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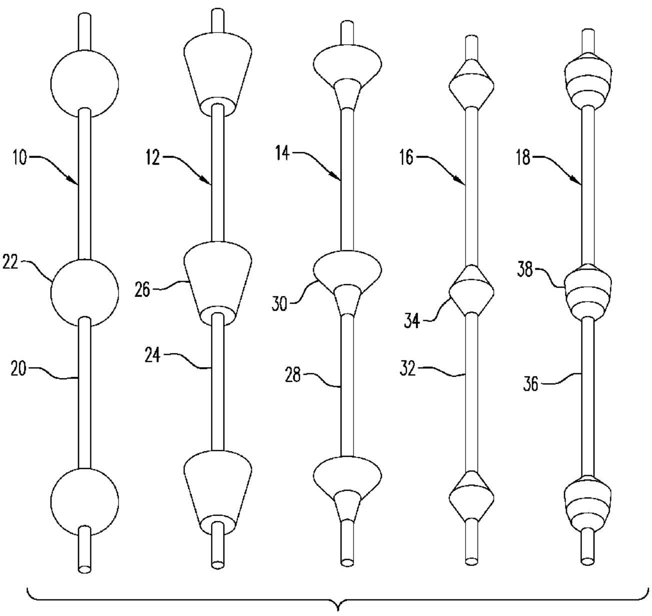


FIG. 1

**(57) Abstract**: A surgical suture system, suture, and tissue engaging member for tissue repair and reattachment of torn tissue to a tissue substrate, medical prosthesis or medical implant. The system includes the elongated flexible suture member having a plurality of longitudinally spaced protuberances along a length thereof and one or a plurality of the tissue engaging members each of which include two closely spaced apart locking apertures sized and configured to receive one of the suture members passed therethrough or a unique single locking aperture to allow longitudinal tensioning and/or restraining movement of the suture member in only one direction through the locking apertures for suture member tightening.

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# TITLE OF THE INVENTION

Surgical Suture System

## CROSS-REFERENCE TO RELATED APPLICATIONS

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

## INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not applicable

## BACKGROUND OF THE INVENTION

### Field of the Invention

This invention relates generally to surgical apparatus and methods for repair of torn tissue, and more particularly to an apparatus and method for arthroscopic and other surgical repair of torn tissue and tissue reattachment by providing a system for suturing and anchoring the torn tissue, together, against other tissue substrates, or for attaching tissue to medical implants.

### Description of Related Art

The rotator cuff is composed of four tendons that blend together to help stabilize and move the shoulder. When a tear occurs in the rotator cuff of the shoulder, it is often necessary to reattach the torn tendon or tendons to the bone of the humeral head. In a common prior art rotator cuff reattachment technique, the torn cuff is punctured by a punch, and prethreaded suture anchor screws (soft tissue fasteners) are drilled into the head of the humerus bone and the sutures threaded through the anchor screws are passed through the cuff in a difficult procedure using suture relay devices to pass the sutures through the tissue. After the suture strands are passed through the tissue, they are knotted and tied together to secure the reattached rotator cuff to the humerus head. Other types of prior art suture anchors are conically shaped members that are pressed into holes drilled into the bone and engage the cancellous mass surrounding the drilled hole.

A major problem with the above described suture anchoring technique is that the threaded suture anchor screws or conically shaped anchors are threadedly or otherwise secured to the cancellous bone mass beneath the near cortex of the head of the humerus, and depend on this cancellous mass for fixation. It is well known that the cancellous bone mass is susceptible to osteopenic changes (diminished amount of bone tissue).

As a result, the pull-out strength of suture anchors which are dependent on the cancellous bone mass beneath the cortex of the bone is subject to becoming diminished with time, and the anchors will tend to loosen, thereby possibly requiring a second operation to remove the loosened suture anchor.

Another problem with the conventional technique is that, in most cases, the sutures are not passed through the tissue when the anchor is set, and thus a difficult procedural step is required using devices such as punches and suture relays to pass and tie the sutures through the torn tissue.

Additionally, many anchor/suture devices require knots to be tied which is difficult with minimally invasive surgery and having a “knotless” solution is an advantage.

In my prior U.S. Patent 6,491,714, an apparatus and method for arthroscopic repair of torn tissue such as a rotator cuff was taught wherein torn tissue such as a rotator cuff is positioned on the bone exterior by a tissue grasper. A cannula is inserted through the skin substantially to the torn tissue. A drill guide is inserted into the cannula, a drill bit is inserted into the drill guide, and a hole is drilled through the torn tissue and completely through the bone. The drill bit is removed and an inner cannula is passed through the drill guide until its distal end is engaged on the torn tissue or alternatively passed through the hole until its distal end is at the far end of the drilled hole. A soft tissue anchor having expandable wings at its distal end and sutures secured to an eyelet at its proximal end is releasably connected to the distal end of a tubular deployment tool with the free ends of the sutures extending through the deployment tool.

The deployment tool is passed through the inner cannula and a hole is drilled until the expandable wings clear the far end of the hole, a sufficient distance to allow the wings to expand to a diameter larger than the diameter of the drilled hole. The deployment tool, inner cannula, drill guide and cannula are removed and tension is applied to the suture to engage the expanded wings of the anchor on the exterior surface of the bone surrounding the drilled hole. A button is run down on the sutures through the cannula and secured on the torn tissue by the sutures such that the torn tissue is secured to the bone and the sutures are anchored to the hard exterior surface of the bone by the expanded anchor.

Unlike conventional soft tissues anchors which are anchored in the cancellous bone mass beneath the near cortex of the bone, the ‘714 teaching in one embodiment provides a suture anchor which is engaged on the exterior of the far cortex of the bone and completely bypasses the cancellous bone mass. The cortex of the bone is much less susceptible to osteopenia than the cancellous interior of the bone. The sutures are passed through the tissue when the anchor is set, and thus the difficult procedural step and use of devices such as punches and suture relays to pass and tie the sutures through the torn tissue is eliminated.

Calibrated markings on the ‘714 deployment system allow for precise measurement of the far cortex and precise measurement of the depth of insertion and engagement of the anchor device on the far cortex, such that structures beyond the cortex are not violated, and the button hold-down feature eliminates the traditionally difficult arthroscopic tying techniques.

In another broader aspect of the ‘714 invention, the surgical apparatus includes any form of a tissue substrate anchor of a conventional well-known structure, an elongated suture member securable at its proximal end to the anchor, and a separate torn tissue retainer which lockably engages as desired along the length of the suture member. The suture member extending through the torn tissue from the anchor and the tissue substrate. The torn tissue retainer is movable along the length of the exposed portion of the suture member until it is tightly positioned against the torn tissue and automatically locked in that position by non-reversible lockable engagement with the suture member. A separate tissue gripping member formed preferably as a semi-flexible plate or disc having a substantially larger surface area than the tissue retainer is also provided for enhanced retention of the torn tissue in place against the outer surface of the tissue substrate.

Still another broad aspect of this ‘714 invention is directed to a surgical apparatus which includes an integrally formed tissue substrate anchor having an elongated suture member formed as a unit therewith. A separate disc-shaped retainer lockingly engages with the exposed distal end of the suture portion at any desired point along the suture interlocking portion. The tissue retainer is therefore moveable along the length of the exposed engaging members of the suture member for tightening the tissue layer against the tissue substrate. Utilized another way, a tear such as that found within a torn meniscus may be reconnected utilizing this embodiment of the invention.

Currently, soft-tissue fixation products that utilize “knot-less” technology and screws rely on an “interference-fit” for holding power between the screw and bone. In general, non-screw anchors have a pullout strength near 200 newtons, and screws can have upwards of 400 newtons of pullout strength.

The patent technology allows for the introduction of a revolutionary type of anchor for soft-tissue fixation to bone. Screws, as opposed to hook-type anchors, have the strongest pullout strength, “ZIP-TIE” patented technology will introduce its technology to the eyelet of screws. Specifically, it will attach one member of the suture to screws and this will allow for a ratcheting of the suture member through the suture capture or retainer or suture anchor, thereby creating a very strong construct.

The traditional repair of soft tissue requires sutures to be passed through the tissue. A knot is tied, which holds the torn tissue together, allowing for healing. Minimally invasive surgical techniques are being utilized through “button-hole” size incisions. Surgery is performed with instruments that pass through cannulas (like drainage culverts or pipes). Knots that would be utilized for this type of repair are tied and must be slid down through these cannulas. This technique can be difficult, result in adequate repair strength, provide for poor tissue approximation, for some surgeons, it may result in an inability to proceed with a minimally invasive approach secondary to the advanced technical difficulty, and finally, can add significant operative time to surgical procedures. USCO’s patented technology is akin to a "cable or tie-wrap" that is utilized for holding electric wire or cables together. Based upon the patented interface, a "pipe-line" of products will be created using knot-less, self-locking interface as a technology development platform.

The foregoing examples of the related art and limitations related therewith are intended to be illustrative and not exclusive. Other limitations of the related art will become apparent to those skilled in the art upon a reading of the specification and a study of the drawings.

## BRIEF SUMMARY OF THE INVENTION

The present disclosure is broadly directed to a surgical suture system for tissue repair and reattachment of torn tissue to a tissue substrate, medical prosthesis or medical implant. The system includes an elongated flexible suture member having a plurality of longitudinally spaced protuberances along a length thereof, and a plurality of tissue engaging members such as suture tissue restraints, anchors, and medical implants each including two spaced apart locking apertures sized to receive the suture member passed therethrough to allow longitudinal movement of the suture member in only one direction through the locking apertures for suture member tightening and retention.

It is therefore an object of this invention to provide a surgical suture system for tissue repair and reattachment of torn tissue together, to a tissue substrate or medical implant.

It is another object of this invention to provide a surgical suture system for repair of torn tissue such as a torn rotator cuff utilizing uniquely configured tissue engaging members, each of which include a double locking aperture arrangement of two closely spaced together locking apertures which receive the unique suture and cooperate for only one-way movement during tightening of the suture to bring torn tissue into a desired healing orientation.

