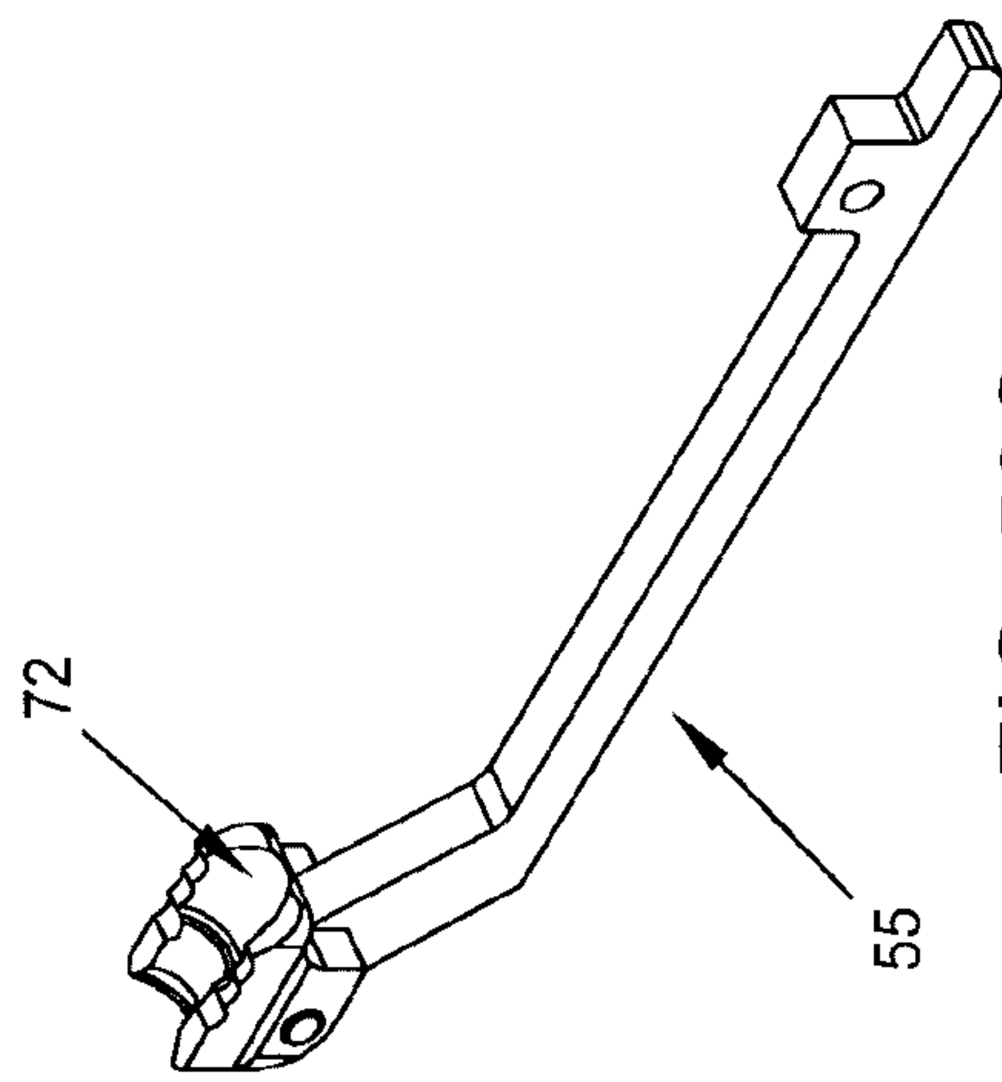


FIG. 50C

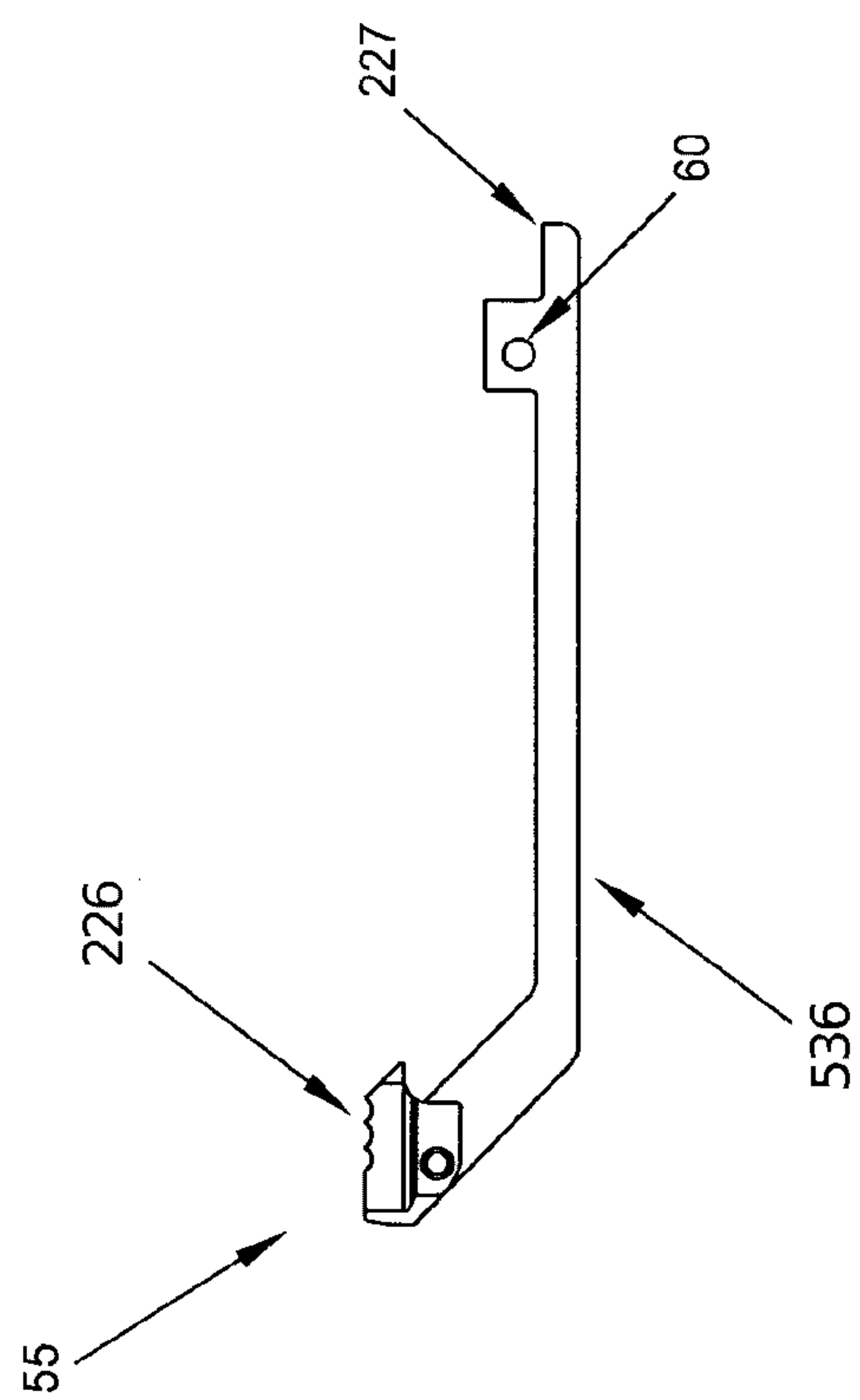


FIG. 50A

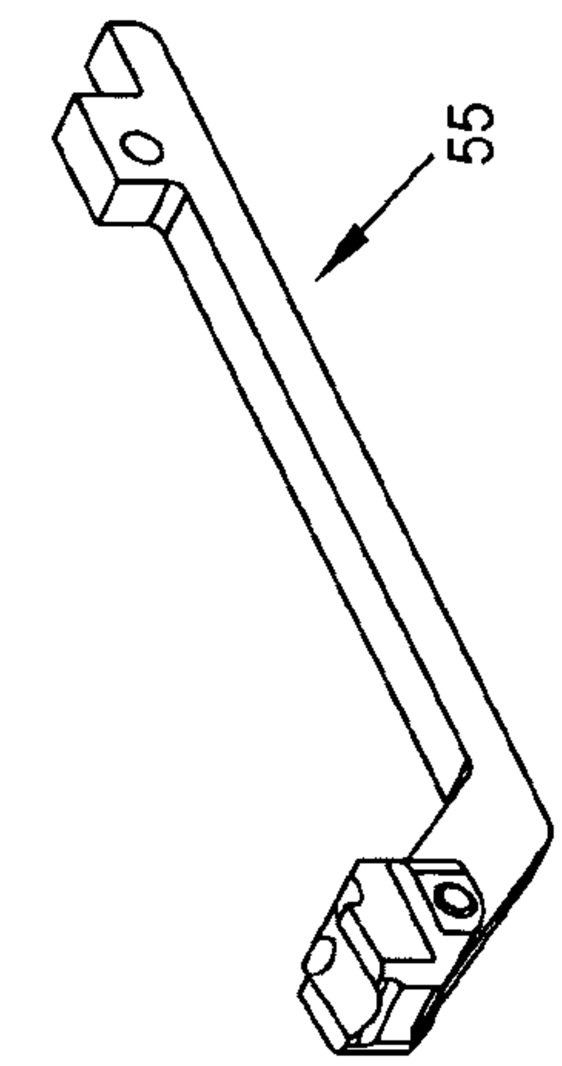


FIG. 50E

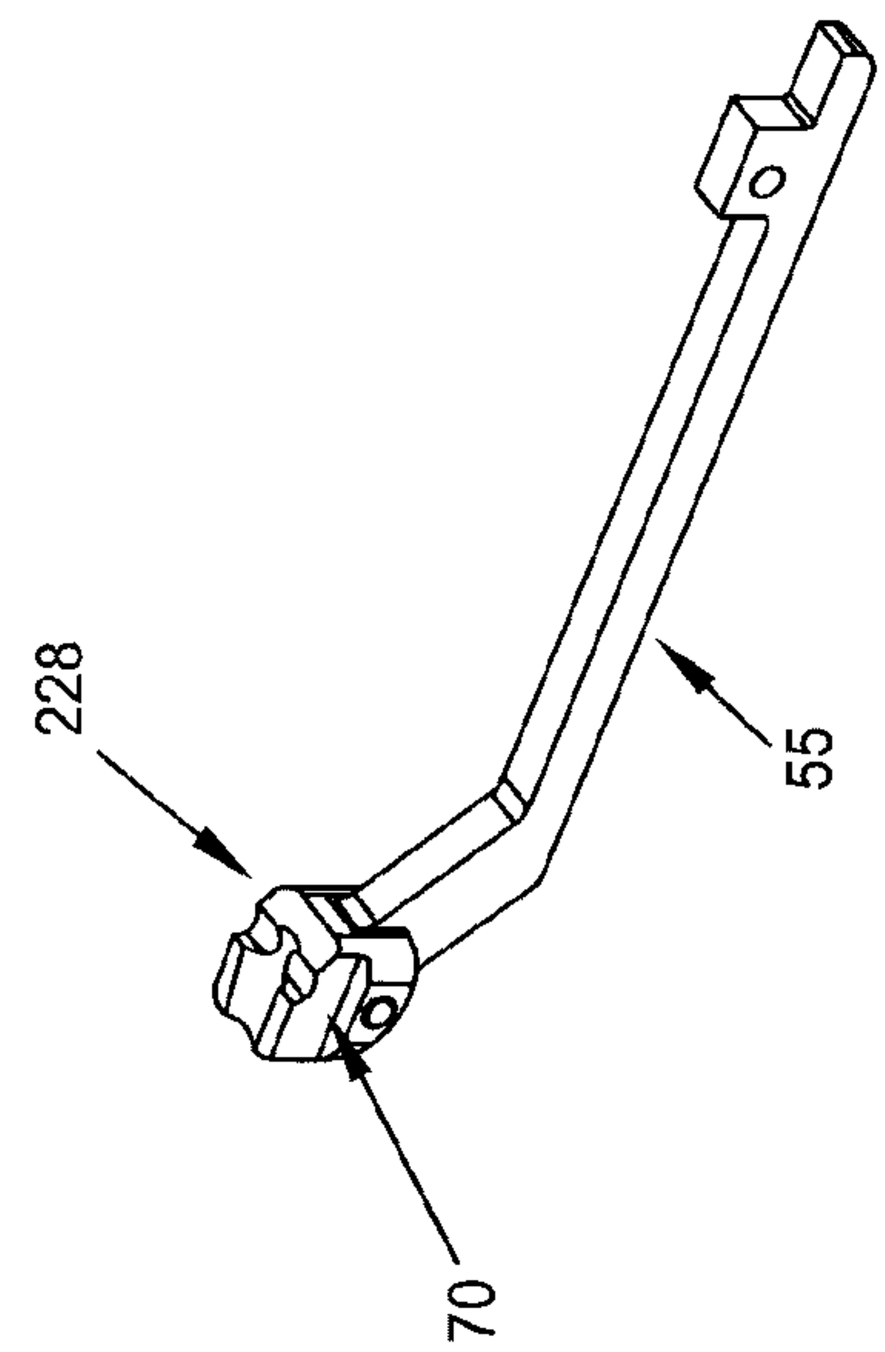


FIG. 50F

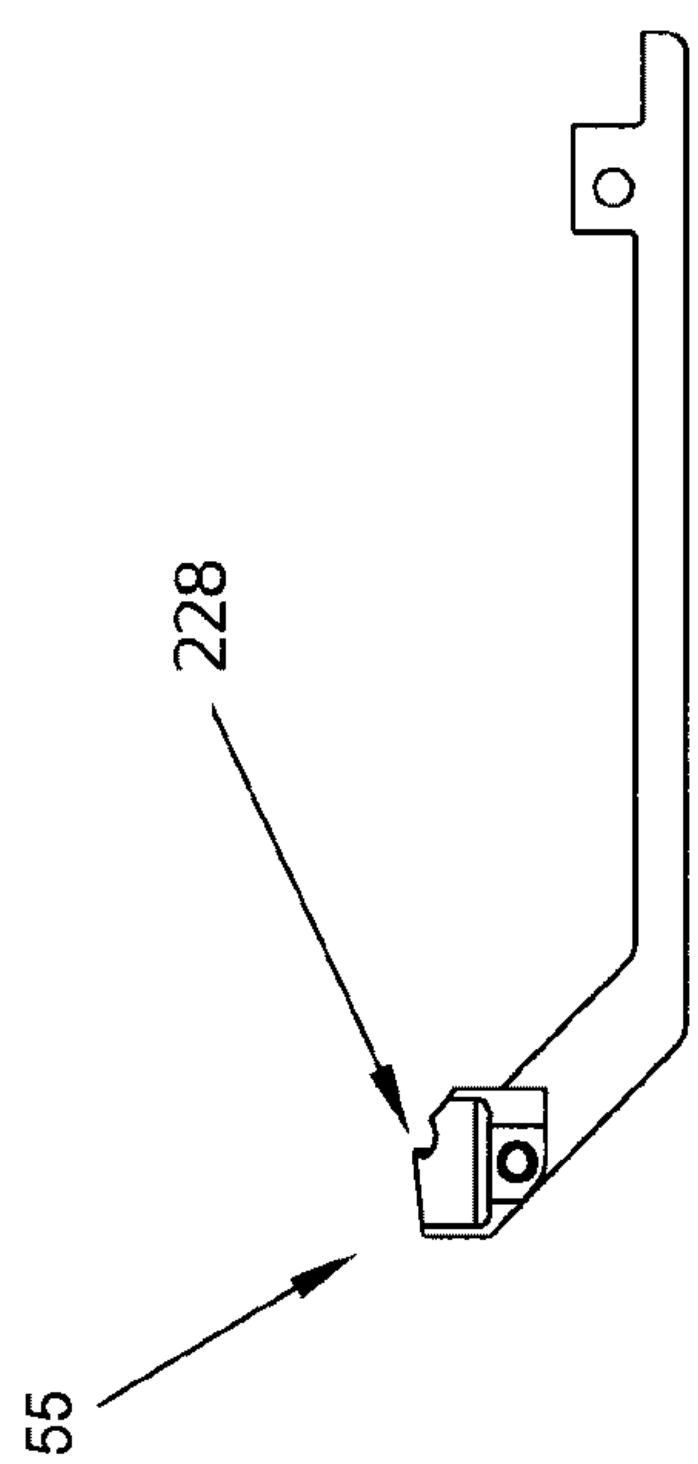


FIG. 50D

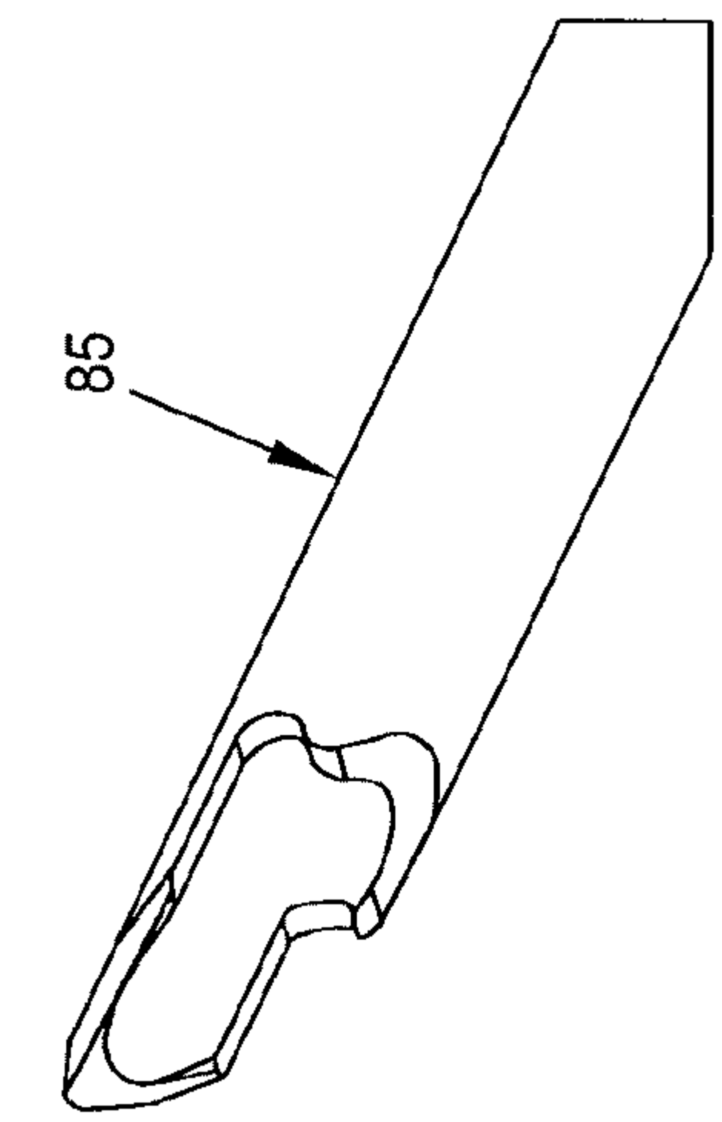


FIG. 52

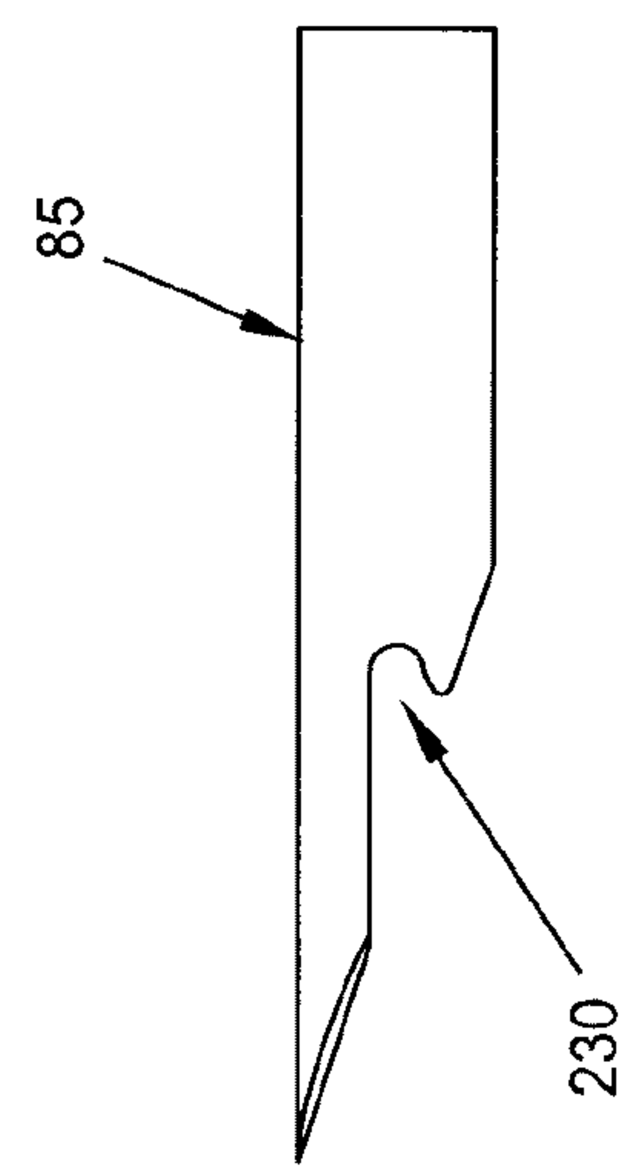


FIG. 51

