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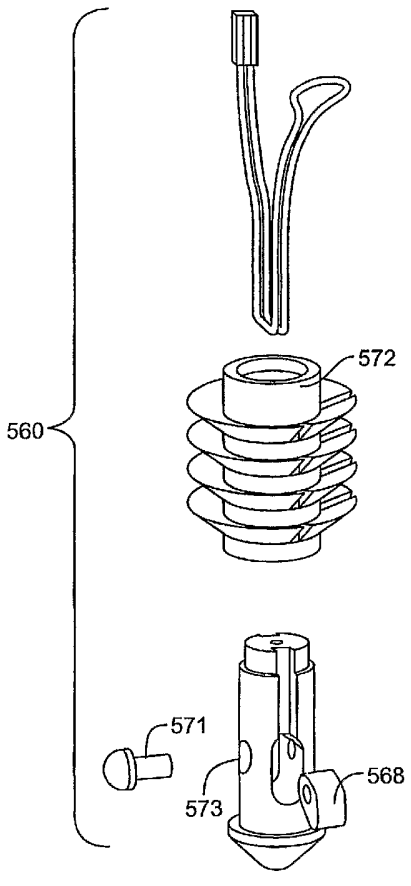

(57) Abstract: The present invention relates to apparatus and methods for securing tissue to bone using a suture anchoring system that provides enhanced tactile feedback and does not require tying a suture knot. In each embodiment, a surgeon can individually tension the free ends of the suture to fine-tune the placement of the tissue with respect to the bone, and then secure the suture without tying a knot. In several embodiments of the present invention, the device may be transformed between locked and unlocked suture states, thereby allowing further fine-tuning of the tension in the suture.

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APPARATUS AND METHODS FOR SECURING TISSUE TO BONE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation in part of U.S. Patent Application No. _____ filed April 15, 2005 entitled APPARATUS AND METHODS FOR SECURING TISSUE TO BONE, by inventors Fanton et al., which claims priority from provisional application 60/562,778, filed April16, 2004 by inventors Fanton et al., all of which are hereby incorporated by reference

FIELD OF THE INVENTION

The present invention relates to the field of surgical arthroscopy, and more particularly, to apparatus and methods for facilitating the attachment of tissue to bone using a suture anchoring system that provides enhanced tactile feedback and does not require tying a suture knot.

BACKGROUND OF THE INVENTION

Many attempts have been made to provide devices that allow the arthroscopic securing of torn tissue to a substrate bone. For example, there have been numerous devices designed for the shoulder to allow a torn rotator cuff to be secured to the humeral head.

Typically, in a first step, a hole is drilled into the bone under arthroscopic visualization. A length of a suture generally is employed to permit securing of the tissue to the bone. The suture length is threaded through a portion of the tissue, and also is coupled to a bone anchor configured to be inserted into the hole in the bone. One or both of the suture ends may extend outside of the arthroscopic site, so that the suture can be manipulated by a physician.

Once the suture is coupled between the tissue and the bone anchor, the bone anchor is inserted into the hole. The bone anchor generally is configured to lock itself within the hole in the bone upon deployment therein. Several means for securing the bone anchor within the hole of a bone are known in the art.

Once the bone anchor is secured within the hole in the bone, a physician may tension one or both ends of the suture to approximate the positioning of the tissue with respect to the bone. Once the tissue is positioned as desired, the suture is locked in place to maintain the tension in the suture. The free end or ends of the suture then are clipped under arthroscopic visualization to complete the procedure.

There are various drawbacks associated with such previously-known suture anchoring systems. For example, many of the previously-known systems require the physician to tie a knot to lock the suture, thereby maintaining the tensile forces that hold the tissue in place. However, when performing the procedure under arthroscopic visualization and having minimal clearance, it is often difficult for the surgeon to perform the maneuvers necessary to tie a knot in the confined working space.

Further, previously-known suture anchoring systems generally do not allow the surgeon direct tactile feedback of the tension in the suture between the tissue and the bone. For example, in those systems where only one free end of the suture may be manipulated by a physician, difficulties may arise in approximating the position of the tissue with respect to the bone. By contrast, when a physician can manipulate both ends of a suture independently, two different forces may be applied to the tissue to facilitate positioning of the tissue with respect to the bone.

Still other previously-known suture anchoring systems have relied on urging tissue towards a bone anchor by tightening a knot. In such systems, the suture is threaded through tissue and a knot is tied proximal to the tissue. As the knot is tightened, the tissue is pushed towards the bone. However, such systems have various drawbacks, including not being able to manually determine the tension of the tissue, and also risking the possibility that the knot will become embedded within the tissue.

An example of a previously-known method and apparatus for attaching tissue to bone using a knotless suture anchoring device is described in U.S. Patent No. 6,585,730 to Foerster. Foerster describes a device having a distal anchor portion and a wedge body. A suture length has a bound end and a free end. The bound end of the suture is coupled to the tissue, and the suture extends around the wedge body at the distal end of the device, such that a free end of the suture may be manipulated by a physician.

Once the distal anchor portion is secured within the bone, the practitioner pulls the free end of the suture to draw the soft tissue towards the bone. Tension in the suture draws the wedge body up into the lumen of the distal anchor portion. At this time, the length of suture wrapped around the wedge body becomes pinched between the wedge body and the distal anchor portion.

The Foerster patent suggests that the pinching force imposed upon the suture creates a self-locking mechanism. Further, the patent suggests that applying a tensile force to the free suture end, after it has been clamped, will cause the wedge body to move distally to unlock the previously-pinched suture and enable "reversibility" of the device for further fine-tuning.

The device described in the Foerster patent has several drawbacks. First, the device appears to rely on tension alone to secure the tissue to the bone. Specifically, merely tensioning the free end of the suture is expected to lock the device, since the suture is clamped between the wedge body and the distal anchor portion. Then, the Foerster patent suggests that simply pulling the free end of the suture will unlock the device, since the pinched suture wants to straighten out when the free end is tensioned. Therefore, the device is both locked and unlocked by tensioning the free end of the suture. Accordingly, it is possible that incidental tensile forces applied to the free suture end may unexpectedly unlock the device. In short, when tensioning the free end of the suture is the means for locking and unlocking the device, it may be difficult to lock the device in a desired position, or the device may come unlocked at an undesirable time.

Another drawback of the device described in the Foerster patent is that one of the suture ends is "bound" to the tissue. It is expected that if a physician can tension both ends of the suture, it will facilitate positioning of the tissue with respect to the bone.

Another previously-known knotless suture anchor is described in U.S. Patent No. 6,692,516 to West et al. ("West"). The embodiment of FIGS. 15-17 of the West patent describes a device having a shaft with a distal crown portion. The shaft is disposed through an outer member, such that the crown portion is disposed distal to the outer member.

The shaft has an elongated opening through which the two free suture ends can be threaded. Therefore, in use, the suture is threaded through tissue to form a loop, and the two free ends of the suture are threaded through the elongated opening in the shaft, such that the free ends then can be manipulated by a physician.

In operation, a physician approximates the positioning of the tissue with respect to the bone. A proximally-directed force then is applied to the shaft to cause the shaft to move proximally with respect to the outer member. This causes the suture, which is threaded through the opening in the shaft, to be pinched between the shaft and the outer member, thereby locking the suture in place. At the same time, the proximal retraction of the shaft with respect to the outer member causes radially expandable fingers on the crown portion to be deployed outward, thereby securing the device within the hole in the bone.

The device described in the West patent does not appear to permit suture adjustments after the suture is locked in place. This is because the proximal retraction of the shaft with respect to the outer member both pinches the suture in place, and also deploys the expandable fingers to secure the device in the borehole. Therefore, it is not possible to adjust the suture further because it would be necessary to distally advance the shaft to do so, i.e., to remove the compressive force imposed upon the suture. However, the shaft cannot be advanced distally because the expandable members, secured within the bone, would prohibit such movement.

In view of these drawbacks of previously known suture anchoring systems, it would be desirable to provide apparatus and methods for securing tissue to bone that are easy to use and do not require a large incision.

It further would be desirable to provide apparatus and methods for securing tissue to bone that allow a surgeon direct tactile feedback of the tension in the suture between the tissue and the bone.

It also would be desirable to provide apparatus and methods for securing tissue to bone that allow a surgeon to tension both ends of a suture individually to fine-tune the placement of the tissue with respect to the bone.

It still further would be desirable to provide apparatus and methods for securing tissue to bone that allows a suture to be locked in place without tying a knot.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide apparatus and methods for securing tissue to bone that are easy to use and do not require a large incision.

It is also an object of the present invention to provide apparatus and methods for securing tissue to bone that allow a surgeon direct tactile feedback of the tension in the suture between the tissue and the bone.

It is a further object of the present invention to provide apparatus and methods for securing tissue to bone that allow a surgeon to tension both ends of a suture individually to fine-tune the placement of the tissue with respect to the bone.

It is still a further object of the present invention to provide apparatus and methods for securing tissue to bone that allow a suture to be locked in place without tying a knot.

These and other objects of the present invention are accomplished by providing apparatus comprising a bone anchor member configured to be securely disposed in a hole drilled in a bone. A suture length may be coupled between the bone anchor member and tissue, or alternatively, between a plug portion that fits within a bore of the bone anchor member and the tissue. In each embodiment, a surgeon can individually tension each end of the suture to fine-tune the placement of the tissue with respect to the bone, and then secure the suture without tying a knot.

In a first embodiment of the present invention, the apparatus comprises a bone anchor member comprising first and second passages that extend laterally through the bone anchor member. A suture is threaded through the first passage, then threaded through the tissue, and finally threaded back through the second passage, such that the first and second free ends of the suture can be manipulated by a physician. Alternatively, the suture can be threaded through the tissue first, such that the free ends extend from the tissue. The free ends then are threaded through the respective first and second passages of the bone anchor member.

In this embodiment, the first and second passages each comprise a plurality of cleated members that are configured to permit one-way movement of the first and second suture ends, i.e., each suture end can be tensioned in a proximal direction. Accordingly, a physician can incrementally fine-tune the positioning of the tissue with

respect to the bone by individually tensioning the suture ends. When a desired tension is achieved, as determined by tactile feedback, the suture ends are locked in place via the one-way cleated members.

In an alternative embodiment of the present invention, the bone anchor member comprises a bore disposed therein. The bore is configured to receive a plug portion, which may have various configurations. In one embodiment, the plug portion may comprise first and second passages having a plurality of cleated members. The plurality of cleated members are configured to permit one-way movement of the first and second suture ends in their respective passages.

The plug portion may be secured within the bone anchor bore using any number of means, as described hereinbelow. Either before or after the plug portion is secured within the bone anchor member, a physician may individually tension the first and second suture ends, which are disposed through the first and second one-way passages of the plug portion, to secure the tissue to the bone.

In further alternative embodiments of the present invention, the suture may be transformed between locked and unlocked state, as desired. In one of these fully reversible embodiments, the bone anchor member and the plug portion each comprise first and second laterally extending passages. When the plug portion is disposed within the bore of the bone anchor member, the first passage of the plug portion can align with the first passage of the bone anchor member, and the second passage of the plug portion can align with the second passage of the bone anchor member.

In this embodiment, a first suture end is threaded through the first passage of the plug portion and the first passage of the bone anchor member, while the second suture end is threaded through the second passage of the plug portion and the second passage of the bone anchor member. When the first and second passages of the plug portion are aligned with the first and second passages of the bone anchor member, respectively, then the first and second suture ends may be individually tensioned by a physician. When the passages of the plug portion and bone anchor member are misaligned, then the suture ends are pinched and locked in place.

In further alternative embodiments, the plug portion may be rotated with respect to the bone anchor member. When the plug portion is rotated in a first direction, the plug portion pinches the suture to lock the suture in place. When the

plug portion is rotated in an opposing direction, the suture ends are unlocked and may be manipulated by a physician.

In still further alternative embodiments, the bone anchor member may comprise a flexible member disposed therein, and a laterally extending passage disposed distal to the flexible member. The first and second suture ends are configured to be threaded through the passage. When a physician desires to lock the suture in place, a distally-directed force is applied to the flexible member, via the bore, to cause the flexible member to pinch the suture ends and lock the suture in place. If a physician wishes to further adjust the suture ends, then the distally-applied force is removed, thereby allowing movement of the suture.

Alternatively, a threaded cap may be disposed within the bore of the bone anchor member, and configured for movement within a grooved inner portion of the bore. A passage through which the first and second suture ends passes is situated distal to the threaded cap. If a physician wishes to lock the suture in place, then the threaded cap is advanced distally within the bore, e.g., by rotating the cap in a first direction, to cause the cap to pinch the suture. If a physician wishes to unlock the suture, then the threaded cap is rotated in an opposing direction so that it is retracted proximally within the bore.

Several further embodiments of the present invention also are disclosed in detail hereinbelow. Several of the embodiments permit the incremental tensioning of first and second suture ends and locking of the suture without tying a knot.

Methods for using the apparatus of the present invention to facilitate the attachment of tissue to bone also are disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawings and the following detailed description of the preferred embodiments, in which:

FIG. 1 is a schematic of a bone and tissue interface;

FIG. 2A-2C are, respectively, a side view, a front view, and a side-sectional view along line A--A of FIG. 2B showing a first embodiment of the present invention;

FIGS. 3A-3E are, respectively, side views of an alternative embodiment of FIGS. 2A-2C in assembled and open states, top views of the alternative embodiment in assembled and open states, and a side-sectional view along line B—B of FIG. 3B.

FIGS. 4A-4C are, respectively, a side-sectional view of an alternative embodiment of the present invention having a bone anchor member and a plug portion, a side view of the plug portion of FIG. 3A, and an opposing side view of the plug portion;

FIGS. 5A-5C are, respectively, a side-sectional view of a further alternative embodiment of the present invention having a bone anchor member and a plug portion, a side view of the plug portion of FIG. 5A, and an opposing side view of the plug portion;

FIGS. 6A-6C are, respectively, a side view of an alternative embodiment of the present invention in a closed state, a side view of the apparatus in a partially open state, and a top view of the apparatus in a fully open state;

FIG. 7 is an alternative embodiment of the invention of FIGS. 6A-6C depicted in a partially open state;

FIGS. 8A-8C are, respectively, a side view of an alternative embodiment of the present invention in a closed state, a side view of the apparatus in a partially open state, and a top view of the apparatus in a fully open state;

FIG. 9 is a side sectional view of an alternative embodiment of the present invention having at least one adhesive delivery channel;

FIGS. 10A-10B are, respectively, a side-sectional view of a further alternative embodiment of the present invention, and the device of FIG. 10A shown deployed in a hole of a bone;

FIG. 11 is a side sectional view of a further alternative embodiment of the present invention;

FIG. 12 is a side view of an alternative embodiment of the present invention, which is configured for use with a through hole drilled in a bone;

FIGS. 13A-13C are side sectional views illustrating the use of an alternative embodiment of the present invention;

FIG. 14 is an alternative embodiment of the bone anchor member described in FIGS. 13A-13C;

FIGS. 15A-15C are, respectively, a top view of an alternative embodiment of the present invention in an unlocked state, a side sectional view of the device along line C--C of FIG. 15A, and a top view of the device of FIG. 15A in a locked state;

FIG. 16 illustrates use of a suture in connection with the embodiment described in FIGS. 15A-15C;

FIGS. 17A-17B are side sectional views of an alternative embodiment of the present invention in unlocked and locked states, respectively;

FIGS. 18A-18B are side sectional views of a further alternative embodiment of the present invention in unlocked and locked states, respectively;

FIGS. 19A-19B are side sectional views of yet a further alternative embodiment of the present invention in unlocked and locked states, respectively;

FIGS. 20A-20B are, respectively, a top sectional view and a side view of an alternative embodiment of the present invention in an unlocked state;

FIGS. 21A-21B are, respectively, a top sectional view and a side view of the embodiment of FIGS. 20A-20B in a locked state;

FIGS. 22A-22B are side sectional views of a further alternative embodiment of the present invention;

FIGS. 23A-23C are, respectively, a side sectional view, a side view, and a bottom view of an alternative embodiment of the plug portion of FIGS. 22A-22B;

FIGS. 24A-24B are side sectional views of a further alternative embodiment of the present invention; and

FIGS. 25A-25B are side sectional views of an alternative embodiment of the invention of FIGS. 24A-24B.

FIG. 26A shows another bone anchor.

FIG. 26B is a cross-sectional view showing a suture locking mechanism in a locked position.

FIG. 26C is a cross-sectional view showing the suture locking mechanism in an unlocked position.

FIG. 26D is an exploded view of the bone anchor of Fig. 26A

FIG. 27A shows another bone anchor.

FIG. 27B is a cross-sectional view of the anchor.

FIG. 27C is an exploded view of the anchor.

FIG. 28A is a cross-sectional view of yet another anchor.

FIG. 28B shows a release element used to release a suture lock on the anchor.

FIG. 28C is an exploded view of the anchor.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, a schematic of a bone and tissue interface is shown primarily for illustrative purposes. In FIG. 1, tissue **T** has a torn end and it is desirable to secure the torn end to a section of bone **B**. In a first step, hole **H** having diameter $\mathbf{d_H}$ is drilled in bone **B**, as depicted, using techniques that are well known in the art.

Bone anchor member 20, which will be described in greater detail in FIGS. 2A-2C hereinbelow, is shown as a means for securing tissue **T** to bone **B**. Bone anchor member 20 is configured to be used in conjunction with a suture length 30. Suture 30 has first and second ends 32a and 32b, which are coupled to bone anchor member 20, e.g., as described in FIGS. 2A-2C or FIGS. 3A-3E hereinbelow. It should be noted that a central region of suture 30 forms loop 34, which is threaded through a section of tissue **T** near the torn end of the tissue, as depicted in FIG. 1, using techniques that are known in the art.

Referring now to FIGS. 2A-2C, features of bone anchor member 20 are described in greater detail. Bone anchor member 20 has proximal region 22 and distal region 24, as depicted in FIG. 2A. The apparatus further comprises means for securing bone anchor member 20 within hole **H** of bone **B** (see FIG. 1). As depicted, the means for securing bone anchor member 20 comprises plurality of cleated members 42, which preferably are formed on or attached to an exterior surface of bone anchor member 20. Alternatively, other means for securing bone anchor member 20 within hole **H** may be used, such as radially expandable members (not shown) that dig into surrounding bone **B**, or threaded exterior members that screw into surrounding bone.

Referring now to FIGS. 2B-2C, bone anchor member 20 preferably further comprises first and second guide channels 50 and 52, respectively, which preferably are formed within opposing surfaces of bone anchor member 20. First and second guide channels 50 and 52 are configured to accommodate regions of suture 30, so that

the suture regions do not extend outside of the confines of the guide channels when in use.

Bone anchor member 20 further comprises first and second passages 60 and 70. First and second passages 60 and 70 extend laterally through a main body of bone anchor member 20, as depicted in FIG. 2C. First passage 60 communicates with first guide channel 50 via opening 61, and further communicates with second guide channel 52 via opening 62. Similarly, passage 70 communicates with first guide channel 50 via opening 71, and further communicates with second guide channel 52 via opening 72.

In the embodiment of FIGS. 2A-2C, first passage 60 is shown disposed proximal to second passage 70, i.e., the first passage is closer to proximal region 22 of bone anchor member 20. However, as will be apparent to one skilled in the art, the passages also may be disposed adjacent one another, or otherwise positioned, to achieve the objects of the present invention.

First passage 60 and second passage 70 each comprise at least one cleated member 74. Each cleated member comprises angled sections 75 and substantially orthogonal sections 76, which are disposed adjacent one another, thereby forming a cleated shape, as shown in FIG. 2C.

The cleated members are configured such that angled sections 75 are angled towards openings 62 and 72 of passages 60 and 70, respectively, as shown in FIG. 2C. In accordance with one aspect of the present invention, cleated passages 60 and 70 are configured to permit one-way movement of first and second suture ends 32a and 32b, respectively. For example, when first end 32a is pulled in a proximal direction by a physician, angled sections 75 permit movement of the suture end in the proximal direction. However, a physician cannot distally advance suture end 32a within passage 60.

In a preferred embodiment, suture 30 has an outer diameter that is slightly larger than an inner diameter of cleated passages 60 and 70. Therefore, first and second suture ends 32a and 32b can pass through cleated passages 60 and 70 in a proximal direction with relatively little resistance. However, the suture will hold significantly greater force in the distal direction.

In one method for coupling suture 30 between tissue **T** and bone anchor member 20, a central region of suture 30 can be looped through tissue **T** first, such that free ends 32a and 32b extend from the tissue. Free end 32a then is threaded through one-way cleated passage 60 in a proximal direction, while free end 32b is threaded through one-way cleated passage 70, also in a proximal direction.

Alternatively, suture 30 may be coupled to bone anchor member 20 using techniques described hereinbelow with respect to FIGS. 3A-3E or FIGS. 6-8. These techniques allow the suture to be coupled to bone anchor member 20 without the need to thread free ends 32a and 32b through passages 60 and 70, as set forth below.