A broad aspect of this disclosure provides for the reattachment of any torn or damaged tissue or artificial tissue to any form of tissue substrate or together by the use of a uniquely configured substrate anchor or tissue restraint having a double locking aperture arrangement for receiving a suture having spaced apart protuberances along the length of the suture. The suture tissue restraint or substrate anchor, or more broadly the tissue engaging member, is configured for movement of the suture itself through the pair of locking apertures in only one direction so that any tightening movement of the suture within the tissue engaging member is locked from reverse movement therebetween. A variety of spaced protuberance configurations along the length of the flexible elongated suture member are disclosed for this one-way locking movement engagement within one or more of the tissue engaging members each having the two spaced apart locking apertures formed therethrough to lockingly receive the suture members.

The following embodiments and aspects thereof are described and illustrated in conjunction with systems, tools and methods which are meant to be exemplary and illustrative and not limiting in scope. In various embodiments one or more of the above-described problems have been reduced or eliminated while other embodiments are directed to other improvements. In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following descriptions.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Figure 1 is a perspective of a plurality of exemplary configurations of sutures each having spaced apart locking protuberances.

Figure 2 is a perspective view of a suture anchor configured in accordance with this disclosure.

Figure 3 is a side elevation view of Figure 2.

Figure 4 is a section view in the direction of arrows 4-4 in Figure 3.

Figure 4A is a section view similar to Figure 4 depicting an alternate embodiment thereof.

Figure 5 is a perspective view of another alternate embodiment of the suture anchor of Figure 2.

Figure 5A is a section view in the direction of arrows 5A-5A in Figure 5.

Figure 5B is a section view of another alternate embodiment of the suture anchor of Figure 2.

Figure 5C is a top plan view in the direction of arrows 5C-5C in Figure 5B.

Figure 5D is yet another alternate embodiment of the suture anchor of Figure 2.

Figure 5E is top plan view in the direction of arrows 5E-5E in Figure 5D.

Figure 6 is a side elevation view of another embodiment of a suture anchor of this disclosure.

Figure 7 is a broken perspective view of one embodiment of a suture tissue restraint.

Figure 7A is a broken perspective view of another embodiment of a suture tissue restraint.

Figure 8 is a broken perspective view of yet another embodiment of a tissue suture restraint.

Figure 9 is a pictorial view showing a variety of suture anchors and suture tissue restraints (absent tissue or tissue substrate for clarity) in locking engagement with one embodiment of the suture member **10** shown in Figure 1.

Figure 10 is an elevation view of a typical installation arrangement of the elongated suture member **10** in locking engagement with a suture anchor **40** and a suture tissue restraint **66**.

Figure 11 is a simplified pictorial view of one aspect of the invention utilized to repair and restrain a broken distal phalanx of a finger metacarpal.

Figure 12 is an elevation view utilizing another aspect of the present invention to repair torn ACL tissue of a knee joint.

Figure 13 is an elevation view utilizing another aspect of the present invention to repair a torn MCL of a knee joint.

Figure 14 is a side elevation view showing another aspect of the invention utilized to repair a torn medial patella-femoral ligament.

Figure 15 is a simplified section view showing another aspect of the invention utilized to repair a tear in the hip labrum.

Figure 16 depicts another aspect of the invention utilized to reattach the torn distal end of the biceps.

Figure 17 shows a schematic view utilizing another aspect of the invention to reattach the fibula of an ankle syndesmotic disruption.

Figure 18 is a side elevation view depicting another aspect of the invention for reattaching the proximal biceps tendon to the humeral head.

Figure 19 is a simplified section view depicting another aspect of the invention for repairing a tear in the joint capsule which surrounds a shoulder socket.

Figure 20 is an enlargement of area 20 in Figure 19.

Figures 21 to 23 show other aspects of the invention utilized to repair a tear in the shoulder labrum surrounding a shoulder socket.

Figure 24 is a simplified side elevation view showing another aspect of the invention utilized to effect a coracoclavicular ligament repair.

Figure 25 is an elevation view utilizing another aspect of the invention to effect a subscapularis-to-humeral head repair.

Figure 26 is a section view in the direction of arrows 26-26 in Figure 25.

Figure 27 is an elevation view showing another aspect of the invention utilized to reattach a rotator cuff tendon to the top of the humerus.

Figure 28 and Figure 29 depict alternate aspects of the invention utilized to effect the repair shown in Figure 27.

Figures 30 and 31 depict sagittal views depicting alternate aspects of the invention utilized to effect a meniscus tear repair.

Figures 32 and 33 depict alternate aspects of the invention utilized to effect a torn meniscal repair.

Figure 34 is a broken perspective view of another embodiment of a suture operatively engaged with cooperatively structured suture tissue restraint.

Figures 35 to 38 are perspective views of other embodiments of a suture anchor.

Figure 39 is an enlarged view of area **206** of Figure 38.

Figure 39A is an alternate embodiment of area **206** in Figure 39.

Figure 40 shows several alternate cross-sections in the direction of arrows 40-40 in Figure 39.

Figures 41 to 47 are each side elevation views of other embodiments of suture anchors.

Figures 48 to 52 are perspective views of additional exemplary configurations of sutures.

Figure 53 is a perspective view of another embodiment of a suture tissue restraint.

Figure 53A is a view of Figure 53 depicting alternate positions of suture **10** engaged therein.

Figure 54 is a top plan view of Figure 53.

Figure 55 is a section view in the direction of arrows 55-55 in Figure 54.

Figure 56 is a section view in the direction of arrows 56-56 in Figure 54.

Figure 57 is a section view in the direction of arrows 57-57 in Figure 54.

Figure 58 is a perspective view showing an alternate embodiment of the suture tissue restraint shown in Figure 53.

Figure 59 is a perspective view of an expandable suture tissue restraint.

Figure 60 is another perspective view of the suture tissue restraint shown in Figure 59.

Figure 61 is a section view in the direction of arrows 61-61 in Figure 59.

Figure 62 is a section view in the direction of arrows 62-62 in Figure 59 and including an interlock suture **410** therein.

Figure 63 is a view similar to Figure 62 showing another suture **20** lockingly engaged therein.

Figure 64 is yet another view of Figure 62 showing yet another suture **32** lockingly engaged therein.

Figures 65 and 66 are perspective views of an alternate embodiment of the suture tissue restraint **400** shown in Figures 59 and 60, respectively.

Figures 67 and 68 are perspective views of another embodiment of a suture tissue restraint.

Figure 69 is a top plan view of Figure 67.

Figures 70A and B are section views in the direction of arrows 70A-70A and 70B-70B in Figure 69.

Figure 71 is an alternate embodiment of the suture tissue restraint **430** shown in Figure 67.

Figure 72 is a top plan view of Figure 71.

Figures 73A and 73B are sections views of alternate embodiments of the suture tissue restraint **403a** in the direction of arrows 73-73 in Figure 72.

Figure 74 is a perspective view of an alternate embodiment of Figure 71.

Figure 75 is a top plan view of Figure 74.

Figures 76 and 76A are perspective views of alternate embodiments of the suture tissue restraint shown in Figure 68.

Figures 77 to 82 are side elevation views of alternate embodiments of additional sutures engaged within suture tissue restraints.

Figure 83 is a side elevation broken view of another alternate embodiment of the tissue anchor and suture **462** of Figure 77.

Figure 84 is an enlargement of area Fig. 84 in Figure 83.

Exemplary embodiments are illustrated in reference figures of the drawings. It is intended that the embodiments and figures disclosed herein are to be considered to be illustrative rather than limiting.

DETAILED DESCRIPTION OF THE INVENTION

Nomenclature

10. suture
12. suture
14. suture
16. suture
18. suture
20. suture strand
22. bead-shaped protuberance
24. suture strand
26. truncated conical protuberance
28. suture strand
30. two-step conical protuberance
32. suture strand
34. symmetric conical protuberance
36. suture strand
38. segmented bullet-shaped protuberance
40. tissue anchor
41. tissue anchor
42. conical anchor body
43. tissue anchor
44. conical anchor body
45. suture entry cavity
46. suture engagement bar

47. suture exit cavity
48. suture locking aperture
49. suture one-way restriction
50. anchor post
51. suture anchor
52. anchor post cavity
53. suture entry aperture
54. tissue anchor top surface
55. suture exit aperture
56. suture tissue restraint
57. suture transverse passage
58. suture locking aperture
59. tissue gripping member
60. suture one-way lock
61. tissue anchor
62. tissue contact surface
63. tissue engaging member
64. suture severance point
65. suture locking aperture
66. suture tissue restraint
67. suture tissue restraint
68. suture locking aperture
69. aperture bevel
70. suture engagement bar
71. suture clearance aperture
72. tissue contact surface
74. open outer surface
76. tissue gripping member
78. suture clearance aperture
80. suture
82. suture strand
84. suture bare strand segment
86. hip prosthesis
88. suture locking aperture
96. orthopedic plate
98. anchor screw holes
100. suture locking aperture
102. tissue gripping member

104. suture clearance aperture
106. suture loop lock
108. suture locking aperture
110. grooved suture
112. suture tissue restraint
114. locking groove
116. groove locking edge
118. groove ramped edge
120. body
122. suture locking aperture
124. locking protuberance
126. locking edge
128. ramped edge
130. tissue anchor
132. tapered spiral thread
134. head
136. tissue penetrating tip
138. driving socket
140. suture one-way restriction
142. suture entry cavity
144. suture exit cavity
150. tissue anchor
152. tapered spiral coil
154. head
156. tissue penetrating tip
158. driving socket
160. suture one-way restriction
162. suture entry cavity
164. suture exit cavity
170. tissue anchor
172. spiral coil
174. head
176. tissue penetrating tip
178. driving socket
180. suture one-way restriction
182. suture entry cavity
184. suture exit cavity
190. tissue anchor