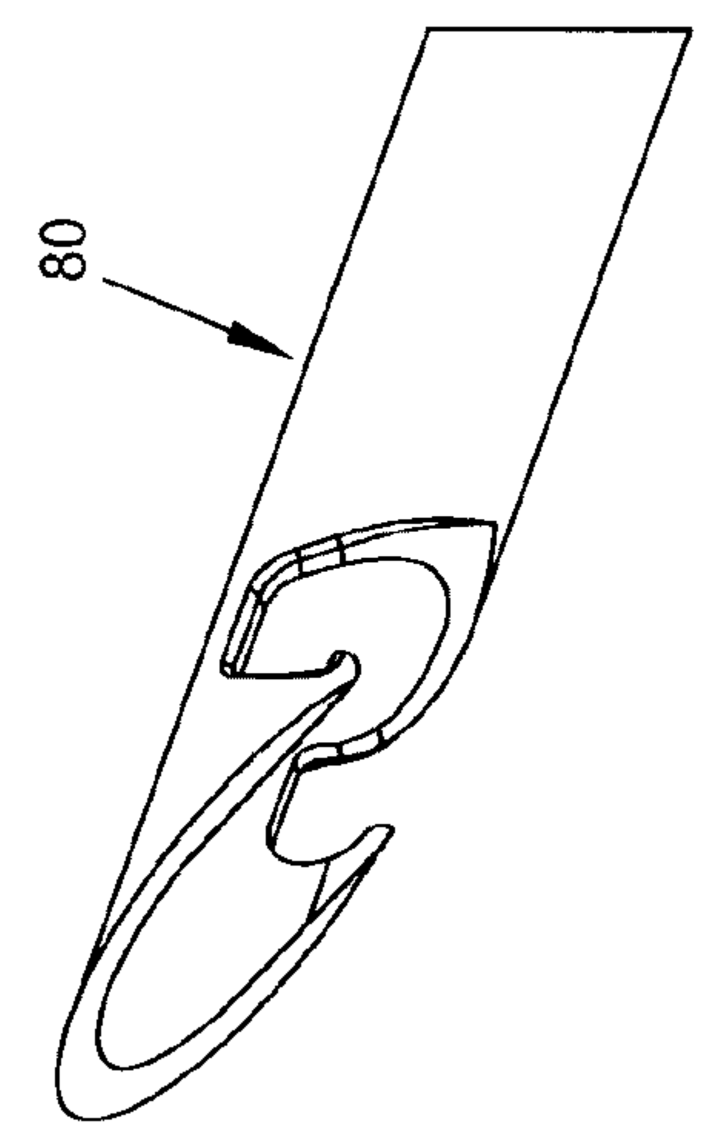


FIG. 54

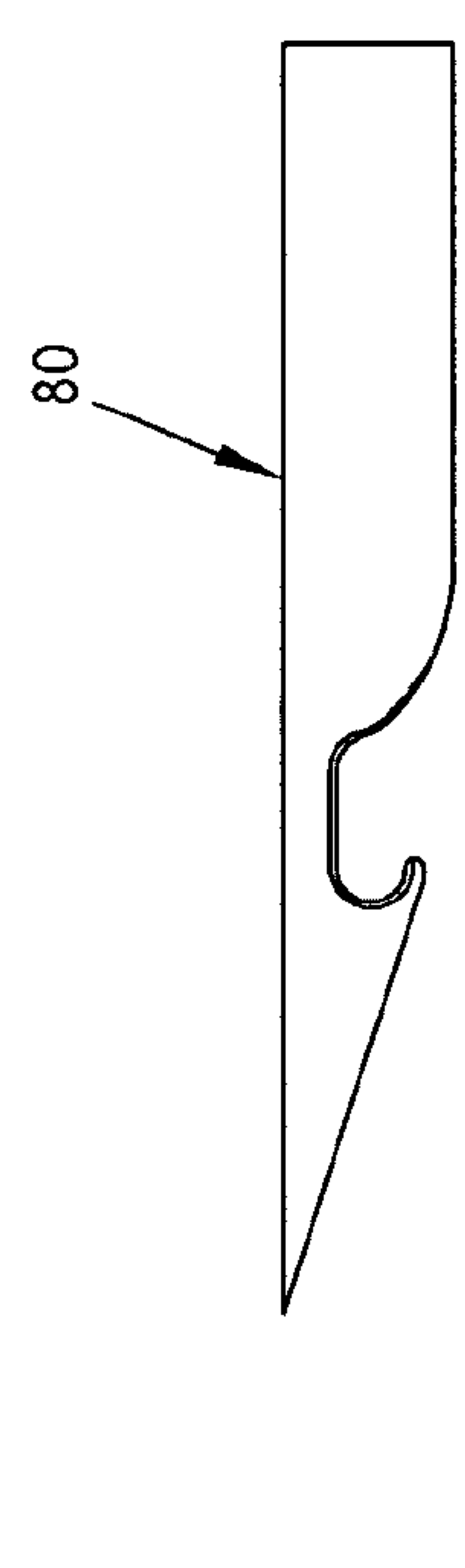


FIG. 53

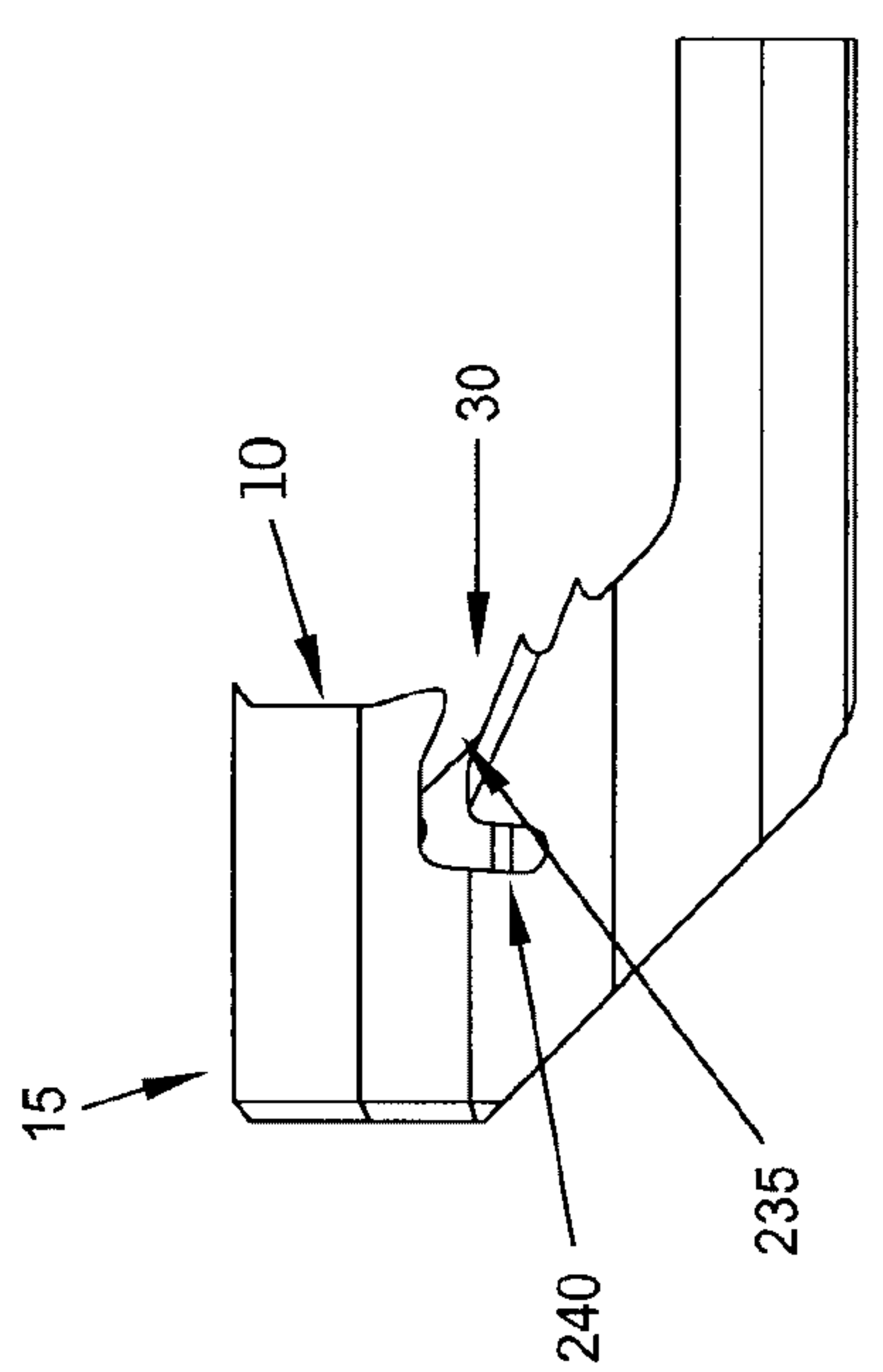


FIG. 55

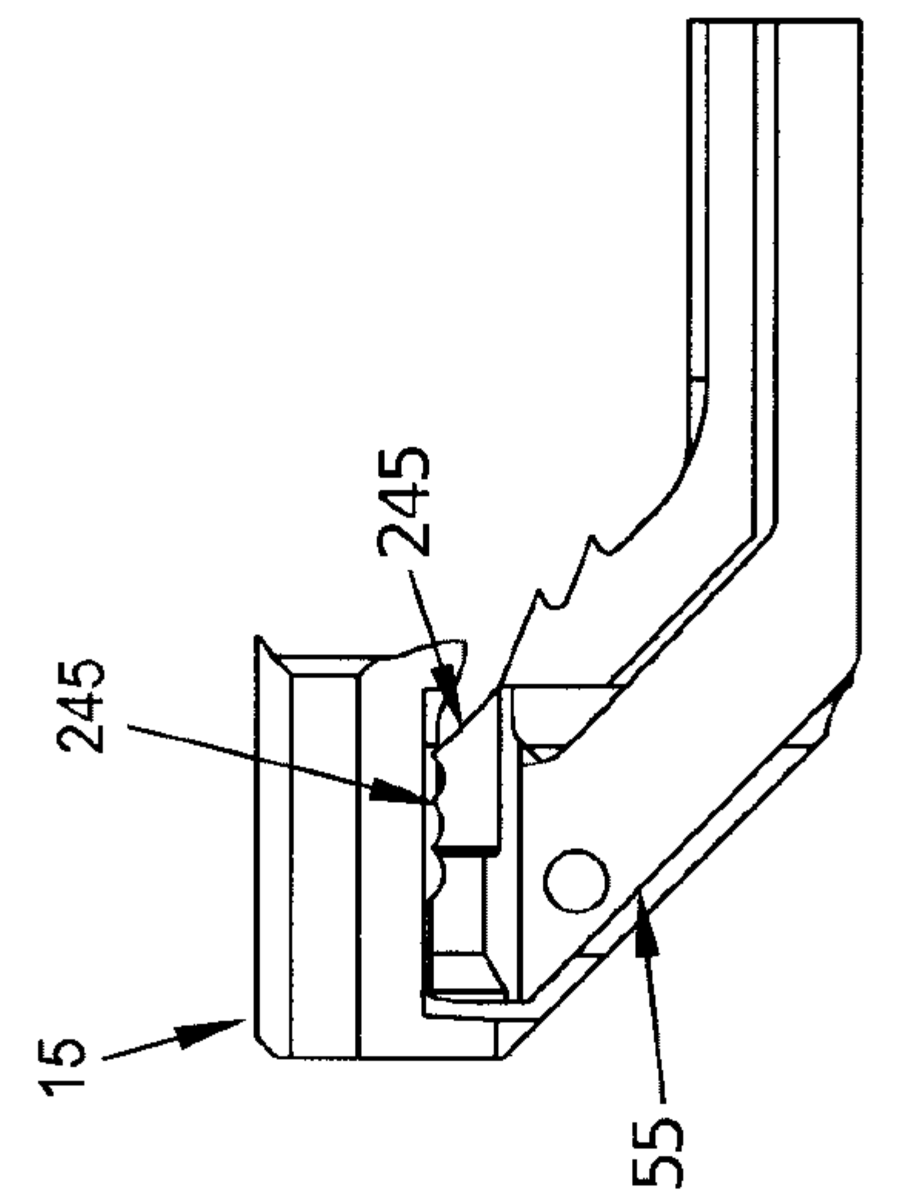


FIG. 56

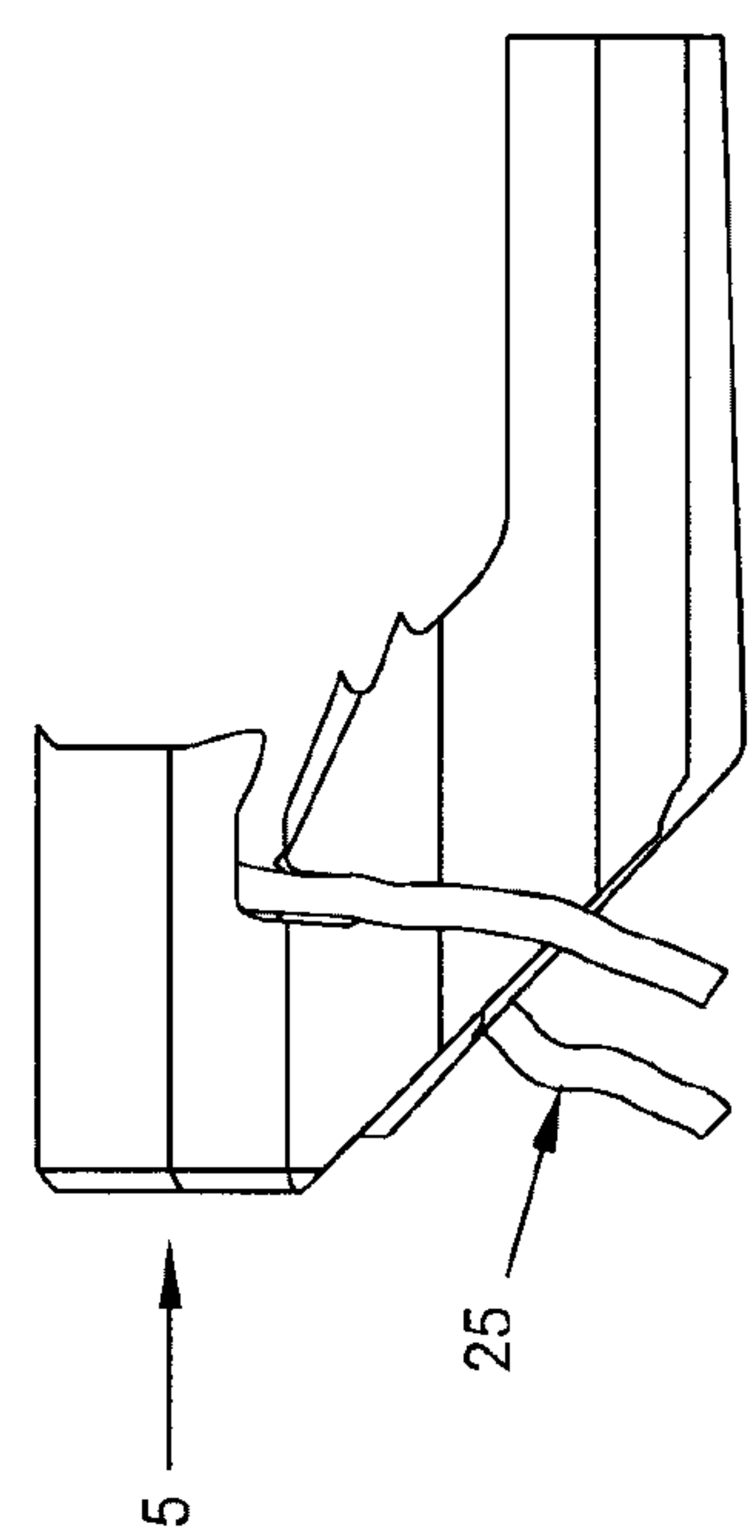


FIG. 57

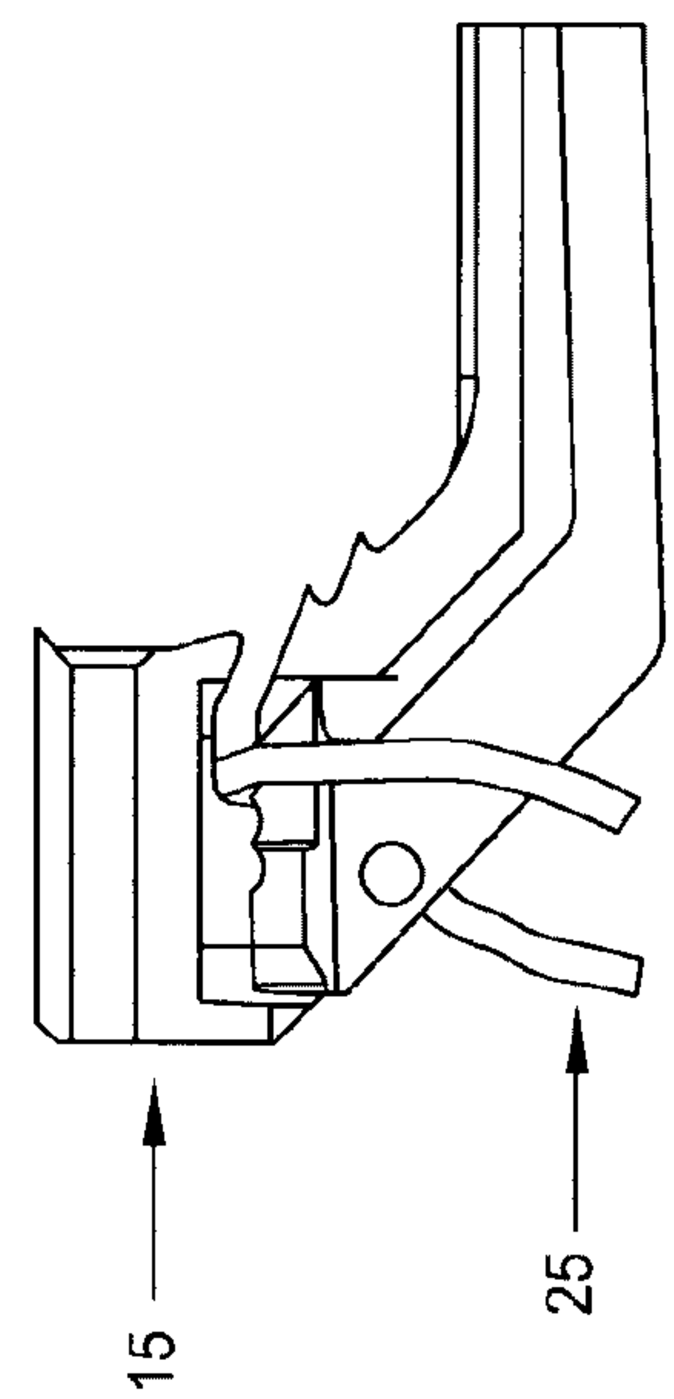


FIG. 58

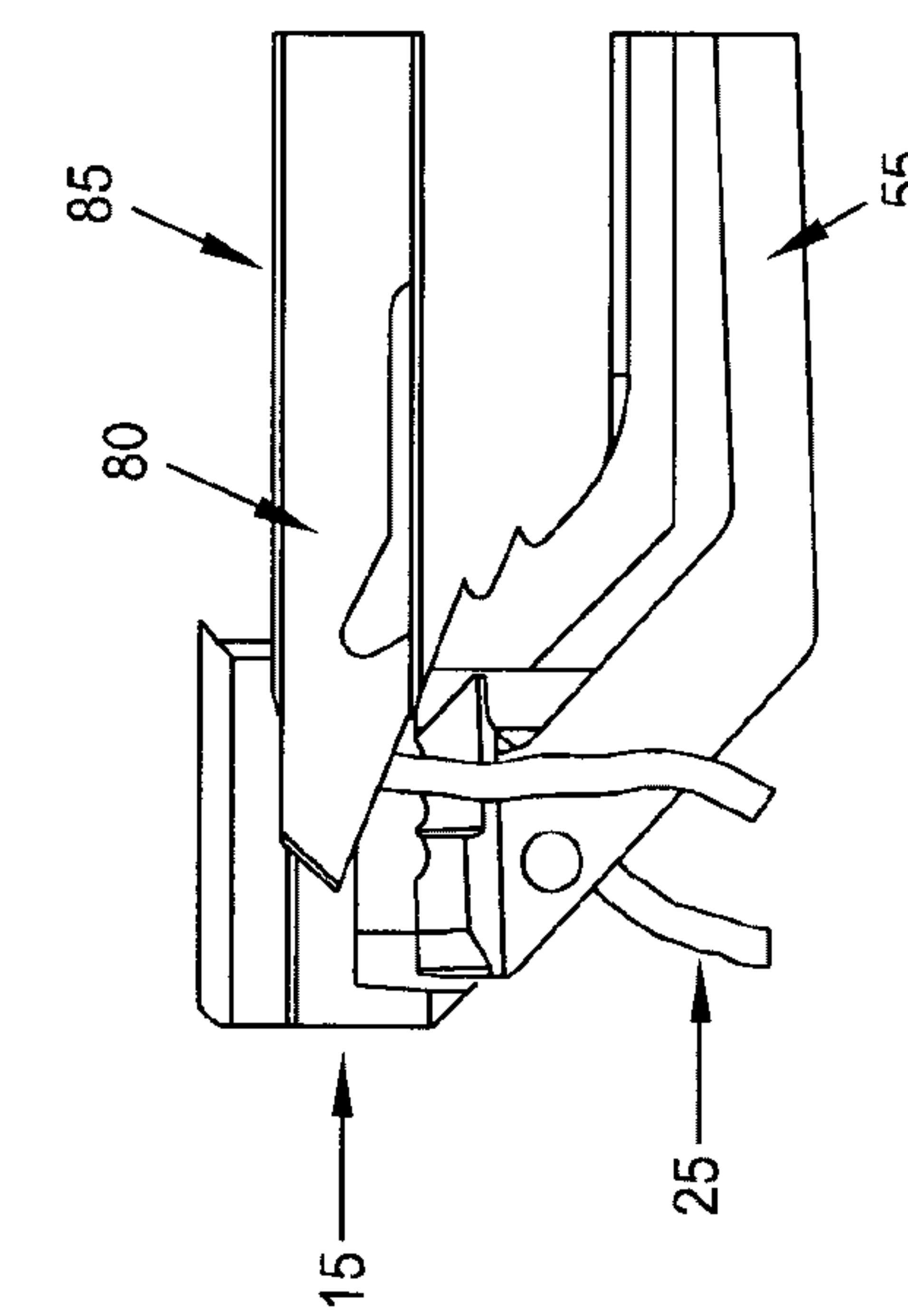


FIG. 60

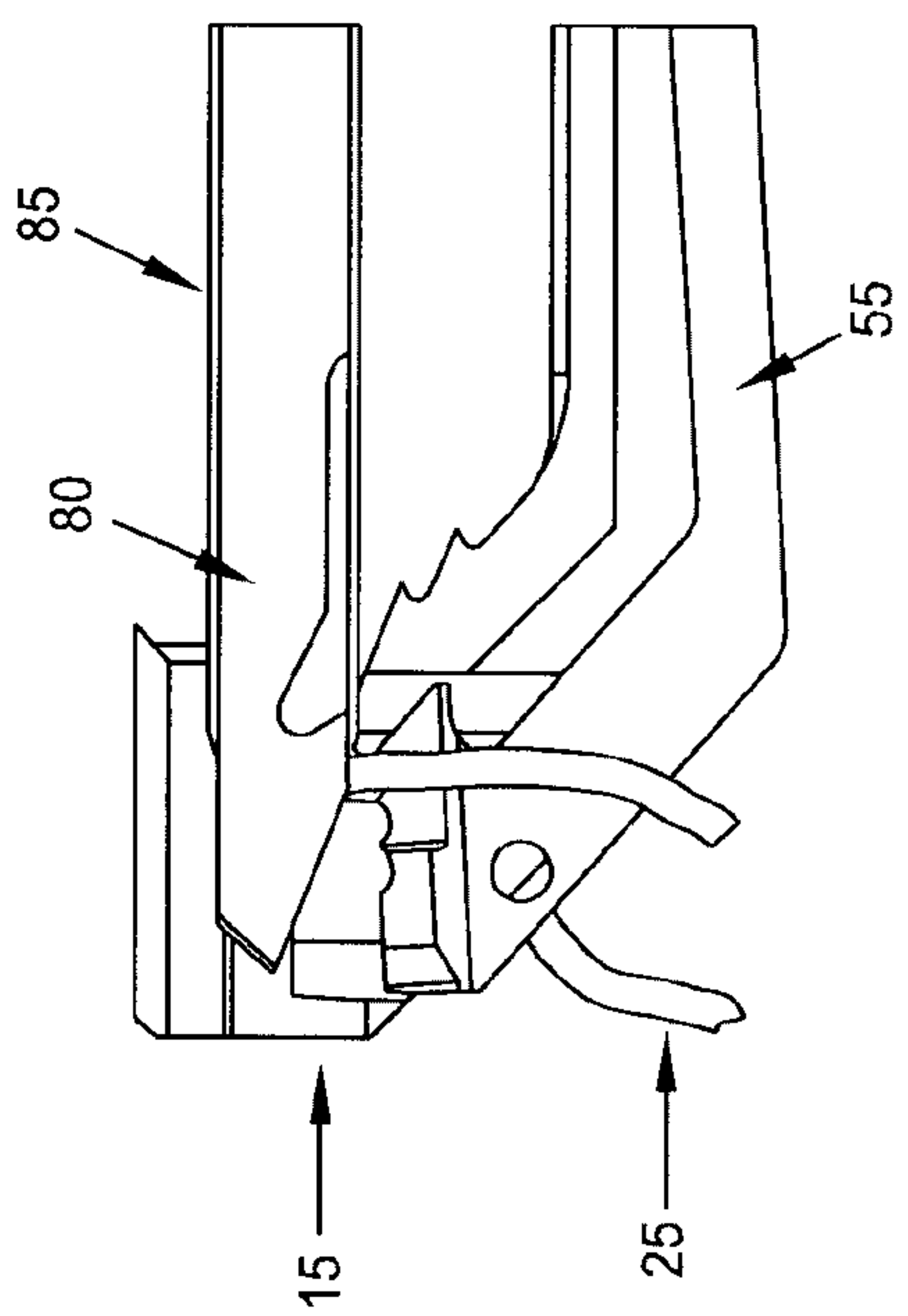