As will be apparent to one skilled in the art, suture 30 may be coupled between tissue **T** and bone anchor member 20 using other threading techniques, so long as the suture ultimately is situated in a manner depicted in FIG. 2C.

At this time, first end 32a of suture 30 is disposed through first passage 60, then transitions into loop portion 34a. Loop portion 34a transitions into loop portion 34b, forming loop 34 therebetween, which is coupled to tissue **T** (see FIG. 1). Loop portion 34b transitions into second end 32b, which is disposed through passage 70, as shown in FIG. 2C. Accordingly, first and second ends 32a and 32b of suture 30 may be independently manipulated by a physician for purposes described hereinbelow.

In operation, after suture 30 is coupled to bone anchor member 20 and tissue **T** as described hereinabove, bone anchor member 20 is distally advanced into hole **H** of bone **B** under arthroscopic guidance. Cleated members 42 of bone anchor member 20 allow the bone anchor member to be advanced distally within hole **H** when an appropriate force is applied, but cleated members 42 inhibit proximal movement of bone anchor member 20 to provide a secure anchor within hole **H**.

At this time, the surgeon can approximate the positioning of tissue **T** with respect to bone **B** (see FIG. 1) by pulling first end 32a and/or second end 32b proximally through cleated passages 60 and 70. Advantageously, the use of two separate passages allows the surgeon to tension each end of the suture independently, which is often desirable when tissue is torn irregularly.

Further, the use of a plurality of cleated passages 60 and 70 permits incremental tensioning of first and second suture ends 32a and 32b. This allows a physician to incrementally adjust the positioning of the tissue, using tactile feedback

as a guide. Once a desired tension is achieved, the physician simply needs to stop retracting the suture ends, and the suture is automatically locked in place. Advantageously, there is no need to tie a knot.

In accordance with another object of the present invention, guide channels 50 and 52 permit the retraction of first and second suture ends 32a and 32b when bone anchor member 20 is secured within hole **H** by providing a clearance between the bone anchor member and the bone itself.

Referring now to FIGS. 3A-3E, an alternative embodiment of the apparatus of FIGS. 2A-2C is described. In FIGS. 3A-3E, bone anchor member 20' comprises first and second mating portions 22a and 22b. In a preferred embodiment, mating portions 22a and 22b are substantially symmetrical, except as noted below.

Mating portion 22a comprises cleated passage portion 60a and cleated passage portion 70a, while mating portion 22b comprises cleated passage portion 60b and cleated passage portion 70b, as shown in FIG. 3B. When in the assembled state, as depicted in FIG. 3A, cleated passage portions 60a and 60b form cleated passage 60', while cleated passage portions 70a and 70b form cleated passage 70'.

Similarly, guide channel portions 50a and 50b of mating portions 22a and 22b, respectively, form guide channel 50' in the assembled state depicted in FIGS. 3A and 3C, while guide channel portions 52a and 52b of FIG. 3D form guide channel 52' in the assembled state.

In the embodiment of FIGS. 3A-3E, mating portion 22a comprises at least one mating pocket 59, as depicted in FIG. 3E. Mating portion 22b comprises at least one protrusion 55, which is configured to securely engage a corresponding pocket 59 in the assembled state of FIGS. 3A and 3C.

In a preferred embodiment, protrusion 55 comprises ledge 57, as shown in Detail "B" of FIG. 3D. If desired, mating pocket 59 may comprise a complementary recess having a slightly larger diameter (not shown), which is configured to receive ledge 57. In this manner, ledge 57 of protrusion 55 may snap into engagement with the larger diameter recess of pocket 59, thereby securing mating portions 22a and 22b.

In operation, a physician may place a first suture end in cleated passage portion 60a, and further place a second suture end in cleated passage portion 70a of

FIG. 3E. In a next step, mating portion 22b is secured to mating portion 22a, e.g., using a snap-lock engagement described above between protrusion 55 and pocket 59.

At this time, the first and second suture ends will be disposed through cleated passages 60 and 70. Advantageously, using this technique of FIGS. 3A-3E, a physician need not thread the suture ends through cleated passages 60 and 70, thereby increasing the speed and ease of use of the device.

Referring now to FIGS. 4A-4C, an alternative embodiment of the present invention is described. In FIG. 4A, apparatus 100 comprises bone anchor member 102 and plug portion 110. Bone anchor member 102 comprises main body 103 having bore 104 disposed therein, as depicted in FIG. 4A. Further, main body 103 of bone anchor member 102 comprises exterior cleated members 106, which are similar to cleated members 42 of bone anchor member 20. Cleated members 106 are configured to be inserted into hole **H** of bone **B** (see FIG. 1) using a frictional force fit.

In operation, once bone anchor member 102 is secured in hole **H**, then plug portion 110 may be inserted into bore 104 of bone anchor member 102. Cleated members 116 of plug portion 110 are configured to permit distal advancement of the plug portion into bore 104, with some friction provided between cleated members 116 and inner wall 105. However, cleated members 116 ensure that plug portion 110 cannot be retracted proximally after advancement into bore 104, thereby securing the plug portion to the bone anchor member.

Referring now to FIGS. 4B-4C, further features of plug portion 110 are described. Plug portion 110 comprises first and second passages 118 and 120. First and second suture ends 32a and 32b may be coupled to plug portion 110 of apparatus 100 in a manner similar to that described in FIG. 2C hereinabove. Specifically, in the embodiment of FIGS. 4A-4C, first end 32a of suture 30 is disposed through first passage 118. After exiting through first passage 118, first end 32a then transitions into loop portion 34a, forms loop 34, and transitions into loop portion 34b (see FIGS. 2A-2C). Loop portion 34b transitions into second end 32b, which extends through second passage 120 of FIGS. 4A-4C.

Alternatively, suture 30 may be coupled to plug portion 110 using techniques described hereinbelow with respect to FIGS. 6-8. These techniques allow the suture

to be coupled to plug portion 110 without the need to thread free ends 32a and 32b through passages 118 and 120, as set forth below.

If desired, passages 118 and 120 of FIGS. 3A-3C may comprise cleated members 74, as described hereinabove with respect to FIG. 2C. If cleated members 74 are employed, then tissue **T** may be secured to bone **B** by individually tensioning first and second ends 32a and 32b of suture 30, as described hereinabove with respect to FIG. 2C.

Plug portion 110 preferably comprises one or more guide channels 125 disposed in a lateral surface of plug body 113. Guide channel 125 preferably is substantially similar to guide channels 50 and 52 of FIG. 2C. In FIG. 4C, guide channel 125 is configured to permit retraction of first and second suture ends 32a and 32b when plug portion 110 is secured within bore 104 by providing a clearance between the plug portion and the bone anchor member.

Alternatively, in the embodiment of FIGS. 4A-4C, passages 118 and 120 may be substantially smooth passages, such that cleated members 74 are not employed. In this case, passages 118 and 120 permit substantially unimpeded movement of suture 30 through the passages. In operation, a physician may individually tension suture ends 32a and 32b prior to insertion of plug portion 110 into bone anchor member 102. When a physician deems that tissue **T** is appropriately secured to bone **B**, then plug portion 110 is forced into bore 104 of bone anchor member 102. This causes suture ends 32a and 32b to be sandwiched between plug portion 110 and bone anchor member 102 when guide channels 125 are not present. Accordingly, the suture is secured between the two portions using a force fit.

Referring now to FIGS. 5A-5C, an alternative embodiment of the present invention is described. In FIG. 5A, apparatus 140 comprises bone anchor member 142 and plug portion 150. Bone anchor member 142 comprises main body 143 having bore 144 disposed therein, as depicted in FIG. 5A. Further, main body 143 of bone anchor member 142 comprises exterior cleated members 146 and interior cleated members 145. Exterior cleated members 146 are configured to be inserted into hole **H** of bone **B** (see FIG. 1) using a force fit, as described hereinabove.

Plug portion 150 comprises main body 153, which preferably has a substantially cylindrical shape and smooth exterior surface 156. Taper 157 preferably is disposed at a distal region of main body 153, as shown in FIG. 5A.

Suture 30 having first and second ends 32a and 32b is coupled to plug portion 150 of apparatus 140, preferably in a manner described hereinbelow with respect to FIGS. 6-8.

In operation, bone anchor member 142 is advanced into hole **H** (see FIG. 1). Exterior cleated members 146 of bone anchor member 142 permit one-way movement of the bone anchor member into the hole.

In a next step, plug portion 150 then is inserted into bore 144 of bone anchor member 142. Exterior surface 156 of plug portion 150 preferably has an outer diameter that is slightly larger than an inner diameter of bore 144. Accordingly, when plug portion 150 is urged distally, a force fit is achieved to secure plug portion 150 within the bore of bone anchor member 142.

Taper 157 of plug portion 150 facilitates the distal advancement of the plug portion with respect to bone anchor member 142. Further, interior cleated members 145 are configured to permit advancement of plug portion 110 into bore 144 in a distal direction only.

First and second suture ends 32a and 32b may be coupled to plug portion 150 in a manner described hereinabove with respect to FIGS. 4A-4C. Specifically, in the embodiment of FIGS. 5A-5C, first end 32a of suture 30 is disposed through first passage 158, then forms a loop that is threaded through tissue **T**, and second end 32b of suture 30 then extends through second passage 160.

First and second passages 158 and 160 of FIGS. 5A-5C may comprise cleated members 74 of FIG. 2C. If cleated members 74 are employed, then tissue **T** may be secured to bone **B** by individually tensioning first and second ends 32a and 32b of suture 30. Cleated members 74 permit incremental tensioning of each suture end, and serve to lock the suture ends within their respective passages 158 and 160, as generally set forth hereinabove with respect to FIG. 2C.

Plug portion 150 preferably comprises one or more guide channels 165 disposed in a lateral surface of plug body 153, as shown in FIG. 5C. Guide channel 165 preferably is substantially similar to guide channel 50 of FIG. 2C, and is

configured to permit retraction of first and second suture ends 32a and 32b when plug portion 150 is secured within bore 144.

Alternatively, in the embodiment of FIGS. 5A-5C, passages 158 and 160 may be substantially smooth passages, such that cleated members 74 are not employed and guide channels 165 are not present. In this case, a physician may individually tension suture ends 32a and 32b prior to insertion of plug portion 150 into bone anchor member 142. When a physician deems that tissue **T** is appropriately secured to bone **B**, then plug portion 150 is forced into bore 144 of bone anchor member 142. This causes suture ends 32a and 32b to be sandwiched between plug portion 150 and bone anchor member 142. Accordingly, the suture is secured between the two portions using a force fit.

Referring now to FIGS. 6A-6C, alternative embodiments of the invention of FIGS. 4A-4C are described. In FIGS. 6A-6C, plug portion 110' comprises first and second plug portions 110a and 110b, which are coupled together using hinge member 115. Hinge member 115 may be integral to first and second plug portions 110a and 110b, or the hinge member may be a third element that couples two distinct portions together.

Hinge member 115 permits plug portion 110' to transition between a closed state, as shown in FIG. 6A, and a partially or fully open state, as depicted in FIGS. 6B-6C, respectively. In the open states of FIGS. 6B-6C, a physician may quickly place a first suture end in passage 118a and may place a second suture end in passage 120a. Alternatively, the first and second suture ends may be placed in passages 118b and 120b, respectively.

With the suture ends in place, a physician may transform plug portion 110' into the closed state, depicted in FIG. 6A, by rotating first and second plug portions 110a and 110b together. In the closed state, first and second plug portions 110a and 110b form first and second passages 118' and 120'. With the sutures ends disposed in their respective passages, the apparatus may be actuated as described hereinabove with respect to FIGS. 4A-4C to secure tissue to bone.

As will be apparent to one skilled in the art, hinge member 115 serves to ensure proper alignment of first and second plug portions 110a and 110b in the closed state. If desired, a securing means, such as protrusion 55 and pocket 59 of FIGS. 3A-

3E, may be employed to secure plug portions 110a and 110b. Further, as will be apparent to one skilled in the art, the securing means may be reversible, such that a physician may separate the plug portions, as shown in FIGS. 6B-6C, to reposition the suture ends.

Referring now to FIG. 7, an alternative embodiment of the invention of FIGS. 6A-6C is described. In FIG. 7, plug portion 110'' comprises first and second plug portions 110a' and 110b', which have different sizes. Hinge member 115 is offset from the center of plug portion 110''. Further, passage portions 118a' and 120a' of plug portion 110a' are each less than 180 degrees. By contrast, passage portions 118b' and 120b' of plug portion 110b' are each greater than 180 degrees.

During operation, a physician may place a first suture end in passage portion 118b', and may place a second suture end in passage portion 120b'. Since these passage portions are each greater than 180, a physician may press the suture ends into the passage portions and the suture ends will be likely to remain in place. With the suture ends in place, plug portion 110'' is transformed to a closed state. In the closed state, passage portions 118a' and 118b' form a first one-way, 360-degree passage through which the first suture end may pass, while second passage portions 120a' and 120b' form a second one-way, 360-degree passage through which the second suture end may pass.

Referring now to FIGS. 8A-8C, a further alternative embodiment of the invention of FIGS. 6A-6C is described. In FIGS. 8A-8C, hinge member 115 is located on a lateral surface of plug portion 110'', as opposed to on the distal end of the plug portion. Like the embodiment of FIGS. 6A-6C, the embodiment of FIGS. 8A-8C facilitates coupling of the suture to the plug portion, and, advantageously, does not require a physician to thread the suture through passages 118 and 120 of the plug portion.

As will be apparent to one skilled in the art, passage portions 118a and 120a may be larger than passage portions 118b and 120b, respectively, as described with respect to FIG. 7 hereinabove.

Referring now to FIG. 9, a further alternative embodiment of the present invention is described. In FIG. 9, bone anchor member 180 is similar to bone anchor member 20 of FIGS. 2A-2C, except as noted hereinbelow. Cleated members 182 of

bone anchor member 180 preferably are similar to cleated members 42 of bone anchor member 20, as described hereinabove, and facilitate anchoring of bone anchor member 180 within hole **H**. Further, guide channels 190 and 192 preferably are similar to guide channels 50 and 52 of FIGS. 2A-2C.

Unlike the embodiments described hereinabove, bone anchor member 180 comprises at least one adhesive delivery channel 188, which is provided within main body 181 as shown in FIG. 9. Adhesive delivery channel 188 may be formed by drilling a hole into an upper surface of main body 181, such that the hole extends through first passage 184 and second passage 186. As will be apparent to one skilled in the art, however, channel 188 may be formed using other known techniques.

In the embodiment of FIG. 9, first and second passages 184 and 186 may comprise cleated members 74 of FIG. 2C, thereby permitting one-way movement of suture ends 32a and 32b through the passages. Alternatively, in the embodiment of FIG. 9, passages 184 and 186 may comprise substantially smooth inner surfaces that permit movement of suture 30 through the passages in either direction.

After bone anchor member 180 is secured in hole **H** of bone **B**, a physician may approximate the positioning of tissue **T** with respect to bone **B** by individually tensioning first and second ends 32a and 32b of suture 30, as described hereinabove. When the suture ends are tensioned as desired, an adhesive is delivered to adhesive delivery channel 188, preferably using a needle-like tube (not shown) disposed within a working cannula (not shown). The needle-like tube preferably has a distal opening that may be placed in close proximity to, or within, adhesive delivery channel 188 to deliver an adhesive thereto.

The adhesive flows distally through adhesive delivery channel 188 and into portions of first and second passages 184 and 186. The adhesive contacts portions of suture 30 that extend through corresponding regions of first and second passages 184 and 186, thereby locking the suture in place. As will be apparent to one skilled in the art, although one adhesive delivery channel 188 is depicted in FIG. 9, multiple adhesive delivery channels may be employed to secure the suture, irrespective of whether cleated members 74 are employed.

Referring now to FIGS. 10A-10B, yet another alternative embodiment of the present invention is described. In FIG. 10A, apparatus 200 comprises bone anchor

member 202 and plug portion 210. Apparatus 200 is similar to apparatus 140 of FIGS. 5A-5C, except as noted below.

Bone anchor member 202 comprises main body 203 having bore 204 disposed therein, as depicted in FIG. 10A. Further, main body 203 of bone anchor member 202 comprises exterior cleated members 206, which are configured to be inserted into hole **H** of bone **B** (see FIG. 1) using a force fit, as described hereinabove.

Plug portion 210 preferably comprises a substantially cylindrical shape and comprises main body 213 having substantially smooth exterior surface 216. Further, taper 217 preferably is disposed at a distal region of main body 213, as shown in FIG. 10A.

Suture 30 having first and second ends 32a and 32b is coupled to plug portion 210, preferably in a manner described hereinabove with respect to FIGS. 6-8.

Main body 213 of plug portion 210 has an outer diameter that is slightly larger than an inner diameter of bore 204. The diameters are selected such that main body 213 of plug portion 210 may be distally advanced into bore 204 when forced distally. Taper 207 of bone anchor member 202 is configured to facilitate advancement of plug portion 210 into bore 204.

In operation, bone anchor member 202 is secured within hole **H** when the bone anchor member is distally advanced into the hole, as depicted in FIG. 10B. Exterior cleated members 206 of bone anchor member 202 permit one-way movement of the bone anchor member into hole **H**.

In a next step, plug portion 210 is advanced distally into bore 204 of bone anchor member 202 and secured therein using a force fit, as described hereinabove. At this time, surrounding regions of bone **B** will apply a compressive force upon bone anchor member 202, as indicated by the larger directional arrows in FIG. 10B. This compressive force upon bone anchor member 202 in turn causes compression upon plug portion 210, as indicated by the smaller directional arrows in FIG. 10B, thereby securely retaining the plug portion within bore 204.

In the embodiment of FIGS. 10A-10B, passages 218 and 219 may comprises cleated members 74 as described hereinabove with respect to FIG. 2C, as a means for locking suture 30. Alternatively, passages 218 and 219 may comprise substantially smooth interior surfaces that permit advancement of suture 30 in either direction.

In either embodiment, it may be desirable to approximate the positioning of tissue **T** (not shown in FIG. 10B) to bone **B** by individually tensioning suture ends 32a and 32b prior to insertion of plug portion 210 into bone anchor member 202. In a preferred embodiment of the method, the tissue position is approximated when passage 219 is disposed just above bore 204. Once the desired positioning of the tissue is achieved, plug portion 210 is advanced distally into bore 204, thereby locking the suture. Specifically, the suture will be sandwiched between exterior surface 216 of plug portion 210 and inner wall 205 of bone anchor member 202.

Referring now to FIG. 11, a further alternative embodiment of the present invention is described. In FIG. 11, apparatus 220 comprises bone anchor member 222 and plug portion 230. Apparatus 220 is similar to apparatus 200 of FIGS. 10A-10B, except as noted below.

Bone anchor member 222 comprises main body 223 having bore 224 disposed therein, as depicted in FIG. 11. Further, main body 223 comprises exterior cleated members 226, which are configured to be inserted into hole **H** of bone **B** (see FIG. 1) using a force fit, as described hereinabove. Unlike previous embodiments, bone anchor member 222 comprises a proximal protrusion having inward taper 227. Proximal stop 228 is formed between inward taper 227 and inner wall 225 of bone anchor member 222, as shown in FIG. 11.

Plug portion 230 preferably comprises main body 233 having proximal region 235, central region 234 and tapered distal region 237. Tapered distal region 237 is sized to pass through taper 227 of bone anchor member 222 when a distally-directed force is applied to plug portion 230. When further force is applied, central region 234 of plug portion 230 is advanced into bore 224 via taper 227. Finally, when yet further force is applied to plug portion 230, proximal region 235 will be advanced past taper 227. Once proximal region 235 is fully inserted into bore 224, proximal stop 228 is configured to abut proximal edge 236 of plug portion 230, thereby securing the plug portion within bone anchor member 222.

As will be apparent to one skilled in the art, apparatus 220 of FIG. 11 may comprise any other features described hereinabove with respect to the embodiments of FIGS. 2-10. For example, passages 238 and 239 may comprise cleated members 74 of FIG. 2C, or alternatively may comprise substantially smooth interior surfaces.

Further, the operation of apparatus 220 preferably is substantially similar to the methods described hereinabove with respect to the embodiments of FIGS. 2-10.

Referring now to FIG. 12, a further alternative embodiment of the present invention is described. In FIG. 12, bone anchor 240 is similar to bone anchor member 20 of FIGS. 1-2, but is configured for use in applications where through hole $\mathbf{H_T}$ is employed. For example, bone **B** may be a thin bone, such that it is possible to arthroscopically operate from both sides of the bone.

Bone anchor 240 comprises main body 242 having proximal and distal ends, flange 245 disposed at the proximal end and taper 246 formed at the distal end. Main body 242 further comprises exterior surface 243 disposed between flange 245 and taper 246, as shown in FIG. 12.