192. tapered spiral coil
192a-h. alternate tapered spiral coils
194. head
196. tissue penetrating tip
198. driving socket
200. suture one-way restriction
202. suture entry cavity
204. suture exit cavity
206. spiral coil segment
206a. spiral coil segment
208. tissue cutting edge
208a-g. tissue cutting edge
210. tissue anchor
212. tapered spiral coil
214. head
216. tissue penetrating tip
218. driving socket
220. suture one-way restriction
222. suture entry cavity
224. suture exit cavity
226. centering shaft
228. tip
230. tissue anchor
230'. tissue anchor
232. tapering spiral coil
234. solid tapered screw
236. head
238. tissue penetrating tip
240. driving socket
242. suture one-way restriction
244. suture entry cavity
246. suture exit cavity
248. centering shaft
249. tip
250. tissue anchor
250'. tissue anchor
252. tapered spiral coil
254. solid tapered screw

256. head
258. tissue penetrating tip
260. driving socket
262. suture one-way restriction
264. suture entry cavity
266. suture exit cavity
268. centering shaft
270. tissue anchor
270'. tissue anchor
272. solid tapered screw
274. tapered spiral coil
276. solid tapered screw
278. head
280. tissue penetrating tip
282. driving socket
284. suture one-way restriction
286. suture entry cavity
288. suture exit cavity
289. centering shaft
290. suture
292. suture strand
294. dome-shaped protuberance
296. suture
298. suture strand
300. mushroom-shaped protuberance
302. cavity
304. suture
306. suture strand
308. cup-shaped protuberance
310. cavity
312. suture
314. suture strand
316. quarter protuberance
320. suture
322. arrow protuberance
324. arrow protuberance
326. tip
330. suture tissue restraint

332. disc-shaped body
336. flexible suture passage aperture
338. radial slot
340. concentric slot
342. suture socket
344. suture strand aperture
346. radial slot
348. concentric slot
350. suture socket
352. suture strand aperture
354. radial slot
356. concentric slot
358. suture socket
360. suture strand aperture
370. suture tissue restraint
372. disc-shaped body
374. suture passage aperture
376. suture socket
378. suture strand aperture
380. radial slot
382. concentric slot
384. suture socket
386. suture strand aperture
388. concentric slot
390. suture socket
392. suture strand aperture
394. concentric slot
400. expandable suture tissue restraint
400'. expandable suture tissue restraint
402. solid segment
404. expandable suture locking aperture
406. expandable aperture segment
408. rigid aperture segment
410. suture
412. conical protuberance
414. locking surface
416. suture bearing surface
418. resilient layer

419. rigid layer
420. resilient O-ring
422. annular groove
430. expandable suture tissue restraint
430a-c. expandable suture tissue restraints
432. disc-shaped body
432'. disc-shaped body
434. rigid sector
436. resilient sector
438. expandable suture locking aperture
440. cylindrical aperture segment
442. aperture inlet segment
444. aperture outlet segment
450. resilient O-ring
452. annular groove
452'. annular groove
454. empty sector
456. tapered segment
456a. semi-spherical segment
458. tissue contact surface
460. suture/tissue restraint
462. suture
464. resilient mushroom protuberance
466. suture strand
468. suture deforming surface
470. suture locking surface
472. suture tissue restraint
474. suture aperture
476. restraint deforming surface
478. restraint locking surface
480. suture and tissue restraint
482. suture
484. resilient suture protuberance
486. suture strand
488. suture deforming surface
490. suture tissue restraint
492. suture strand aperture
494. restraint deforming surface

496. restraint locking surface
498. suture locking surface
500. suture and tissue restraint
502. suture
504. resilient suture protuberance
506. suture strand
508. suture deforming surface
510. suture locking surface
512. suture tissue restraint
514. suture aperture
516. restraint deforming surface
518. restraint locking surface
520. suture and tissue restraint
522. suture
524. resilient cone-shaped protuberance
526. suture strands
528. suture deforming surface
530. suture locking surface
532. suture tissue restraint
534. restraint deforming surface
536. suture aperture
538. restraint locking surface
540. suture and tissue restraint
542. suture
544. arrow-shaped protuberance
546. suture strand
548. suture deforming surface
550. suture tissue restraint
552. suture aperture
554. restraint deforming surface
556. suture locking surface
558. restraint locking surface
560. suture and tissue restraint
562. suture
564. arrow-shaped protuberance
566. suture strand
568. suture deforming surface
570. suture locking surface

572. suture tissue restraint
574. suture aperture
576. restraint deforming surface
578. restraint locking surface
580. tissue anchor
582. tapered spiral thread
584. tissue penetrating tip
586. head
588. suture passage
590. head deforming inlet surface
592. head locking surface
594. driving socket

Referring now to the drawings, and firstly to Figure 1, a number of exemplary elongated flexible sutures shown generally at numerals **10**, **12**, **14**, **16** and **18**. These sutures are preferably formed of flexible or semi-flexible medically implantable material. Each of these sutures include longitudinally spaced, enlarged-in-diameter segments or protuberances **22**, **26**, **30**, **34** and **38** formed along the length of the corresponding slender suture strand **20**, **24**, **26**, **38** and **36**.

Suture **10** is formed having protrusions **22** which are substantially spherical or bead-shaped. Suture **12** includes the protuberances **26** which are in the form of a truncated cone, while suture **14** includes protuberances having a two-step truncated conical structure. Suture **16** includes protuberances **34** having opposing truncated conical portions forming each of the protuberances, while suture **18** has a gradual three step enlargement to each of the protuberances, ending in a sharply truncated conical end or tail portion thereof to interact with suture locking apertures described below.

Referring now to Figures 2 to 4, one embodiment of a tissue anchor within the scope of this invention is there shown generally at numeral **40** and is formed of a medically implantable material. This tissue anchor **40** includes a conical anchor body **42** having outwardly extending spiral threads which tightly lockingly engage into a tissue substrate such as bone or cartilage. As with all of the tissue anchors and suture tissue restraints disclosed within the scope of this invention, this tissue anchor **40** includes a suture engagement bar **46** having a pair of closely spaced apart suture locking apertures **48** which are sized in diameter and having one end thereof beveled so that, as will be described in detail herebelow, restrict an appropriately configured suture as described in Figure 1 hereinabove to pass snugly through each of the suture locking apertures **48** in only direction. That is to say that the suture may be drawn into each of the suture locking apertures **48** and pulled therethrough in one direction, but reversal of movement of the suture within these suture locking apertures **48** is prohibited or substantially inhibited so as to effect a locking position in one-way movement fashion of the suture therethrough.

The suture engagement bar **46** includes an anchor post **50** which snappingly and lockingly engages into a mating anchor post cavity **52** formed into the enlarged head proximal end of the anchor body **42** so that the suture engagement bar **46** may be rotated about the longitudinal axis of the anchor body **42** relatively freely so as to quickly and easily rotationally orient the suture engagement bar **46** to a neutral tension force applied by the suture when tightened.

Referring now to Figure 4A, an alternate embodiment of the tissue anchor **40** is there shown at numeral **40'** wherein the entire suture engagement bar **46** is recessed flush with the upper enlarged top surface **54** of the anchor body **42'**. Thus, once the suture has been passed through the suture locking apertures **48** after the suture engagement bar has been snappingly engaged into anchor post cavity **52'** and the anchor post **50** has been thusly secured therewithin, the top or outer edge of the suture engagement bar **46** is substantially even with the enlarged top surface **54** of the tissue anchor **40'**.

Referring now to Figures 5 and 5A, yet another embodiment of the tissue anchor is there shown generally at numeral **43**. This tissue anchor **43** includes a conical anchor body **44** having outwardly extending spiral threads and a fixed transverse suture engagement bar **46'** which is secured within a circular cavity formed into the head of the anchor body **44**. Again, the suture engagement bar **46'** includes two spaced suture locking apertures **48'** each having cooperatively oriented bevels so that a selected suture will pass in only direction through the pair of suture locking apertures **48'**. This embodiment **43** affords a one-piece structure with the suture engagement bar **46'** secured in place and in flush alignment with the head of the anchor body **44** which is the preferred configuration of a tissue anchor of this type.

Although not shown in Figures 2 to 5, the head of each of the tissue anchors will be provided with tightening cavities formed into the enlarged end of the anchor body so that a separate tool may be used to drivingly engage the spiral threads into the appropriate bone or cartilage substrate. The tissue anchor **43** in Figures 5 and 5A may be rotationally drivingly engaged into the tissue substrate by engagement of an appropriately configured tool onto the suture engagement bar **46**' which is rigidly secured in the position shown.

In Figures 5B and C, another configuration of a tissue anchor **41** is there shown configured similarly to the tissue anchors **40**, **40'** and **43** previously described. However, this tissue anchor **41** includes diagonally oriented intersecting apertures **45** and **47** which converge centrally of the anchor body adjacent to the enlarged head thereof and are sized to receive and permit only one-way movement of the suture **10** in the direction of the arrows. A one-way restriction **49** is provided so as to insure that, once tightened by pulling in the direction of the arrows, the suture **10** may not be moved in the opposite direction.

In Figures 5D and E, yet another tissue anchor is there shown generally at numeral **51** which also includes a pair of spaced parallel suture entry and exit apertures **53** and **55** which are interconnected by a transverse passage **57**. The suture entry aperture **53** is beveled and tapered so as to facilitate only one-way movement of the suture therethrough and exiting from the suture exit aperture **55** only in the direction of the arrows shown.

Referring now to Figure 6, another tissue anchor is there shown generally at numeral **61** formed of a medically suitable material having an elongated shank having two closely spaced apart suture locking apertures **65** and **67** formed therethrough and a plurality of circumferentially spaced radially extending tissue engaging members **63**. The locking apertures **65** include oppositely oriented bevels so that the suture may be drawn through the pair of locking apertures **65** in only the direction of the arrows.

Referring now to Figure 7, one embodiment of a suture tissue restraint is there shown generally at numeral **56**. This tissue restraint **56** may be formed of medically acceptable material. The body is domed-shaped having a flat tissue contact surface **62** and a central suture locking aperture **58** having a one-way suture lock **60** formed around the suture locking aperture **58** which prevents the suture from being drawn downwardly once a suture has been appropriately tensioned upwardly through the locking aperture **58**. A second suture **10a** is permanently connected through the body of the suture tissue restraint **56** extending downwardly from the flat tissue contact surface **62**. However, the suture **10a** may be cut at **64** and removed where a repair of tissue procedure only requires a single suture to be lockingly engaged within the suture locking aperture **58**.