FIG. 62

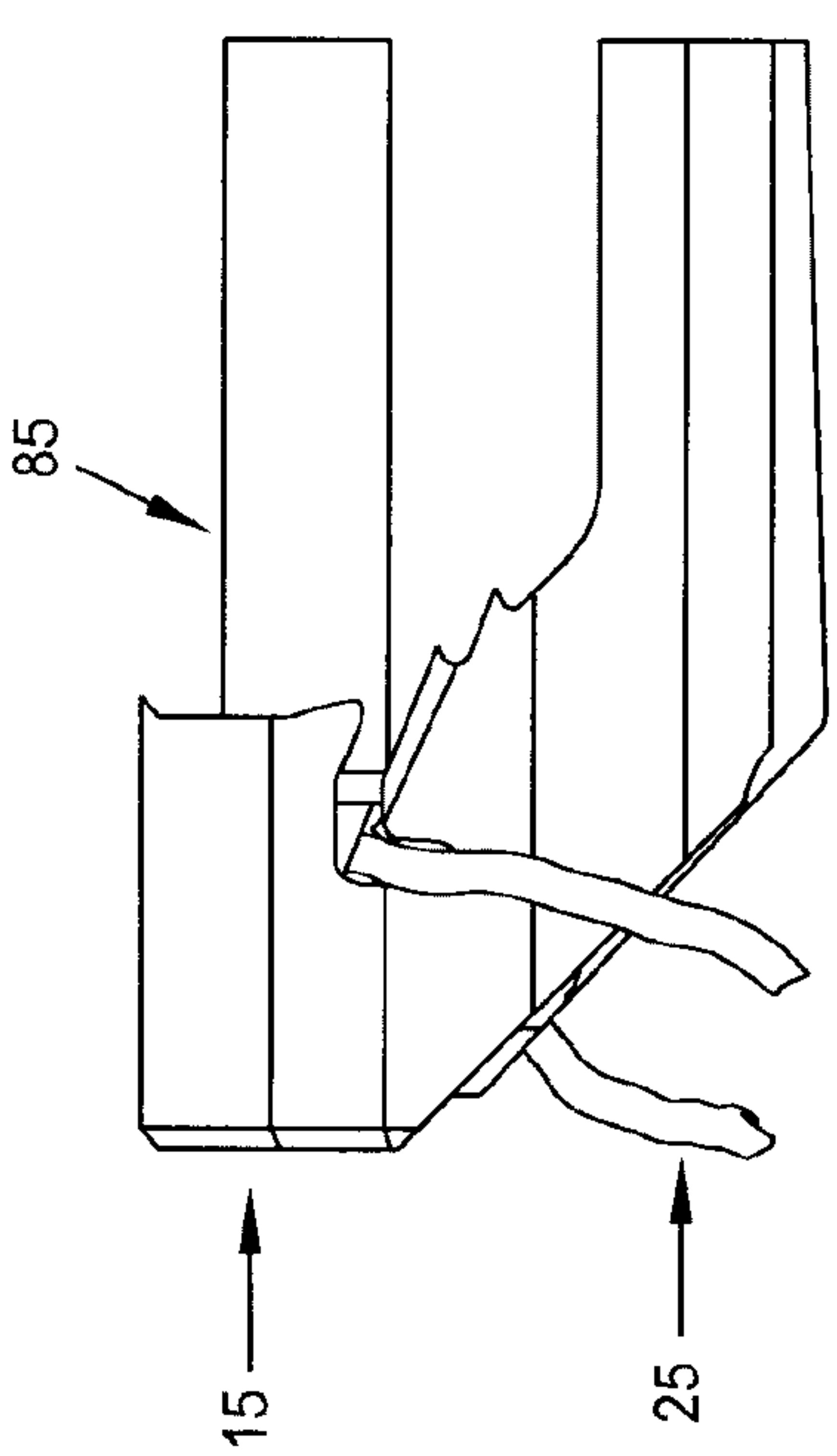


FIG. 59

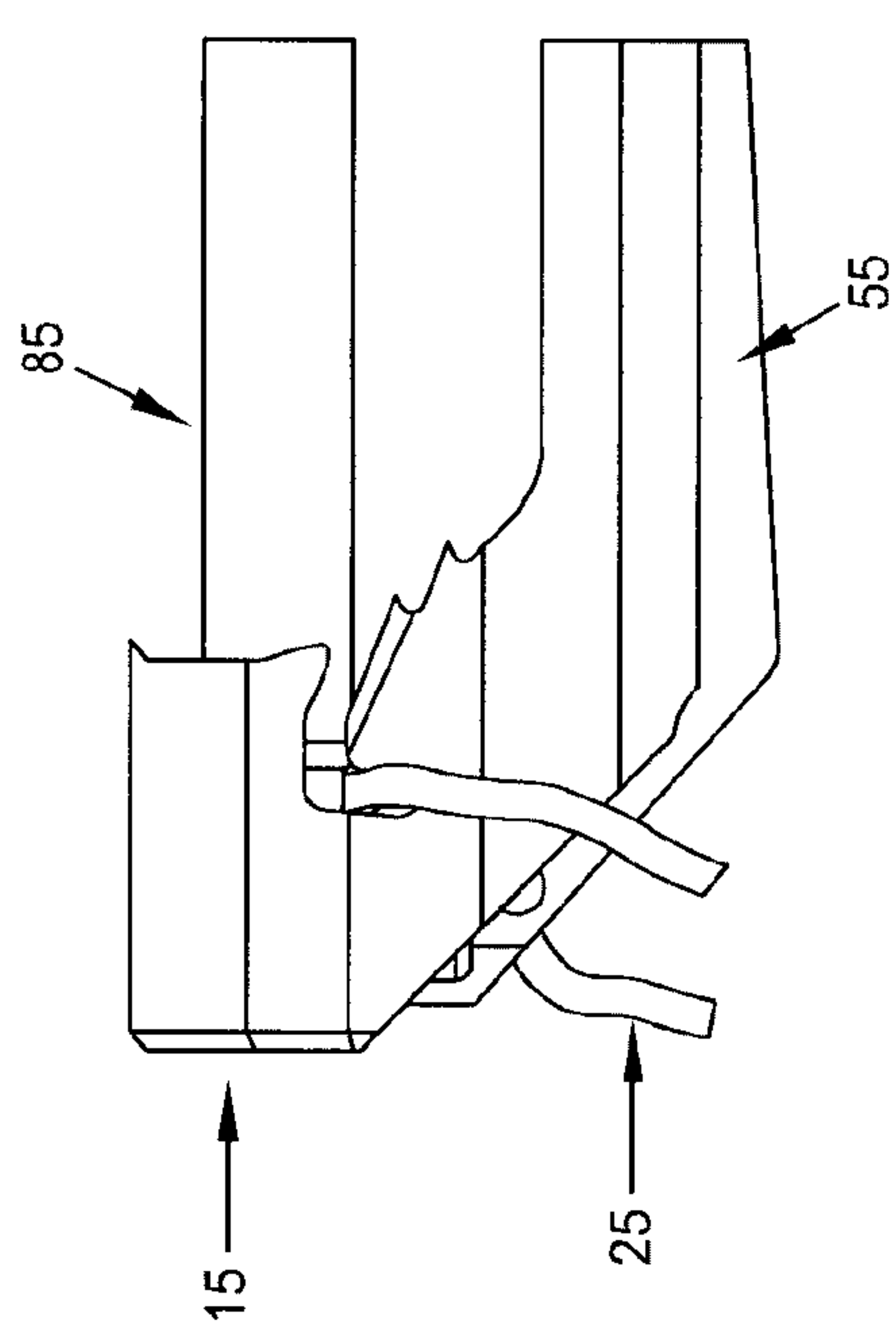


FIG. 61

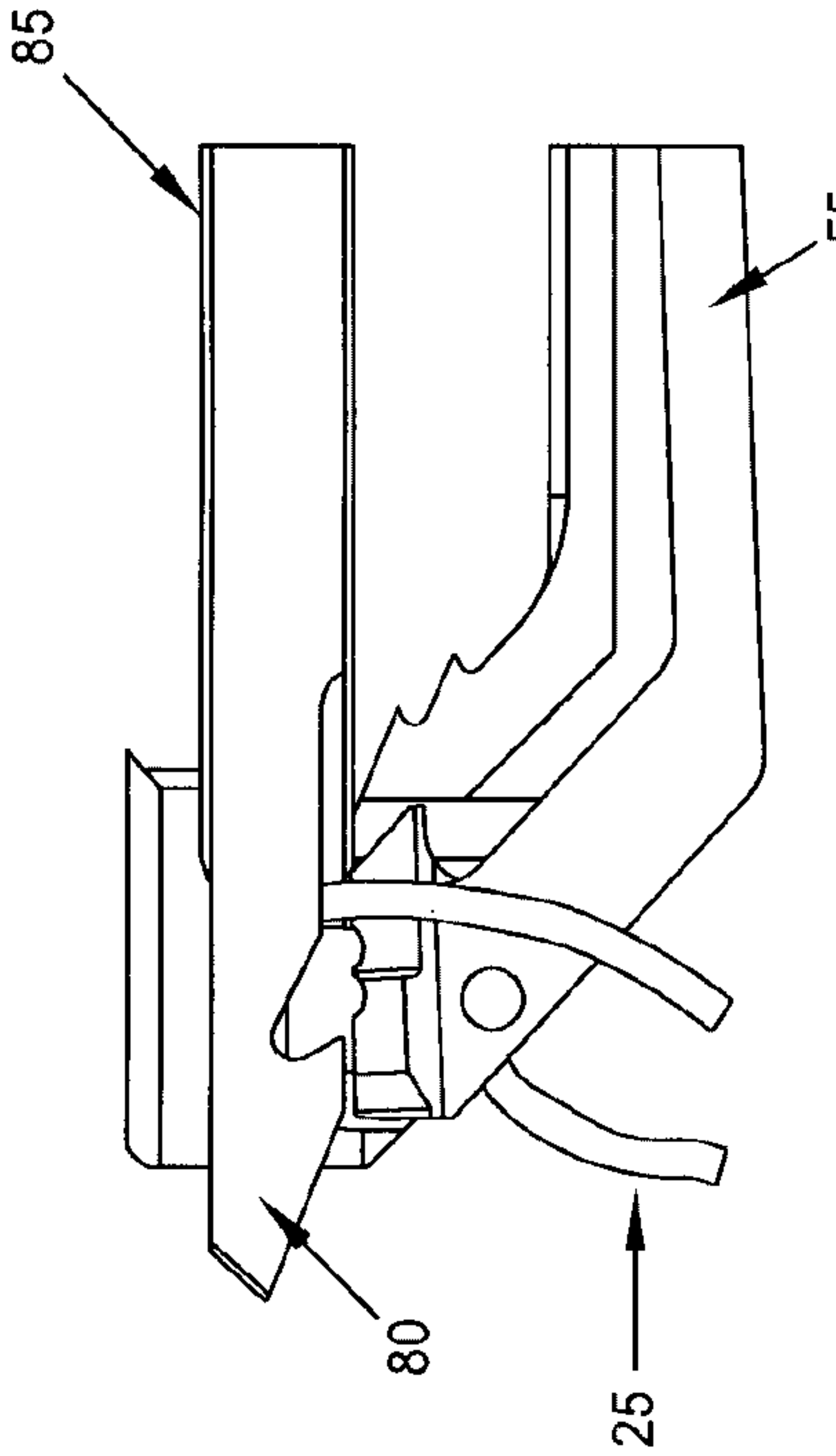


FIG. 64

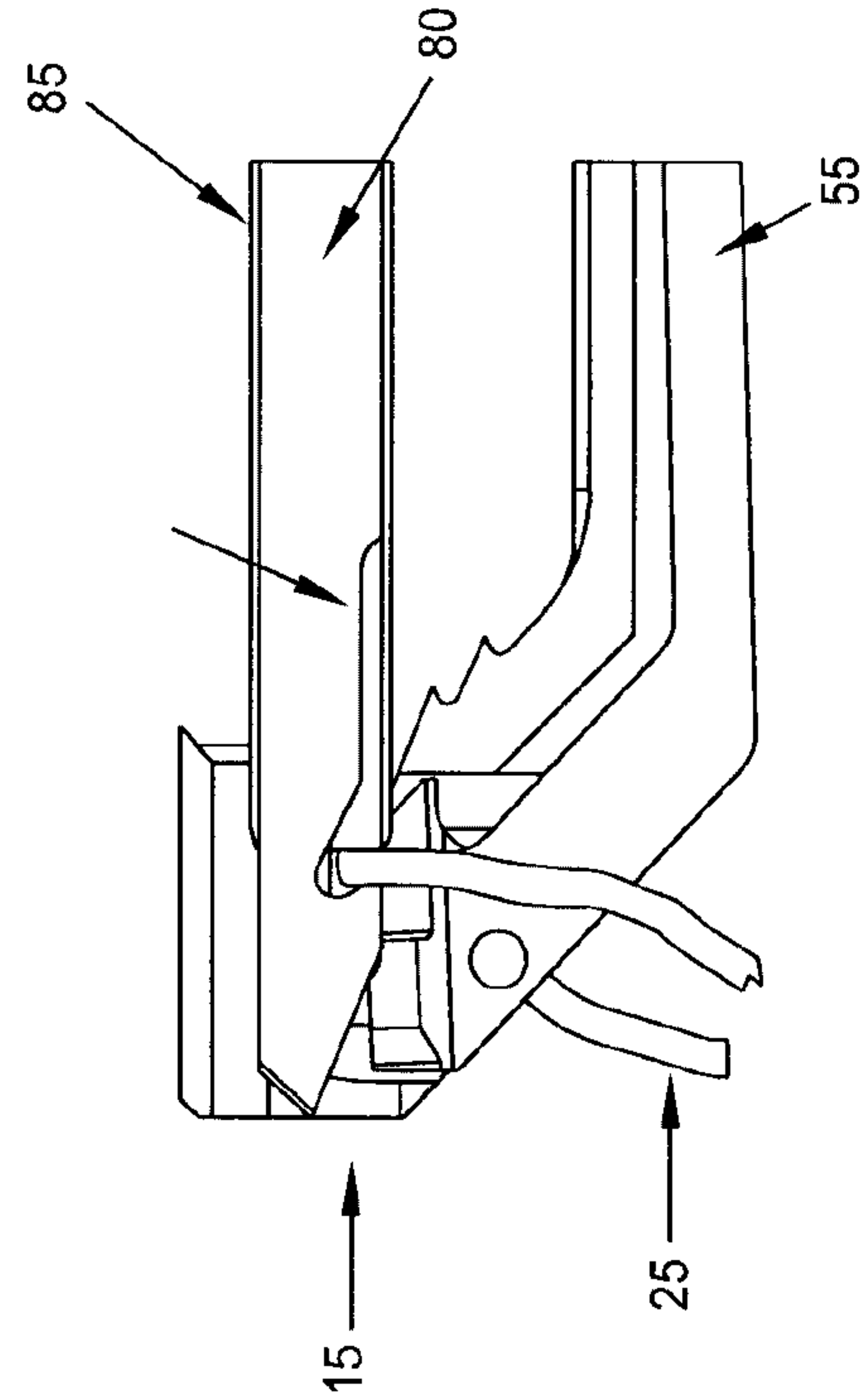


FIG. 66

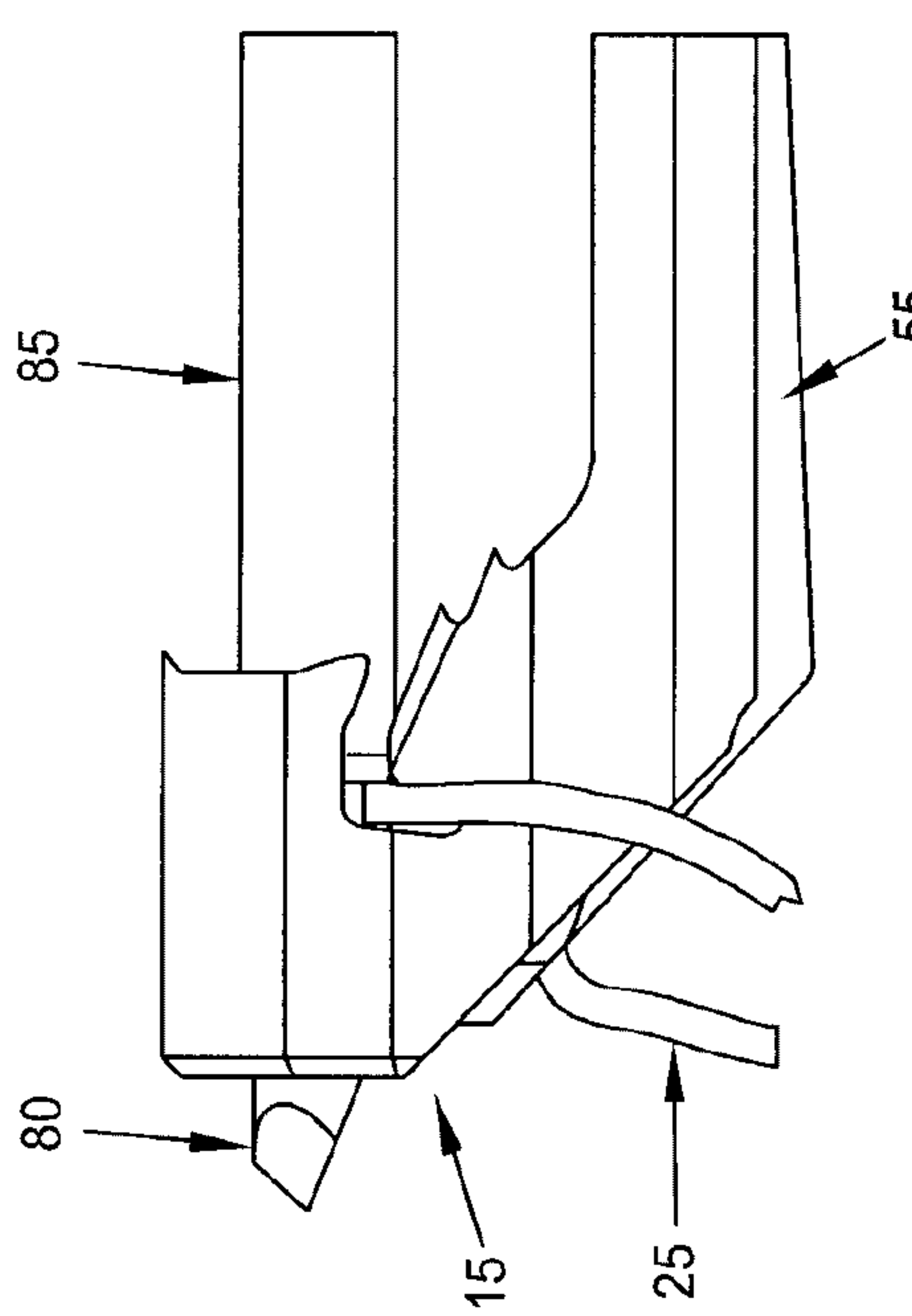


FIG. 63

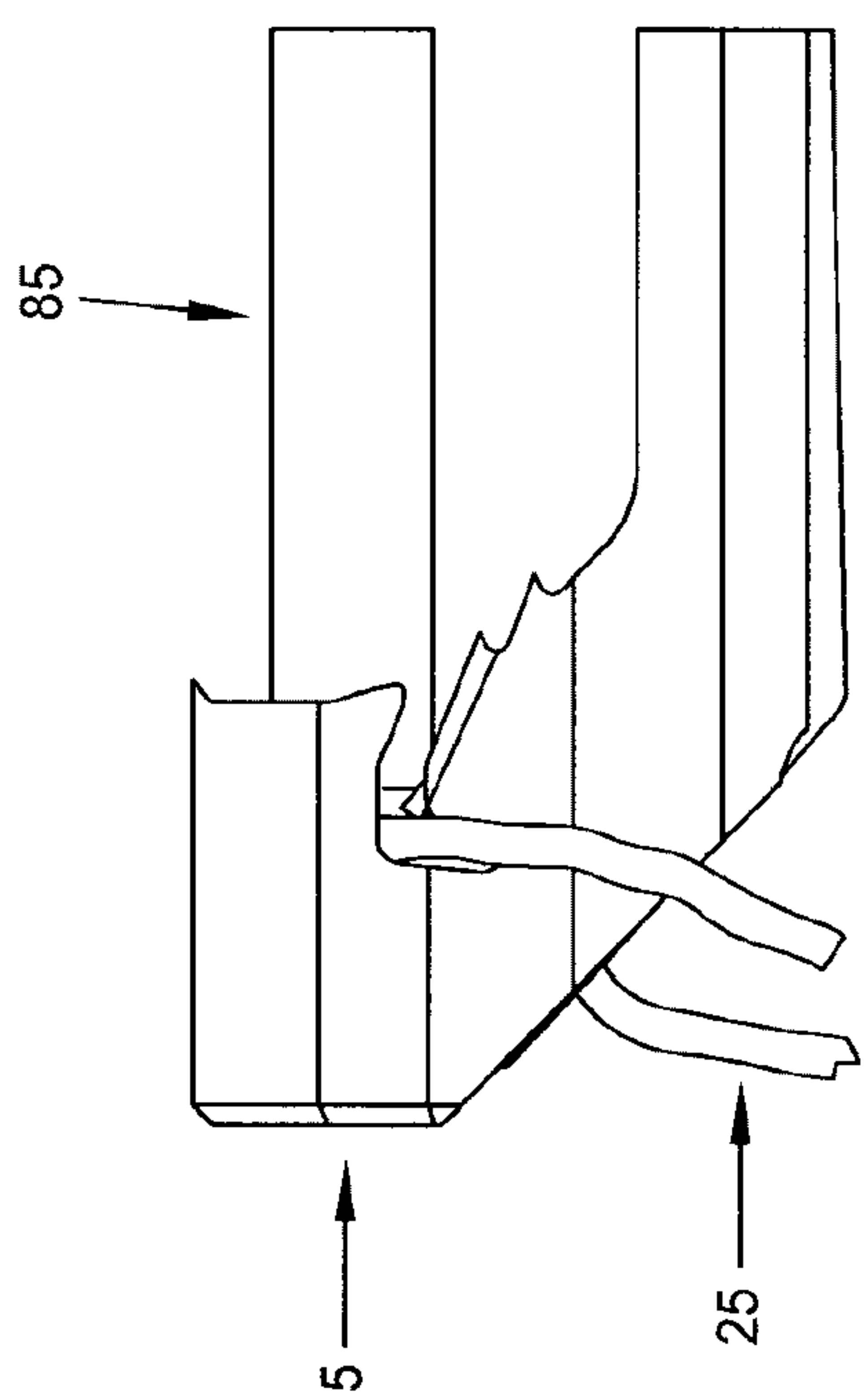


FIG. 65

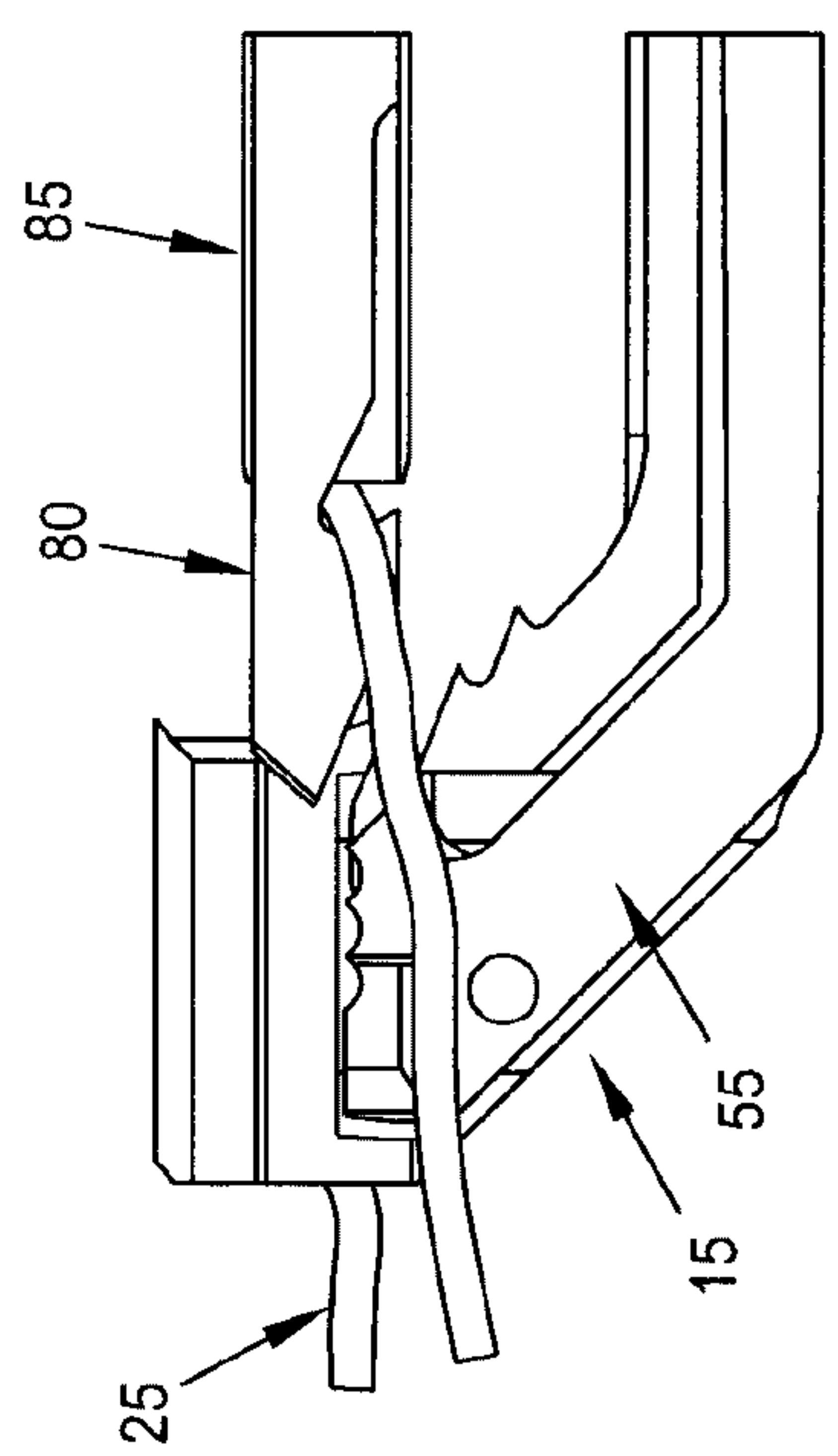


FIG. 68