Bone anchor 240 further comprises first and second passages 250 and 252, each having a plurality of cleated members 254, as shown in FIG. 12. Each of the cleated members comprises angled sections 255 and substantially orthogonal sections 256, which are disposed adjacent one another thereby forming a cleated shape, as described hereinabove with respect to cleated members 74 of FIG. 2C.

In operation, a central region of suture 30 can be looped through tissue **T** first, such that free ends 32a and 32b extend from the tissue. Free end 32a then is threaded through first passage 250 in a proximal direction, while free end 32b is threaded through second passage 252, also in a proximal direction. The suture may be threaded through passages 250 and 252 and tissue **T** by arthroscopically operating on one or both sides of bone **B**.

As will be apparent to one skilled in the art, suture 30 may be coupled between tissue **T** and bone anchor 240 using other arthroscopic threading techniques, so long as the suture ultimately is situated in a manner depicted in FIG. 12.

Once the suture is threaded as shown in FIG. 12, a physician may proximally retract first and second suture ends 32a and 32b, one at a time, to approximate the positioning of tissue **T** with respect to bone **B**. As the suture ends are tensioned, flange 245, which has an outer diameter larger than the diameter of through hole $\mathbf{H_T}$, abuts bone **B**. The system becomes tensioned because flange 245 and tissue **T** are drawn against the bone from opposing directions.

In accordance with one aspect of the present invention, cleated passages 250 and 252 are configured to permit one-way movement of first and second suture ends 32a and 32b, respectively. For example, when first end 32a is pulled in a proximal direction by a physician, angled sections 255 permit movement of that particular suture end in the proximal direction. However, a physician cannot distally advance suture end 32a within passage 250. Advantageously, the use of two separate passages allows the surgeon to tension each end of the suture separately, which is often desirable when tissue **T** is torn irregularly.

As will be apparent to one skilled in the art, the methods described in FIG. 12 may be accomplished using a separate bone anchor member and plug portion. For example, the principles of the embodiments in FIGS. 4-5 and FIGS. 10-11, in which separate bone anchor and plug portions are employed, may be implemented in lieu of one-piece bone anchor 240.

Further, the suture securing methods described in FIG. 12 may be accomplished using substantially smooth passages 250 and 252. Where substantially smooth passages are employed, an interference fit or adhesive may be employed in lieu of the cleated passages to facilitate securing of the suture. The interference fit or adhesive may be used, for example, as described hereinabove with respect to the embodiments of FIGS. 4-5 and FIGS. 10-11.

Referring now to FIGS. 13A-13C, still a further alternative embodiment of the present invention is described. In FIG. 13A, apparatus 270 comprises bone anchor member 272 and plug portion 280.

Bone anchor member 272 comprises main body 273 having bore 274 disposed therein, as depicted in FIG. 13A. Further, main body 273 comprises exterior cleated members 276, which are configured to be inserted into hole **H** of bone **B** (see FIG. 1) using a force fit, as described hereinabove. Like the embodiment of FIG. 11, bone anchor member 272 comprises a proximal protrusion having inward taper 277. Proximal stop 278 is formed between inward taper 277 and an inner wall of bone anchor member 272, as shown in FIG. 13A.

Bone anchor member 272 further comprises first and second spring elements 292a and 292b, which are disposed at a distal region of bore 274. First and second spring members 292a and 292b may be integrally formed with bone anchor body 273,

as depicted in FIG. 13A, or may be separate elements coupled to body 273. As will be described in further detail hereinbelow, first and second spring elements 292a and 292b may be deformed to accommodate plug portion 280 within bore 274, and also to enable locking and unlocking of a suture (not shown in FIGS. 13A-13C) used in conjunction with apparatus 270. As will be apparent to one skilled in the art, one or more spring elements may be employed.

First and second passages 298 and 299 extend laterally through main body 273 of bone anchor member 272, as depicted in FIG. 13A. First and second passages 298 and 299 are configured to be selectively aligned with first and second passages 288 and 289 of plug portion 280, for the purposes described hereinafter.

Referring still to FIG. 13A, plug portion 280 of apparatus 270 preferably comprises main body 283 having proximal and distal ends. The proximal end comprises flange 284. Taper 286 is disposed between flange 284 and main body 283, as shown in FIG. 13A. Further, distal taper 287 is disposed at the distal end of plug portion 280.

Plug portion 280 further comprises first and second passages 288 and 289, which extend laterally through main body 283, as shown in FIG. 13A. In the embodiment of FIGS. 13A-13C, first and second passages 288 and 289 preferably comprise a substantially smooth interior surfaces.

Referring now to FIG. 13B, in a first step, plug portion 280 is inserted into bore 274 of bone anchor member 272, preferably using insertion tool 294. Specifically, when an appropriate force is applied to plug portion 280, tapered distal end 287 is configured to pass through taper 277 of bone anchor member 272. When further force is applied, a central region of plug portion 280 is advanced into bore 274 via taper 277. Finally, when yet further force is applied to plug portion 280, the proximal region having taper 286 and flange 284 will be advanced past taper 277.

When plug portion 280 is fully inserted into bore 274, first and second spring elements 292a and 292b will be inclined to urge plug portion 280 in a proximal direction, such that flange 284 will abut proximal stop 278 (see FIG. 13C). However, when a sufficient distally-directed force is applied to plug portion 280, e.g., using insertion tool 294, first and second spring elements may be deformed distally, as shown in FIG. 13B.

Insertion tool 294 may be a rod or other substantially rigid member configured to transfer a distally-directed force from a physician to plug portion 290. In a preferred embodiment, insertion tool 294 is configured to engage mating slot 295, as shown in FIG. 13B.

The provision of a distally-directed force acting on plug portion 280 causes first and second passages 288 and 289 to become substantially aligned with first and second passages 298 and 299 of bone anchor member 27, respectively, as shown in FIG. 13B. At this time, suture 30 is threaded through aligned first passages 288 and 298. The suture then is threaded through tissue **T**, as described hereinabove, and then threaded back through aligned second passages 289 and 299. In effect, first suture end 32a extends through first passages 288 and 298, while second suture end 32b extends through second passages 289 and 299.

Once the suture is coupled to apparatus 270 in this manner, apparatus 270 is inserted into hole **H** of bone **B** under arthroscopic guidance. Cleated members 276 secure apparatus 270 within hole **H**, as described hereinabove. At this time, first and second suture ends 32a and 32b will extend outside of the arthroscopic site for manipulation by a physician.

A physician may selectively tension first and second suture ends 32a and 32b to approximate the positioning of tissue **T** with respect to bone **B** when first and second passages 288 and 289 are aligned with first and second passages 298 and 299, respectively. During tensioning of the suture ends, insertion tool 294 urges plug portion distally to cause the passages to align, as shown in FIG. 13B.

When a desired positioning of tissue **T** is achieved, the force applied to plug portion 280 is removed, e.g., by proximally retracting insertion tool 294, as shown in FIG. 13C. At this time, first and second spring elements 292a and 292b are inclined to bias proximally, thereby urging flange 284 of plug portion 280 against proximal stop 278 of bone anchor member 272. This movement of plug portion 280 with respect to bone anchor member 272 causes a misalignment between first passage 288 of plug portion 280 and first passage 298 of bone anchor member 272. Also, a misalignment occurs between second passages 289 and 299. Accordingly, the misalignments cause first suture end 32a to become pinched between first passages

288 and 298, while second suture end 32b is pinched between second passages 289 and 299. These misalignments lock the suture in place.

If it becomes necessary to adjust the positioning of tissue **T** with respect to bone **B** during the procedure, then insertion tool 294 may be inserted into mating slot 295, as shown in FIG. 13B, to urge plug portion 280 distally. As described hereinabove, when first and second passages of plug portion 280 and bone anchor member 272 are aligned (see FIG. 13B), a physician may manipulate suture ends 32a and 32b to adjust the positioning of tissue **T**.

Referring now to FIG. 14, an alternative embodiment of the invention of FIGS. 13A-13C is described. In FIG. 14, alternative bone anchor member 272' comprises spring element 292' disposed at a distal end of main body 273. Spring element 292' comprises a distally concave configuration having a central region 293, as shown in FIG. 14.

Alternative bone anchor member 272' is used in conjunction with plug portion 280 in a manner similar to that described hereinabove with respect to FIGS. 13A-13C. Specifically, after plug portion 280 is inserted into bore 274, the provision of a further distally-directed force acting on plug portion 280 will cause central region 293 of spring element 292' to be deformed in a distal direction. When the central region of spring element 292' is deformed distally, first and second passages 288 and 289 of plug portion 280 are substantially aligned with first and second passages 298 and 299 of bone anchor member 272', respectively. In this state, first suture end 32a may move substantially unimpeded through aligned first passages 288 and 298, while second suture end 32b may move through aligned second passages 289 and 299, respectively, as described hereinabove with respect to FIG. 13B.

When a desired positioning of tissue **T** is achieved, the force imposed upon plug portion 280 is removed, e.g., by proximally retracting insertion tool 294, as described in FIG. 13C. At this time, central region 293 of spring elements 292' will return in a proximal direction to its preferred orientation. This causes flange 284 of plug portion 280 to be urged against proximal stop 278 of bone anchor member 272'. As described hereinabove, the movement of plug portion 280 with respect to bone anchor member 272' causes a misalignment between first passages 288 and 298, and

also a misalignment between second passages 289 and 299. These misalignments pinch suture ends 32a and 32b to lock the suture in place.

Referring now to FIGS. 15-16, a further alternative embodiment of the present invention is described. Apparatus 300 comprises bone anchor member 302 and plug portion 310, as shown in FIGS. 15A-15B. Bone anchor member 302 is similar to the bone anchor members described hereinabove and comprises main body 303 having plurality of cleated members 306, which are configured to anchor plug portion 302 within hole **H** of bone **B** (see FIG. 1). Bone anchor member 302 further comprises central bore 304, which is configured to receive plug portion 310, as described hereinbelow.

Plug portion 310 of apparatus 300 comprises main body 311 having distal region 318 and central bore 312, as shown in FIG. 15B. Main body 311 has an outer diameter that is slightly smaller than an inner diameter of bore 304. Accordingly, plug portion 310 is configured for circumferential rotation within bore 304 of bone anchor member 302, as described hereinbelow.

Bone anchor member 302 further comprises first and second semi-circular channels 305a and 305b, which preferably are formed at diametrically opposing surfaces of main body 303, as shown in FIGS. 15A-15B. Further, plug portion 310 comprises first and second semi-circular channels 315a and 315b, which preferably are formed at diametrically opposing surfaces on main body 311, as shown in FIGS. 15A-15B.

Apparatus 300 also comprises actuation knob 321, which is disposed on an outer surface of plug portion 310, as shown in FIG. 15A. Actuation knob 321 is configured to be disposed within first recess 322 of bone anchor member 302 in an unlocked state, and disposed within second recess 323 in a locked state, as described in further detail hereinbelow.

When actuation knob 321 is disposed within first recess 322, first and second semi-circular channels 305a and 305b of bone anchor member 302 are aligned with first and second semi-circular channels 315a and 315b of plug portion 310, respectively, thereby forming first and second circular channels, as shown in FIGS. 15A-15B.

When actuation knob 321 is disposed within second recess 323, first and second semi-circular channels 305a and 305b of bone anchor member 302 are not aligned with corresponding channels 315a and 315b of plug portion 310, as shown in FIG. 15C.

In operation, suture 30 preferably is coupled to apparatus 300 in a manner shown in FIG. 16. Specifically, first suture end 32a extends through central bore 312 of plug portion 310. First suture end 32a passes through aperture 327 in plug portion 310 (see FIG. 15B) and transitions into loop portion 34a. Loop portion 34a is threaded through the first circular channel formed by semi-circular channels 305a and 315a, as shown in FIG. 16.

Loop portion 34a then is threaded through tissue **T** and transitions into loop portion 34b. Loop portion 34b is threaded through the second circular channel formed by semi-circular channels 305b and 315b, as shown in FIG. 16. Loop portion 34b passes through a second aperture 327 and transitions into second suture end 32b. Second suture end 32b extends through central bore 312 of plug portion 310, as shown in FIG. 16.

In accordance with one aspect of the present invention, a physician may selectively tension first and second suture ends 32a and 32b when actuation knob 322 is disposed within first recess 322, as shown in FIGS. 15A-15B. This is because first and second semi-circular channels 305a and 305b of bone anchor member 302 are aligned with first and second semi-circular channels 315a and 315b of plug portion 310, respectively, to form the first and second circular channels through which the suture can freely pass.

It should be noted that, as first and second ends 32a and 32b are individually tensioned, rounded edges 328 of plug portion 310 (see FIG. 15B) serve to reduce the shear stresses imposed upon the suture ends as they pass through apertures 327.

When a physician desires to lock the suture in place, plug portion 310 is rotated with respect to bone anchor member 302 to cause actuation knob 321 to be advanced into second recess 323. The rotation of plug portion 310 may be achieved by inserting an actuation tool such as a hexagonal key (not shown) into mating slot 325. Once knob 321 is secured within second recess 323, as shown in FIG. 15C, the

suture will be locked in place because the misaligned semi-circular channels pinch the first and second ends of the suture.

Advantageously, if a physician desired to tweak the positioning of tissue **T** with respect to bone **B** after the suture has been locked, then a physician simply needs to insert the actuation tool into mating slot 325 to cause knob 322 to rotate in an opposing direction into first recess 322. As described above, this forms two fully circular channels through which the suture may be advanced or retracted to facilitate positioning of the tissue with respect to the bone.

Referring now to FIGS. 17A-17B, a further alternative embodiment of the present invention is described. In FIG. 17A, bone anchor member 340 comprises main body 343 having proximal and distal regions. Bone anchor member 340 preferably comprises plurality of cleated members 346, and further comprises opposing guide channels 348 and 349, which preferably are similar to guide channels 50 and 52 of FIG. 2C.

Bone anchor member 340 further comprises at least one passage 352, which extends laterally through main body 343, and further comprises flexible member 350, which is disposed proximal to passage 352, as shown in FIGS. 17A-17B. Flexible member 350 has a preferred relaxed configuration in which it assumes a convex shape, i.e., bowed away from passage 352. In the relaxed configuration, shown in FIG. 17A, there is sufficient clearance between flexible member 350 and passage 352 to permit suture 30 to move substantially unimpeded through the passage.

In use, before bone anchor member 340 is inserted into hole **H** in bone **B**, first suture end 32a is passed through passage 352. The first suture end then becomes loop portion 34a, which is threaded through tissue **T**, as described hereinabove. Loop portion 34a extends through the tissue to become loop portion 34b. Loop portion 34b passes back through passage 352 and becomes second suture end 32b. First and second suture ends 32a and 32b extend outside of the arthroscopic site and may be individually tensioned by a physician.

After suture 30 is coupled to apparatus 340 and tissue **T**, bone anchor member 340 is advanced distally into hole **H** of bone **B** (see FIG. 1), whereby cleated members 346 serve to anchor the device in hole **H**. As described above, a physician then may individually tension first and second suture ends 32a and 32b to

approximate the positioning of tissue **T** with respect to bone **B**. During this time, no external forces are applied to flexible member 350, thereby permitting movement of the suture within passage 352.

Once a desired tissue positioning is achieved, the suture may be locked in place by apply a distally-directed force upon flexible member 350, as depicted in FIG. 17B. Flexible member 350 preferably assumes a concave shape in which distal knob 354 is urged towards corresponding pocket 355 in bone anchor member 342. The distally-directed force locks the suture in place by pinching the suture and inhibiting its movement within passage 352.

As will be apparent to one skilled in the art, any number of mechanisms may be employed to apply a distally-directed force upon flexible member 350, and further, to lock the flexible member in the concave position depicted in FIG. 17B. For example, a plug may be inserted into bore 358, and then wedged against flexible member 350 to hold the flexible member in place. Alternatively, bone anchor member 340 may comprise taper 277 and proximal stop 278 (see FIG. 17A) such that the plug will remain in place within bore 358. In either case, the plug will serve to apply a compressive force to hold the suture in the locked state.

Alternatively, the flexible member may be "bi-stable," such that the flexible member has only two stable states. In the first state, the flexible member is positioned as shown in FIG. 17A. When a sufficient distally-directed force is applied, the flexible member is configured to "snap" from the first state into a second state, as shown in FIG. 17B. There are no stable positions between the first and second state. Accordingly, the flexible member is either provided in a locked or unlocked state. Means for applying a proximally-directed force to the flexible member may be used to cause the flexible member to snap from the second state, shown in FIG. 17B, to the first state, shown in FIG. 17A, thereby unlocking the device.

In an alternative embodiment, a threaded member may be used to hold the suture in a locked state. As shown in FIGS. 18A-18B, threaded cap 360 has exterior thread 361, which is adapted to engage grooved interior section 371 of bore 358'. In a preferred embodiment, threaded cap 360 further comprises a proximal region having mating slot 365 and a distal region having distal protrusion 362.

In an unlocked state, threaded cap 360 is situated proximally within bore 358', as shown in FIG. 18A. Once a physician wishes to lock the suture in place, locking tool 375 may be inserted into mating slot 365 and then rotated clockwise to advance threaded cap in a distal direction, in a manner similar to tightening a screw. This causes a distal region of threaded cap 360, and preferably, distal protrusion 362, to urge flexible member 350 distally, thereby impinging upon a suture length disposed through passage 352. This effectively locks the suture in place.

If a physician subsequently desires to re-adjust the suture, then locking tool 375 can be rotated counterclockwise within mating slot 365 to proximally retract the threaded cap. This will remove the forces imposed upon the suture, as depicted in FIG. 18A.

In the embodiment of FIGS. 18A-18B, it will be apparent to one skilled in the art that flexible member 350 may be omitted entirely. In this case, threaded cap 360 will directly pinch the suture in passage 352 to lock the suture in place.

Referring now to FIGS. 19A-19B, a further alternative embodiment of the bone anchor of FIGS. 17A-17B is described. Operation of bone anchor member 340" is substantially the same as that of bone anchor 340, with the main exception that locking member 380 is provided in lieu of flexible member 350.

Locking member 380 preferably comprises cylindrical body 381, which is configured to be confined within recess 391 of main body 343", as shown in FIG. 19A. Locking member 380 further comprises distal protrusion 382, which is configured to extend at least partially through aperture 390 of main body 343".

First and second support members 383a and 383b are disposed beneath cylindrical body 381, and preferably are formed integrally with locking member 380. As shown in FIG. 19A, the first and second support members 383a and 383b rest on support ledge 395 of main body 343", thereby elevating locking member 380 within recess 391.

In operation, suture 30 is secured to tissue **T** and disposed through passage 352", as described hereinabove with respect to FIGS. 17A-17B. Bone anchor member 340" then is advanced distally into hole **H** of bone **B** (see FIG. 1), such that cleated members 346 anchor the device in hole **H**.

When locking member 380 is elevated within recess 391, distal protrusion 382 does not substantially extend into passage 352", thereby permitting movement of the suture within passage 352". At this time, a physician may individually tension first and second suture ends 32a and 32b to approximate the positioning of tissue **T** with respect to bone **B**.

Once a desired positioning is achieved, the suture may be locked in place by any number of techniques that cause first and second support members 383a and 383b to be lowered or eliminated, thereby lowering cylindrical body 381 within recess 391 and urging distal protrusion 382 towards corresponding pocket 355", as depicted in FIG. 19B. The distally-directed force applied by distal protrusion 382 secures the suture in place.

In one embodiment, first and second support members 383a and 383b may be fused with support ledge 395 of main body 343". In this embodiment, ultrasonic energy may be delivered to a proximal surface of locking member 380, via bore 358", using techniques that are known in the art. The provision of ultrasonic energy causes first and second support members 383a and 383b to fuse with support ledge 395, thereby lowering locking device 380 and locking the suture disposed within passage 352" in place.

In the embodiments of FIGS. 17-19, while only one passage 352 is depicted, it will be apparent to one skilled in the art that a second passage may be provided, e.g., disposed adjacent to the first passage. If two adjacent passages 352 are provided, then the suture can be threaded through the first passage, through tissue **T**, and threaded back through the second passage.

Further, it will be apparent to one skilled in the art that an adhesive, for example, cyanoacrylate, epoxy, bone cement and so forth, may be employed in conjunction with any of the embodiments described in FIGS. 17-19. Such an adhesive may be used in conjunction with apparatus including, but not limited to, flexible member 350, threaded cap 360, locking member 380, and any associated components.

Referring now to FIGS. 20-21, a further alternative embodiment of the present invention is described. In the embodiment of FIGS. 20-21, apparatus 400 comprises bone anchor member 402 and plug portion 410.

Bone anchor member 402 comprises main body 403 having cleated members 406, which are configured to secure bone anchor member 402 in hole **H** of FIG. 1, as described hereinabove. Further, bone anchor member 402 comprises first and second passages 408 and 412, which extend laterally through main body 403, as shown from a top view in FIG. 20A.