In Figure 7A, another suture tissue restraint is there shown generally at numeral **67** or **67'** and formed having a domed-shaped body similar to that shown in Figure 7. However, in this embodiment **67/67'**, two spaced apart suture locking apertures **58'** are formed through the dome portion of the tissue restraint **67/67'** in closely spaced relationship facing the tissue engaging side of this tissue restraint **67** so that a suture may be tensioned upwardly or away from the tissue contact surface. However, the bevels of the suture locking apertures **58'** may be oriented oppositely one another to form suture tissue restraint **67'** to lockingly engage a single suture for one directional movement only. Note that, if formed as shown without the missing portions, these suture tissue restraints may be snappingly engaged over a suture and they continue to function as above described.

Note that hereinbelow, tissue anchors and suture tissue restraints are sometimes collectively referred to as "tissue engaging members".

Referring now to Figure 8, another suture tissue restraint is there shown generally at numeral **66** having a ring-shaped body with a flat tissue contact surface **72** and an open outer surface **74**. A transversely oriented suture engagement bar **70** formed as a unit with the ring-shaped body is also provided. Two spaced apart suture locking apertures **68** are oppositely beveled at **69** so as to provide the one-way locking engagement of a suture passing therethrough as previously described.

Referring now to Figure 9, a pictorial view showing a variety of tissue engaging members in relation to sutures **10** and **10a** are there shown. The suture **10** is lockably engaged through the two spaced locking apertures of the suture tissue restraint **66** when positioned against a flexible tissue gripping member **59** which provides a larger tissue contact surface which will biasingly flex against the tissue or tissue substrate to maintain tension produced by the suture when suitably positioned through a suture clearance aperture **71** formed centrally through the tissue gripping member **59**. Suture **10** is also shown passing through another suture clearance aperture **78** formed centrally through an enlarged tissue gripping member **76** and in one-way locking engagement with another suture tissue restraint **66**.

The suture **10** also extends through the suture locking aperture of the suture tissue restraint **56** for tensioning of the suture in the direction of the arrow. The suture **10a** which is permanently engaged at one end thereof into the body of the suture tissue restraint **56** as previously described then extends to one of the locking apertures of suture tissue restraint **67** while another portion suture **10** extends from the other locking aperture of the suture tissue restraint **67** for engagement through the dual locking apertures of the suture engagement bar **46** of the tissue anchor **40**. This portion of suture **10** is then shown continuing on for locking engagement through suture entry and exit cavities **45** and **47** of tissue anchor **41** and then returning to the suture tissue restraint **66** through suture clearance aperture **71**.

Still referring to Figure 9, another suture **10** may also be lockingly passed through spaced locking apertures **100** formed through an elongated orthopedic plate **96** which is also provided with spaced anchor screw holes **98**. Again, the spaced locking apertures **100** are cooperatively arranged and configured to allow for movement of the suture **10** in only direction therethrough. This suture **10** is shown continuing on to be lockingly engaged for one directional movement only through suture locking apertures **88** formed through a suitable portion of a typical hip prosthesis **86** or other medical implant, knee prosthesis, breast implant, cardiac pacemakers as examples but not to represent an all inclusive list, to which the suture **10** may be suitably anchored and tensioned as previously described.

Referring now to Figure 10, another exemplary installation arrangement utilizing the elongated suture **10** is there shown. In this embodiment, the suture **10** is passed at each end thereof through the spaced locking apertures **68** of the suture tissue restraint **66** which is positioned against a flat enlarged tissue gripping member **102** formed of thin surgical steel or other suitable material and having a suture clearance aperture **104** formed therethrough positionable in alignment with the locking apertures **68** of the suture tissue restraint **66**. A mid portion of the suture **10** is lockingly engaged for one directional movement only through the suture engagement bar **46** of the tissue anchor **40** as previously described.

In Figure 11, a pictorial view of another aspect of the invention utilized to repair and restrain a broken distal phalanx of a finger metacarpal is there depicted. The suture **10** is lockingly passed through passageways drilled or formed through the broken bone ends, a mid portion of the suture **10** passing lockingly through the spaced locking apertures of the suture tissue restraint **66**, each end of the suture **10** then lockingly passed through the suture tissue restraint **67** and tensioned in the direction of the arrows to secure the fracture for healing.

In Figure 12, repair of a torn ACL tissue of a knee joint is there depicted. The suture **10** is passed through passageways formed in the femur and the tibia in aligned opposing fashion, a mid portion of the suture passing through the spaced locking apertures of the suture tissue restraint **66** and the free ends of the suture **10** lockingly engaged through the locking apertures formed through the suture tissue restraint **67**.

In Figure 13, a torn MCL of a knee joint is shown being repaired wherein a modified suture **80** having no protuberances along one end **84** thereof is shown surgically attached to the torn end of the MCL, the suture **80** then passing through spaced locking apertures of the suture engagement bar **46** of the tissue anchor **40** which has been previously secured into the lower end of the femur.

In Figure 14, the repair of a torn medial patella-femoral ligament is there shown wherein one end **84** of a the suture **80** not having protuberances is surgically attached to the torn distal end of the ligament, the suture **80** then extending to the pair of locking apertures formed through the suture engagement bar **46** of tissue anchor **40** as previously described. The suture **80** then extends to the distal tip of the torn ligament passing therethrough and being secured in position by a suture tissue restraint **56'**, for added reattaching strength. The suture tissue restraint **56'** is as previously described in Figure 7 wherein the proximal protuberance **22** of suture **10a** has been cleavered or cut at **64** and removed as being unnecessary.

The repair of a tear in a labrum surrounding a hip socket is shown in Figure 15. The suture **10** is passed through the locking apertures of the suture engagement bar **46** of tissue anchor **40** which has previously been secured into the hip socket. The suture **10** is then passed through the tear and through the locking apertures of the surgical tissue restraint **67** and tensioned in the direction of the arrows to tighten and repair the tear.

In Figure 16, the repair of a distal biceps which has become detached is there shown. A modified suture **80** which is absent protuberances at one end thereof at **84** is surgically attached to the distal end of the biceps and then passed through a passageway drilled through the radius and then lockingly engaged through the locking apertures formed through the suture tissue restraint **67'**. The free end of the suture **80** may be then passed back through the passageway and through the distal biceps and tensioned in the direction of the arrow to re-secure the biceps for healing.

Reattachment of the fibula in an ankle syndesmodic disruption is shown in Figure 17. The suture **10** is passed through a drilled transverse passageway adjacent the end of the tibia. A mid portion of the suture **10** is lockingly engaged through the locking apertures of the suture tissue restraint **66** pressed against the tibia. Another suture tissue restraint **67** then receives both ends of the suture **10** after being passed through the lower end of the fibula and tensioned in the direction of the arrows to secure the repair.

Reattachment of the proximal biceps tendon is shown in Figure 18 wherein a modified suture **80** absent protuberances along a mid portion thereof is wrapped around the proximal biceps tendon and there secured. The protuberance-carrying ends of the suture **80** are passed through the locking passageways of two spaced apart tissue anchors **41**, each of which have been previously surgically anchored into the humeral head. The ends of the suture **80** are then tensioned in the direction of the arrows to secure the repair.

In Figures 19 and 20, a disc-shaped suture loop lock **106** is provided with spaced apart locking apertures **108** to secure the crisscrossed ends of each suture **10** which is initially passed around the tear formed through the capsule around a shoulder socket. This repair is notably accomplished without the typical tissue anchors, relying upon the tension locking features of each of the suture loop locks **106** as shown in Figure 20.

Figures 21, 22 and 23 show alternate repair techniques utilizing the invention to repair a tear in the shoulder labrum. Figure 21 provides a total of three separate segments of suture **10** passing therethrough while in Figure 22, only two separate lengths of sutures **10** are provided. However, in Figure 23 a total of four segments of two sutures **10** more tightly draw the tear together for repair.

Repair of a detached coracoclavicular ligament is shown in Figure 24 which utilizes two separate sutures **10** each passing through drilled passageways formed through the clavicle and the coracoid as shown. The ends of each of the suture **10** are secured through modified suture tissue restraints **56'** as previously described. Tensioning of all four ends of the sutures **10** provide for both strength and refined tension adjustment of the repair.

In Figures 25 and 26, the repair of a subscapularis detachment is there shown wherein two sutures **10** each pass through a passageway formed through the humeral head with modified suture tissue restraints **56'** restraining each end of each of the sutures **10** as previously described.

The attachment of a torn rotator cuff tendon is shown in Figure **27** utilizing a single suture row technique. The suture **10** is passed at each end thereof through the locking apertures of each tissue anchor **40** which have been previously secured into the ends of the humerus. The suture **10** is then previously passed through the rotator cuff tendon and tensioned at each end thereof in the direction of the arrows. In Figures 28 and 29, a double row repair of the rotator cuff tendon is there shown where two parallel sutures **10** are each passed through tissue anchors **40** and through the rotator cuff tendon as shown. In Figure 29, an additional locking and retaining function against the rotator cuff tendon is provided by a modified suture tissue restraint **56'**.

Meniscus repair is demonstrated by the use of the invention in Figures 30 and 31. In Figure 30, the meniscal tear is longer requiring a total of four suture segments therethrough using two separate sutures **10**. One of the sutures **10** is passed three times through the tear and anchored at a mid-portion thereof through suture tissue restraint **66** and permanently at one end thereof within suture tissue restraint **56**. The permanently secured suture **10** of the suture tissue restraint **56** is then passed through the repair, exiting the opposite surface of the meniscus as shown.

In Figures 32 and 33, an alternate technique for meniscal tear repair is there shown wherein, in Figure 32, a single suture **10** is passed three times through the tear utilizing the suture tissue restraints **66** and **56'** as shown. In Figure 33, a total of four passes through the tear is provided wherein the free ends of the suture **10** are drawn from the torn meniscus without the need for suture restraint.