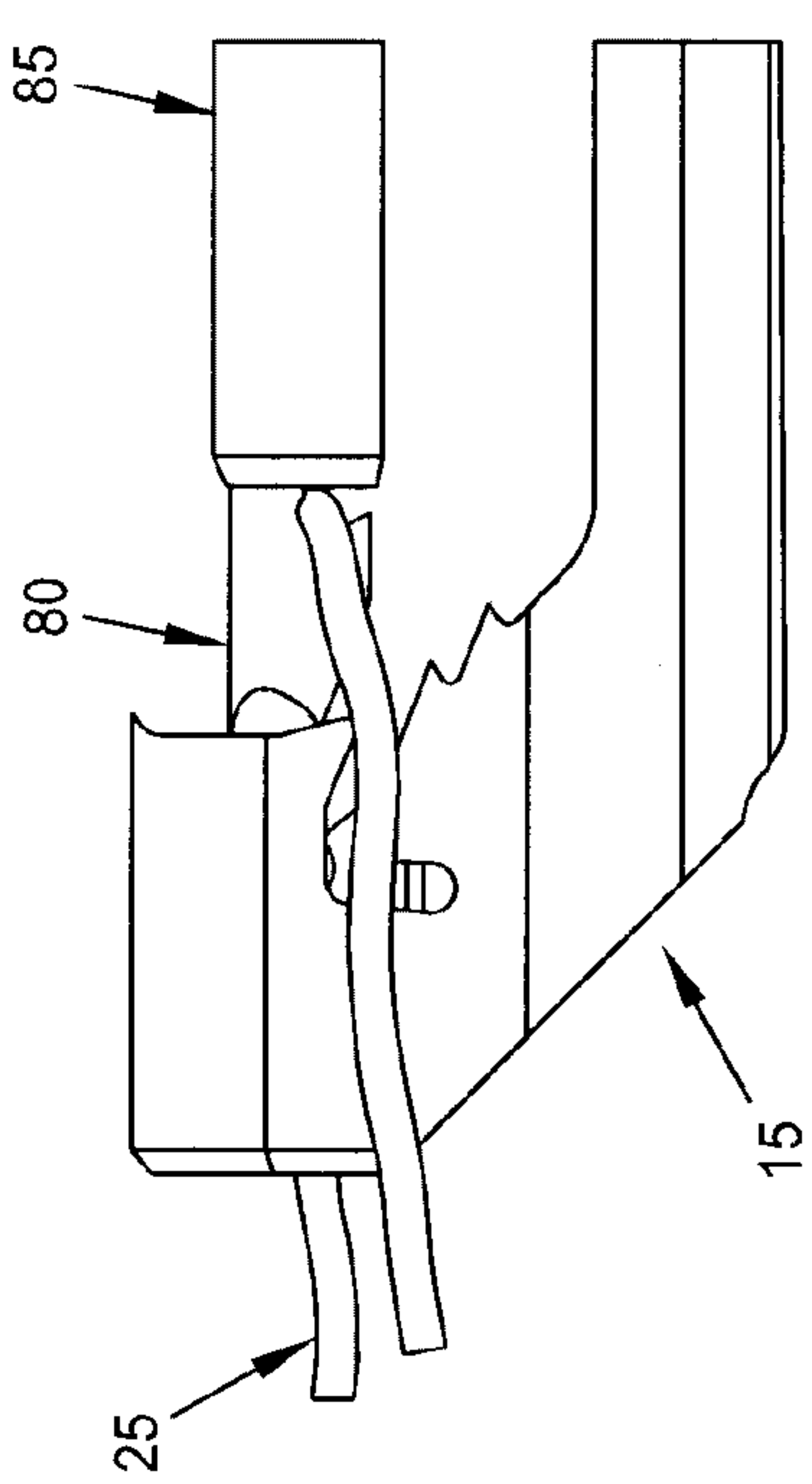


FIG. 67

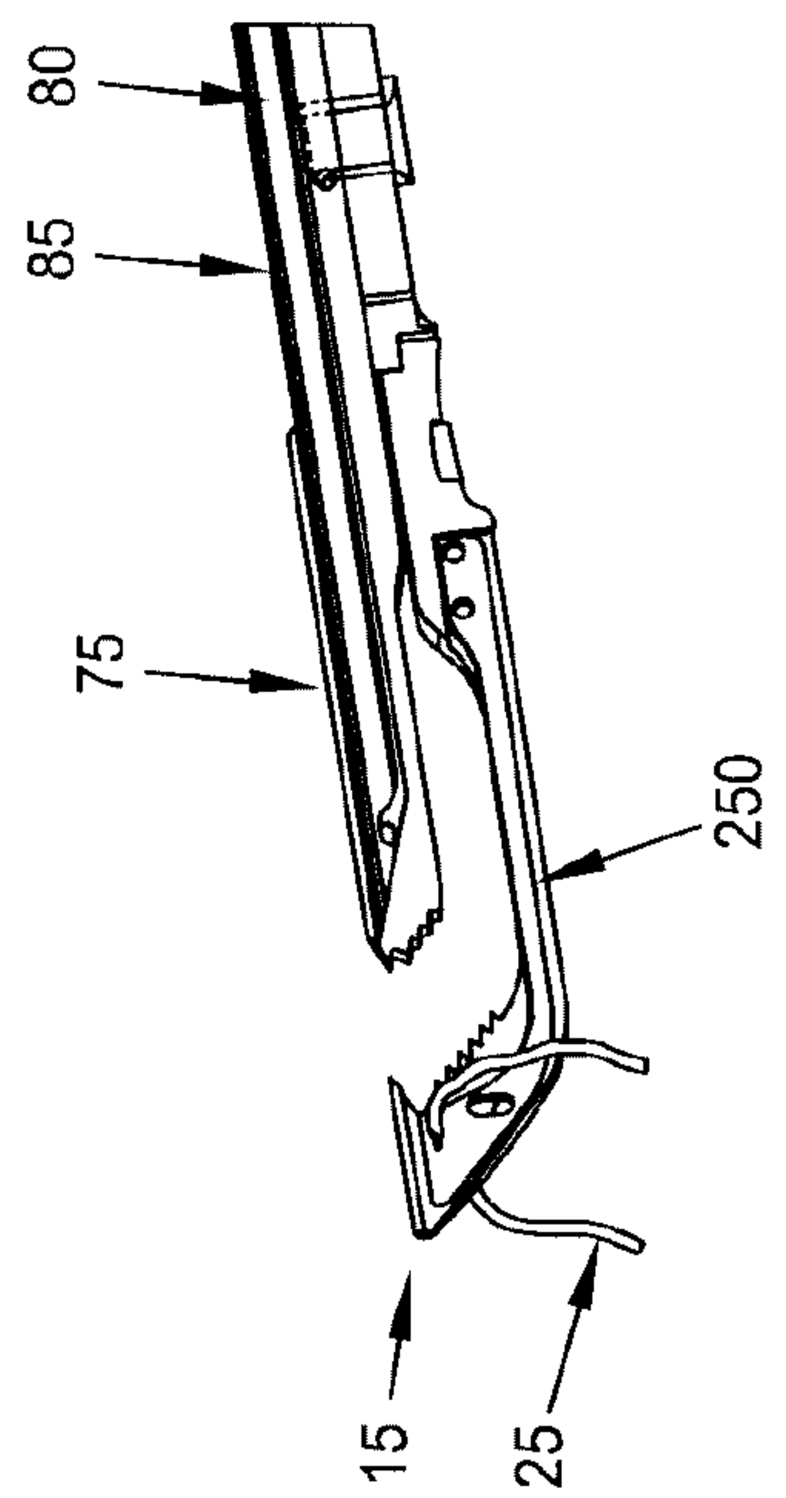


FIG. 70

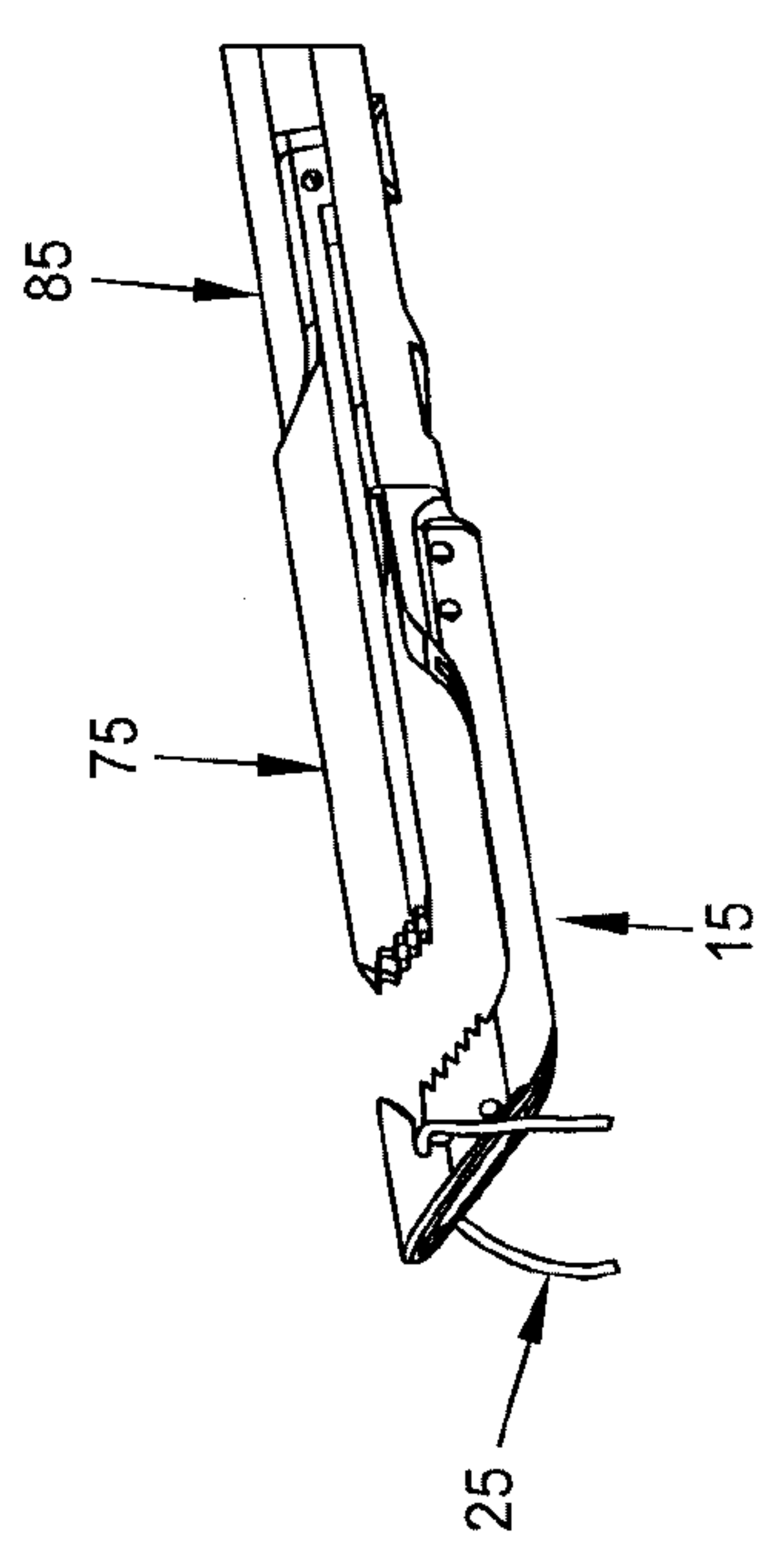


FIG. 69

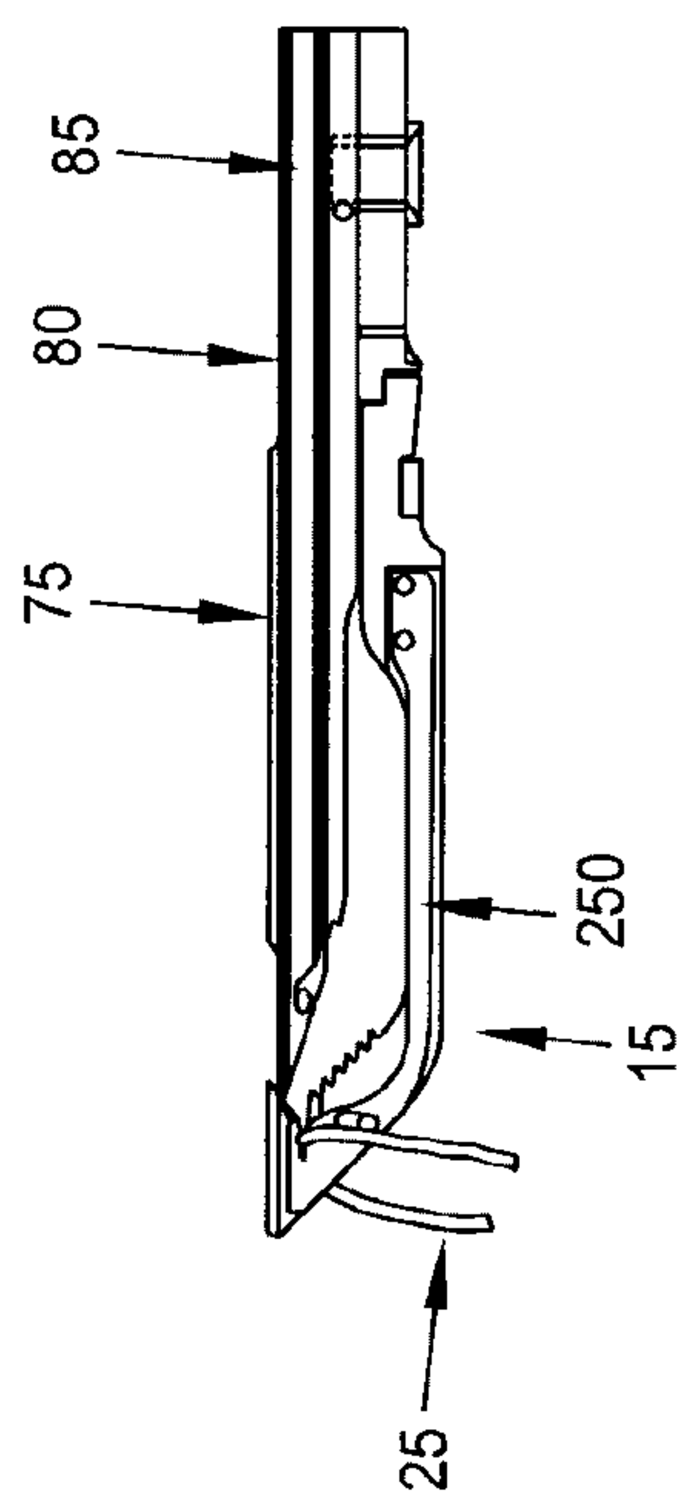


FIG. 72

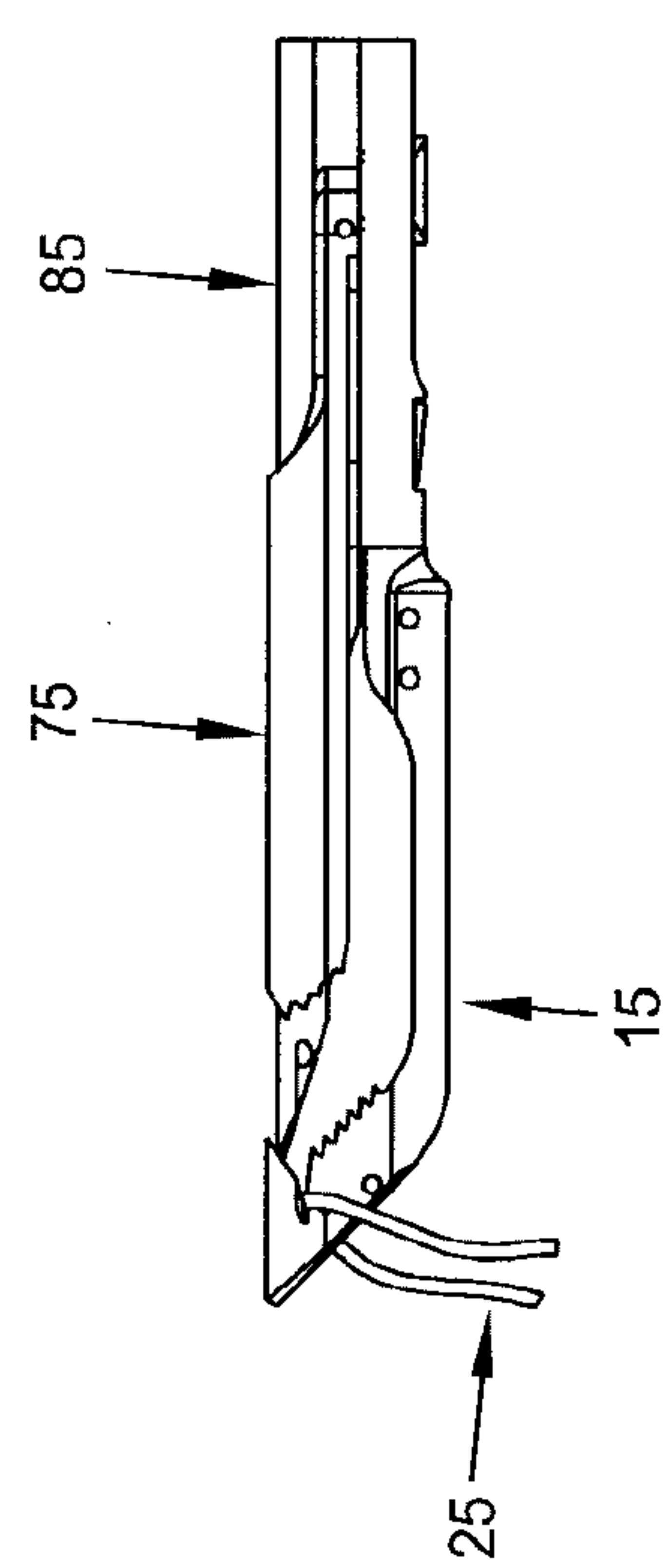


FIG. 71

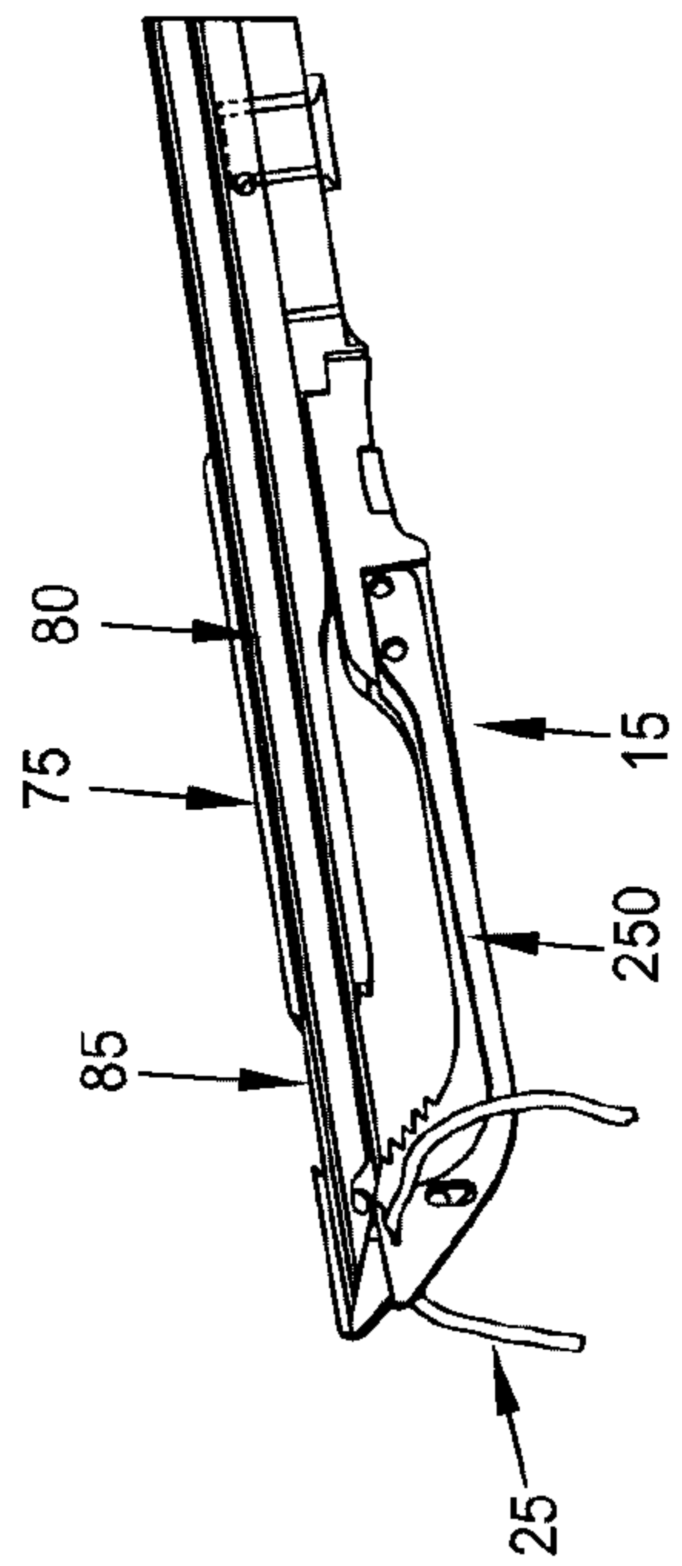


FIG. 74

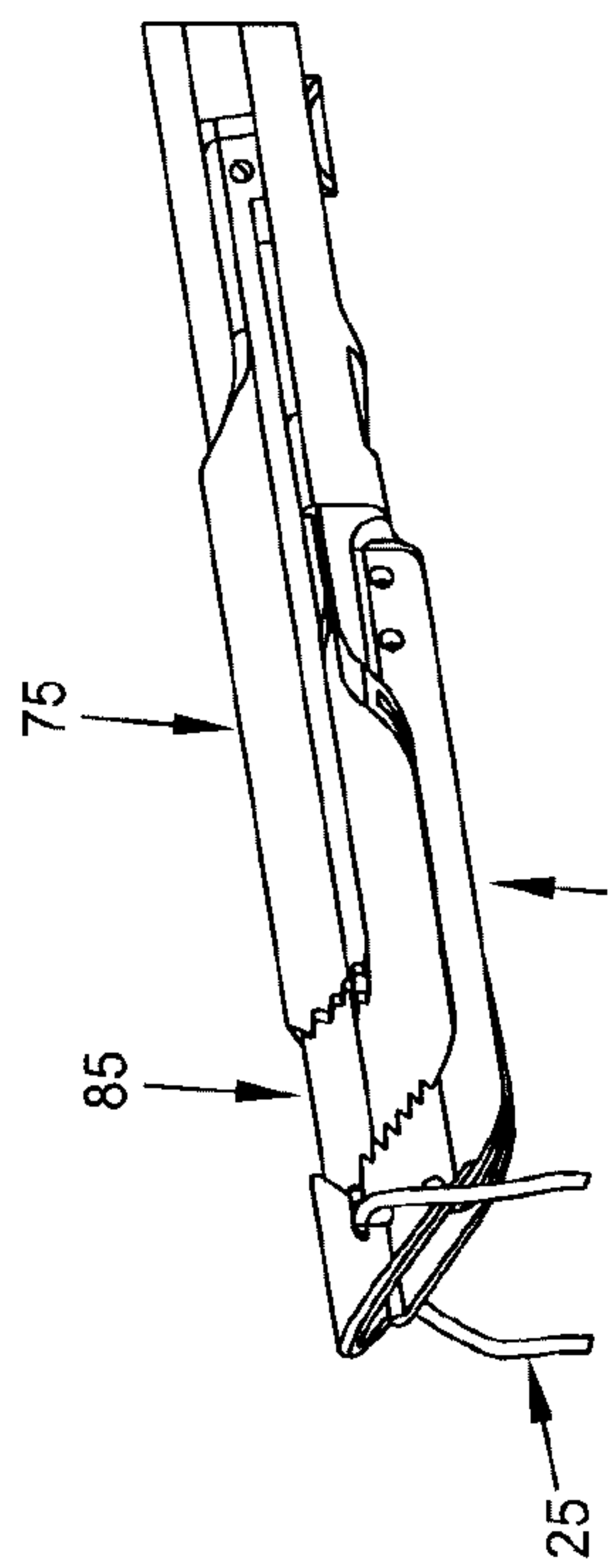


FIG. 73

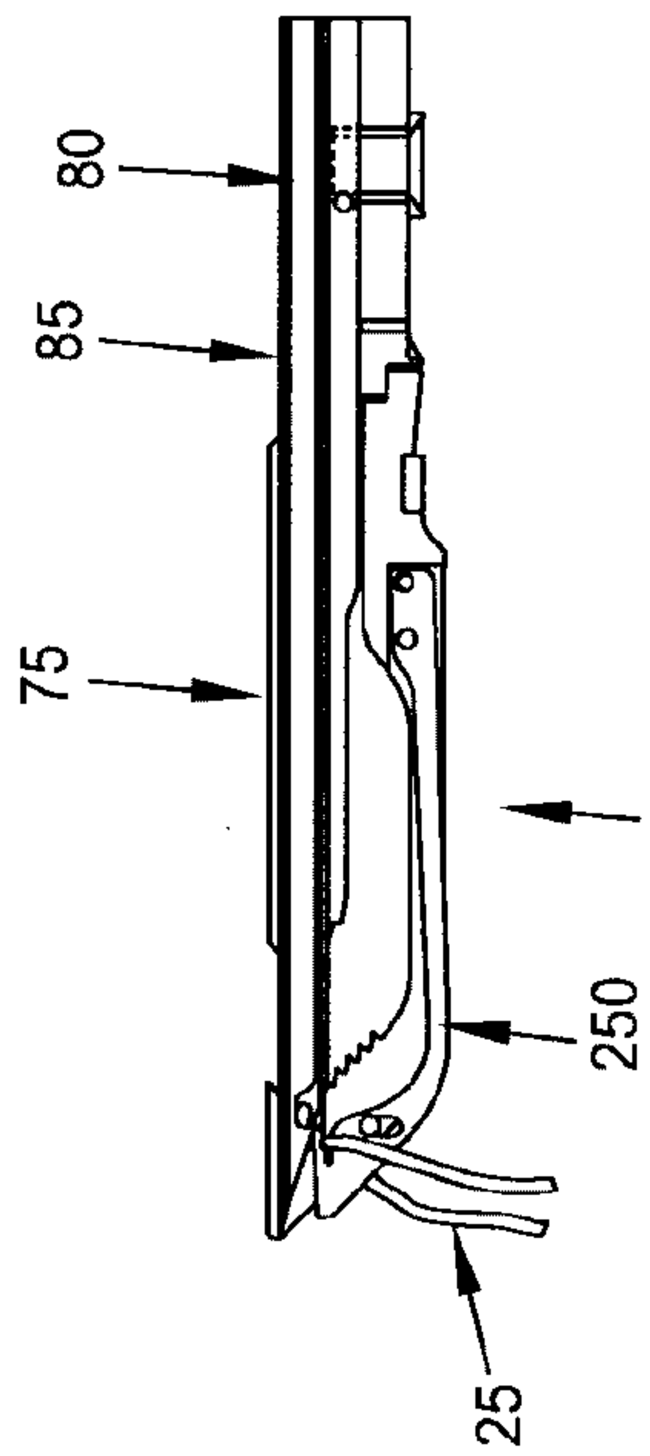