Bone anchor member 402 further preferably comprises guide channels 409a, 409b, 413a and 413b, which are disposed in exterior surfaces of main body 403, as shown in FIGS. 20A-20B. The guide channels preferably are similar to guide channels 50 and 52 of FIGS. 2A-2C, except that four guide channels are employed in the present embodiment.

In use, first suture end 32a passes through guide channel 409a, through passage 408 and through guide channel 409b. The first suture end then transitions into loop 34, which is threaded through tissue **T**, as described in FIGS. 1-2 hereinabove. Loop 34 of suture 30 then transitions into second suture end 32b. Second suture end 32b passes through guide channel 413b, through passage 412, and through guide channel 413a. Accordingly, the suture is coupled between the tissue and apparatus 400.

Plug portion 410 having main body 411 is configured to be disposed within a central bore of bone anchor member 402. Plug portion 410 comprises actuation knob 422, which is configured to be disposed in first recess 423 of bone anchor member 402 in an unlocked state, and disposed within second recess 424 in a locked state.

In the unlocked state, i.e., when knob 422 is disposed within first recess 423, plug portion 410 is oriented such that main body 411 does not substantially overlap with first and second passages 408 and 412 of bone anchor member 410, as depicted in FIGS. 20A-20B.

In accordance with one aspect of the present invention, a physician may selectively tension first and second ends 32a and 32b of suture 30 when knob 422 is disposed within first recess 423, as shown in FIGS. 20A-20B. This is because first and second passages 408 and 412 provide a substantially unimpeded circular channel within which the suture can pass.

When a physician desires to lock the suture in place, plug portion 410 is rotated to cause knob 422 to be advanced into second recess 424. The rotation of plug

portion 410 with respect to bone anchor member 402 may be achieved by inserting an actuation tool such as a rectangular key (not shown) into mating slot 427. Once knob 422 is secured within second recess 424, the suture will be locked in place because main body 411 of plug portion 410 impinges upon passages 408 and 412, as depicted in FIGS. 21A-21B.

Advantageously, if a physician desires to tweak the positioning of tissue **T** with respect to bone **B** after the suture is in the locked state, then the physician simply needs to insert the actuation tool into mating slot 427 to cause knob 422 to rotate back into first recess 423 (see FIGS. 20A-20B). This removes the compressive forces imposed upon the suture, such that the first and second ends of the suture may be individually tensioned to facilitate re-positioning of the tissue.

Referring now to FIGS. 22A-22B, yet a further alternative embodiment of the present invention is described. In FIG. 22A, apparatus 440 comprises bone anchor member 442 and plug portion 450. Bone anchor member 442 comprises main body 443 having cleated members 446, which are configured to secure bone anchor member 442 in hole **H** of FIG. 1, as described hereinabove. Further, bone anchor member 442 comprises central bore 444 and circumferential protrusion 449, which is disposed near a distal end of bore 444, as shown in FIG. 22A.

Plug portion 450 has main body 451 having proximal and distal regions. The proximal region comprises first and second guide channels 456 and 457, which are recessed in opposing lateral surfaces of main body 451. The distal region of main body 451 comprises circumferential recess 453 and distal taper 454, as shown in FIG. 22A. Plug portion 410 also has a central region having passage 448 disposed laterally therethrough, as depicted in FIG. 22A.

Before plug portion 450 is inserted into bore 444, first suture end 32a is passed through passage 448. The first suture end then becomes loop portion 34a, which is threaded through tissue **T**. Loop portion 34a extends through the tissue to become loop portion 34b. Loop portion 34b passes back through passage 448 and becomes second suture end 32b. First and second suture ends 32a and 32b may be manipulated by a physician, as described in further detail hereinbelow.

Alternatively, as described hereinabove, a central region of suture 30 may be threaded through tissue **T**, and the free ends of the suture then may be passed through

passage 448 in a proximal direction to achieve the suture positioning depicted in FIG. 22A.

In a preferred method of use, bone anchor member 442 is inserted into hole **H** of bone **B** before plug portion 450 is inserted into bore 444. Once bone anchor member 442 is securely disposed within hole **H**, plug portion 450 is positioned slightly above bone anchor member 442, so that passage 448 is proximal to bore 444. At this time, a physician may individually tension first and second suture ends 32a and 32b to approximate the positioning of tissue **T** with respect to bone **B** (see FIG. 1).

Once the desired positioning is achieved, the physician advances plug portion 450 distally into bore 444 of bone anchor member 442. An insertion tool, such as insertion tool 294 of FIGS. 13A-13C, may be inserted into mating slot 458 to advance plug portion 450 distally. The provision of a sufficient distally-directed force urges taper 454 over circumferential protrusion 449, thereby locking the plug portion within the bone anchor member, as shown in FIG. 22B.

At this time, first and second suture ends 32a and 32b are compressed within guide channel 456, while suture loop portions 34a and 34b are compressed within guide channel 457, as depicted in FIG. 22B. Guide channels 456 and 457 may be sized to ensure that the suture is completely locked in place when plug portion 450 is inserted into bore 444. Alternatively, guide channels 456 and 457 may be sized to permit incremental adjustments of the suture, such that applying a sufficient tension to free ends 32a and 32b will overcome the frictional forces between the suture, plug portion 450 and bone anchor member 442.

Referring now to FIGS. 23A-23C, an alternative plug portion, which may be used in lieu of plug portion 450 of FIGS. 22A-22B is described. In FIG. 23A, plug portion 450' comprises distal passage 466, in lieu of passage 448 of FIGS. 22A-22B. Distal passage 466 is formed as a slot recessed in the distal end of main body 451, as shown in FIGS. 23A-23C. Distal passage 466 preferably is in communication with opposing guide channels 456 and 457.

The operation of a bone anchor system using plug portion 450' is substantially similar to the steps described in FIGS. 22A-22B, with the exception that first and second suture ends 32a and 32b are disposed within distal passage 466. Specifically,

in use, the suture ends can be looped around the distal end of plug portion 450', and need not be inserted by threading through central passage 448. Once the suture ends are looped around the distal end of plug portion 450' and confined within passage 466, then a physician may hold the suture in place while inserting plug portion 450' into bone anchor member 442. Once the plug portion is locked into place via circumferential protrusion 449, as described in FIG. 22B, then the suture is compressed between plug portion 450' and bone anchor member 442.

Referring now to FIGS. 24A-24B, a further alternative embodiment of the invention is described. In FIG. 24A, the apparatus comprises alternative bone anchor member 442" and alternative plug portion 450". The alternative bone anchor member and plug portion are similar to bone anchor member 442 and plug portion 450 of FIGS. 22A-22B, except as noted below.

Alternative plug portion 450" comprises main body 451' having first suture clearance channel 456' formed in a first lateral surface of the body, and second suture clearance channel 457' formed in an opposing lateral surface of the body. Plug portion 450" further comprises clearance recess 455 on a distal region of main body 451', along with suture channel 466'.

Main body 451' further comprises plurality of cleated members 459a, which are formed adjacent to suture channel 466'. Also, bone anchor portion 442" comprises plurality of cleated members 459b formed in bore 444, as shown in FIG. 24A. Cleated members 459b are configured to oppose cleated members 459a when plug portion 450" is disposed in bore 444 of bone anchor member 442", as shown in FIG. 24B.

In a preferred method of use, suture length 30a is coupled to bone anchor member 442" by first forming loop 470 between regions 35a and 35b of the suture. A central portion of suture 30a then is looped around suture channel 466' of plug portion 450". At this time, proximal suture ends 33a and 33b are in the vicinity of clearance channel 456', while suture regions 35a and 35b are in the vicinity of clearance channel 457'. In a next step, plug portion 450" then is lowered into bore 444 of bone anchor member 442", as depicted in FIG. 24B.

When an appropriate force is applied, distal taper 454 of plug portion 450" passes over protrusion 449 of bone anchor member 442". At this time, protrusion 449

is confined within recess 453, as shown in FIG. 24B, to substantially inhibit movement of plug portion 450" with respect to bone anchor member 442". Further, at this time, proximal suture ends 33a and 33b are disposed within clearance channel 456', while suture regions 35a and 35b are disposed within clearance channel 457'.

In one embodiment of FIGS. 24A-24B, suture loop 470 may be coupled directly to tissue **T**, as generally set forth hereinabove. In this embodiment, tensioning suture ends 33a and 33b will directly effect positioning of tissue **T**. Further, as set forth above, cleated members 459a and 459b form a one-way channel that facilitates tensioning of the suture ends, and locks the suture ends in place.

However, as described in the alternative embodiment of FIGS. 25A-25B, a second suture length may be employed. In this embodiment, second suture length 30b is used in conjunction with first suture length 30a of FIGS. 24A-24B.

In FIG. 25A, second suture length 30b has loop 471, which is coupled directly to tissue **T**. As depicted in FIG. 25A, loop 471 is formed between suture portions 34a and 34b. Proximal to suture portions 34a and 34b, second suture 30b comprises proximal ends 32a and 32b, which are configured to be manipulated by a physician, as set forth below.

Referring still to FIG. 25A, second suture 30b is coupled to first suture 30a by pulling proximal ends 32a and 32b through loop 470, as shown in FIG. 25A. At this time, four proximal suture ends will extend proximally from the access cannula (not shown). Specifically, proximal ends 32a and 32b of second suture 30b, along with proximal ends 33a and 33b of first suture 30a, will all extend from the access cannula. Advantageously, a physician may individually tension each of the four suture ends.

As each of the four suture ends 32a, 32b, 33a and 33b are selectively tensioned by a physician, loop 470 and suture regions 35a and 35b are urged towards clearance channel 457', as shown in FIG. 25B. When loop 470 is drawn towards clearance channel 457', second suture 30b also is drawn towards the clearance channel, i.e., because proximal ends 32a and 32b of the second suture have been previously pulled through loop 470.

At this time, the various suture regions that are drawn towards clearance channel 457' become jammed within the clearance channel to effectively lock the sutures in place. In effect, as tension is applied to the four suture ends 32a, 32b, 33a

and 33b, tissue **T** is approximated to bone, and ultimately, the sutures are locked in place.

Advantageously, the method steps of FIGS. 24-25 may save a physician considerable time and effort during a surgical procedure. For example, bone anchor member 442", plug portion 450" and first suture 30a (including loop 470) may be provided to the physician in an already assembled state, as shown in FIG. 24B. The physician need not assemble these components during the surgical procedure.

Then, at an appropriate time, a physician may couple second suture 30b to tissue **T** via loop 471. Advantageously, in the embodiment of FIGS. 25A-25B, a physician need not thread proximal suture ends 32a and 32b through plug portion 450" or bone anchor member 442" after suture 30b is coupled to tissue **T**. Rather, the physician simply needs to pull suture ends 32a and 32b through loop 470 of first suture 30a. In short, the physician simply needs to couple first suture 30a to tissue **T**, then guide proximal ends 32a and 32b through previously-provided loop 470, thereby saving operating time and effort.

Referring to Figs. 26A-26D, another suture anchor 500 is shown. The suture anchor 500 includes a main body 502 and an insert 504. The main body 502 has cleats 506 which are used to secure the anchor 500 to bone as discussed above. Of course, the main body 502 may have any other suitable feature to secure the anchor 500 to bone, such as an expandable portion, without departing from the scope of the invention.

The insert 504 is positioned in a recess 508 in the main body 502. The suture enters the anchor 500 through the proximal end of the recess 508 and extends through a space between the main body 502 and the insert 504. The suture then passes through a hole 510 in the insert 504. The hole 510 is somewhat triangular shaped to accommodate different size suture as shown in Fig. 26D.

The insert 504 is movable between the closed position of Fig. 26B and the open position of Fig. 26C. The recess 508 has a bevelled surface 512 on each side facing the throughhole 510 in the insert 504. The suture is captured between the bevelled surface 512 and an upper end 514 of the throughhole 510 when the insert 504 is in the closed position of Fig. 26B. The insert 504 is naturally biased toward the closed position by a spring portion 516 on the insert 504. The spring portion 516 is

formed by a spiral cut 518 in the insert 504. The insert 504 also has a pinned connection 520 with the main body 502 near the distal end. A pin 522 extends through a hole 524 in the insert 504 to provide the pinned connection 520. Although the spring portion 516 is formed integral with the insert 504 a separate spring may also be provided similar to other embodiments described herein.

The insert 504 may be moved to the unlocked position of Fig. 26C by pulling on an insert manipulator 524. The manipulator 524 may simply be a flexible tether 526 which is pulled to move the insert 504 to the unlocked position. When the procedure is completed, the tether 526 may be cut and removed. The manipulator 524 provides the user with the ability to adjust suture tension as needed. The anchor 500 is used in the same or similar manner as the other anchors described herein and the discussion concerning use of the other anchors is expressly incorporated here.

Referring to Figs. 27A-27B, another bone anchor 530 is shown. The bone anchor 530 has a main body 532 with cleats 531 used to secure the anchor to bone although any other feature may be provided to secure the anchor 530 to bone. The suture is locked with a suture lock 533 which permits the suture to be advanced in the direction of arrow 556 but prevents movement in the other direction. The suture extends around a bearing surface 534 which may be a roller 536 although a non-rotating member may also be used. The roller 536 is mounted within a hole 538. The suture lock 533 has a first locking portion 540 and a second locking portion 542 but may include any number of locking portions.

The first and second locking portions 540, 542 are integrally formed as a ring clip 550 which seats within an annular recess 552 in the main body 532. Each suture lock 540, 542 has a suture engaging portion 554 extending from the ring clip 550. The suture locks 540, 542 also have an integrally formed living hinge 556 which permits the suture engaging portion 554 to deflect inwardly when suture is pulled in the direction of arrow 556. The suture lock 533 permits the suture to be pulled in the direction of arrow 556 and prevents the suture from being moved in the opposite direction. The anchor 530 is used in the same manner as the other anchors described herein and the discussion concerning use of the other anchors is expressly incorporated here.

Referring to Figs. 28A and 28B, still another bone anchor 560 is shown wherein the same or similar reference numbers refer to the same or similar structure. The anchor 560 has a suture lock 564 which permits the suture to be pulled in the direction of arrow 566 and prevents movement in the other direction. The suture lock 564 includes a cam 568 having a pinned connection 570 formed by a pin 571 rotatable within hole 573. The suture is locked when trapped between the cam 568 and an inner surface 574 of the main body 572. The anchor 560 is used in substantially the same manner as the other anchors described herein and such use is expressly incorporated here.

The anchor 560 also includes a release element 576 for releasing the suture lock 564. The release element 576 may be part of an introducer 578 which is used when advancing the anchor 560 into bone as is known in the art. The release element 576 extends through a lumen in the introducer 578. The release element 576 may have a threaded connection with the main body 572 so that the release element 576 may be rotated and advanced to the release position of Fig. 28B. The release element contacts an upper portion of the cam 568 and pivots the cam 568 to the open position of Fig. 28B thereby permitting manipulation of the suture in either direction.

In each of the embodiments described hereinabove, it will be apparent to those skilled in the art that various means for securing a bone anchor member within hole **H** of bone **B** may be employed. Cleated members 42 of FIG. 2A, which are depicted in most of the embodiments herein, are merely one exemplary means for securing. Other alternative means for securing may be used in conjunction with the apparatus and methods of the present invention. As an example, the bone anchor member may employ one or more radially expandable members that extend into the surrounding bone.

Further, while some of the embodiments of the present invention describe use of a bone anchor member only, and other embodiments describe use of a bone anchor member and a plug portion, many of these features may be interchanged. It will be apparent to one skilled in the art that many embodiments depicting a bone anchor member only may be performed using a bone anchor member and plug portion, and vice versa.

Also, for those embodiments described hereinabove having a bone anchor member and a plug portion, it will be apparent to those skilled in the art that the suture ends may be tensioned either before or after the plug portion is inserted into the bore of the bone anchor member.

It will also be apparent to one skilled in the art that the plug portion may be securely disposed within the bore of the bone anchor member using various means not specifically disclosed herein. For example, after the plug portion is inserted into the bore of the bone anchor member, an adhesive, for example, cyanoacrylate, epoxy, bone cement and so forth, may be delivered to affix the plug portion to the bone anchor member. Alternatively, an exterior surface of the plug portion may be coated with a biocompatible adhesive that affixes to the bone anchor member after the plug portion is inserted into the bore of the bone anchor member. In yet a further alternative embodiment, heat energy may be applied to fuse the plug portion to the bone anchor member. It will be apparent to one skilled in the art that still further means for securing the plug portion to the bone anchor member may be employed.

In still further embodiments of the present invention, the objective of the present invention may be achieved using multiple bone anchor members, or multiple bone anchor members coupled to respective plug portions. In each embodiment, one or more sutures may be coupled between a desired tissue region and the bone anchor member or plug portion. If multiple sutures and bone anchor members are employed, enhanced sequential tensioning of the tissue may be achieved.

finally, while the above-described embodiments reference use of apparatus and methods for facilitating attachment of tissue to bone, it will be apparent to one skilled in the art that such apparatus and methods may also be used to secure tissue to tissue and bone to bone.

While preferred illustrative embodiments of the invention are described above, it will be apparent to one skilled in the art that various changes and modifications may be made therein without departing from the invention. The appended claims are intended to cover all such changes and modifications that fall within the true spirit and scope of the invention.

IN THE CLAIMS:

1. Apparatus suitable for coupling tissue to bone via a suture loop, the apparatus comprising:

a bone anchor member; and

means for locking a suture coupled between the bone anchor member and tissue,

wherein positioning of the tissue with respect to the bone is effected by individually tensioning first and second ends of the suture.

2. The apparatus of claim 1 further comprising a plurality of cleated members disposed on an exterior surface of the bone anchor member and configured to secure the bone anchor member within a hole drilled in the bone.

3. The apparatus of claim 1 wherein the means for locking comprises a first passage disposed laterally through the bone anchor member.

4. The apparatus of claim 3 wherein the first passage comprises at least one cleated member configured to permit incremental tensioning of the first suture end.

5. The apparatus of claim 4 wherein the cleated member permits movement of the first end of the suture in a proximal direction only.

6. The apparatus of claim 5 wherein the cleated member comprises an angled section disposed adjacent to a substantially orthogonal section.

7. The apparatus of claim 3 wherein the means for locking further comprises a second passage disposed laterally through the bone anchor member.

8. The apparatus of claim 7 wherein the second passage comprises at least one cleated member configured to permit incremental tensioning of the first suture end.

9. The apparatus of claim 8 wherein the cleated member permits movement of the second end of the suture in a proximal direction only.

10. The apparatus of claim 1 further comprising a first guide channel disposed in an outer surface of the bone anchor, wherein the first guide channel is configured to permit movement of the suture when the bone anchor member is disposed within the hole of the bone.

11. The apparatus of claim 10 further comprising a second guide channel disposed in an outer surface of the bone anchor at a location substantially diametrically opposing the first guide channel.

12. The apparatus of claim 1 wherein the bone anchor member comprises at least one adhesive delivery channel.

13. The apparatus of claim 1 wherein the hole drilled in the bone is a through hole, and the bone anchor member further comprises a proximal end having a flange configured to abut the bone when a main body of the bone anchor member is disposed in the through hole.

14. The apparatus of claim 13 wherein the bone anchor member further comprises first and second passages configured to receive the first and second suture ends.

15. The apparatus of claim 14 wherein the first and second passages each comprise at least one cleated member configured to permit proximal retraction of the first and second suture ends.

16. The apparatus of claim 1 wherein the means for locking comprises:

a locking member having a cylindrical body, a distal protrusion, and at least one support member, wherein the locking member is configured to be received within a bore of the bone anchor member; and

at least one passage extending laterally through the bone anchor member, the passage disposed distal to the cylindrical body of the locking member,

wherein distal advancement of the locking member is configured to cause the distal protrusion to extend into the passage to lock the suture in place.

17. The apparatus of claim 16 further comprising:

a support ledge disposed between the cylindrical body and the passage, the support ledge having an aperture through which the distal protrusion at least partially extends,

wherein the support members are configured to rest upon the support ledge in an unlocked state to permit movement of the suture within the passage.

18. Apparatus suitable for facilitating attachment of tissue to bone, the apparatus comprising:

a bone anchor member having a bore; and

a plug portion configured to be inserted into the bore of the bone anchor member,

wherein positioning of the tissue with respect to the bone is effected by individually tensioning first and second ends of a suture coupled between the plug portion and the tissue.

19. The apparatus of claim 18 wherein the plug portion has an outer surface having at least one cleated member, wherein the cleated member is configured to secure the plug portion within the bore of the bone anchor member.

20. The apparatus of claim 18 wherein the plug portion has a substantially smooth exterior surface configured to engage at least one interior cleated member disposed in the bore of the bone anchor member.

21. The apparatus of claim 18 wherein the plug portion comprises a first passage extending laterally therethrough, wherein the first passage is sized to allow passage of the first end of the suture therethrough.