Referring now to Figure 34, reversal of locking protuberances and apertures is there demonstrated to be within the broad scope of this invention. Flexible elongated suture **110** is shown lockingly engaged for one-directional movement only within a pair of closely spaced locking apertures **122** of a suture tissue restraint **112**. The suture has a series of spaced locking grooves formed therein which have a locking edge **116** and a ramped edge **118**. Each of these grooves **114** are matingly engageable with radially inwardly extending protuberances **124** each having a square locking edge **126** and a ramped edge **128** to accomplish unidirectional movement of the suture **110**.

Referring now to Figures 35 to 47, a number of alternate embodiments of the tissue anchor are there shown. In Figure 35, this tissue anchor **130** is formed thereof having a solid tapered spiral thread **132** with a tissue-penetrating tip **136** at the distal end. A solid tapered head **134** includes a coaxial driving socket **138** at the proximal end of this tissue anchor **130**. The head **134** also includes two intersecting suture entry and exit cavities **142** and **144** having a suture restriction **140** therebetween to insure that, once a suture is pulled through these cavities **142** and **144**, it may not be removed by pulling in the opposite direction.

In Figure 36, another tissue anchor **150** includes a solid head **154** and a hollow tapered spiral coil **152** extending therefrom. This coil **152** is formed of surgical stainless steel wire, spiral wound and having a sharpened tissue-penetrating tip **156** at the distal end thereof. Being hollow, less tissue is displaced as the spiral coil **152** is driven into tissue, particularly bone and tendons. Intersecting suture entry and exit cavities **162** and **164**, separated by a suture one-way restriction **160**, function as previously described in Figure 35 for one-way insertion of a suture in accordance with this teaching.

Figure 37 discloses yet another tissue anchor **170** having a hollow cylindrically wound spiral coil **172** formed of surgical steel wire with a sharpened tissue penetrating tip **176** at its distal end. The head **174** includes an axially aligned driving socket **178** and intersecting suture entry and exit cavities **182** and **184** with a one way restriction **180** therebetween.

Another tissue anchor **190** is shown in Figure 38 having a hollow tapered spiral coil **192** again with a tissue penetrating tip **196** at its distal end. The opposite end of the tapered spiral coil **192** is anchored into head **194** having a coaxial driving socket **198** at its proximal end. Suture entry and exit cavities **202** and **204** are separated within the head **194** by a suture one way restriction **200**. As best seen in Figure 39, the outer edge **208** of the tapered spiral coil **192** is sharpened for enhanced tissue cutting and securement of the spiral coil **192** as its is driven into both soft and hard tissue for enhanced permanent anchoring thereof within the tissue.

As seen in Figure 39A, one form of outer edge enhancement is in the form of a serrated edge **208a**. In Figure 40, several alternate embodiments of the cross section of the spiral coil **192b**,**c**,**d**,**e**,**f**,**g**,**h** include tissue cutting outer edges at **208b**,**c**,**d**,**e**,**f**,**g**.

In Figure 41, another tissue anchor is shown at **210** also having a hollow tapered spiral coil **212** with a sharpened distal tissue-penetrating tip **216**. The opposite end of the coil **212** is secured into the solid head **214**. Also secured within the head **214** is a coaxial cylindrical centering shaft **226** having a sharpened tip **228** which serves to center the tissue anchor **210** as it is being rotationally driven into tissue by a suitable power unit engaged into driving socket **218**. Once anchored into the tissue, a suture is passed through the intersecting suture entry and exit cavities **222** and **224**, the suture being permitted only one way movement therethrough by a suture one way restriction **220** therebetween.

Additional embodiments of the tissue anchor shown in Figures 42 to 47 generally at **230**, **250**, **270**, **230'**, **250'**, and **270'** all include combinations of tapered tissue penetrating segments in the form of tapered spiral coils **232**, **252** and **274** and solid tapered screw segments **234**, **254** and **276**. Each suture embodiment also includes a distal tissue penetrating tip **238**, **258** or **280**. Each of the solid heads **236**, **256** and **278** have a driving socket **240**, **260** and **282** which coaxially extend from the proximal end thereof. Intersecting suture entry and exit cavity pairs **244**/**246**, **264**/**266** and **286**/**288** are each separated for only one way suture movement therethrough by suture one way restrictions **242**, **262** and **284**, respectively, as previously described. The embodiments **230'**, **250'** and **270'** in Figures 45, 46 and 47 also include coaxially aligned centering shafts **248**, **268**, and **289**. Centering shaft has a pointed distal tip **249** which serves to center the tissue anchor **230'** during driven rotation into tissue. Centering shafts **269** and **289** are present for stabilization and added strength between the head **256** and **278** and the screw segments **254** and **276**.

A variety of exemplary additional embodiments of the suture are shown in Figures 48 to 52 at **290**, **296**, **304**, **312** and **320**. Each of these suture embodiments are configured for only one way movement through appropriately configured capture arrangements formed in one or more suture tissue restraints, tissue anchors and virtually all other medical implants and devices requiring permanent securement within human tissue or bone. Each of these sutures includes an elongated flexible suture strand **292**, **298**, **306** and **314**. Each of these sutures also includes longitudinally spaced, enlarged-in-diameter segments or protuberances **294**, **300**, **308**, **316** and **322**/**324**. Protuberances **294** are domed shaped, protuberances **300** are mushroom shaped having a cavity **302** formed immediately adjacent the suture strand **298**, protuberances **308** are cupped-shaped also having an enlarged cavity **310** extending inwardly from the locking surface, while protuberances **316** extend around only ¼ of the circumference of the entire strand **314** demonstrating that protuberance may be nonsymmetrical. In Figure 52 this suture **320**, absent a literal suture strand, includes spaced 90° offset or staggered arrow-shaped protuberances **322** and **324**. A lead-in tip **326** facilitates insertion of the lead arrow **322** into tissue or the appropriately configured one-direction capture arrangement associated with various configurations of suture tissue restraints, tissue anchors and various other surgical implants and medical devices in accordance with the teaching of this disclosure.

Referring now to Figures 53 to 57, another uniquely configured suture tissue restraint is shown generally at **330**. This tissue restraint **330** provides finer suture tension adjustability than may be available by simply tensioning the free end of the suture to the next available protuberance within other non-adjustable tissue suture restraints. This tissue suture restraint **330** includes a disk-shaped body **332**. The non-tissue contacting surface is generally concaved toward the central suture passage aperture **336**, which is sized for free suture movement therethrough. A plurality of radial slots **338**, **346** and **354** extend from the suture passage aperture **336**, each being sized in width for the suture strand to freely pass therealong. The suture strand is then moved along through concentric slots **340**, **348** or **356** into alignment with one of the selected suture strand apertures **344**, **352** or **360**. As best seen in Figure 53A, the exemplary suture **10** may then be position so that one of its protuberances nests into a selected suture socket **342**, **350** or **358**.

As best seen in Figures 55, 56 and 57, each of these suture sockets **342**, **350** and **358** are spaced from the tissue contact surface a different distance **Ta**, **Tb** and **Tc** which affords a much finer gradation of suture tensioning capability than normally afforded by simply pulling the suture to the next available protuberance along the length of the suture strand.

An alternate embodiment of this form of adjustable suture tissue restraint is shown in Figure 58 at **370**. This suture tissue restraint **370** includes a disk-shaped body **372** having a centrally positioned suture passage aperture **374** sized for free suture passage therethrough. However, only a single radial slot **380** is included which facilitates moving the suture strand of the suture therealong into concentric slot **382** and into alignment with suture strand aperture **378** or further along concentric slot **388** into alignment with suture strand **386** or still further along concentric slot **394** into suture strand aperture **392**. The appropriate protuberance is then nestled securely into the corresponding suture socket **376**, **384** or **390** in a manner similar to that shown in Figure 53A.

Referring now to Figures 59 to 64, an expandable suture tissue restraint is there shown at numeral **400**. This concept incorporates circumferential expandability in direction of the arrow in Figure 59 to accommodate one-way passage of each suture protuberance through the expandable suture-locking aperture **404**. This restraint **400** includes a plurality of circumferentially spaced solid segments **402** spaced apart by a series of expandable aperture segments **406**. The inward tapered surfaces of these segments **402** and **406** define the tapered walls of a locking aperture **404**.

Each expandable aperture segment **406** includes alternating resilient layers **418** and solid layers **419** bonded together and to the ends of the corresponding solid segments **402**. As a suture **410** shown in Figure 62 having tapered truncated conical-shaped spaced saw tooth-shaped protrusions 412 is drawn through the suture locking aperture **404**, the circumference of the locking aperture **404** expands in the direction of arrows **59** best seen in Figures 63 and 64 to allow the suture **410** to be pulled therethrough only in the direction of the arrow in Figure 62, surfaces **416** and **418** interacting to prevent reverse movement of the suture **410**.

Referring additionally to Figures 63 and 64, alternate configurations of the protuberance **22** and **34**, respectively, will also be lockingly passable in one way fashion in the direction of the arrow causing the expansion of the resilient segments **418** as the corresponding protuberance **22** or **34** passes forcibly therethrough.

In Figures 65 and 66, an alternate embodiment to that shown in Figure 59 is shown generally at numeral **400'** which includes substantially the same elements of embodiment **400** except for the addition of an elastic resilient O-ring **420** tightly fitted into an annular grove **422** formed inwardly into each of the solid segments **402'**. The O-ring **420** has a relaxed diameter smaller than that of the annular grove **422** such that, when stretched into place within the annular grove **422**, resistance to elastically stretching the diameter of the suture-locking aperture **404** is increased.

In Figures 67 to 73, two embodiments of a pie-shaped expandable suture tissue restraint are there shown at **430** and **430a**. These embodiments, **430** and **430a**, have a generally button or disk shaped body **432** and are preferably compatible with sutures having a spherical protuberance as described above and include a plurality of spaced apart rigid sectors **434** which are separated by very thin and thus resilient flat disk **436** as best seen in Figure 70B. Alternately, this resilient flat disk **436** may be formed of a more resilient elastomeric material. The expandable suture-locking aperture **438** is configured having cylindrical aperture segments **440** and outwardly tapered inlet aperture segments **432** configured to allow a spherical protuberance or the like of a suture to pass downwardly therethrough in the direction of the arrow in Figures 70A and 70B by the elastic expansion of suture-locking aperture **438**. The outlet aperture segments **444** seat the spherical protuberance but will not allow it to pass back through the suture-locking aperture **438**, thus locking the suture in place relative to the expandable suture restraint **430**.