FIG. 76

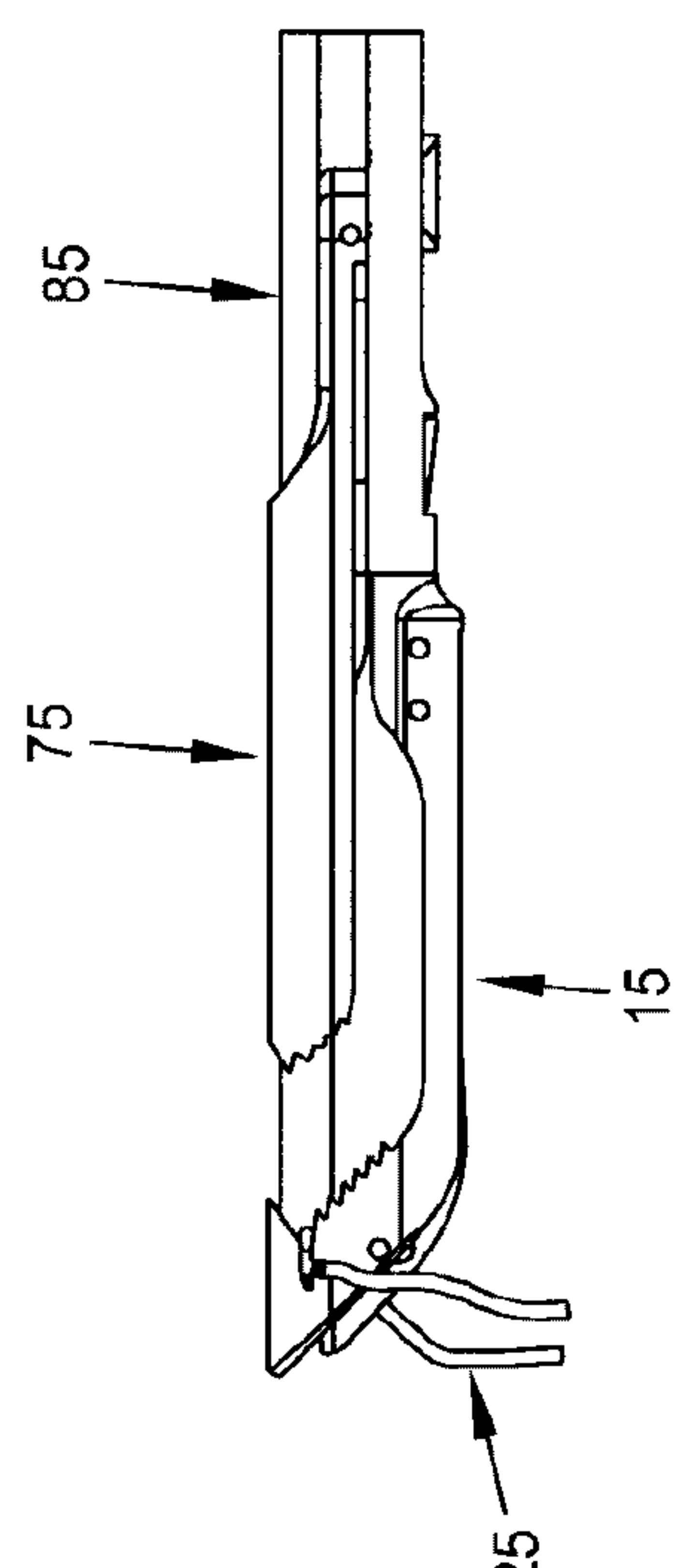


FIG. 75

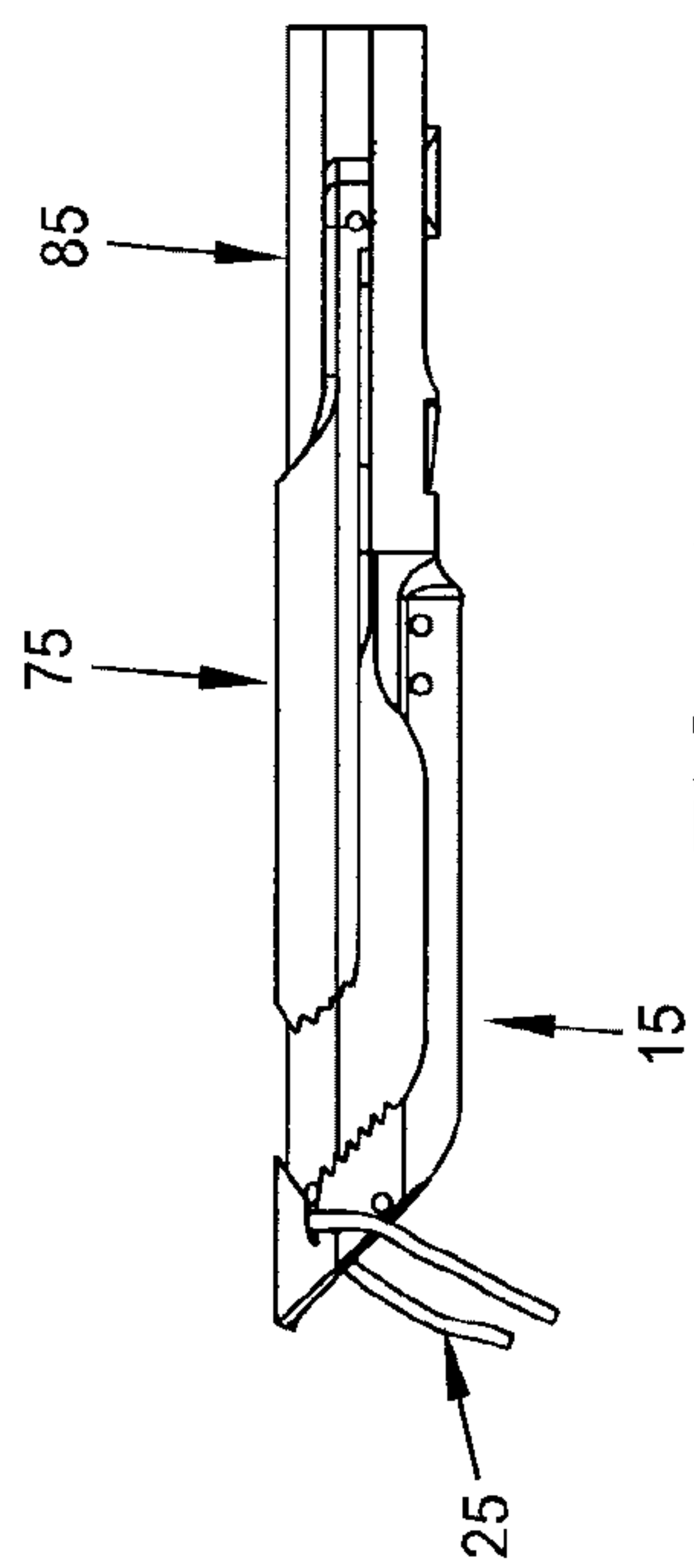


FIG. 77

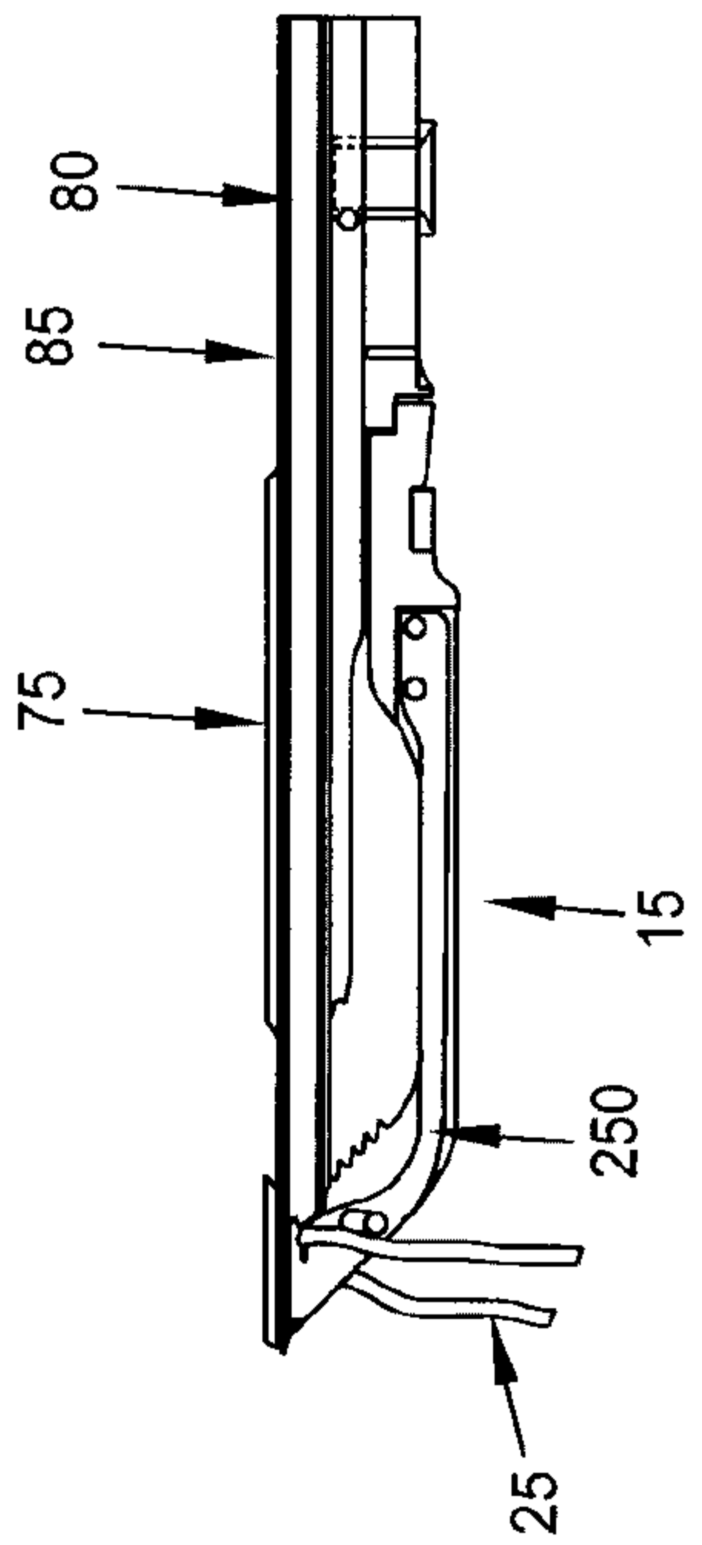


FIG. 78

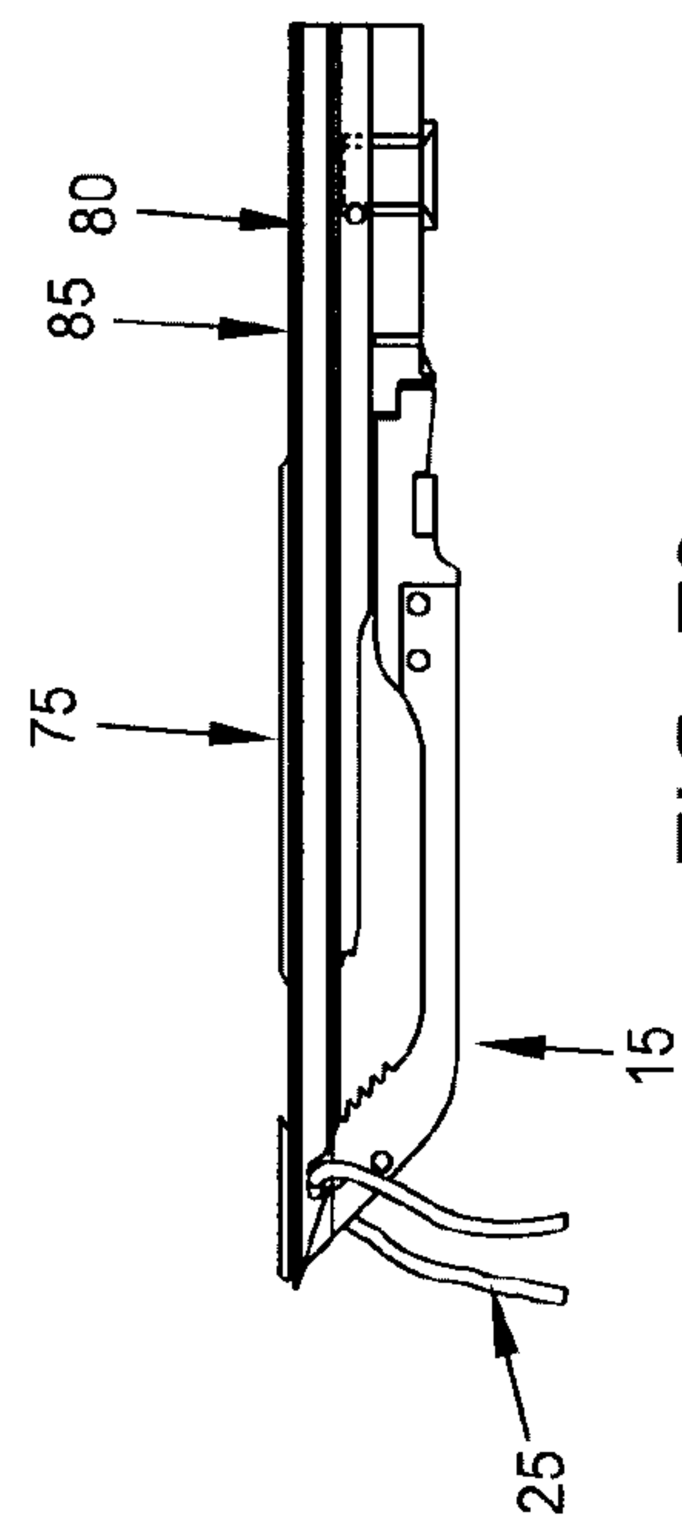


FIG. 79

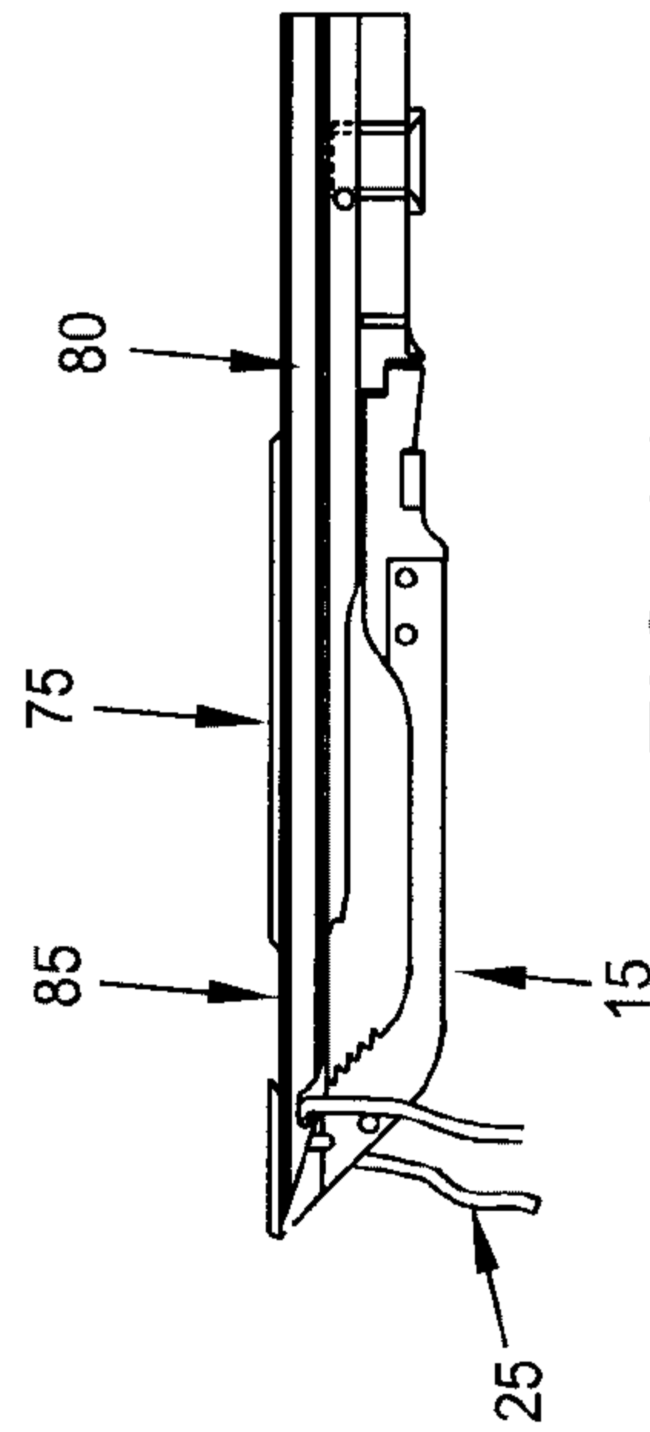


FIG. 80

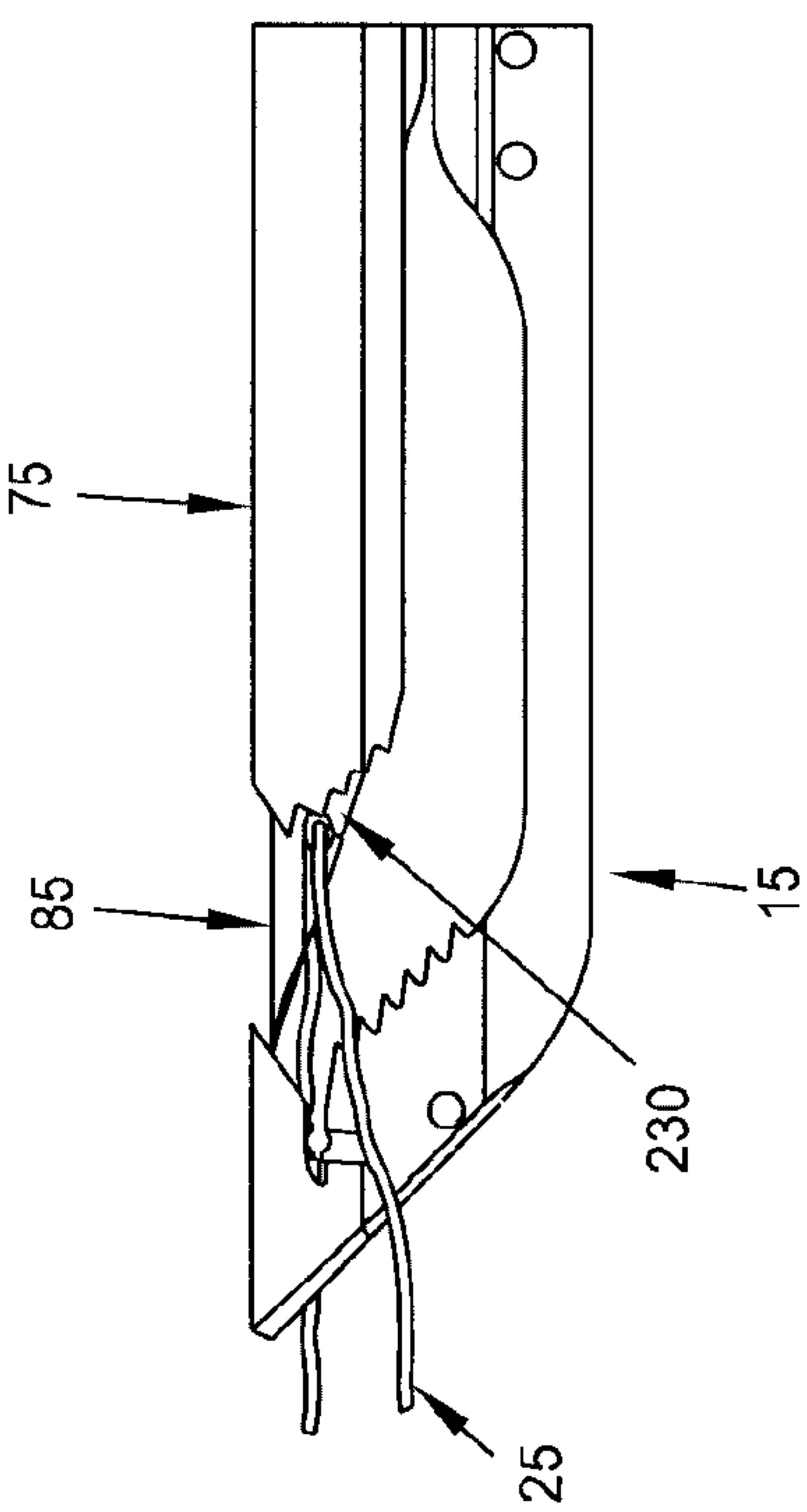


FIG. 81

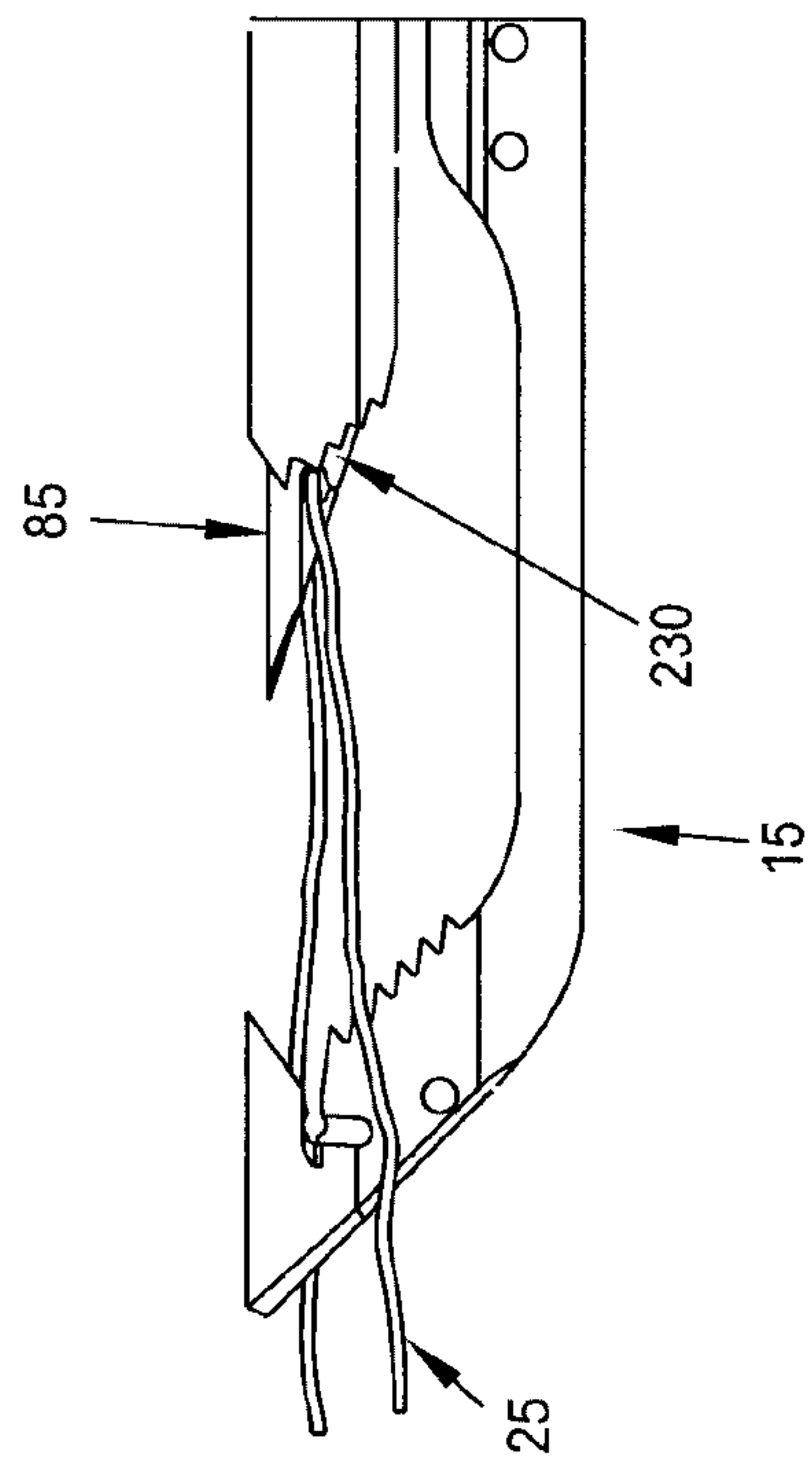