22. The apparatus of claim 21 wherein the first passage comprises at least one cleated member.

23. The apparatus of claim 21 wherein the plug portion further comprises a second passage extending laterally therethrough, wherein the second passage is sized to allow passage of the second end of the suture therethrough.

24. The apparatus of claim 23 wherein the second passage comprises at least one cleated member.

25. The apparatus of claim 18 further comprising a first guide channel disposed in an outer surface of the plug portion and configured to permit movement of the suture when the plug portion is disposed within the bone anchor member.

26. The apparatus of claim 25 wherein the plug portion comprises a second guide channel substantially opposing the first guide channel.

27. The apparatus of claim 18 wherein an outer diameter of the plug portion is slightly larger than an inner diameter of the bore of the bone anchor member to permit a frictional fit therebetween.

28. The apparatus of claim 27 further comprising:

a taper disposed at a distal end of the plug portion; and

a taper disposed at a proximal end of the bore to facilitate insertion of the plug portion into the bore.

29. The apparatus of claim 18 further comprising:

an inward taper disposed at a proximal region of the bone anchor member; and

a proximal stop formed between the inward taper and an inner wall of the bore,

wherein the proximal stop is configured to retain the plug portion within the bore after the plug portion is advanced distally beyond the inward taper.

30. The apparatus of claim 18 further comprising:

a circumferential protrusion disposed near a distal end of the bore; and

a circumferential recess disposed at a distal region of the plug portion,

wherein the circumferential protrusion is configured to be secured within the circumferential recess when the plug portion is inserted into the bone anchor member.

31. The apparatus of claim 30 further comprising a passage extending laterally though a central region of the plug portion, the passage configured to receive the first and second suture ends.

32. The apparatus of claim 30 further comprising a distal passage formed as a slot in a distal end of the plug portion, the distal passage configured to receive the first and second suture ends.

33. Apparatus suitable for facilitating attachment of tissue to bone, the apparatus comprising:

a bone anchor member;

means for locking a suture having first and second ends; and

means for unlocking the suture to enable movement of the first and second ends.

34. The apparatus of claim 33 further comprising a plurality of cleated members disposed on an exterior surface of the bone anchor member and configured to secure the bone anchor member within a hole drilled in the bone.

35. The apparatus of claim 33 wherein the means for locking and the means for unlocking comprises:

a flexible member formed in a bore of the bone anchor member; and

at least one passage extending laterally through the bone anchor member, the passage disposed distal to the flexible member,

wherein the suture is configured for movement within the passage in an unlocked state.

36. The apparatus of claim 35 wherein the application of a distally-directed force acting upon the flexible member is configured to lock the suture within the passage.

37. The apparatus of claim 36 wherein removal of the distally-directed force is configured to permit movement of the suture within the passage.

38. The apparatus of claim 36 wherein the flexible member comprises a distal knob configured to pinch the suture in a locked state.

39. The apparatus of claim 35 wherein the flexible member has only two stable states.

40. The apparatus of claim 39 wherein the application of a distally-directed force acting upon the flexible member is configured to transform the flexible member to a second stable state that substantially inhibits movement of the suture.

41. The apparatus of claim 40 wherein the application of a proximally-directed force acting upon the flexible member is configured to transform the flexible member to a first stable state that permits movement of the suture.

42. The apparatus of claim 33 further comprising first and second guide channels disposed in opposing outer surfaces of the bone anchor member and

configured to permit movement of the suture when the bone anchor member is disposed in the hole in the bone.

43. The apparatus of claim 33 wherein the means for locking and the means for unlocking comprises:

a threaded cap;

a grooved interior section disposed in a bore of the bone anchor member, the grooved interior section configured to receive the threaded cap; and

a passage extending laterally through the bone anchor member, the passage disposed distal to the threaded cap,

wherein distal advancement of the threaded cap within the grooved interior section is configured to pinch the suture to lock the suture in place.

44. The apparatus of claim 43 wherein proximal movement of the threaded cap within the grooved interior section is configured to unlock the suture to allow movement of the suture within the passage.

45. The apparatus of claim 43 further comprising:

a mating slot disposed in a proximal surface of the threaded cap; and

a locking tool configured to engage the mating slot,

wherein rotation of the locking tool in a first direction is configured to cause rotation of the threaded cap to lock the suture in place.

46. The apparatus of claim 45 wherein rotation of the locking tool in a second direction is configured to cause rotation of the threaded cap to unlock the suture.

47. The apparatus of claim 33 wherein the bone anchor member further comprises:

a bore; and

first and second passages extending laterally through the bone anchor member.

48. The apparatus of claim 47 wherein the means for locking and the means for unlocking comprises:

a plug portion configured to be received within the bore of the bone anchor member, the plug portion having first and second passages extending laterally therethrough,

wherein the first end of the suture is configured to be threaded through the first passage of the bone anchor member and the first passage of the plug portion, and the second end of the suture is configured to be threaded through the second passage of the bone anchor member and the second passage of the plug portion.

49. The apparatus of claim 48 wherein the first passage of the bone anchor member and the first passage of the plug portion are configured to be substantially aligned to permit movement of the first end of the suture in an unlocked state.

50. The apparatus of claim 49 wherein the second passage of the bone anchor member and the second passage of the plug portion are configured to be substantially aligned to permit movement of the second end of the suture in the unlocked state.

51. The apparatus of claim 49 wherein the first passage of the bone anchor member and the first passage of the plug portion suture are configured to be misaligned to prohibit movement of the first end of the suture in a locked state.

52. The apparatus of claim 51 wherein the second passage of the bone anchor member and the second passage of the plug portion suture are configured to be misaligned to prohibit movement of the second end of the suture in the locked state.

53. The apparatus of claim 48 further comprising at least one spring member disposed near a distal region of the bore, the spring member configured to affect the positioning of the plug portion with respect to the bone anchor member.

54. The apparatus of claim 53 wherein the spring member has a first state in which the plug portion is disposed proximally within the bore to lock the suture in place.

55. The apparatus of claim 54 wherein the spring member has a second state in which the spring member is deformed distally to permit movement of the suture.

56. The apparatus of claim 55 wherein the plug portion comprises a proximal flange configured to hold the plug portion within the bore of the bone anchor member.

57. The apparatus of claim 47 wherein the means for locking and the means for unlocking comprises:

a plug portion configured to be received within the bore of the bone anchor member,

wherein the first end of the suture is configured to be threaded through the first passage of the bone anchor member, and the second end of the suture is configured to be threaded through the second passage of the bone anchor member,

wherein the plug portion is configured to be rotated circumferentially within the bone anchor.

58. The apparatus of claim 57 wherein the plug portion is configured to be rotated in a first direction to lock the first and second suture ends within the first and second passages, respectively.

59. The apparatus of claim 58 wherein the plug portion is configured to be rotated in a second direction to unlock the first and second suture ends, thereby permitting movement of the first and second suture ends within the first and second passages, respectively.

60. The apparatus of claim 59 wherein the plug portion comprises an actuation knob configured to engage a first recess of the bone anchor member in a locked state.

61. The apparatus of claim 60 wherein the actuation knob is configured to engage a second recess of the bone anchor member in an unlocked state.

62. The apparatus of claim 33 wherein the means for locking and the means for unlocking comprises:

a first semi-circular channel formed in a main body of the bone anchor member; and

a plug portion having a first semi-circular channel,

wherein the first semi-circular channel of the bone anchor member is configured to be aligned with the first semi-circular channel of the plug portion to form a first circular channel, wherein the first circular channel is configured to permit movement of the first suture end therein.

63. The apparatus of claim 62 wherein rotation of the plug portion with respect to the bone anchor member is configured to misalign the first semi-circular channel of the plug portion and the first semi-circular channel of the bone anchor member to lock the first suture end in place.

64. The apparatus of claim 62 further comprising:

a second semi-circular channel formed in the main body of the bone anchor member; and

a second semi-circular channel formed in the plug portion,

wherein the second semi-circular channel of the bone anchor member is configured to be aligned with the second semi-circular channel of the plug portion to form a second circular channel, wherein the second circular channel is configured to permit movement of the second suture end therein.

65. The apparatus of claim 64 wherein rotation of the plug portion with respect to the bone anchor member is configured to misalign the second semi-circular channel of the plug portion and the second semi-circular channel of the bone anchor member to lock the second suture end in place.

66. A method for facilitating attachment of tissue to bone, the method comprising:

providing apparatus comprising a bone anchor member having first and second passages extending laterally therethrough;

inserting a first end of a suture through the first passage and a second end of the suture through the second passage to form a loop therebetween, wherein the loop is coupled to tissue; and

tensioning the first end of the suture to draw the tissue towards the bone.

67. The method of claim 66 further comprising tensioning the first end of the suture prior to insertion of the bone anchor member into a hole drilled in the bone.

68. The method of claim 66 further comprising tensioning the first end of the suture after insertion of the bone anchor member into a hole drilled in the bone.

69. The method of claim 66 further comprising tensioning the second end of the suture to draw the tissue towards the bone.

70. The method of claim 66 further comprising:

providing at least one cleated member in the first passage;

incrementally tensioning the first suture end; and

locking the first suture end within the first passage using the cleated member.

71. The method of claim 70 further comprising:

providing at least one cleated member in the second passage;

incrementally tensioning the second suture end; and

locking the second suture end within the second passage using the cleated member.

72. A method for facilitating attachment of tissue to bone, the method comprising:

providing apparatus comprising a bone anchor member having a first passage extending laterally therethrough;

threading a suture through the first passage;

coupling the suture to tissue to form a loop;

guiding the suture back through the first passage, so that first and second ends of the suture may be manipulated by a physician; and

tensioning the first end of the suture to draw the tissue towards the bone.

73. The method of claim 72 further comprising:

providing a flexible member at a location proximal to the first passage; and

causing distal advancement of the flexible member to pinch the suture and lock the suture in place.

74. The method of claim 73 further comprising permitting proximal movement of the flexible member to unlock the suture.

75. The method of claim 72 further comprising:

providing a threaded cap configured for proximal and distal movement within a grooved interior section of the bone anchor member, wherein the threaded cap is disposed proximal to the first passage; and

distally advancing the threaded cap to pinch the suture and lock the suture in place.

76. The method of claim 75 further comprising proximally retracting the threaded cap to unlock the suture.

77. The method of claim 72 further comprising:

providing a locking member having a cylindrical body, a distal protrusion, and at least one support member, wherein the locking member is configured to be received within a bore of the bone anchor member; and

distally advancing the locking member to cause the distal protrusion to pinch the suture and lock the suture in place.

78. A method for facilitating attachment of tissue to bone, the method comprising:

providing apparatus comprising a bone anchor member and a plug portion;

inserting the bone anchor member into a hole drilled into the bone;

inserting the plug portion into a bore of the bone anchor member; and

tensioning at least one end of a suture coupled between the plug portion and the tissue.

79. The method of claim 78 further comprising:

threading a first end of the suture through a first passage in the plug portion and a first passage in the bone anchor member;

threading a second end of the suture through a second passage in the plug portion and a second passage in the bone anchor member; and

aligning the first passage in the plug portion with the first passage in the bone anchor member to permit movement of the first end of the suture.

80. The method of claim 79 further comprising misaligning the first passage in the plug portion with the first passage in the bone anchor member to lock the first end of the suture.

81. The method of claim 79 further comprising aligning the second passage in the plug portion with the second passage in the bone anchor member to permit movement of the second end of the suture.

82. The method of claim 81 further comprising misaligning the second passage in the plug portion with the second passage in the bone anchor member to lock the second end of the suture.

83. The method of claim 79 further comprising deforming at least one spring member disposed near a distal region of the bore to cause the first passage of the plug portion to become aligned with the first passage of the bone anchor member.

84. The method of claim 78 further comprising:

threading a first end of the suture through a first passage of the bone anchor member;

threading a second end of the suture through a second passage of the bone anchor member; and

rotating the plug portion circumferentially with respect to the bone anchor member to lock the suture in place.

85. The method of claim 84 wherein the plug portion is rotated in a first direction to lock the first and second suture ends within the first and second passages, respectively.

86. The method of claim 85 further comprising rotating the plug portion in a second direction to unlock the first and second suture ends, thereby permitting movement of the first and second suture ends within the first and second passages, respectively.

87. The method of claim 86 further comprising securing an actuation knob of the plug portion within a first recess of the bone anchor member in a locked state.

88. The method of claim 87 further comprising securing the actuation knob of the plug portion in a second recess of the bone anchor member in an unlocked state.

89. The apparatus of claim 1 wherein the bone anchor member comprises first and second mating portions.

90. The apparatus of claim 89 wherein the first mating portion comprises first and second cleated passage portions.

91. The apparatus of claim 90 wherein the second mating portion comprises first and second cleated passage portions that are configured to be in communication with the first and second cleated passage portions, respectively, of the first mating portion.

92. The apparatus of claim 89 wherein the first mating portion comprises at least one mating pocket, and wherein the second mating portion comprises at least one protrusion configured to securely engage the mating pocket.

93. The apparatus of claim 92 wherein the protrusion comprises a ledge to enhance the engagement between the first and second mating portions.

94. The apparatus of claim 18 wherein the plug portion comprises first and second plug portions.

95. The apparatus of claim 94 wherein the first and second plug portions are coupled together using a hinge member.

96. The apparatus of claim 95 wherein the hinge member is coupled between distal ends of the first and second plug portions.

97. The apparatus of claim 95 wherein the hinge member is coupled between lateral surfaces of the first and second plug portions.

98. The apparatus of claim 94 wherein the first plug portion comprises first and second cleated passage portions.

99. The apparatus of claim 98 wherein the second plug portion comprises first and second cleated passage portions that are configured to be in communication with the first and second cleated passage portions, respectively, of the first plug portion.

100. The apparatus of claim 99 wherein the first and second cleated passage portions of the first plug portion are larger than the first and second cleated passage portions of the second plug portion.

101. Apparatus suitable for facilitating attachment of tissue to bone, the apparatus comprising:

a bone anchor member having a bore;

a plug portion configured to be inserted into the bore of the bone anchor member;

a first suture length having first and second ends and a loop disposed therebetween, wherein the first suture length is coupled to the bone anchor member; and

a second suture length having first and second ends and a loop coupled to tissue,

wherein the second suture length is coupled to the first suture length.

102. The apparatus of claim 101 wherein the second suture length further is coupled between the plug portion and the loop of the first suture length.

103. The apparatus of claim 101 wherein a physician may individually tension any of the first and second ends of the first suture length, or the first and second ends of the second suture length, to approximate positioning of the tissue with respect to a bone.

104. The apparatus of claim 101 further comprising a clearance channel formed between the bone anchor member and the plug portion.

105. The apparatus of claim 104 wherein the first and second ends of the second suture length are locked in place by jamming the second suture length within the clearance channel.

106. A method of securing suture to bone, comprising the steps of:

providing an anchor having a main body and an insert, the insert having a throughhole, the insert being movable relative to the main body between an open position and a closed position, the insert being biased by a spring force toward the closed position;

introducing the main body into a bone;

positioning a suture in the throughhole;

moving the insert to the open position by overcoming the spring force;

tensioning the suture after the moving step; and

permitting the insert to move back toward the closed position after the tensioning step.

107. The method of claim 107, wherein:

the providing step is carried out with the main body having longitudinal axis, the insert moving longitudinally when moving between the open and closed positions.

108. The method of claim 107, wherein:

the providing step is carried out with the insert including a spring portion which creates the spring force.

109. The method of claim 107, wherein:

the providing step is carried out with the insert having a pinned connection with the main body.

110. The method of claim 107, wherein:

the providing step is carried out with the suture anchor having an insert manipulator coupled to the insert; and

the moving step is carried out by tensioning the insert manipulator to move the insert toward the open position.

111. The method of claim 111, wherein:

the providing step being carried out with the insert manipulator being a flexible tether.

112. The method of claim 112, wherein:

the moving step is carried out with the flexible tether being free to extend from the proximal end of the main body in any direction.

113. The method of claim 107, further comprising the step of:

removing the manipulator from the anchor.

114. The method of claim 114, wherein:

the removing step is carried out by cutting and removing the manipulator.

115. A device for securing suture to bone, comprising:

a main body having a recess; and

an insert positioned in the recess, the insert being movable within the recess between an unlocked position and a locked position, the insert being biased by a spring force toward the locked position, the insert having a throughhole which receives suture, wherein suture in the throughhole is locked when the insert is in the locked position and is free to move in the throughhole when the insert is in the unlocked position.

116. The device of claim 116, wherein:

the main body has longitudinal axis, the insert being longitudinally movable within the recess when moving between the locked and unlocked positions.

117. The device of claim 116, wherein:

the insert includes a spring portion which creates the spring force.

118. The device of claim 116, wherein:

the insert has a pinned connection with the main body.

119. The device of claim 116, further comprising:

a manipulator coupled to the insert, the manipulator being tensioned to move the insert to the locked position.

120. The device of claim 120, wherein:

the manipulator is a flexible tether.

121. The device of claim 112, wherein:

the flexible tether is free to extend from the proximal end of the main body in any direction.

122. The device of claim 116, wherein:

the manipulator is removable.

123. A method of securing suture to bone, comprising the steps of:

providing a bone anchor and a length of suture, the bone anchor having a first suture lock, a proximal end, a distal end and a first suture passage;

positioning a first suture portion from the length of suture in the first suture passage, the length of suture having a first side and a second side extending

from each side of the first suture portion, the first and second sides extending from the proximal end of the anchor;

coupling the first side of the length of suture to a tissue structure;

introducing the bone anchor into bone in a distal direction so that the distal end is embedded in the bone;

pulling the second side to increase tension in the first side of the length of suture after the introducing step, the first and second sides extending from the proximal end of the bone anchor; and

releasing tension on the first side of the length of suture, the first suture portion being automatically locked by the suture lock upon releasing tension on the first suture.

124. The method of claim 124, wherein:

the providing step is carried out with the bone anchor having a main body, the main body having a bearing surface;

the positioning step is carried out with the suture extending around the bearing surface, the first suture lock permitting the suture to be pulled in one direction and preventing the suture from being pulled in the other direction.

125. The method of claim 125, wherein:

the providing step is carried out with the bone anchor having a second suture lock;

the positioning step is carried out with the first suture lock positioned between the bearing surface and the proximal end, the first side of the length of suture extending from the first suture lock, the second suture lock positioned between the bearing surface and the proximal end, the second side of the length of suture extending from the second suture lock.

126. The method of claim 126, wherein:

the providing step is carried out with the first and second suture locks being integrally formed with one another.

127. The method of claim 124, wherein:

the providing step is carried out with the first suture lock having an integrally formed hinge section;

the pulling step is carried out with the hinge section being elastically deformed to permit pulling the suture.

128. The method of claim 124, wherein:

the providing step is carried out with the anchor having a main body, the first suture lock including a cam pivotally coupled to the main body.

129. The method of claim 124, wherein:

the positioning step is carried out with the length of suture extending from the proximal end of the anchor distally to the cam, the length of suture extending from the cam proximally back to the proximal end of the anchor.

130. The method of claim 124, further comprising the step of:

pivoting the cam in an unlocking direction which releases the suture; and

adjusting tension on the length of suture during the pivoting step.

131. The method of claim 124, wherein:

the introducing step is carried out with the anchor mounted to an introducer;

the pulling step being carried out after removing the introducer; and

the pivoting step being carried out by coupling the anchor to the introducer.

132. The method of claim 124, wherein:

the pivoting step is carried out by moving an actuating element into contact with the cam to pivot the cam.