Referring additionally to Figures 71 and 72, an alternate embodiment to that shown in Figure 67 is there shown at **430a** which includes a disk-shaped body **432a** having spaced apart rigid sectors **434a** held together by thinner resilient disk **436** as previously described. A resilient O-ring **450** is stretchingly embedded into an annular groove **452** formed into the outer ends of each of the rigid sectors **434a** for enhanced elasticity of the expandable suture locking aperture **438** as previously described.

Referring now to Figures 74 and 75, another alternate embodiment of the expandable suture restraint of Figure 67 is there shown generally at numeral **430b**. In this embodiment **430b**, one of the rigid sectors **434b** is deleted as shown at **454**. All other features of this embodiment **430b** are as described with respect to Figure 71. This disk-shaped body thus acts as a C-shaped body and is free to elastically expand in the direction of the arrows to allow resilient enlargement of locking aperture **438** to **438'** when a protuberance is forcibly urged therethrough only in the direction of the arrow.

Referring now to Figures 76 and 76A, two additional alternative embodiments of the expandable suture tissue restraint of Figure 1 are there shown generally at numerals **430c** and **430d**. Each of these embodiments **430c** and **430d** provide tapered segments **456** and **456a** of each rigid sector **434c** and **434d**, respectively, which collectively define a centered extension of the tissue contact surfaces **458** and **458a** which serve to better avoid lateral movement of the suture tissue restraint **430c** and **430d** when embedded into soft tissue as the suture is tensioned.

Referring now to Figures 77 to 82, a series of suture/tissue restraint arrangements **460**, **480**, **500**, **520**, **540**, and **560** including sutures **462**, **482**, **502**, **522**, **542** and **562** inserted into suture tissue restraints **472**, **492**, **512**, **532**, **550** and **572** are there shown. In these arrangements, the protuberances **464**, **484**, **502**, **524**, **544** and **564** which are attached to or formed as a part of the corresponding suture strand **466**, **486**, **506**, **526**, **546** and **566** resiliently deform as they are pulled through the respective suture apertures **474**, **492**, **514**, **536**, **552** and **574** in the direction of the corresponding arrows. The protuberances are resiliently deformed by the displacing interaction of the surfaces **468**/**476**, **488**/**494**, **508**/**516**, **528**/**534**, **548**/**554**, and **568**/**576**. Locking resistance to reverse direction movement of each of these sutures is achieved by the overall configuration of each of the protuberances and the mating configurations of surfaces **470**/**478**, **498**/**496**, **510**/**518**, **530**/**538**, **556**/**558**, and **570**/**578**.

Referring lastly to Figures 83 and 84, another embodiment of the tissue anchor is there shown at numeral **580**. This exemplary embodiment **580** includes a solid tapered spiral thread **582** having a distal tissue penetrating tip **584** and a tapered head **586** formed having an axially aligned driving socket **594** formed into the proximal end of the tissue anchor **580**. This embodiment **580** utilizes the resilient protuberance concept previously described in Figures 77 to 82, wherein the suture passage **588** is arcuately configured for smooth passage of the resiliently collapsed protuberances **464'** as they are forced against the head deforming inlet surface **590** as the suture is pulled in the direction of the arrow. Reverse movement of the suture is prohibited by the interaction of surface **470** of the backside of each protuberance **464** against the head locking surface **492**.

While a number of exemplary aspects and embodiments have been discussed above, those of skill in the art will recognize certain modifications, permeations and additions and subcombinations thereof. It is therefore intended that the following appended claims and claims hereinafter introduced are interpreted to include all such modifications, permeations, additions and subcombinations that are within their true spirit and scope.

CLAIM OR CLAIMS

1. A surgical suture system for tissue repair and reattachment of torn tissue to a tissue substrate or medical implant to tissue comprising:

an elongated flexible suture member having a plurality of longitudinally spaced protuberances along a length thereof;

a tissue engaging member having a body including two closely spaced apart locking apertures sized to receive said suture member passed therethrough for longitudinal movement of said suture member in only one direction through said locking apertures.

2. A surgical suture system as set forth in Claim 1, wherein:

said tissue engaging member is formed as a tapering conical-shaped threaded tissue anchor having said locking apertures formed through a head or body thereof.

3. A surgical suture system as set forth in Claim 1, wherein:

said tissue engaging member is shaped similar to a grapnel-type anchor having said locking apertures formed through an elongated shank thereof.

4. A surgical suture system as set forth in Claim 1, wherein:

said tissue engaging member is formed having a mushroom button shape having said locking apertures formed transversely therethrough.

5. A surgical suture system as set forth in Claim 1, wherein:

said tissue engaging member has a domed button shape having one said locking aperture positioned centrally thereof and one said suture member permanently secured in another of said locking apertures.

6. A surgical suture system as set forth in Claim 1, wherein:

said tissue engaging member is formed having an annular ring with a suture engaging bar extending centrally between an inner surface of said annular ring;

said locking apertures being formed through said suture engaging bar.

7. A surgical tissue engaging member for tissue repair and reattachment of torn tissue to a tissue substrate, medical prosthesis, or medical implant in conjunction with an elongated slender flexible suture member having a plurality of longitudinally spaced protuberances along a length thereof, said tissue engaging member comprising:

a body including two closely spaced apart locking apertures each sized to receive said suture member passed therethrough to cooperatively restrict longitudinal movement of said suture member to only one direction through said locking apertures.

8. The tissue engaging member as set forth in Claim 7, wherein:

said tissue engaging member is formed as a tapering conical-shaped threaded tissue anchor having said locking apertures formed through a head thereof.

9. The tissue engaging member as set forth in Claim 7, wherein:

said tissue engaging member is formed as a grapnel-type anchor having said locking apertures formed through an elongated shank thereof.

10. The tissue engaging member as set forth in Claim 7, wherein:

said tissue engaging member is formed as a mushroom button shape having said locking apertures formed transversely therethrough.

11. The tissue engaging member as set forth in Claim 7, wherein:

said tissue engaging member is formed having a domed button shape having one said locking aperture positioned centrally thereof and one said suture member permanently secured in another of said locking apertures.

12. The tissue engaging member as set forth in Claim 7, wherein:

said tissue engaging member is formed having an annular ring with a suture engaging bar extending centrally between an inner surface of said annular ring;

said locking apertures being formed through said suture engaging bar.

13. The improvement as set forth in Claim 7, wherein:

said tissue anchor is formed having a hollow spiral-shaped coil.

14. A medically implantable device for tissue repair and reattachment of torn tissue to a tissue substrate or to a medical implant in conjunction with an elongated flexible suture having a plurality of longitudinally spaced protuberances along a length thereof, said device comprising:

a body including at least one locking aperture formed therethrough and being sized and configured to receive a suture being inserted into said aperture for continued longitudinal movement of the suture in only one direction through said aperture.

15. A medically implantable device as set forth in Claim 14, wherein:
said body includes two said locking apertures closely spaced apart and cooperatively acting to prevent reverse movement of the suture from that of the one direction.

16. A medically implantable device as set forth in Claim 14, wherein:
said body is formed as a tapering conical-shaped threaded tissue anchor having said locking apertures formed through a head thereof.

17. A medically implantable device as set forth in Claim 14, wherein:
said body is formed having a mushroom button shape having said locking apertures formed transversely therethrough.

18. A medically implantable device as set forth in Claim 14, wherein:
said body is formed having an annular ring with a suture engaging bar extending centrally between an inner surface of said annular ring;
said locking apertures being formed through said suture engaging bar.

19. A medically implantable device as set forth in Claim 14, wherein:
said body is formed having a hollow spiral-shaped coil.

20. A medically implantable device as set forth in Claim 14, wherein:
said body includes a plurality of spaced apart said locking apertures, each said aperture lockingly positioning one protuberance at a different distance from a tissue contact surface of said body.

21. A medically implantable device as set forth in Class 14, wherein:

said body includes spaced resilient, elastic layers connected between rigid, solid segments wherein said suture locking aperture is expandable responsive to forced movement of each protuberance therethrough.