FIG. 82

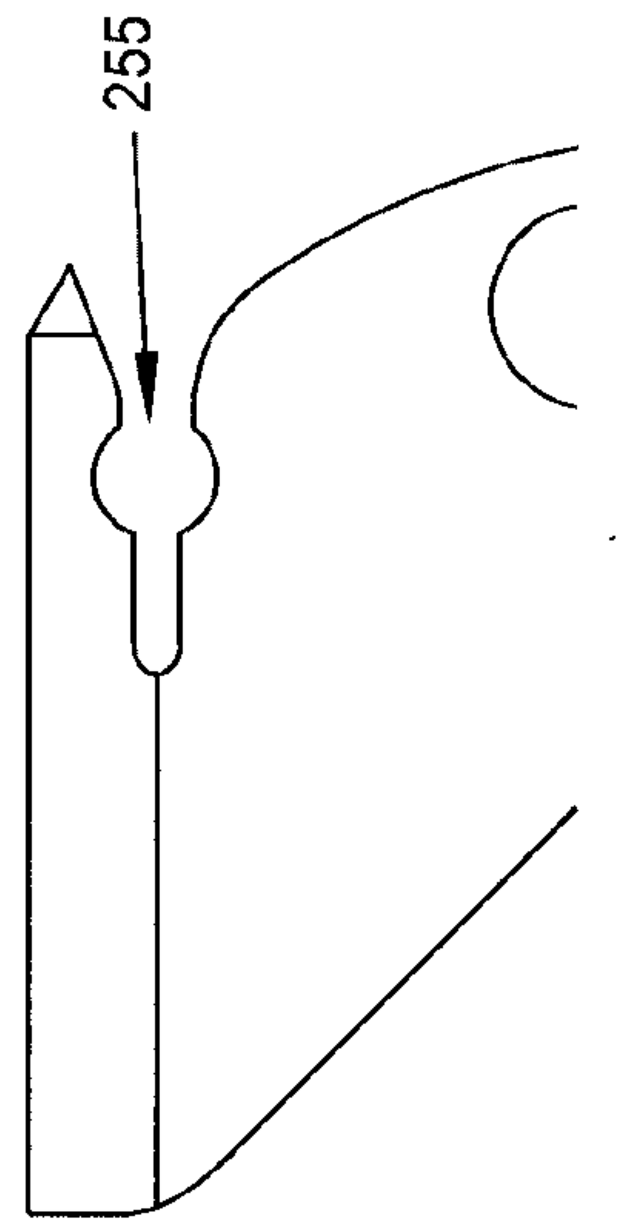


FIG. 84

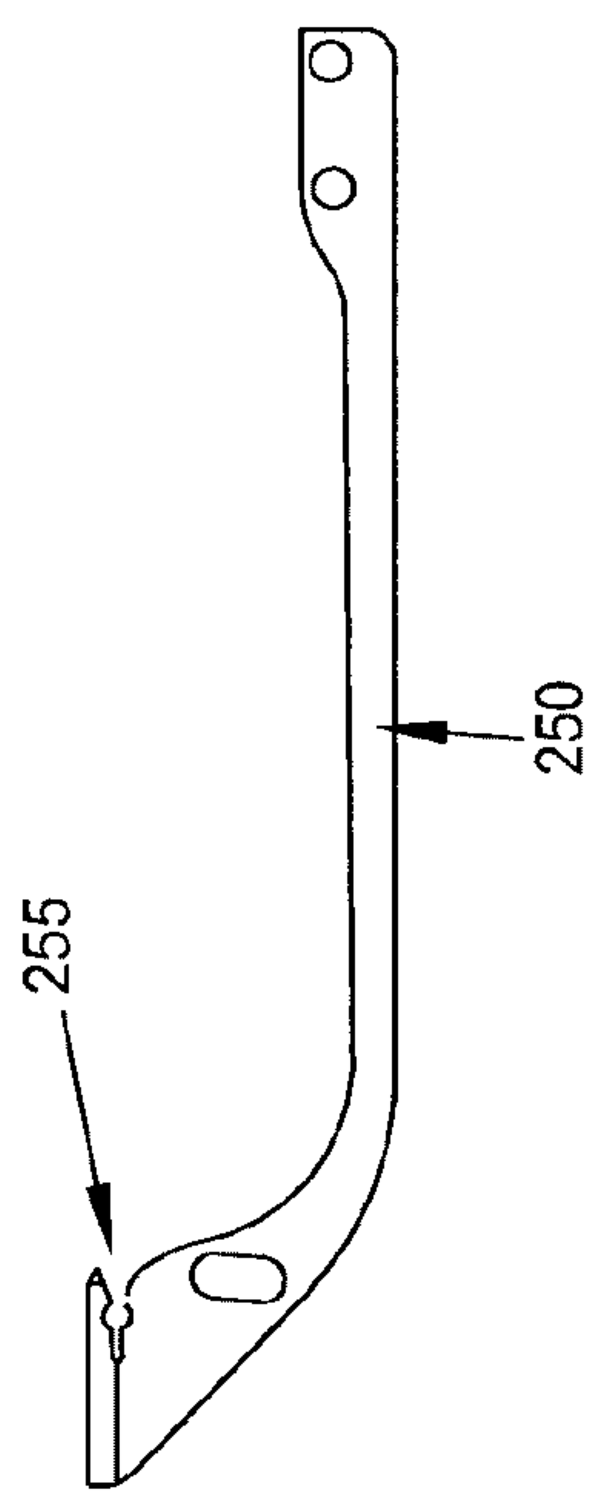


FIG. 83

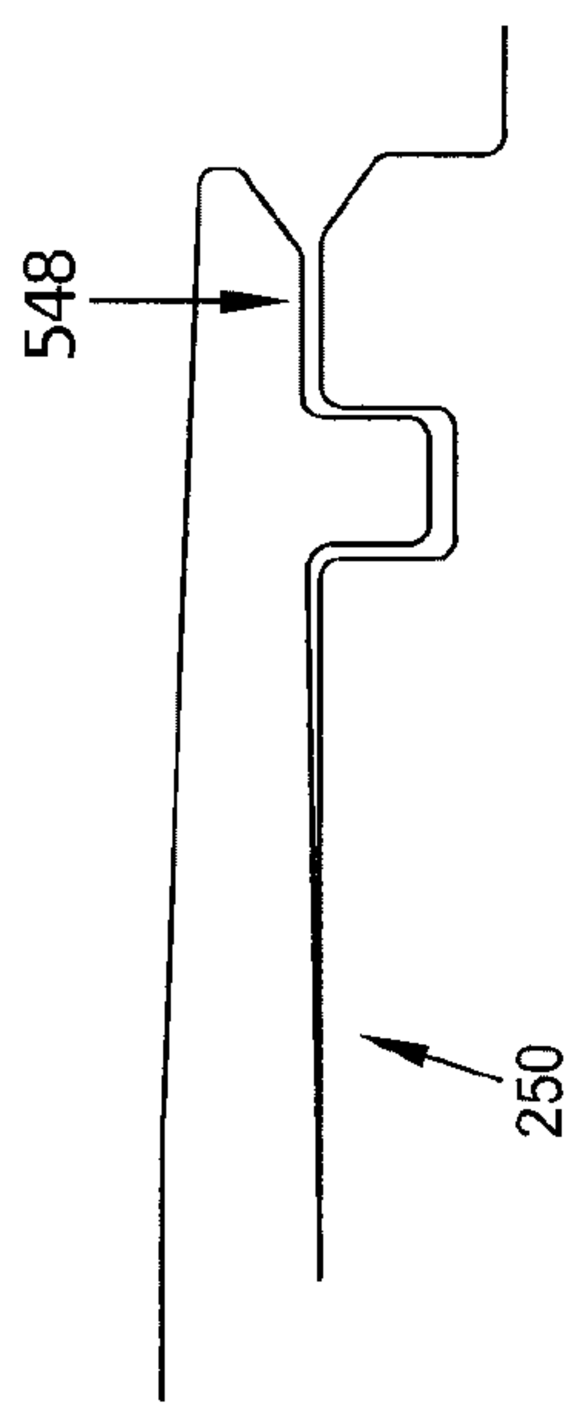


FIG. 86

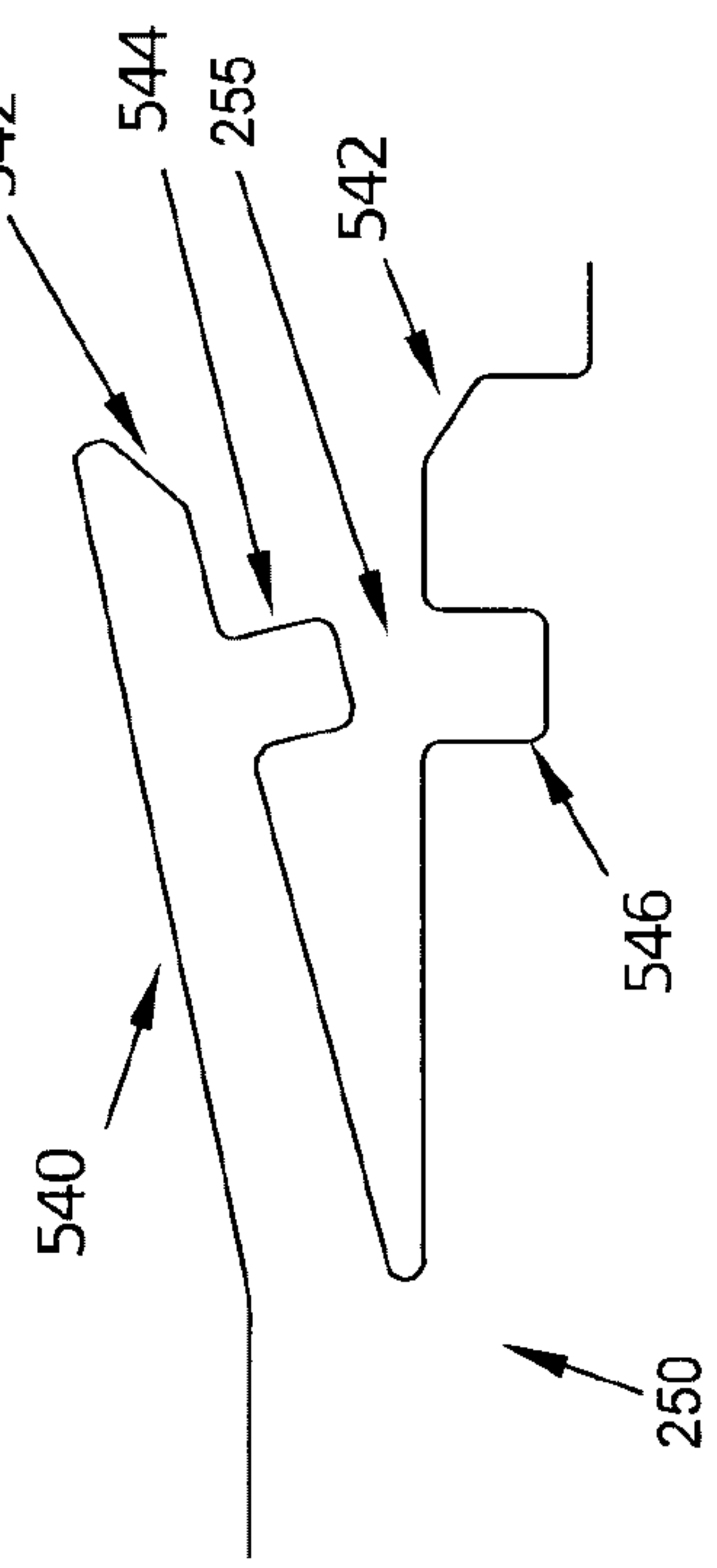


FIG. 85

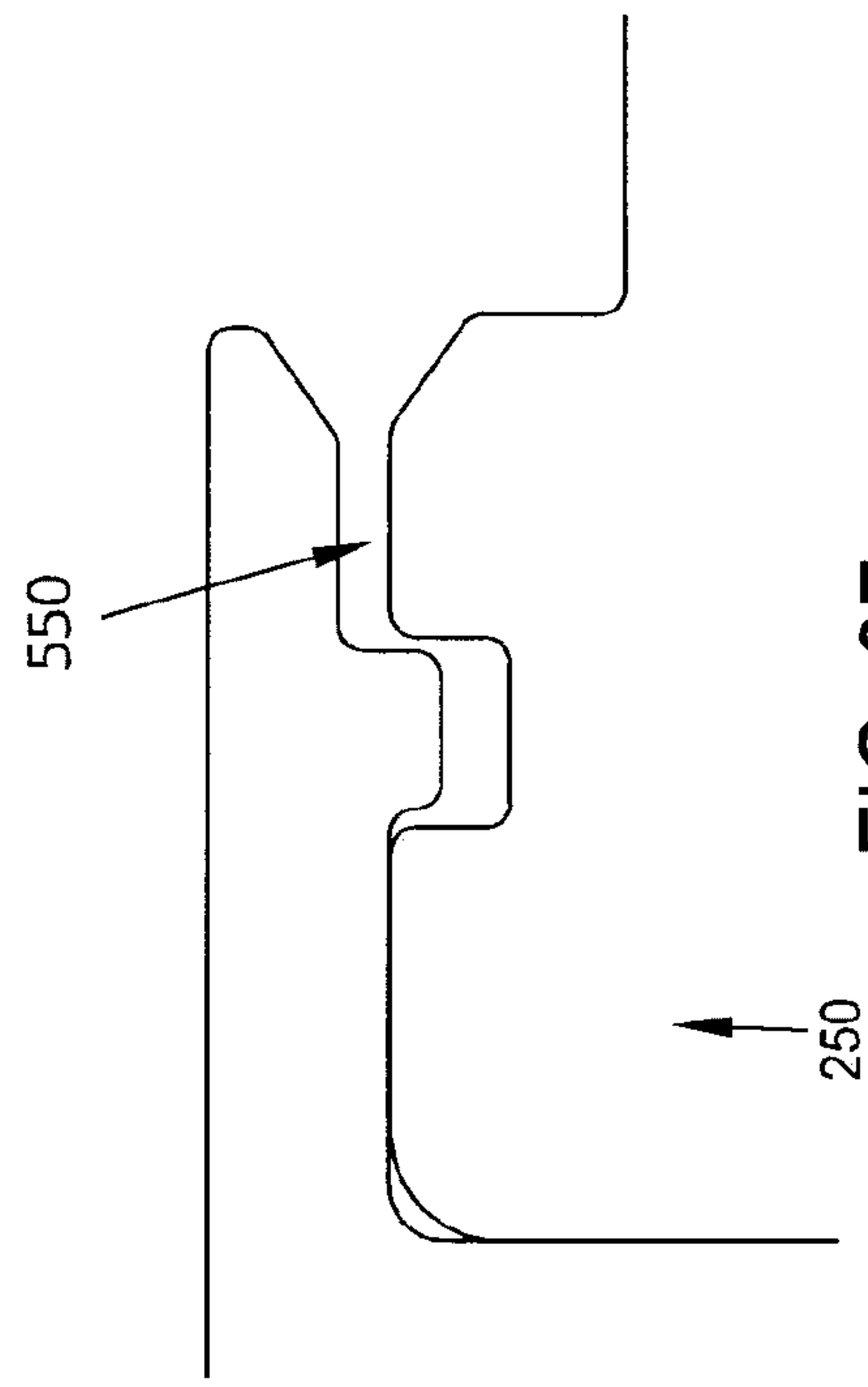


FIG. 87

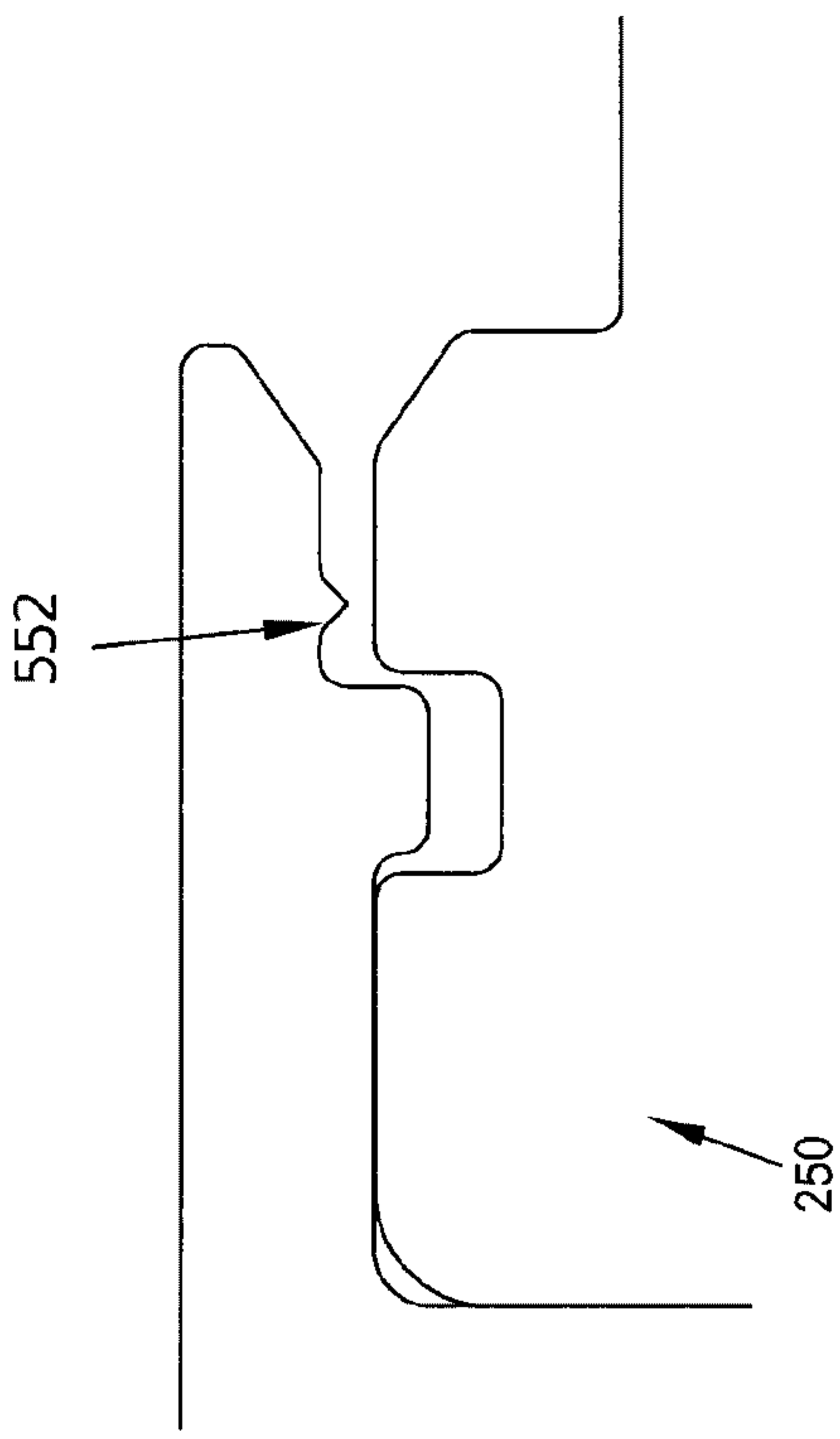


FIG. 88

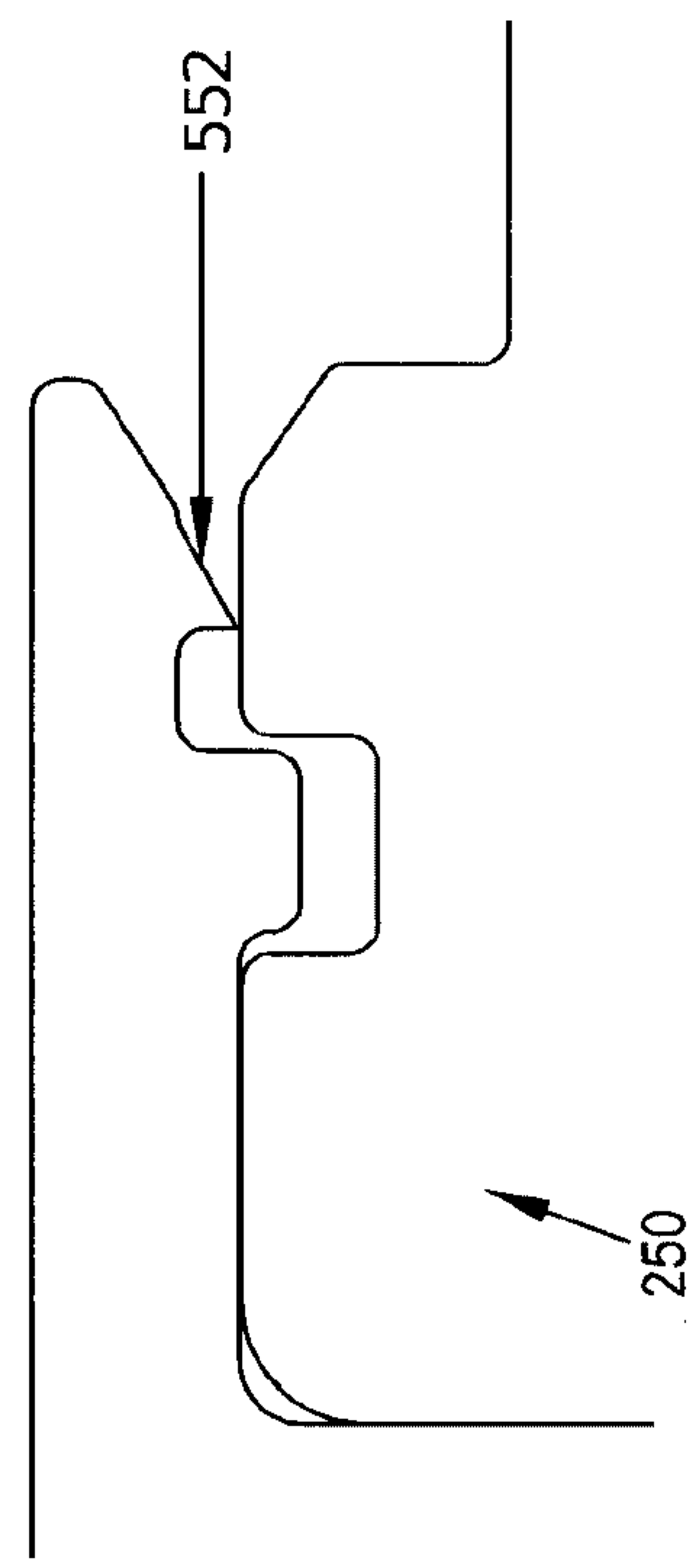


FIG. 89