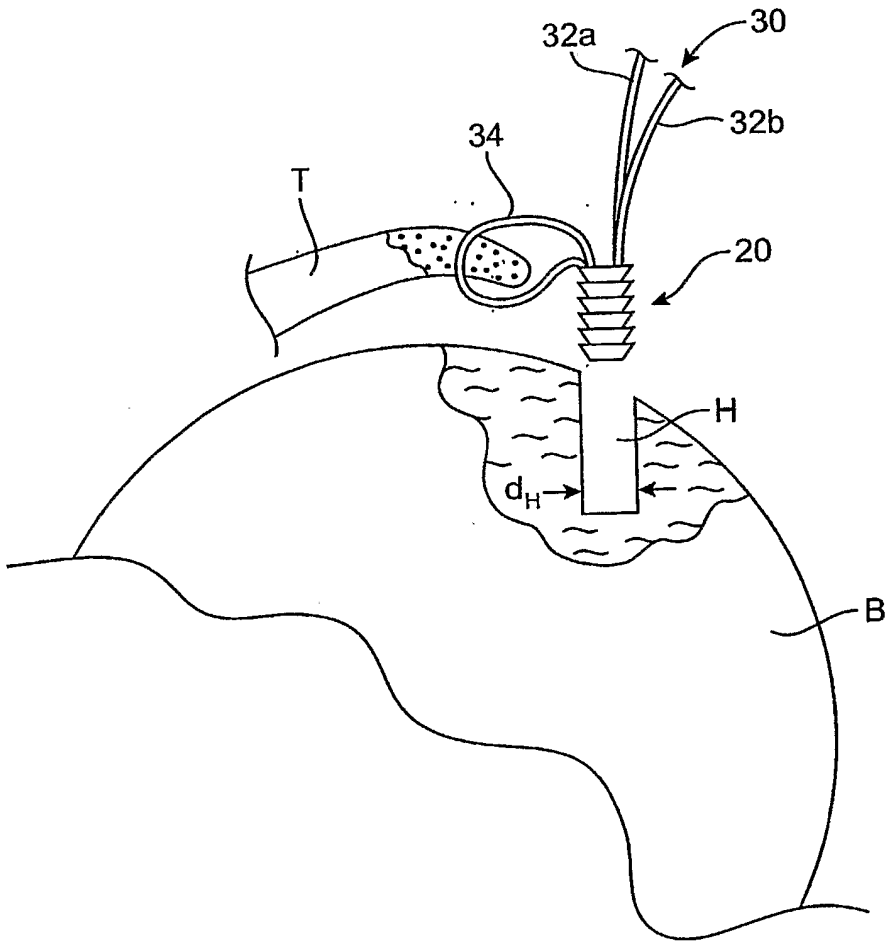

FIG. 1

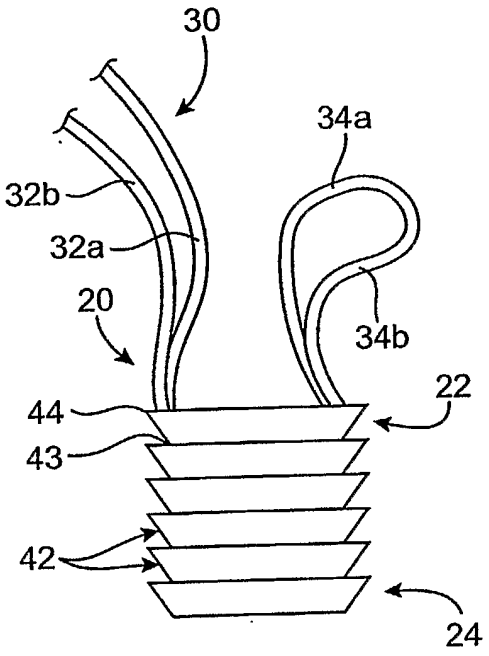

FIG. 2A

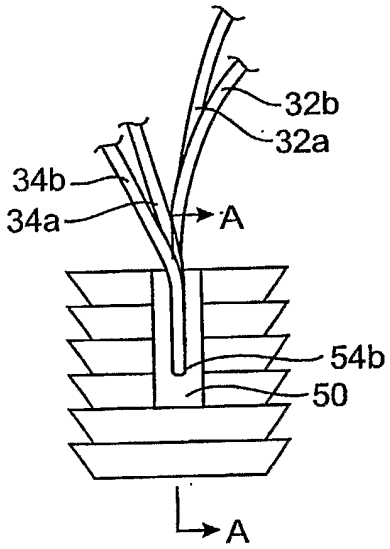

FIG. 2B

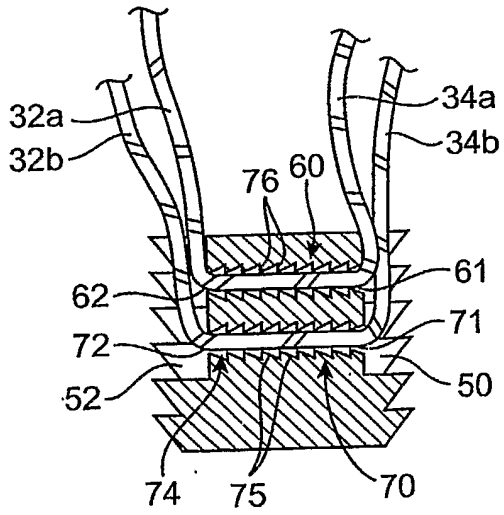

FIG. 2C

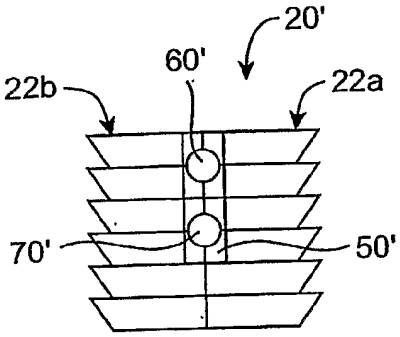

FIG. 3A

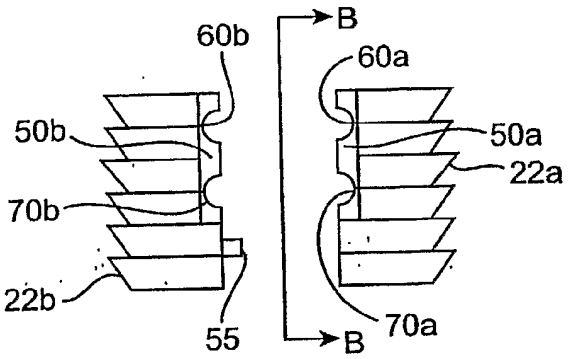

FIG. 3B

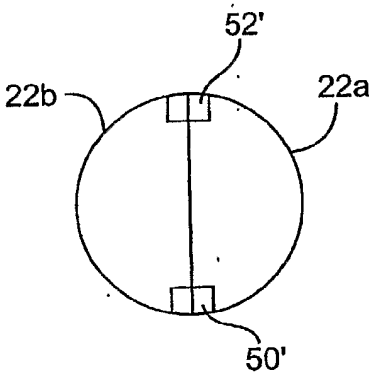

FIG. 3C

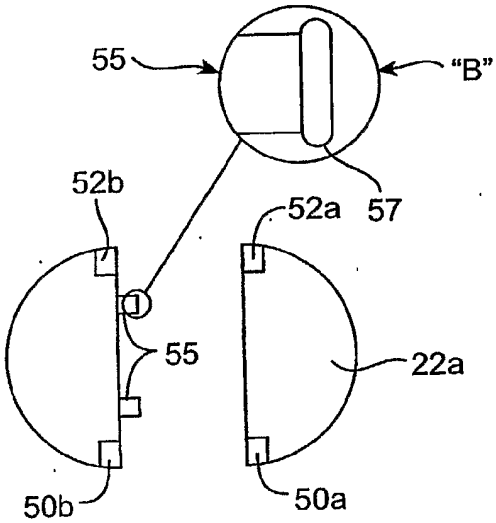

FIG. 3D

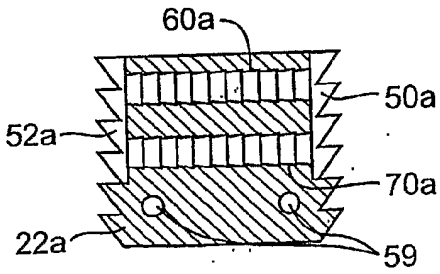

FIG. 3E

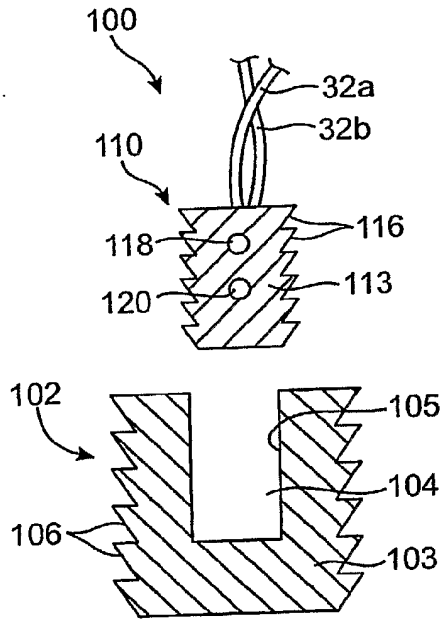

FIG. 4A

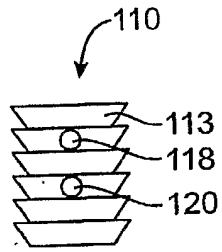

FIG. 4B

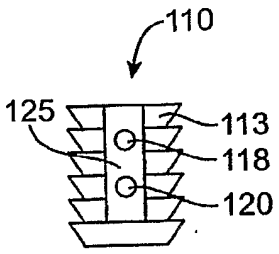

FIG. 4C

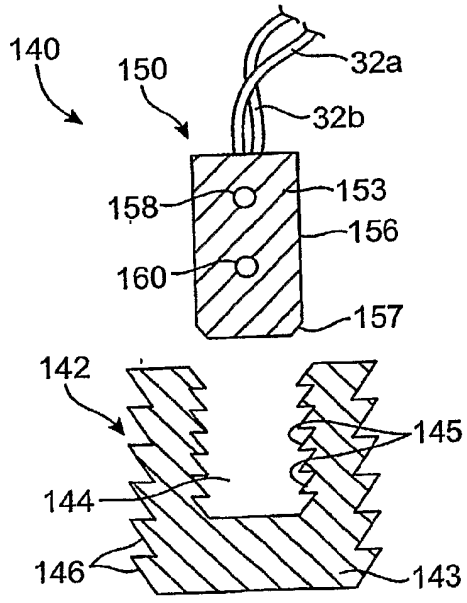

FIG. 5A

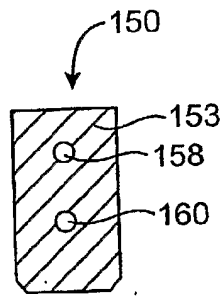

FIG. 5B

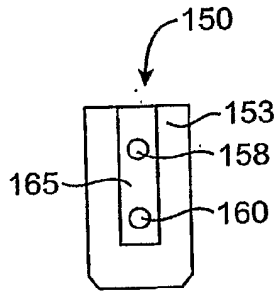

FIG. 5C

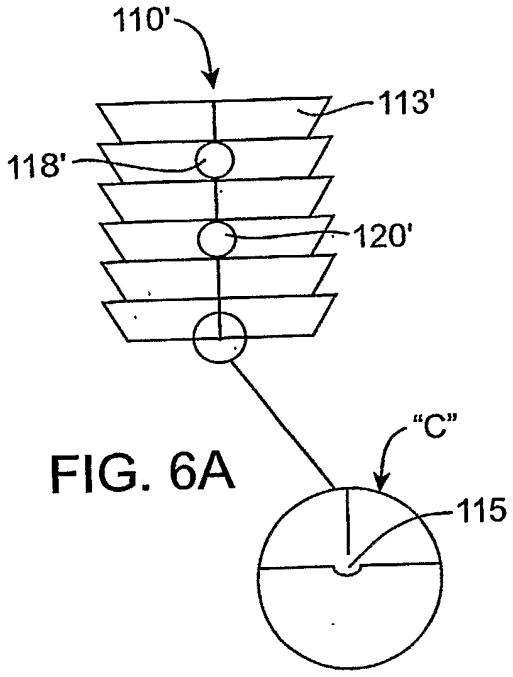

FIG. 6A

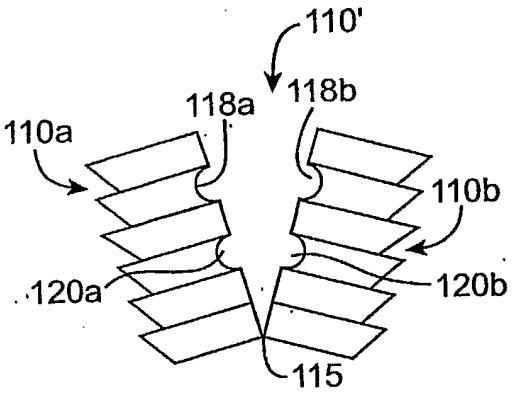

FIG. 6B

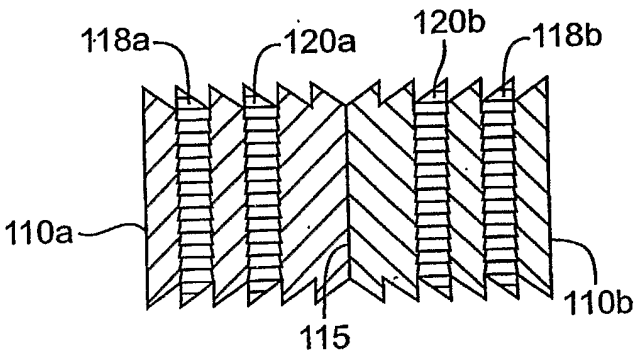

FIG. 6C

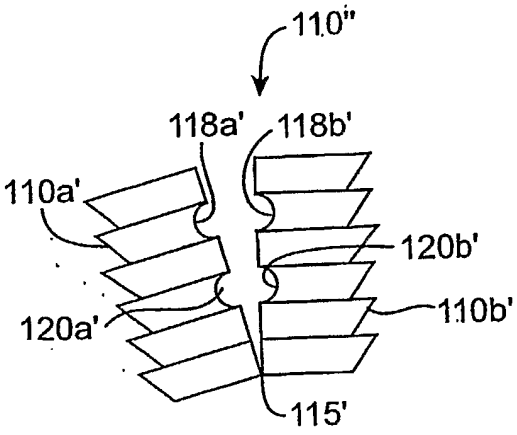

FIG. 7

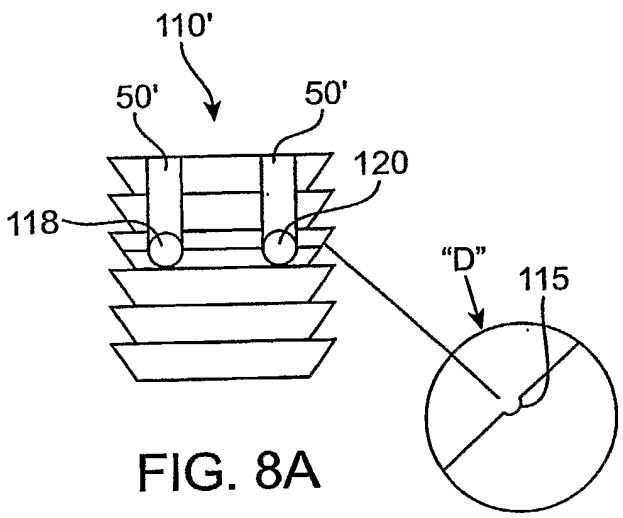

FIG. 8A

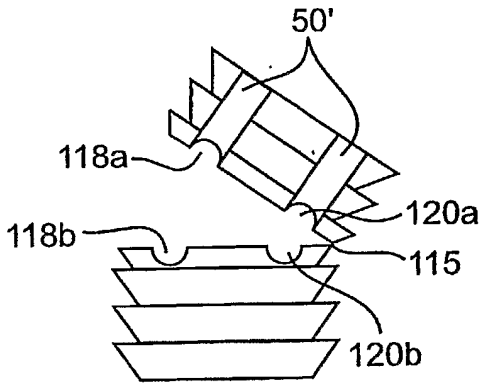

FIG. 8B

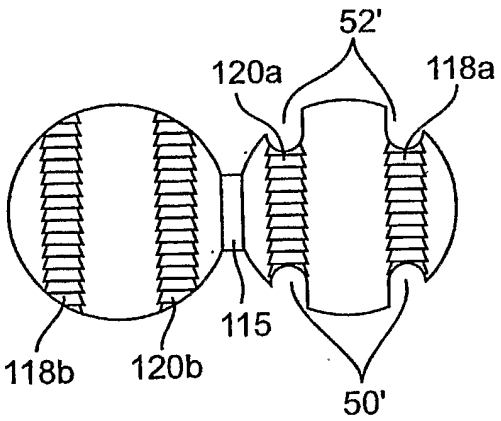

FIG. 8C

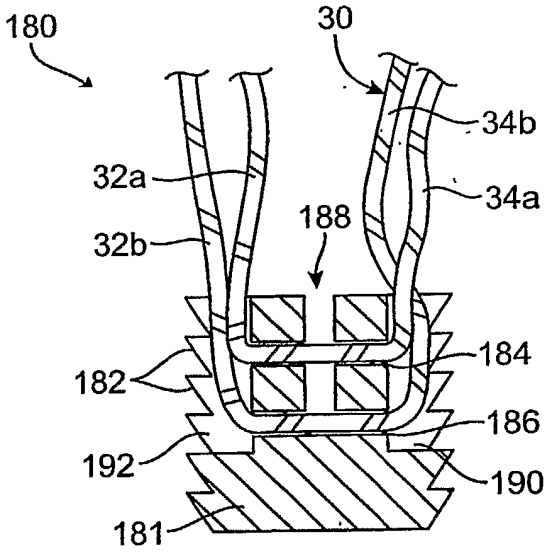

FIG. 9

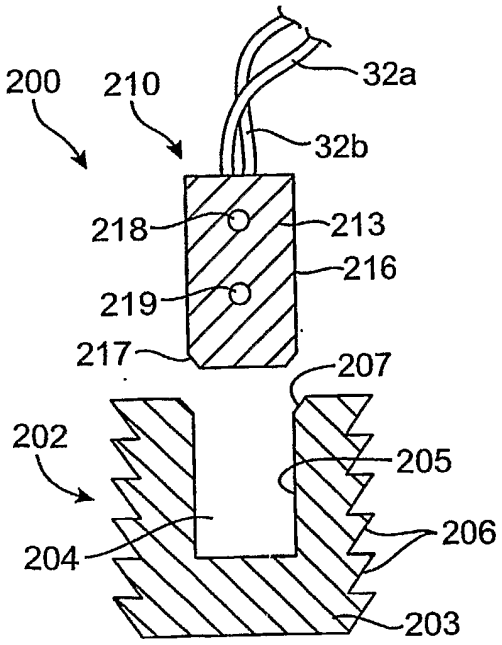

FIG. 10A

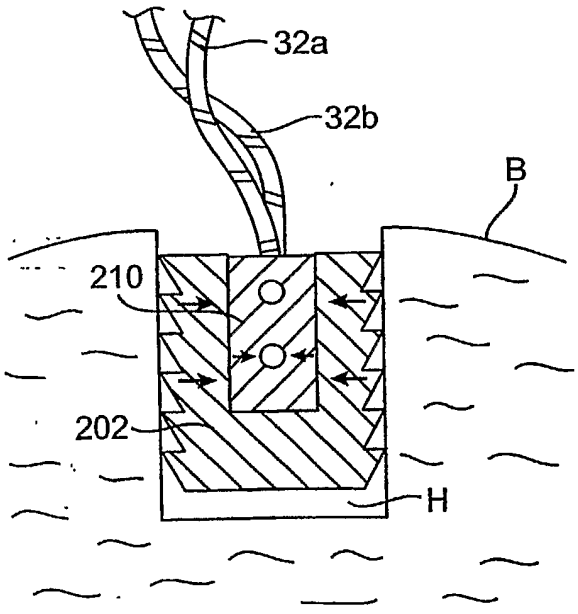

FIG. 10B

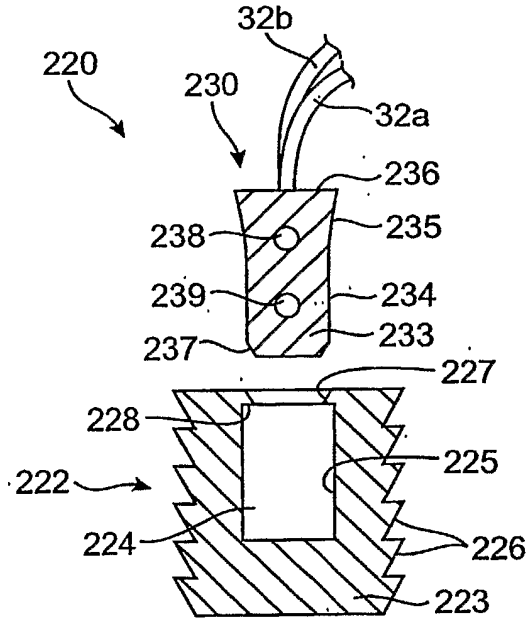
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FIG. 11