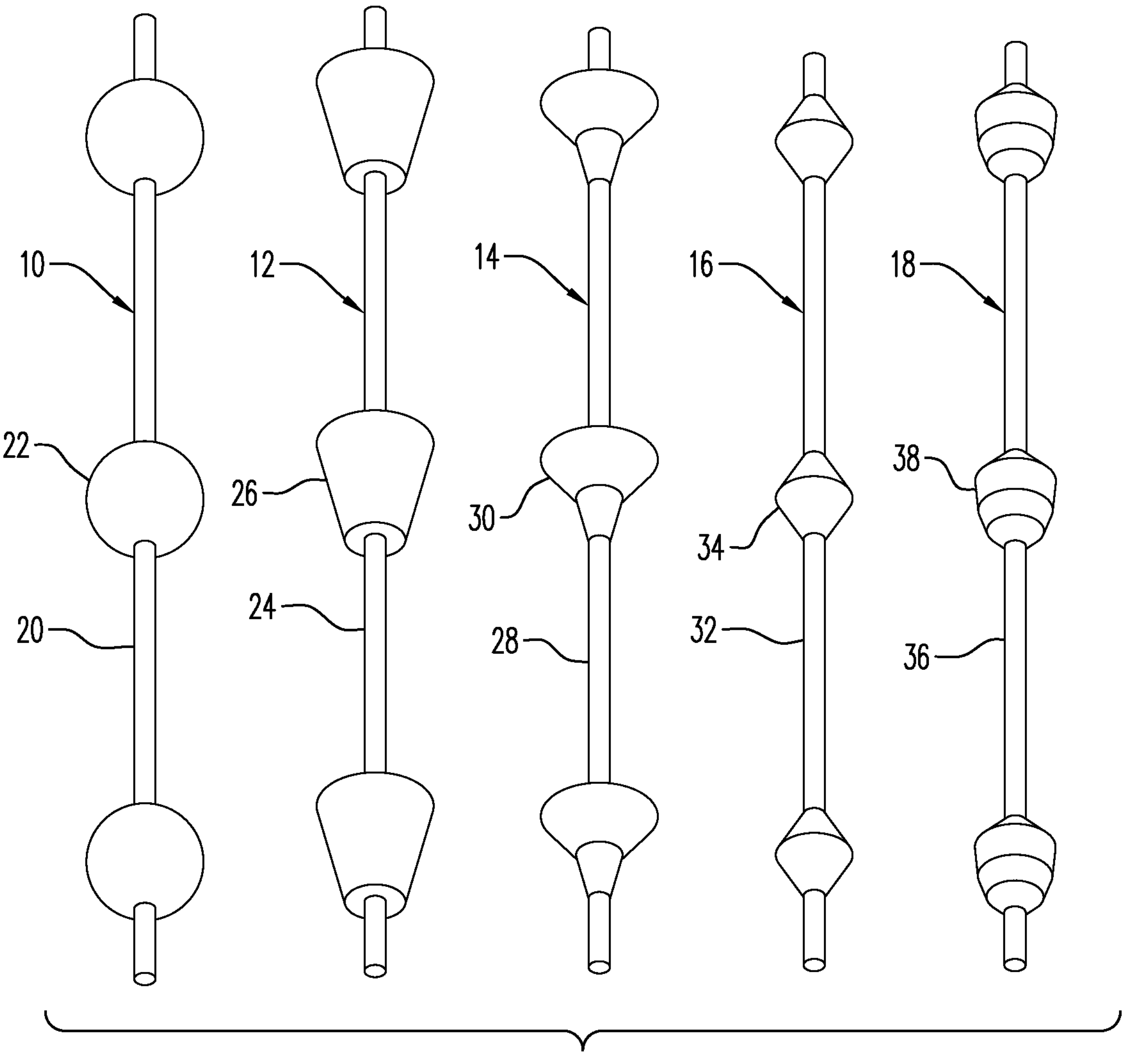



FIG. 1

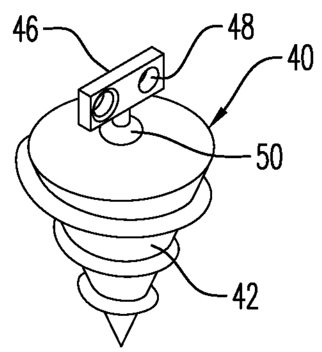



FIG. 2

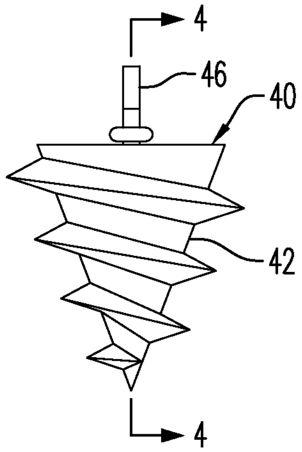



FIG. 3

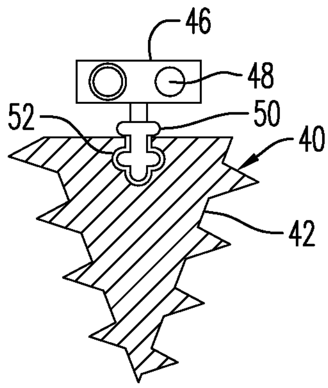



FIG. 4

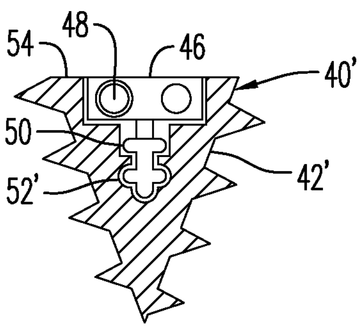



FIG. 4A

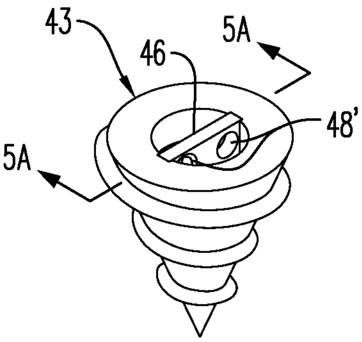



FIG. 5

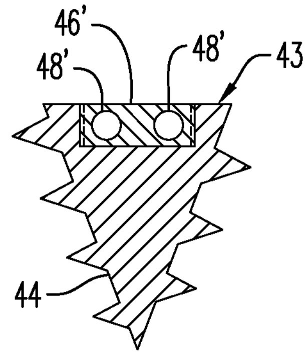



FIG. 5A

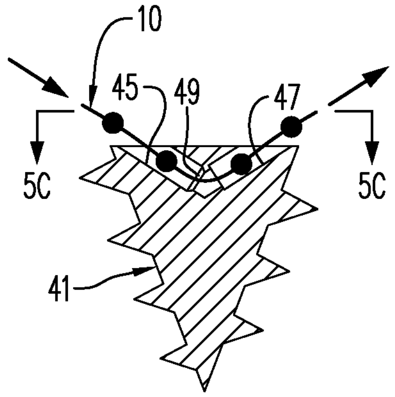



FIG. 5B

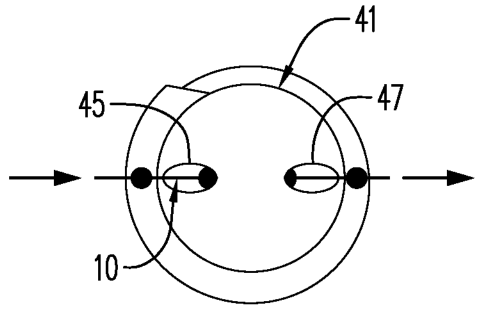



FIG. 5C

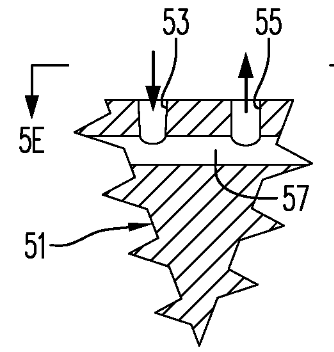



FIG. 5D

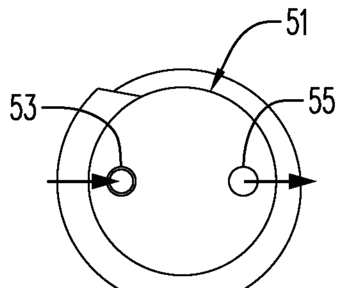



FIG. 5E

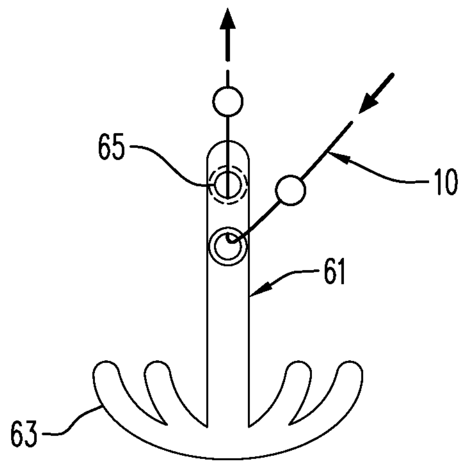