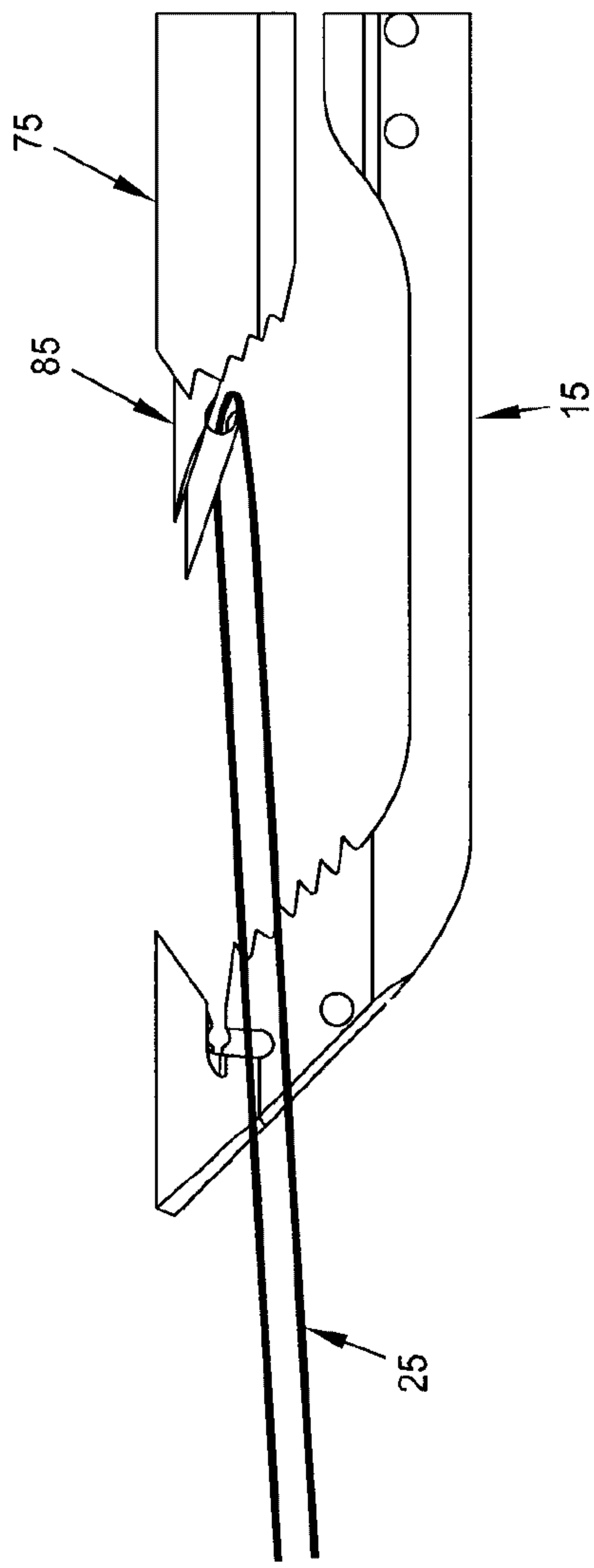


FIG. 90

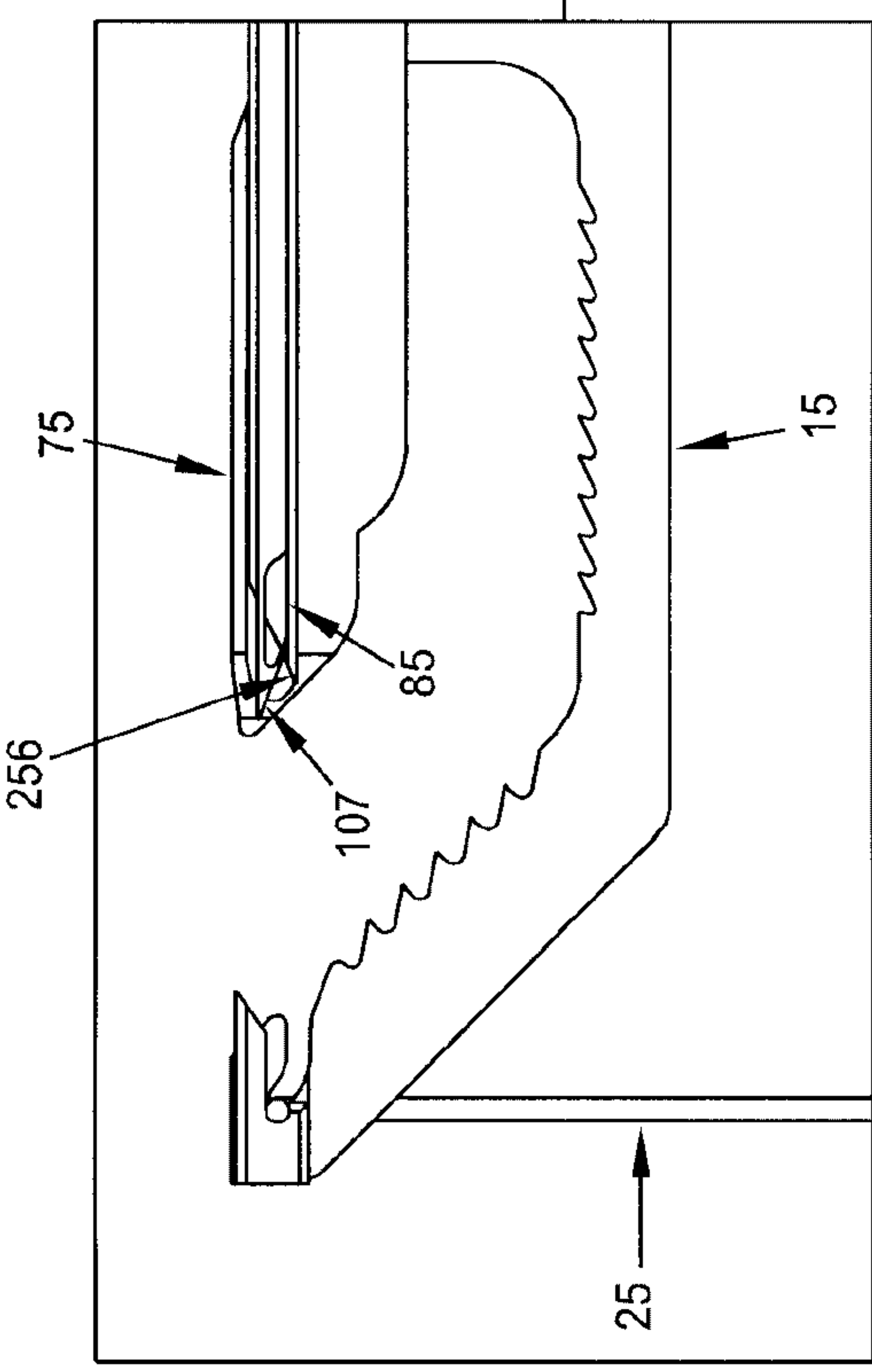


FIG. 90A

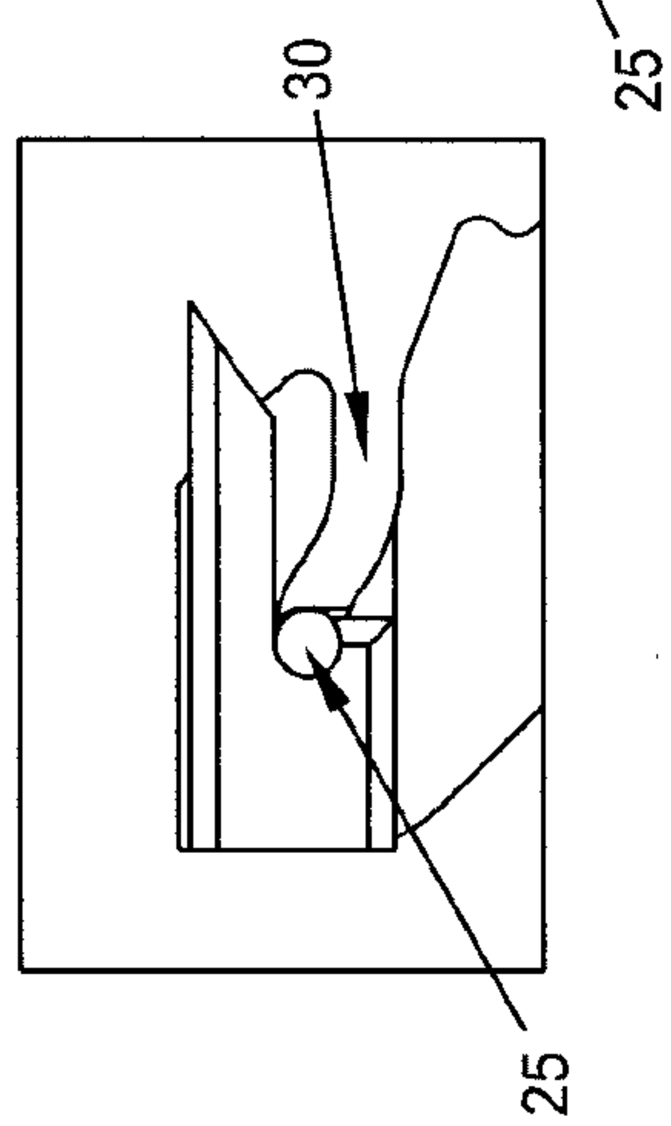


FIG. 90B

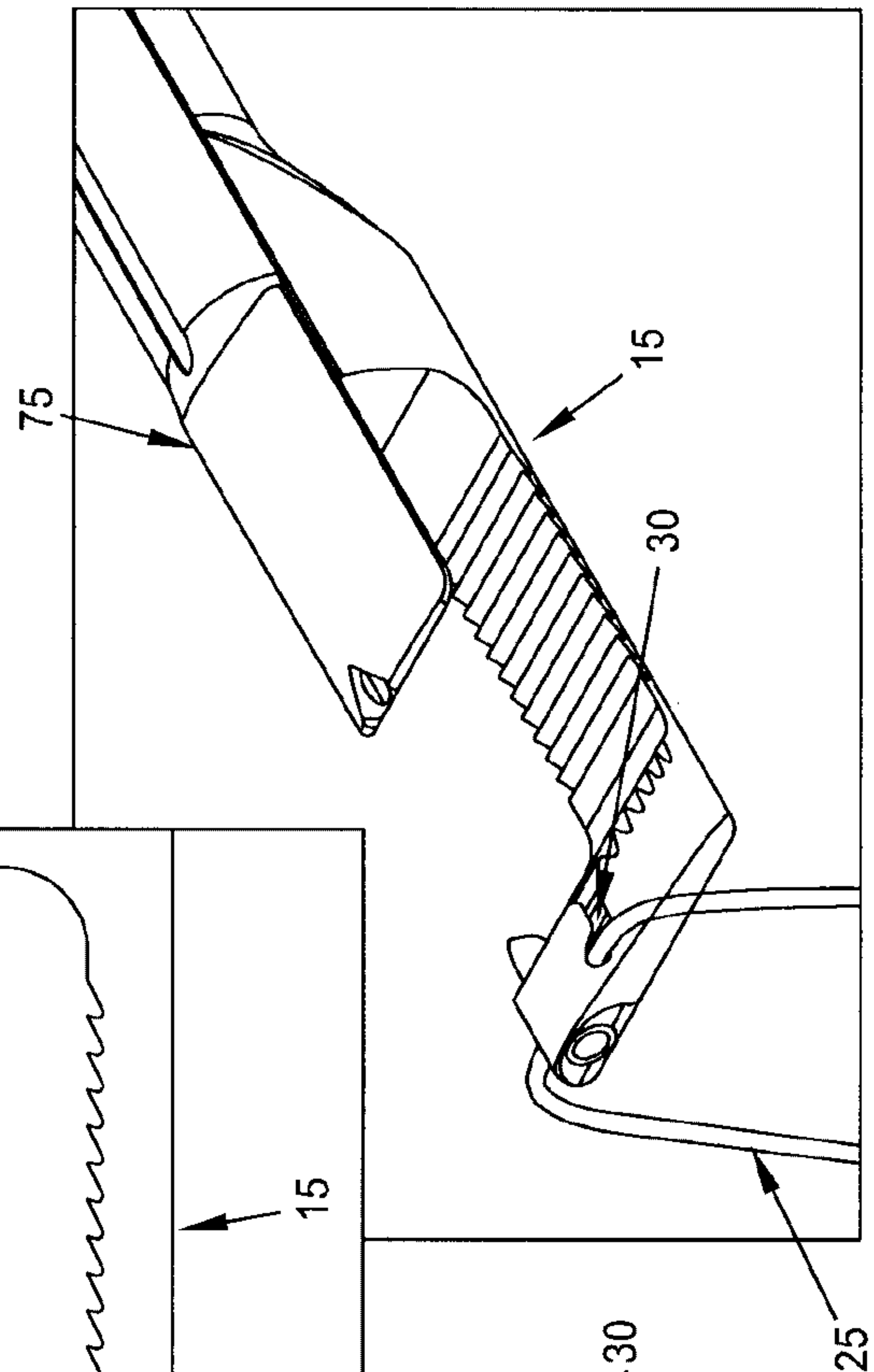


FIG. 90C

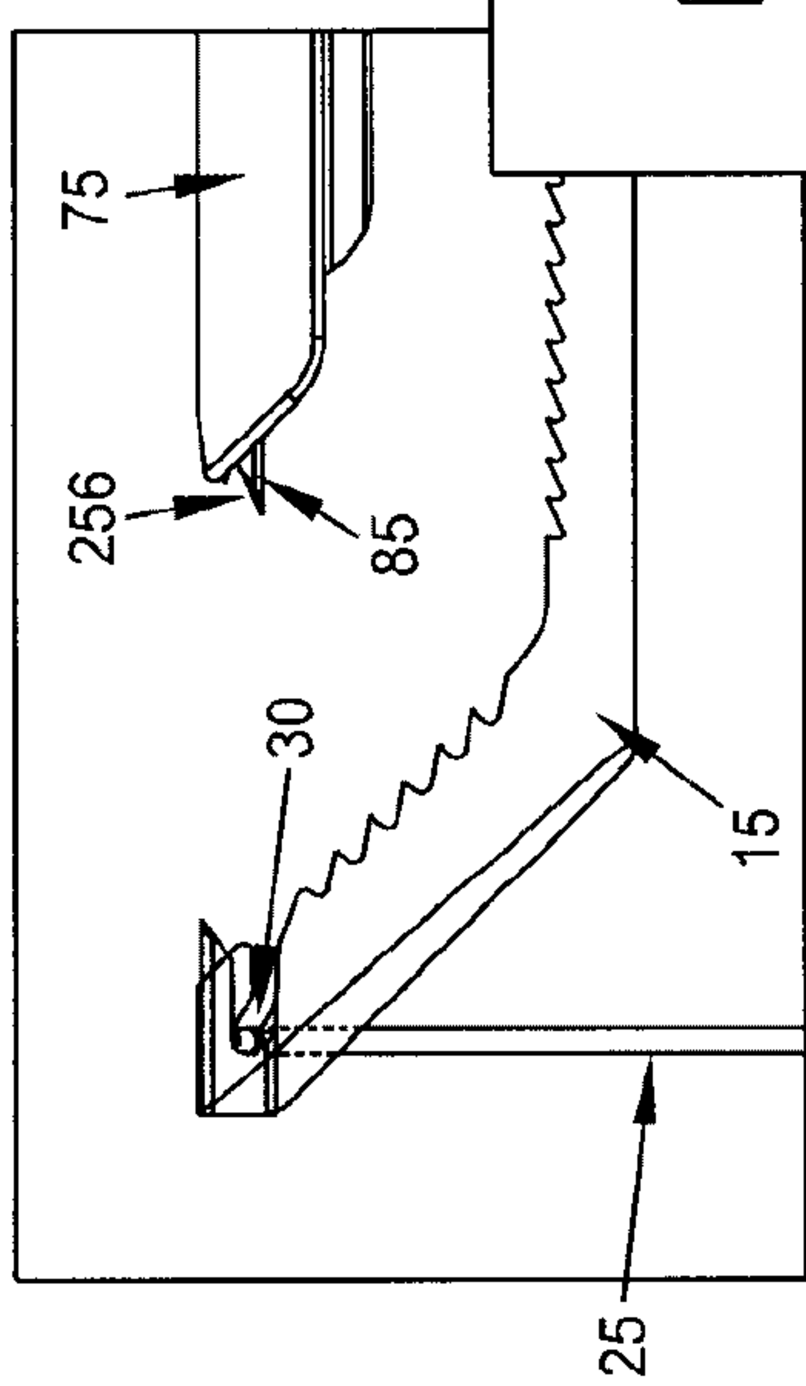


FIG. 90D

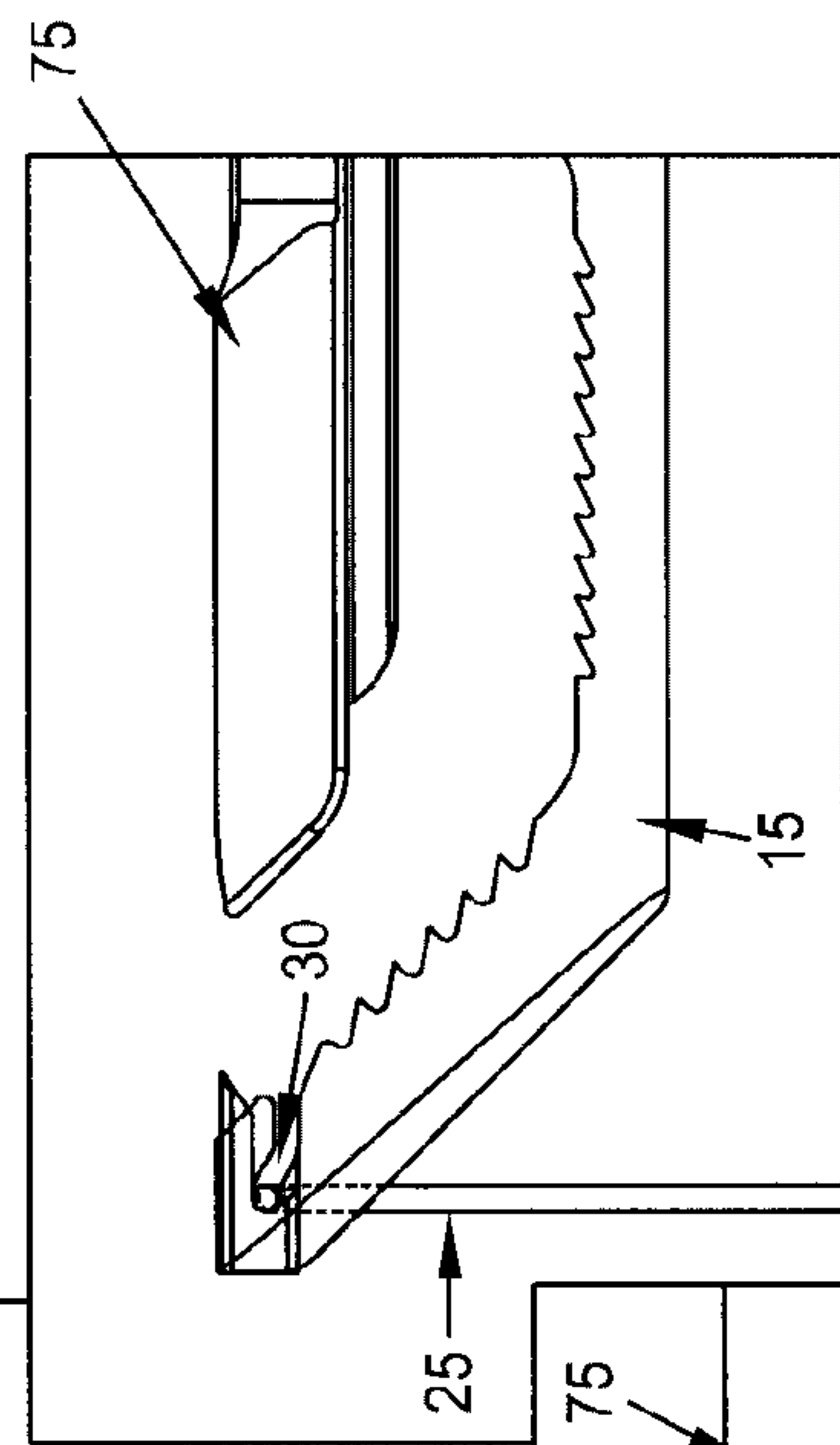


FIG. 90E

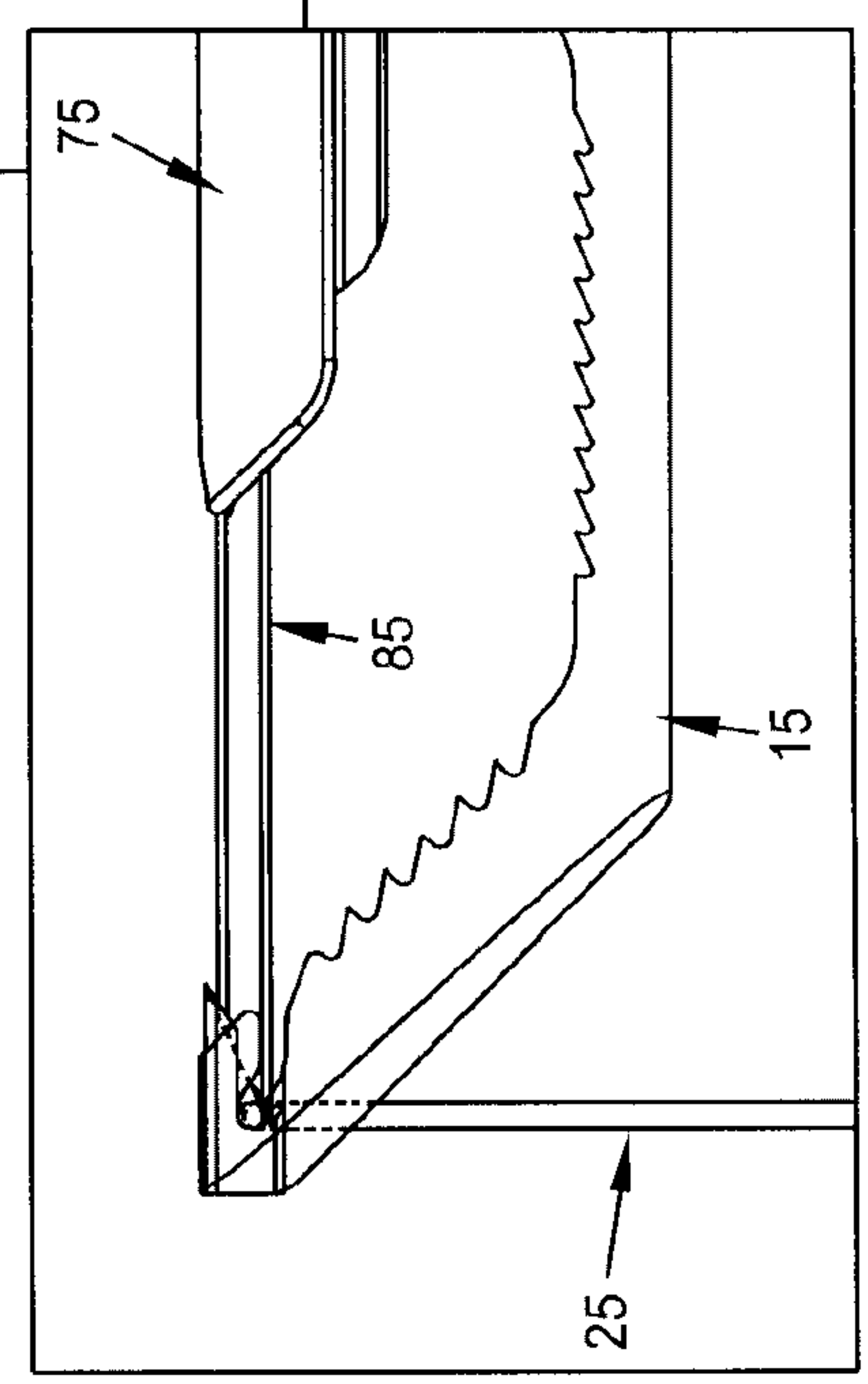
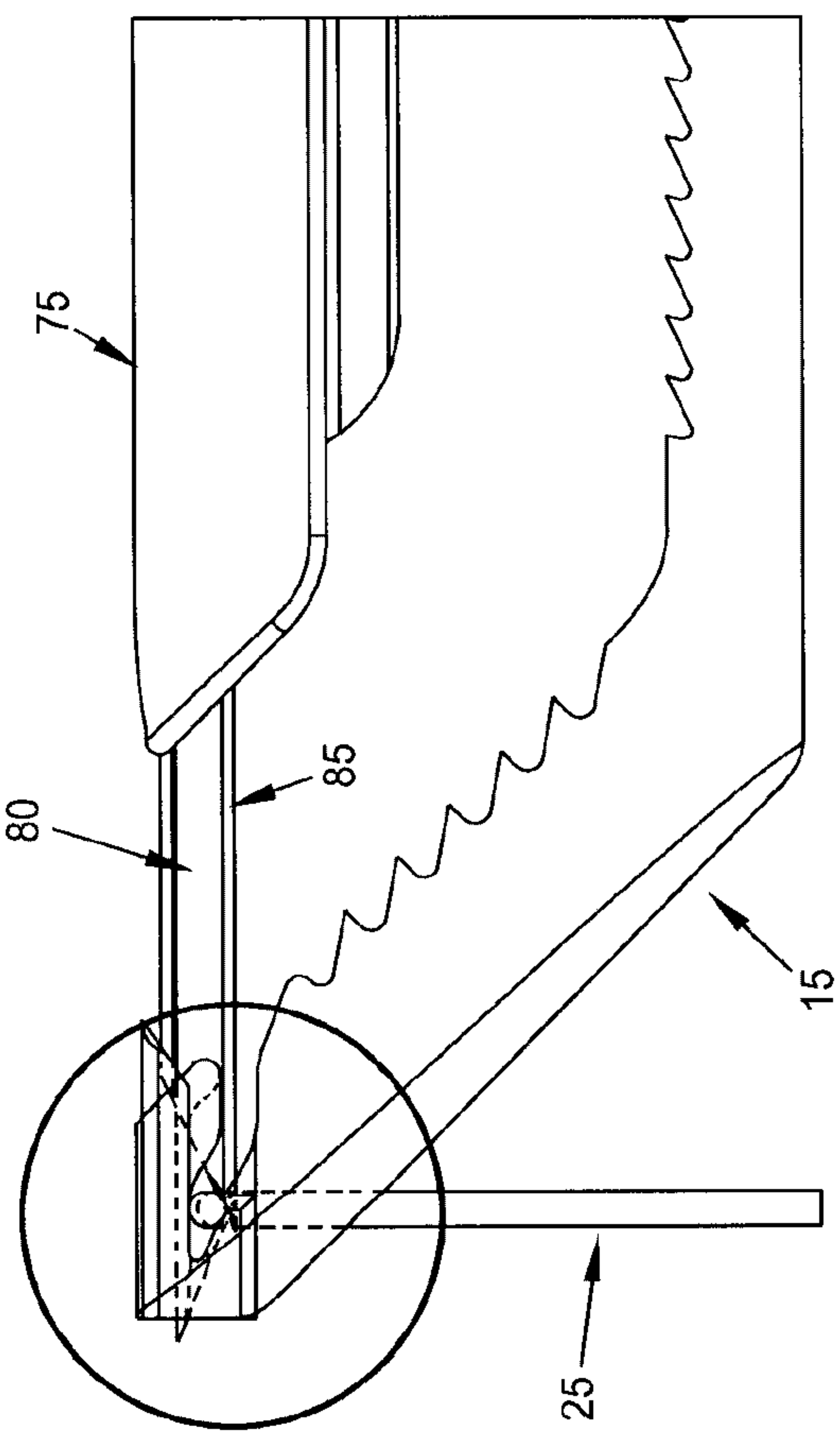