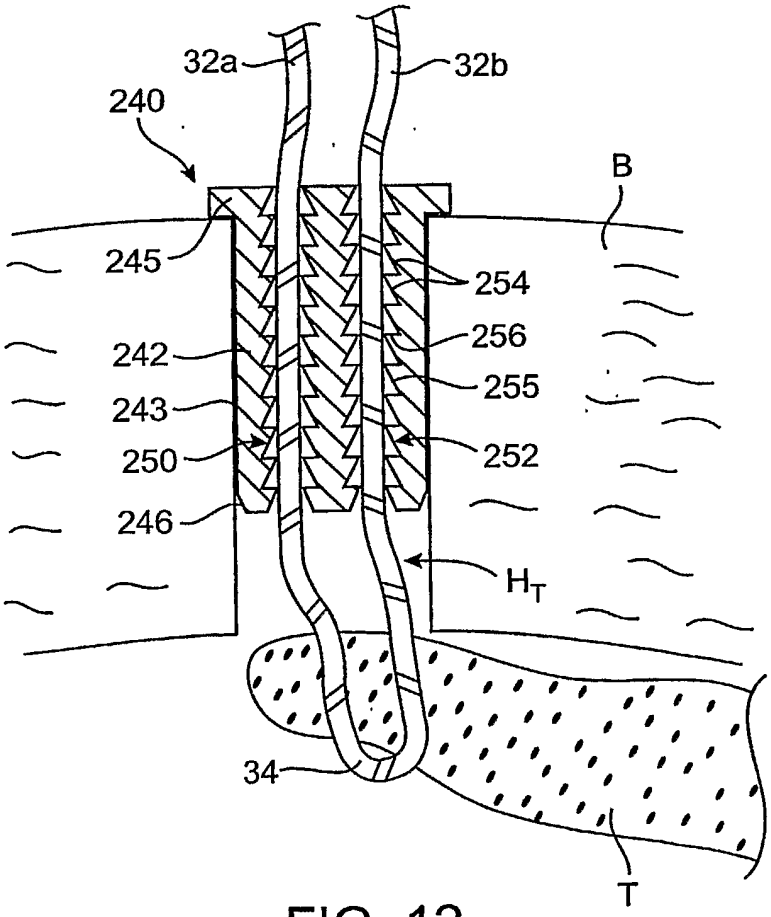
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FIG. 12