FIG. 90F

FIG. 90G



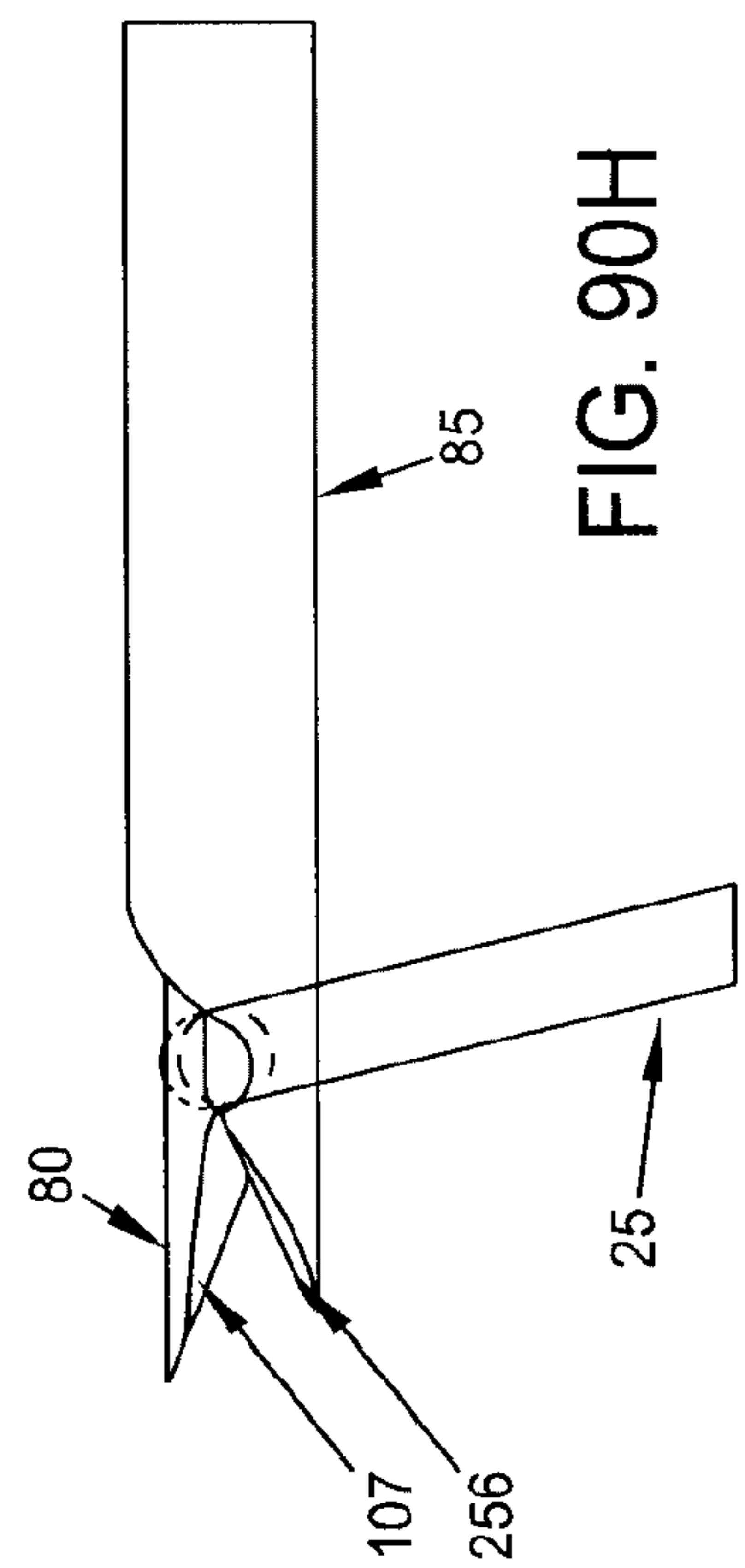


FIG. 90H

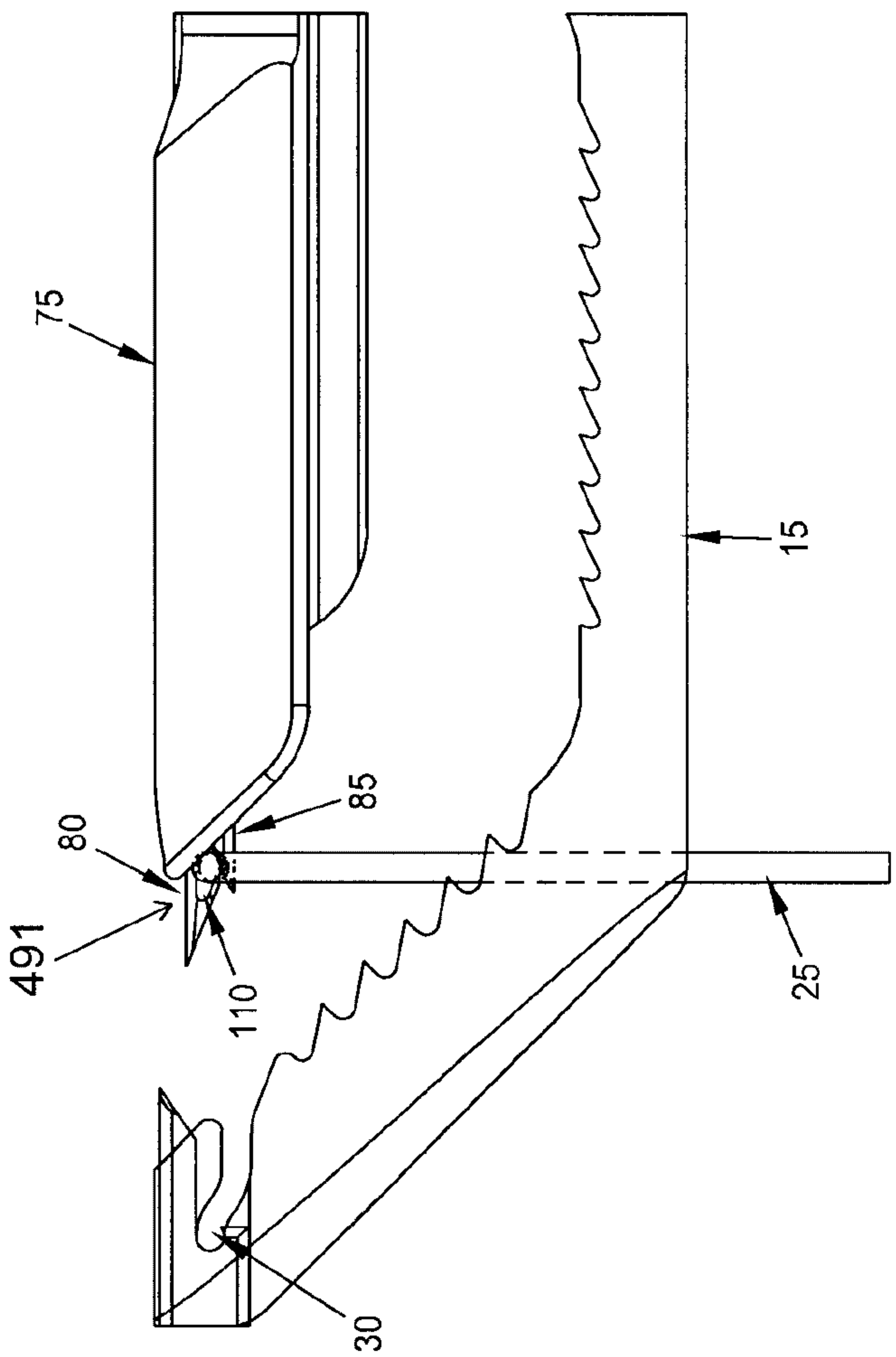


FIG. 90I

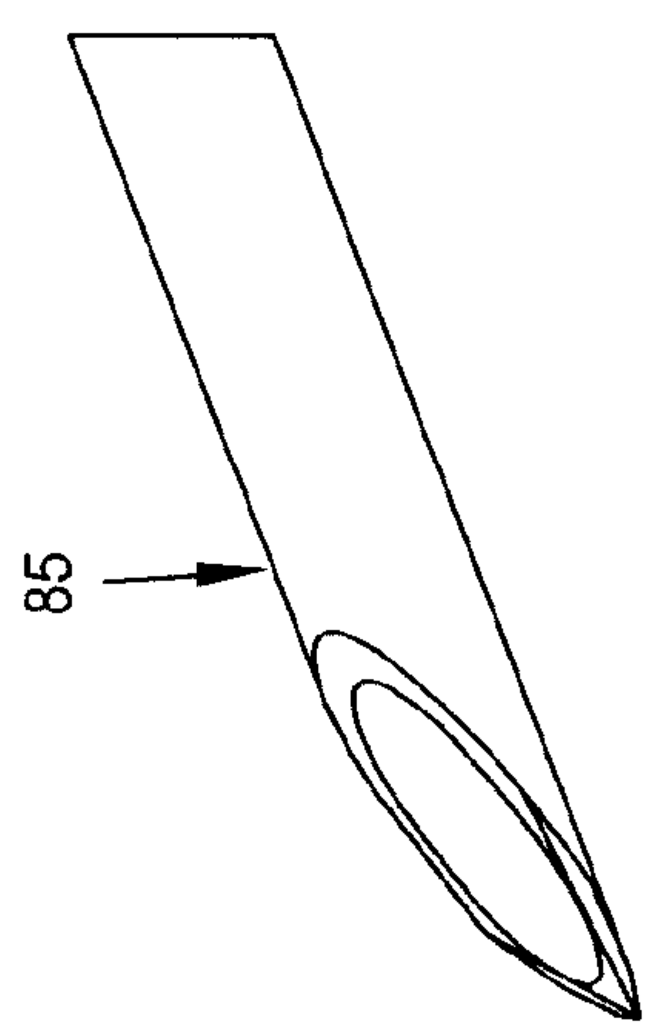


FIG. 91

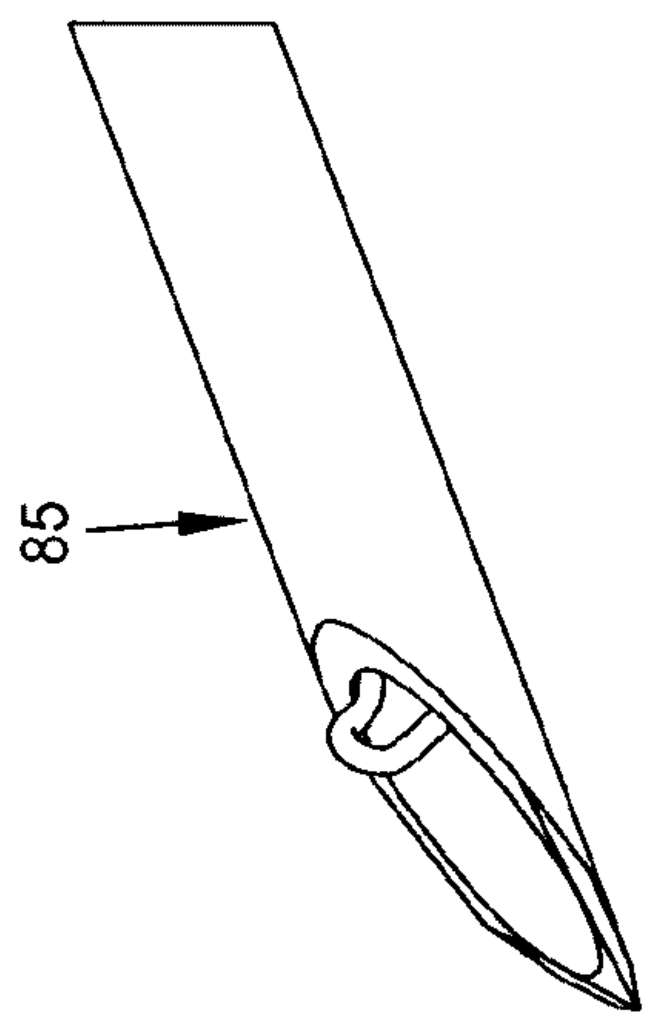


FIG. 92

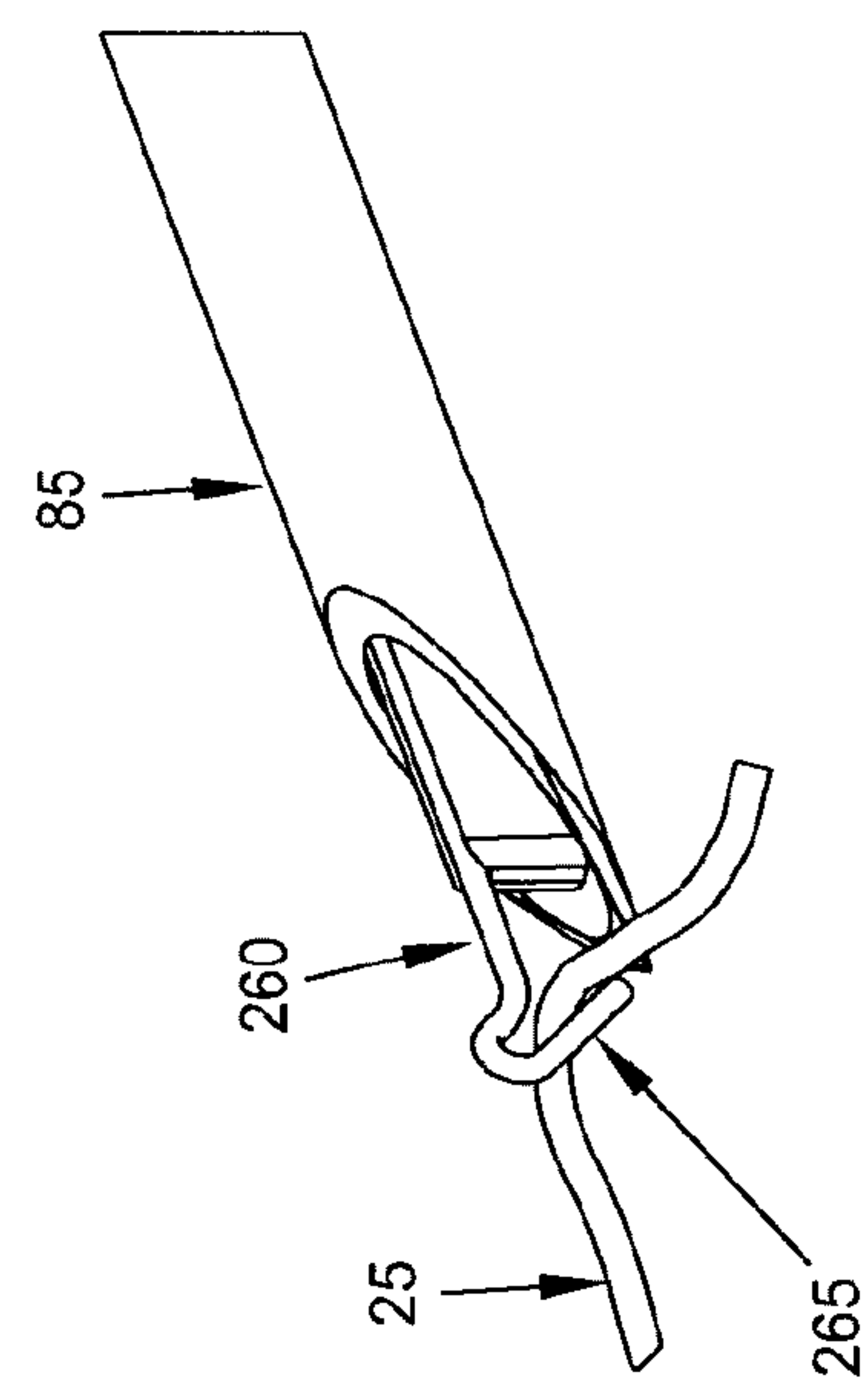


FIG. 93

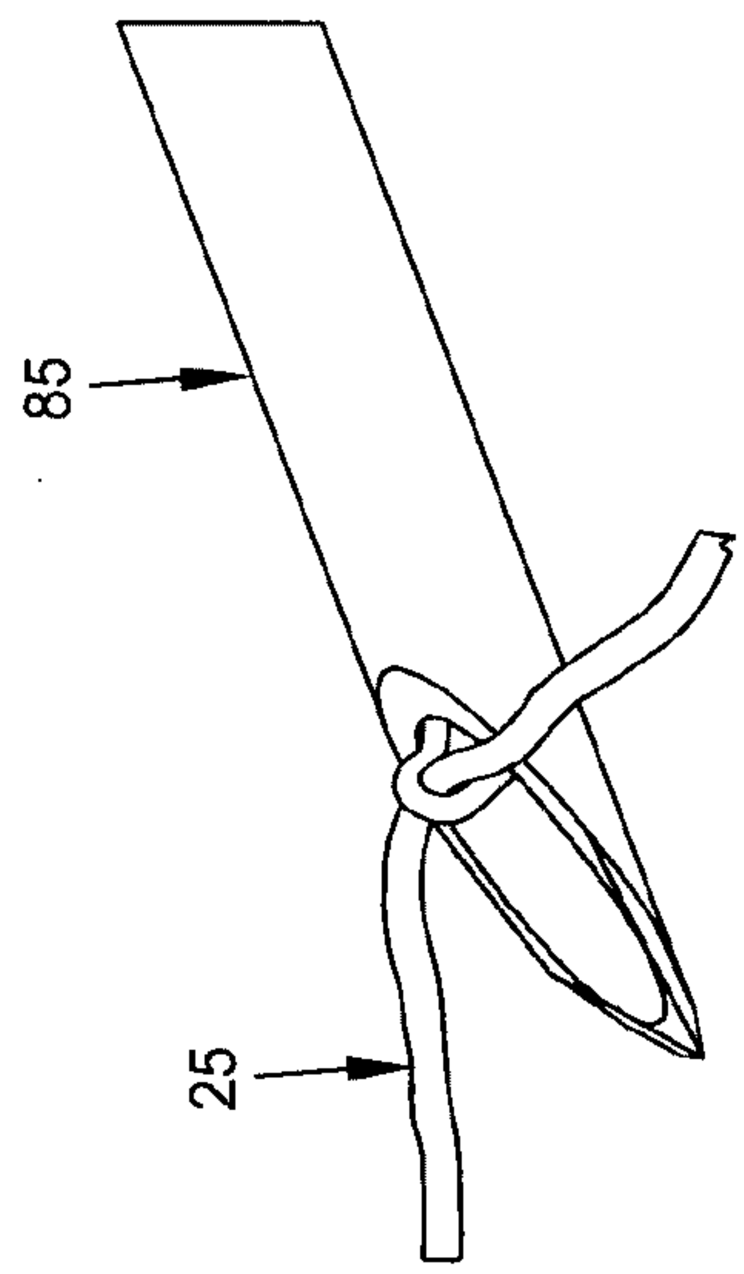


FIG. 94

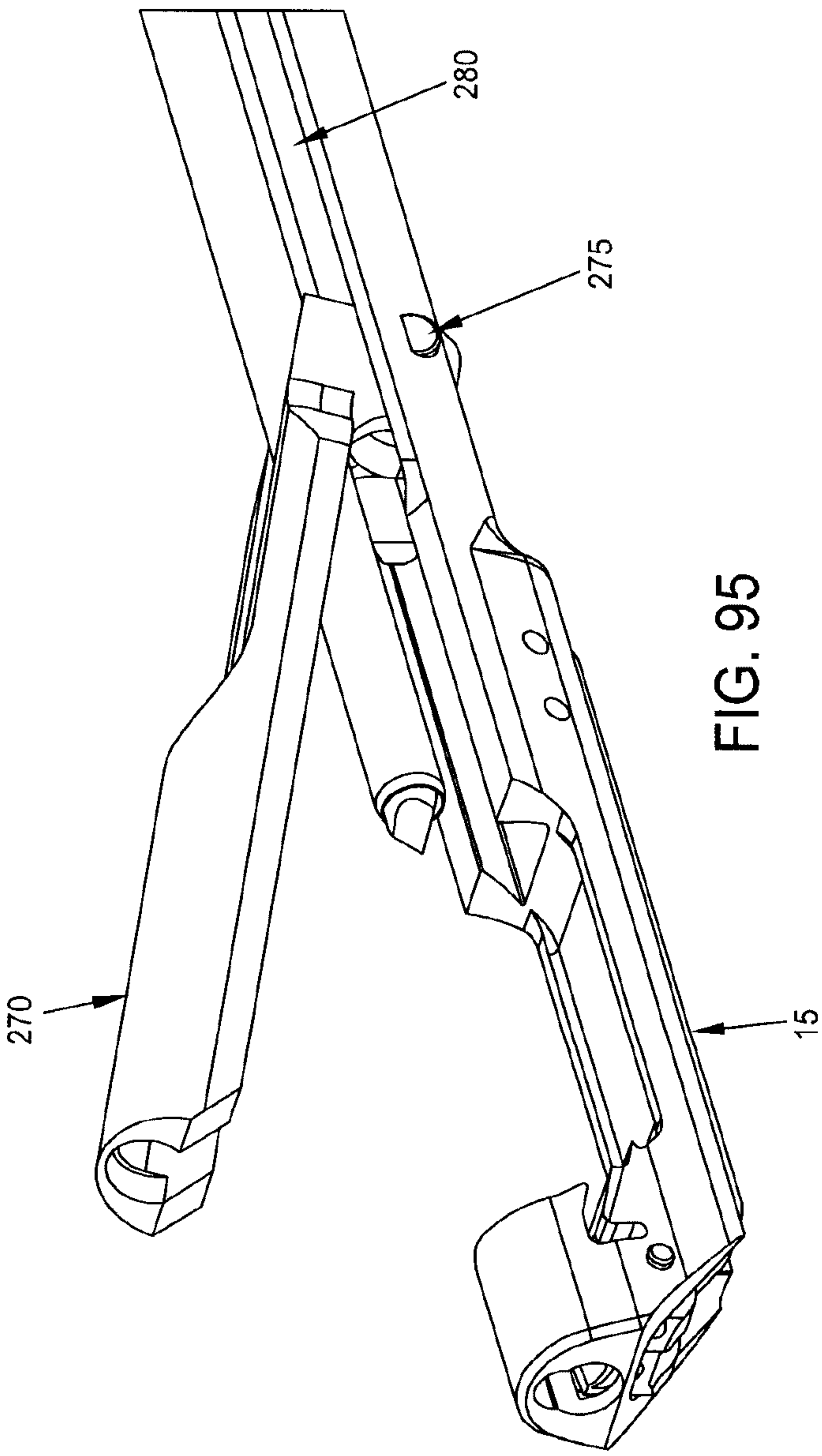
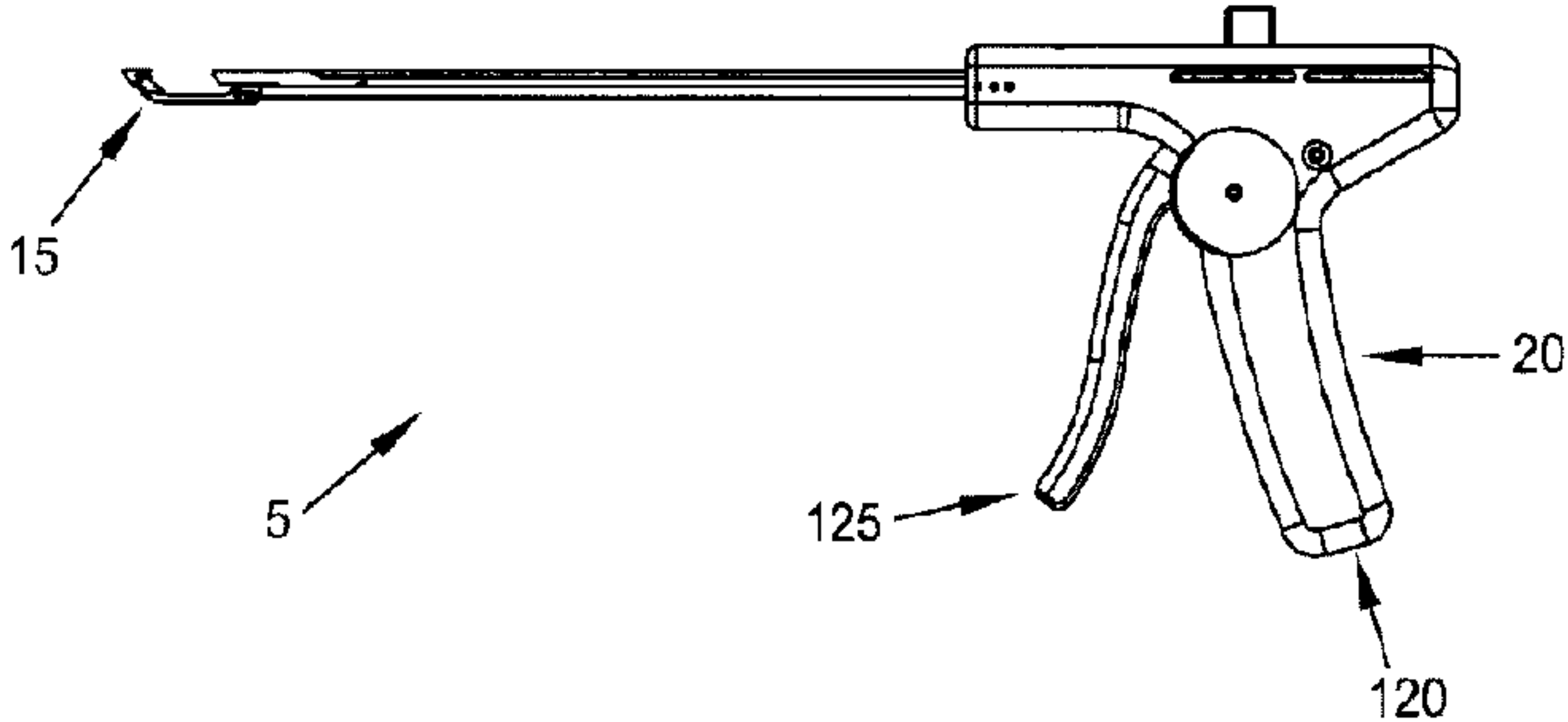


FIG. 95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