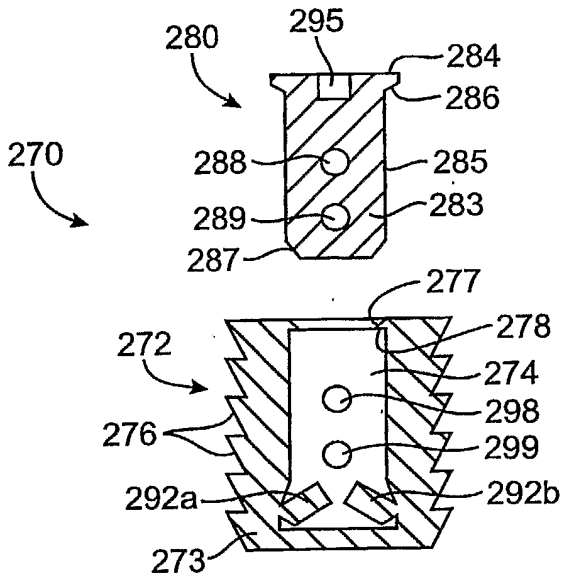

FIG. 13A

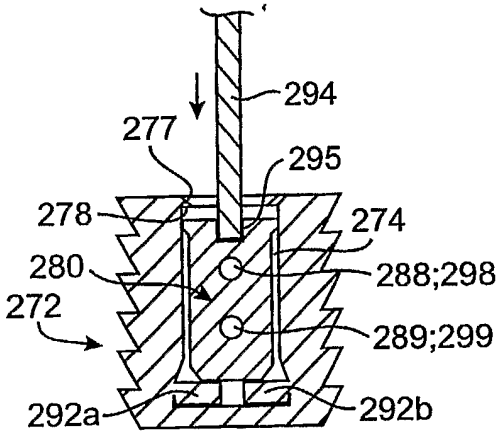

FIG. 13B

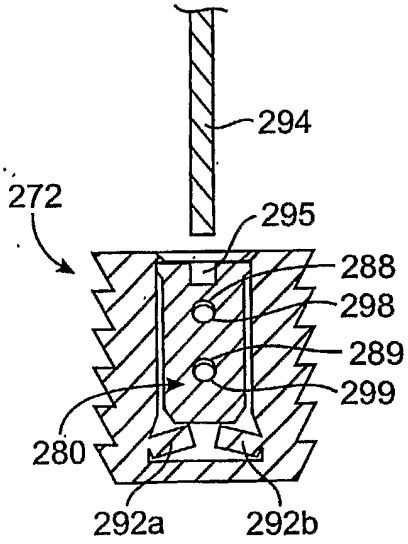

FIG. 13C

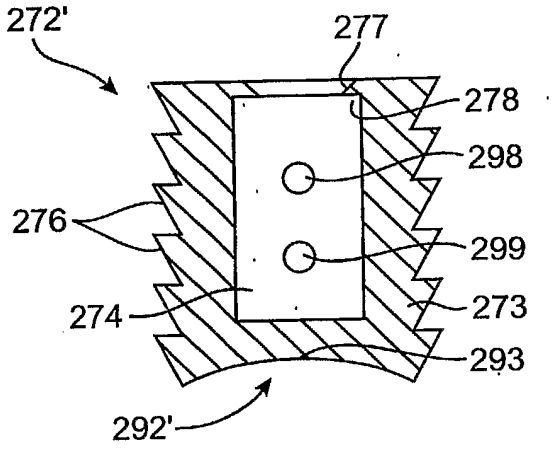

FIG. 14

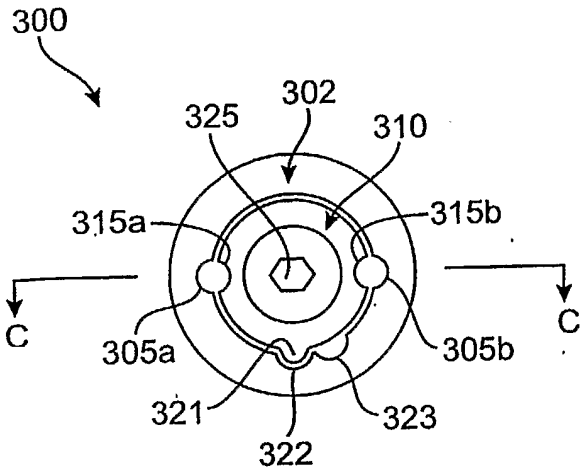

FIG. 15A

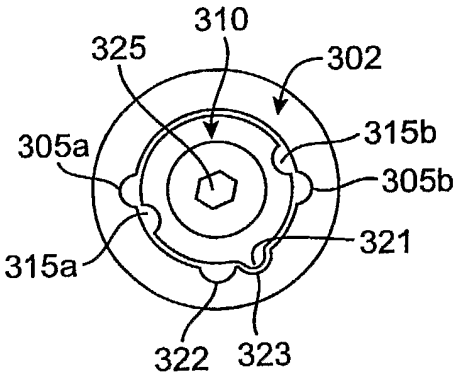

FIG. 15C

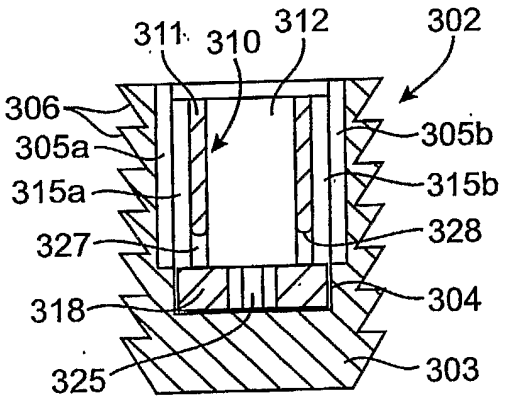

FIG. 15B

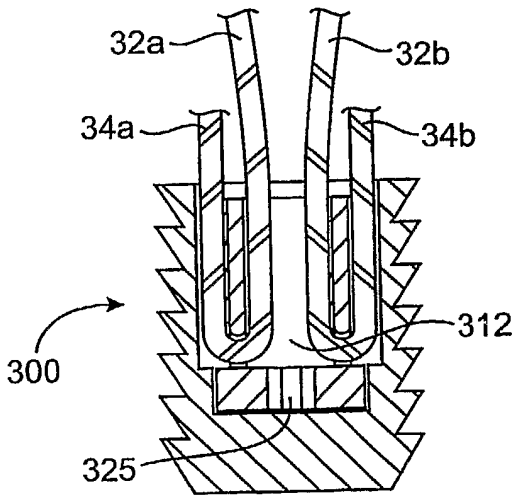

FIG. 16

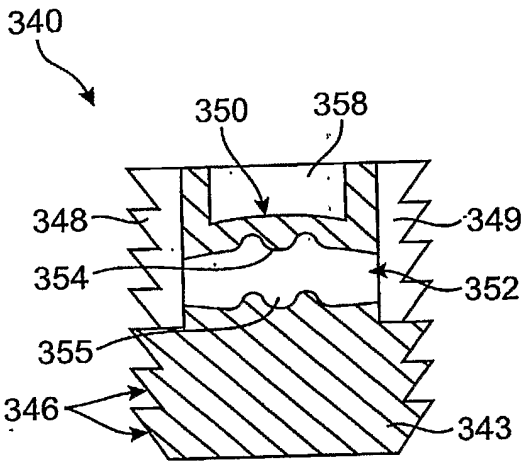

FIG. 17A

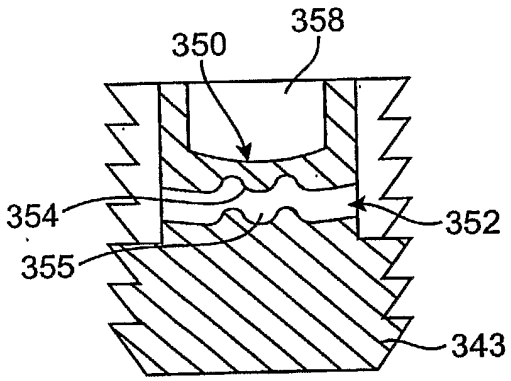

FIG. 17B

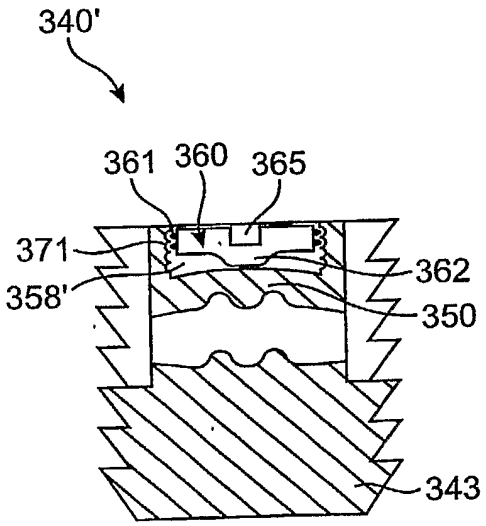

FIG. 18A

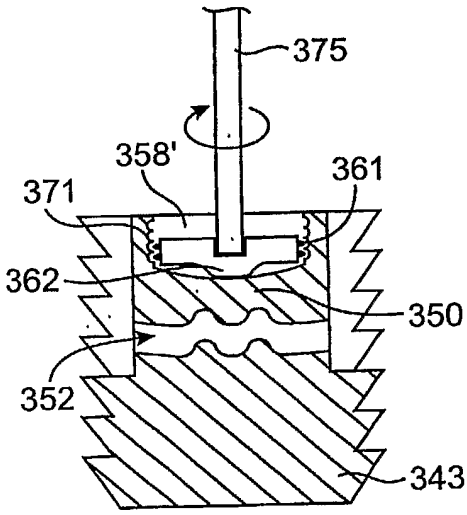

FIG. 18B

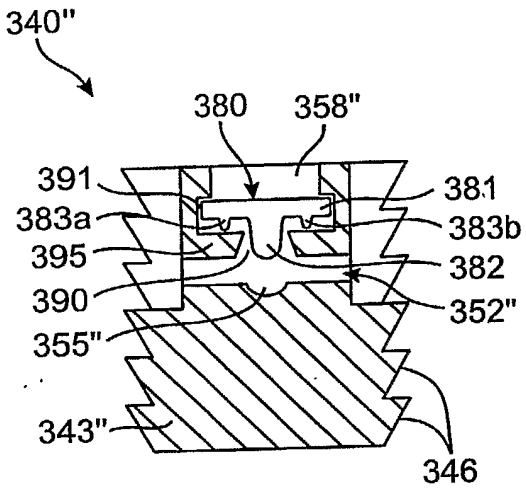

FIG. 19A

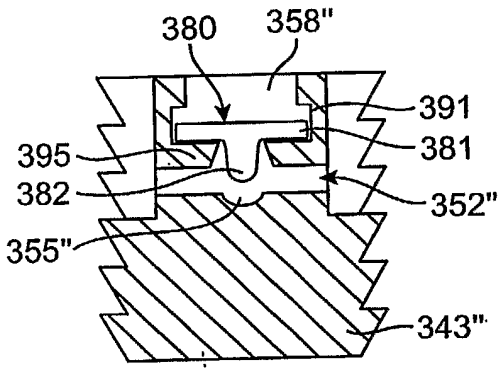

FIG. 19B

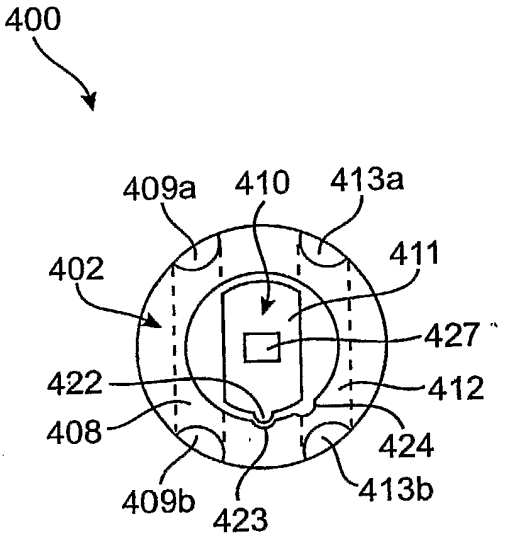

FIG. 20A

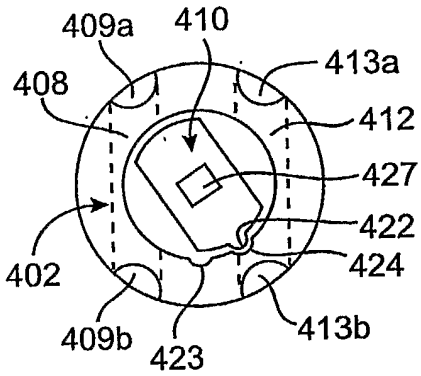

FIG. 21A

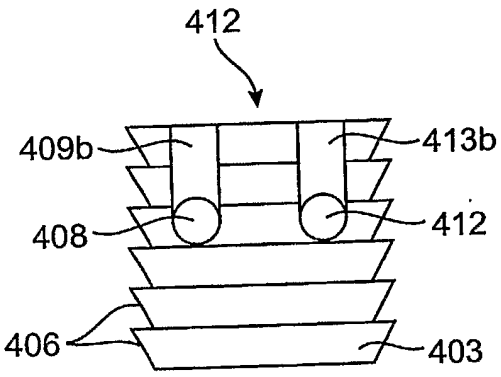

FIG. 20B

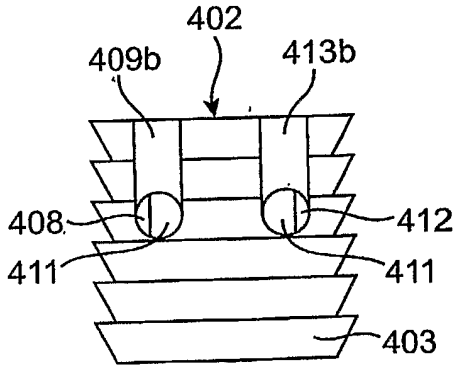

FIG. 21B

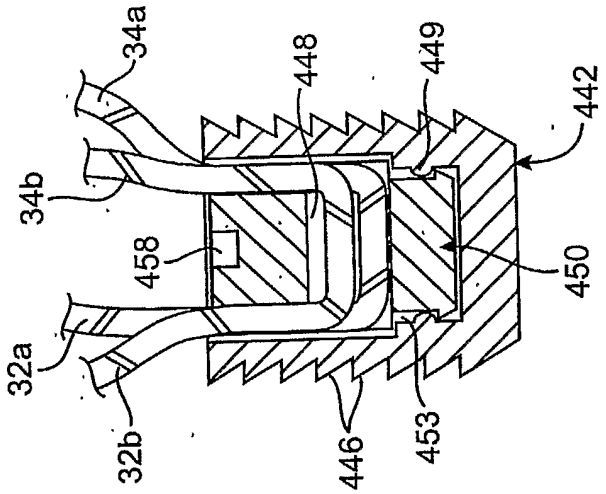

FIG. 22B

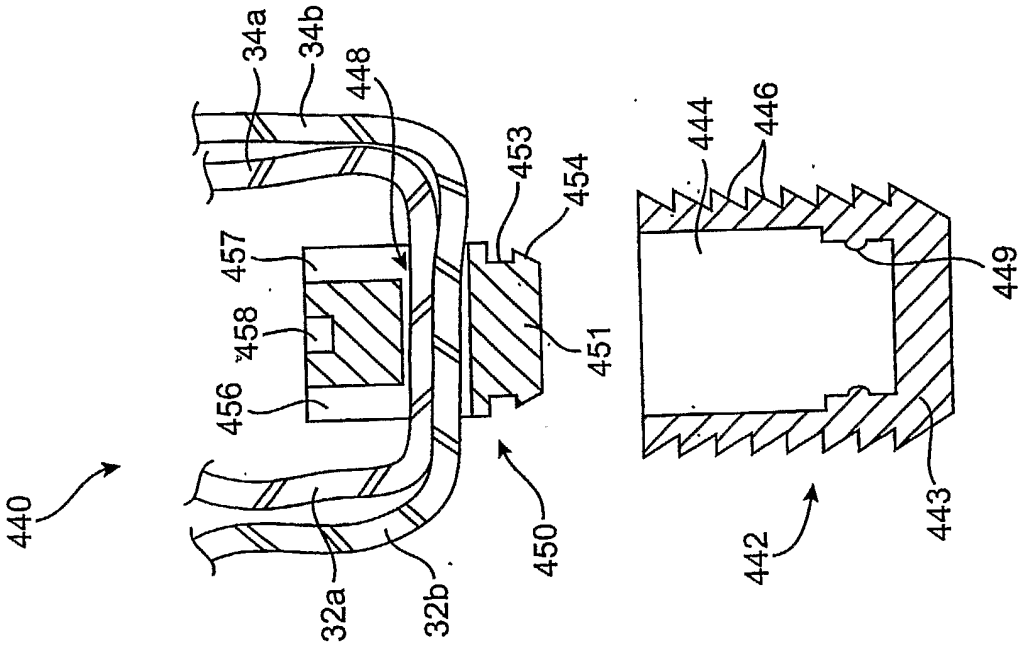

FIG. 22A

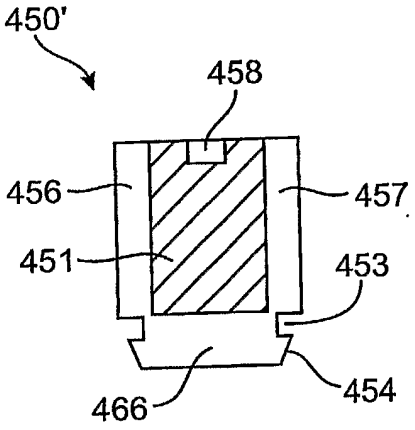

FIG. 23A

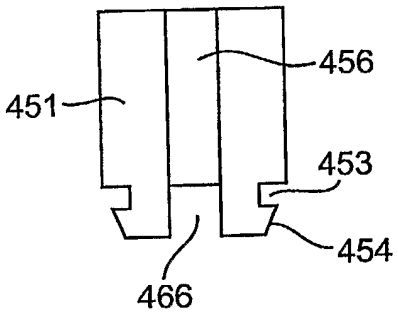

FIG. 23B

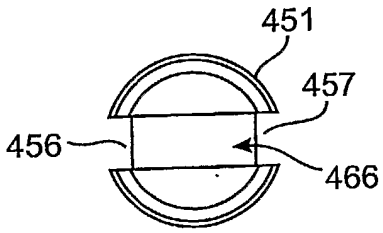

FIG. 23C

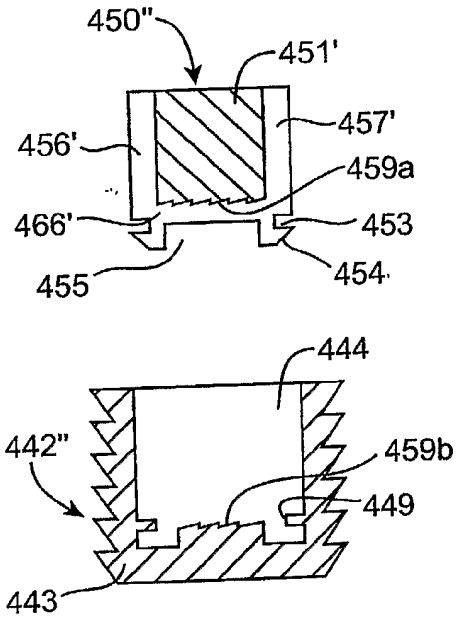

FIG. 24A

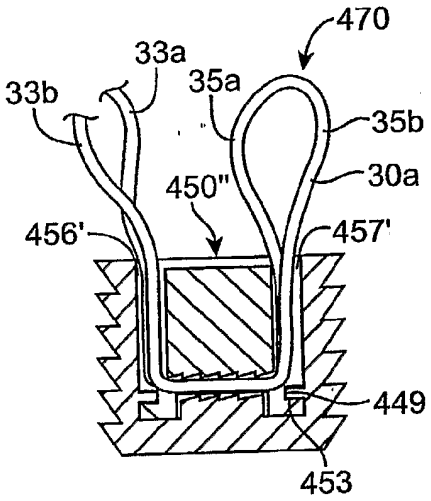

FIG. 24B

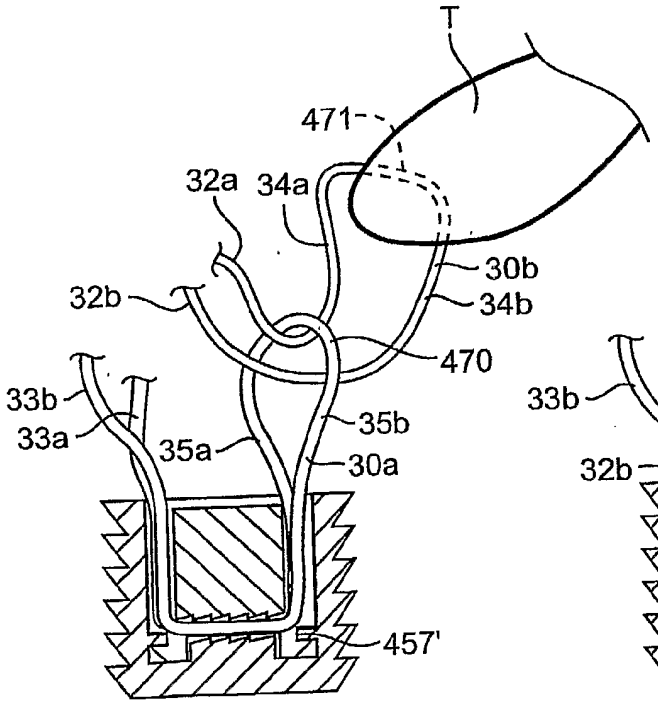

FIG. 25A

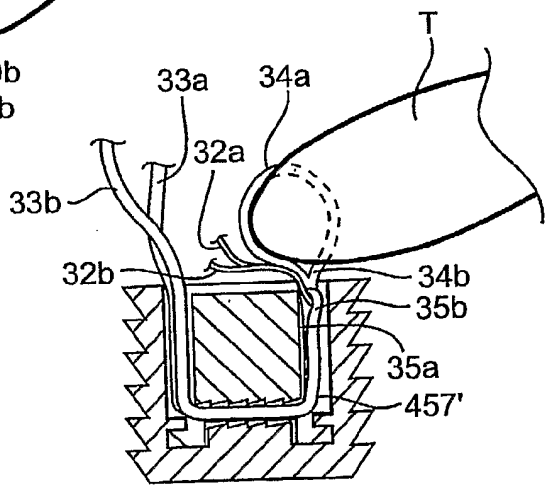

FIG. 25B

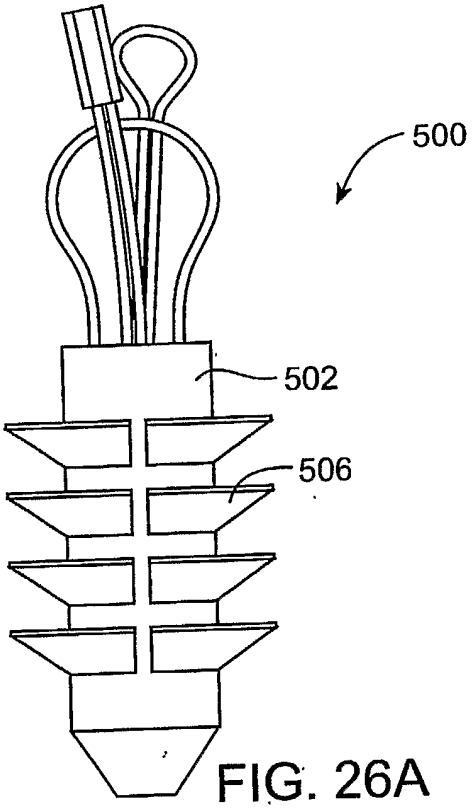

FIG. 26A

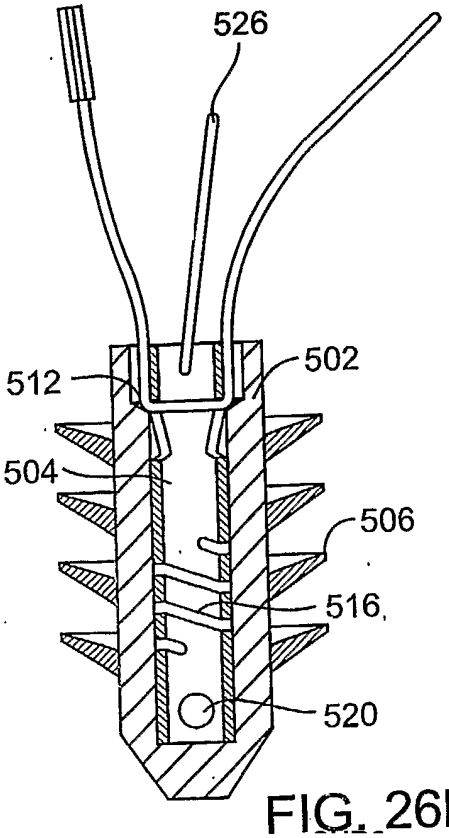

FIG. 26B

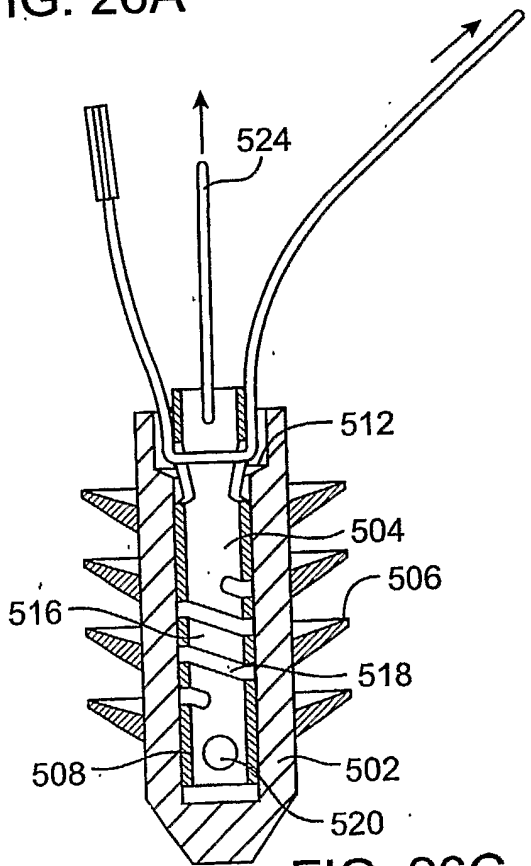

FIG. 26C

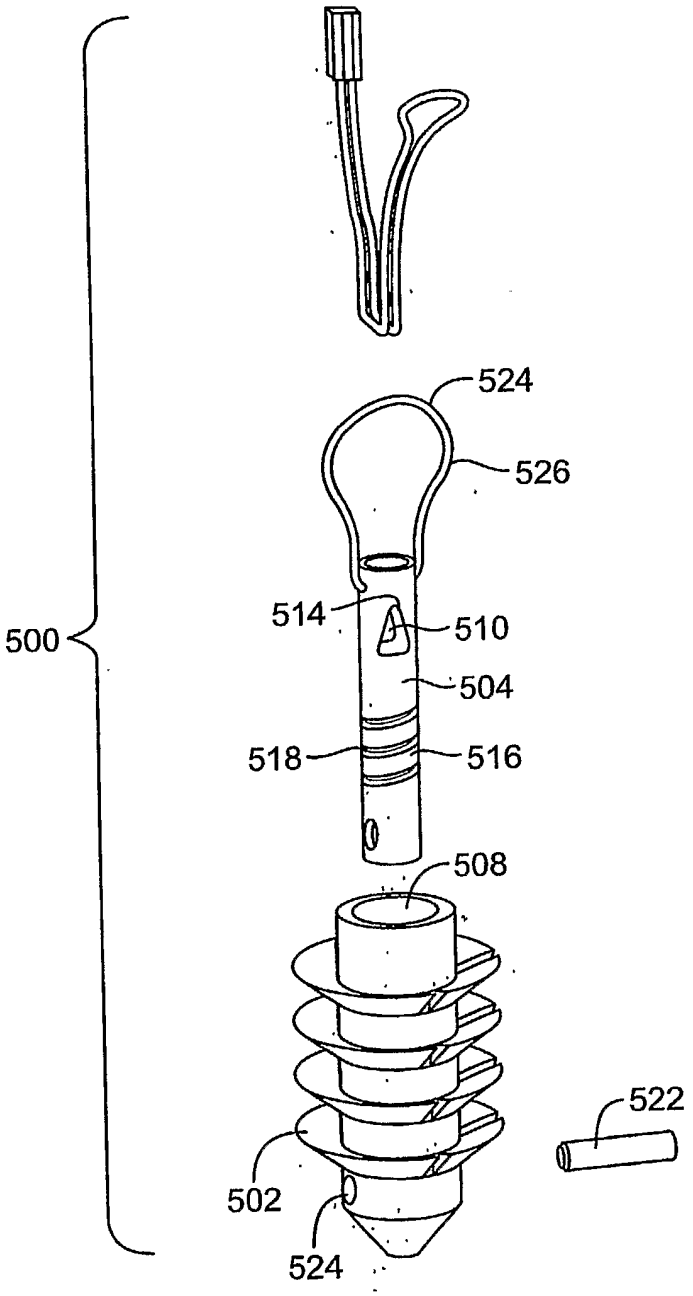

FIG. 26D

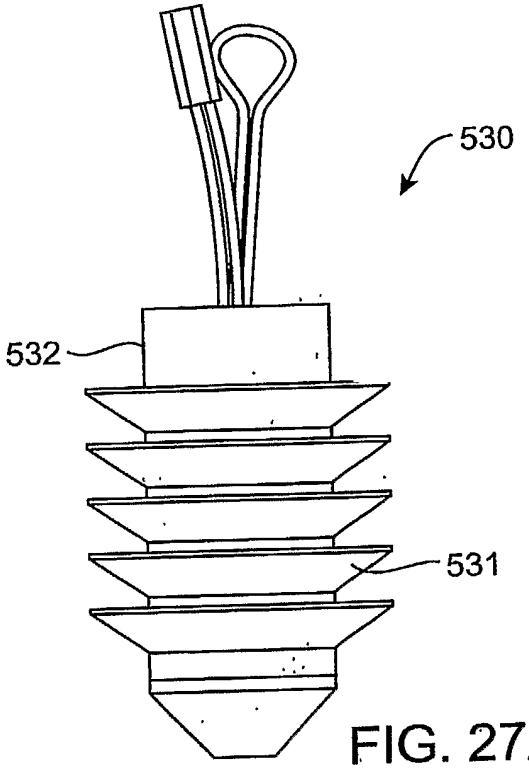

FIG. 27A

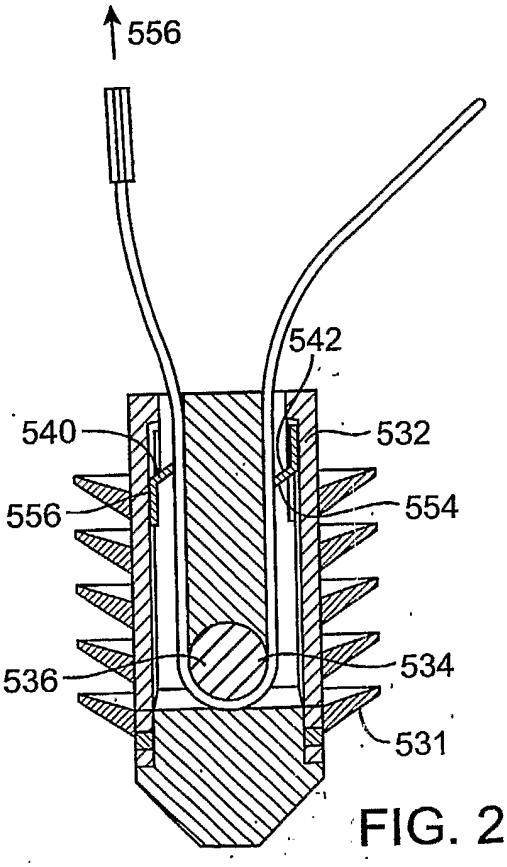

FIG. 27B

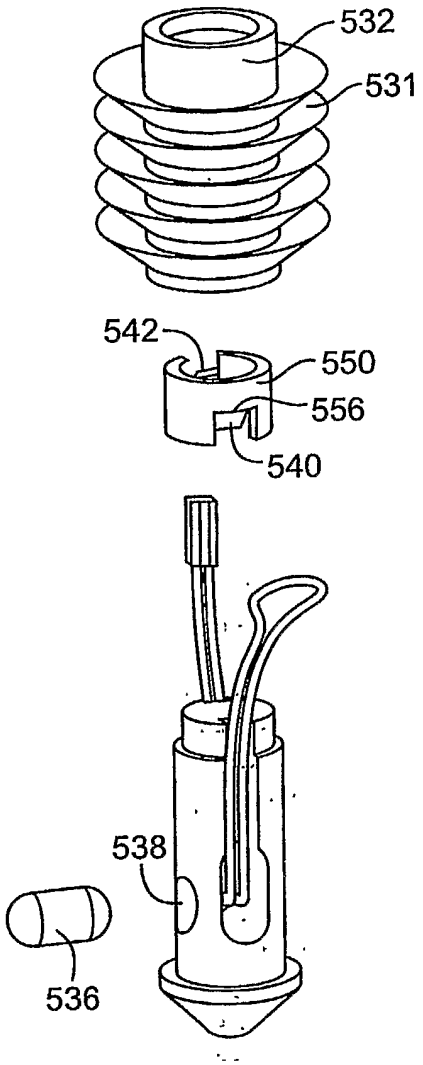

FIG. 27C

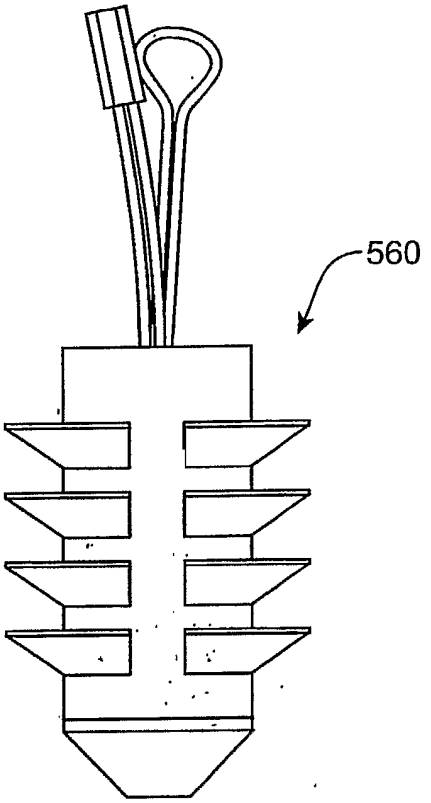

FIG. 28A

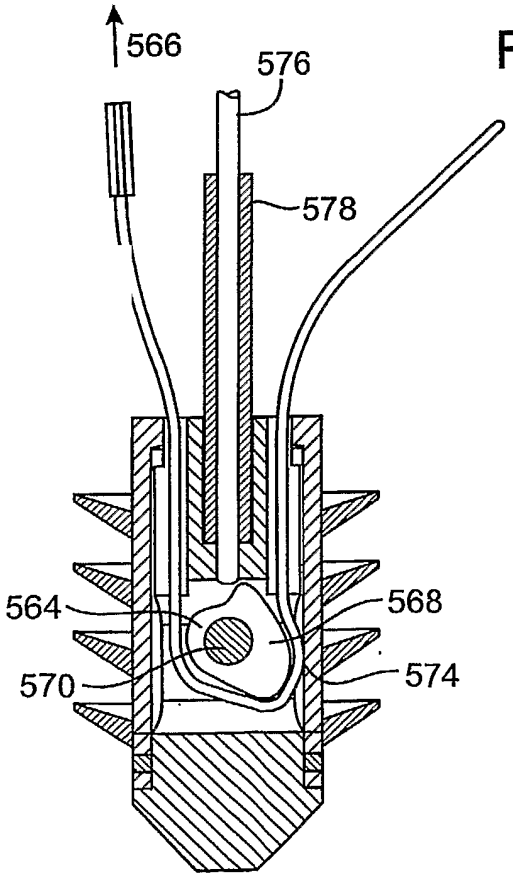

FIG. 28B

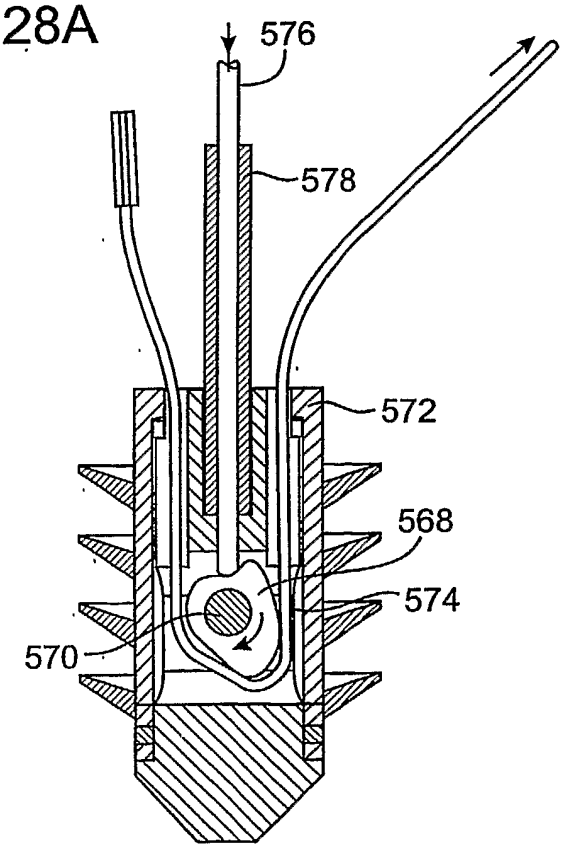

FIG. 28C

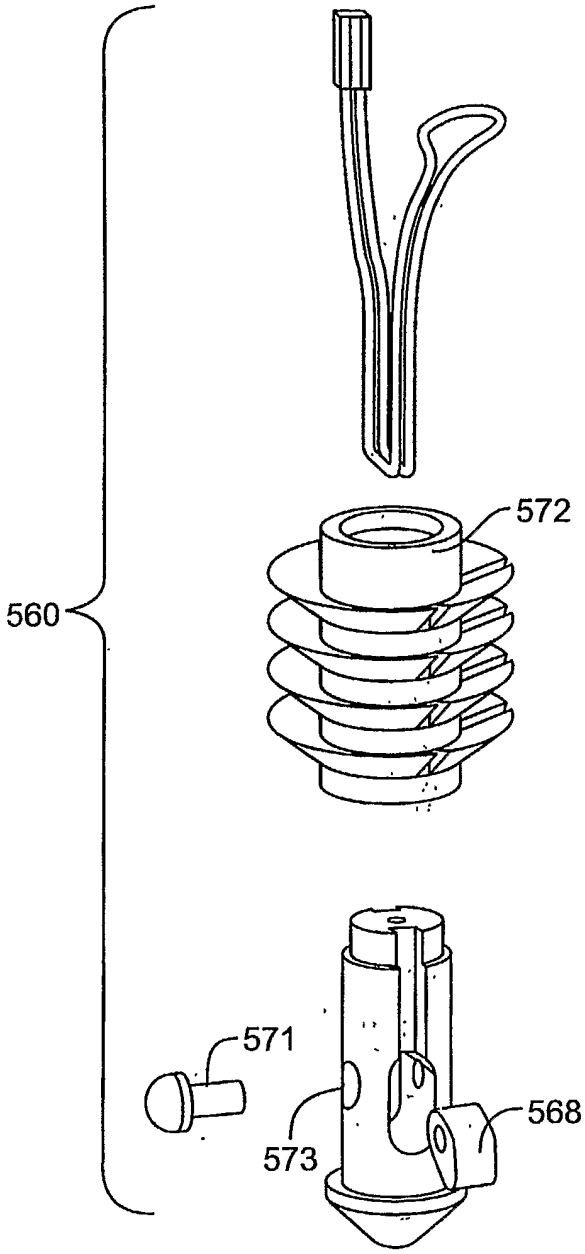

FIG. 28D