FIG. 6

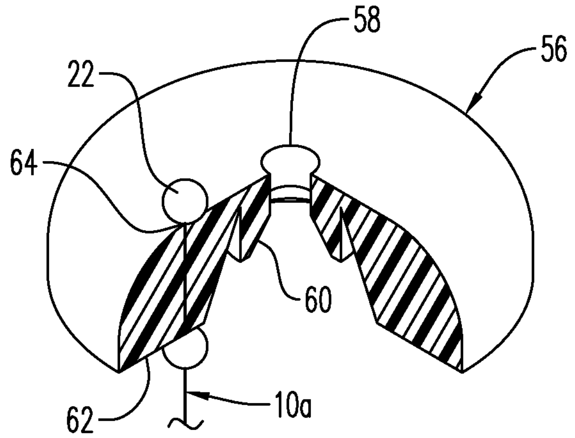



FIG. 7

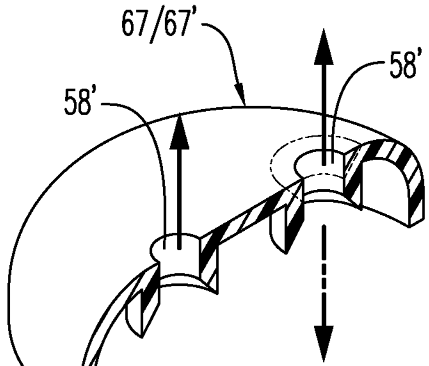



FIG. 7A

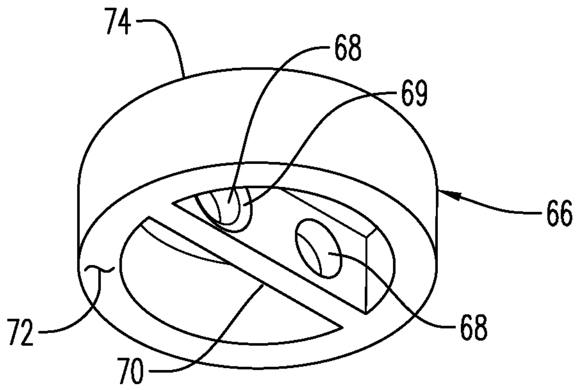



FIG. 8

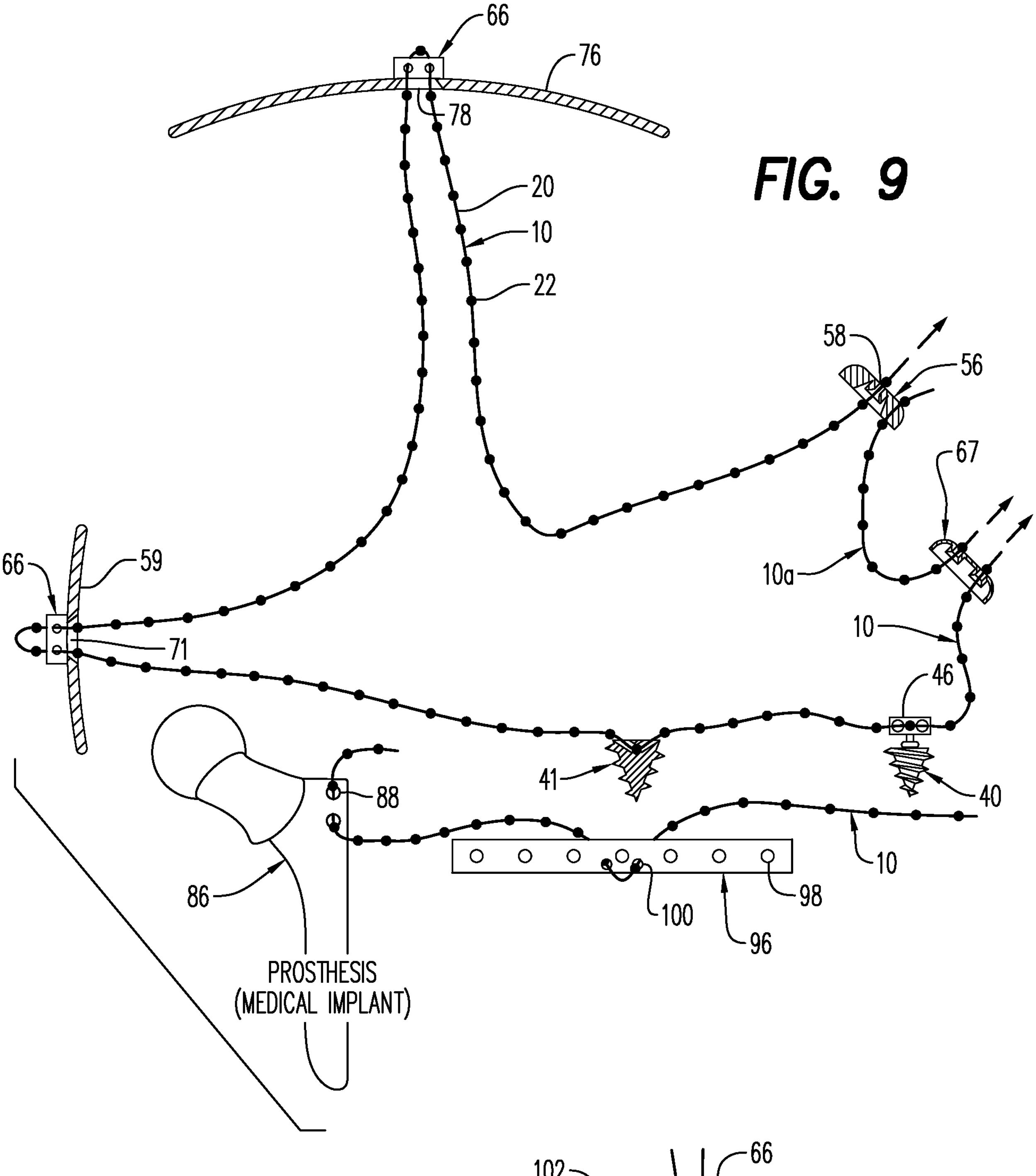

66
76
78
20
10
22
58
56
67
66
59
10a
71
10
46
41
40
88
10
86
100
98
96
PROSTHESIS
(MEDICAL IMPLANT)

FIG. 9

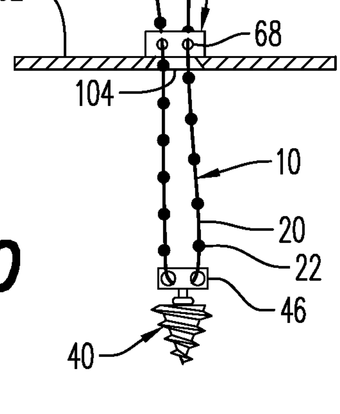

102
66
68
104
10
20
22
46
40

FIG. 10

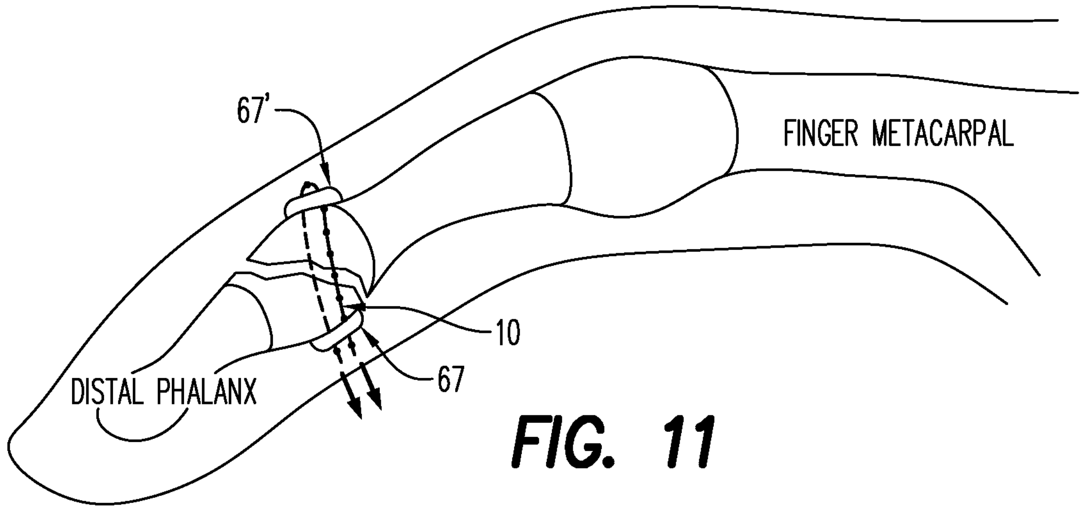



FIG. 11

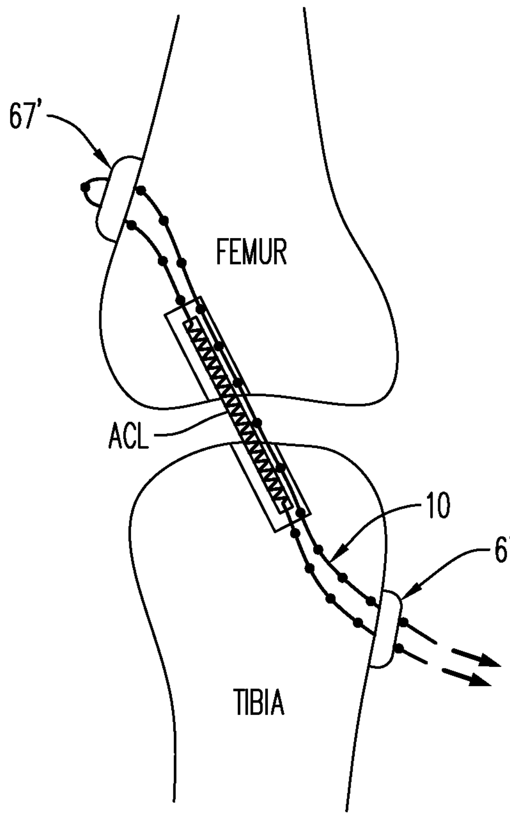



FIG. 12

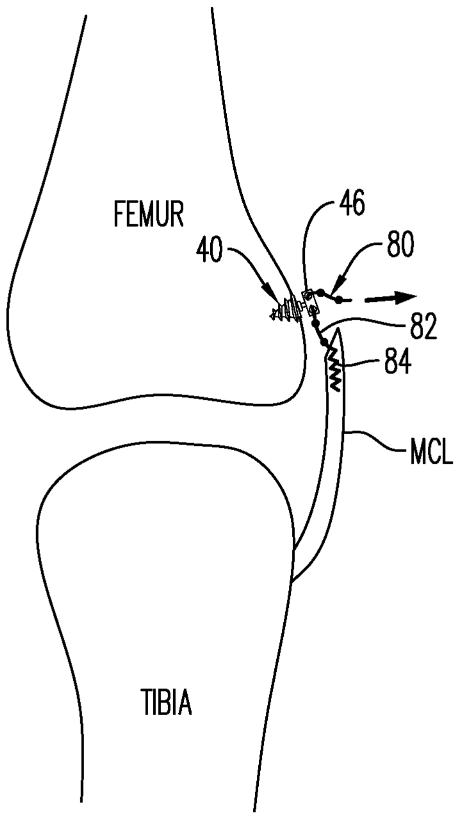



FIG. 13

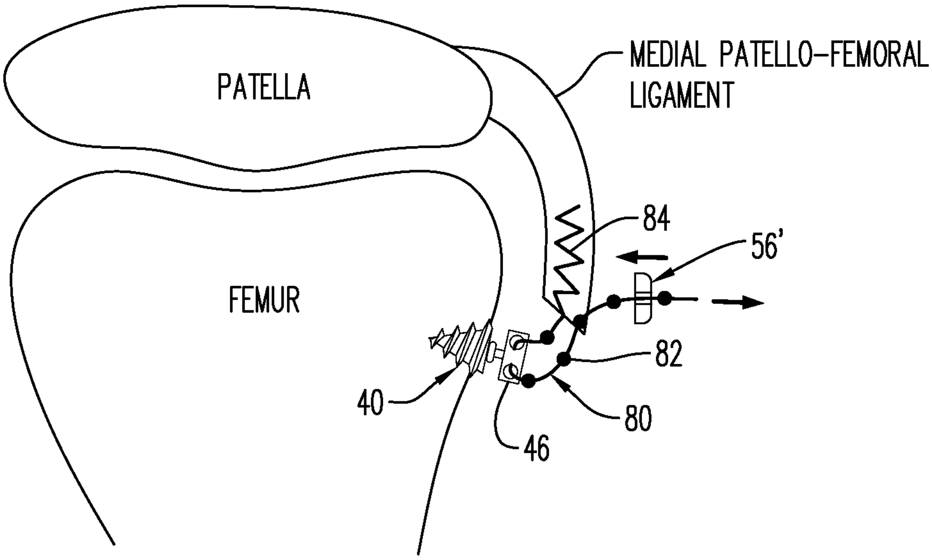



FIG. 14

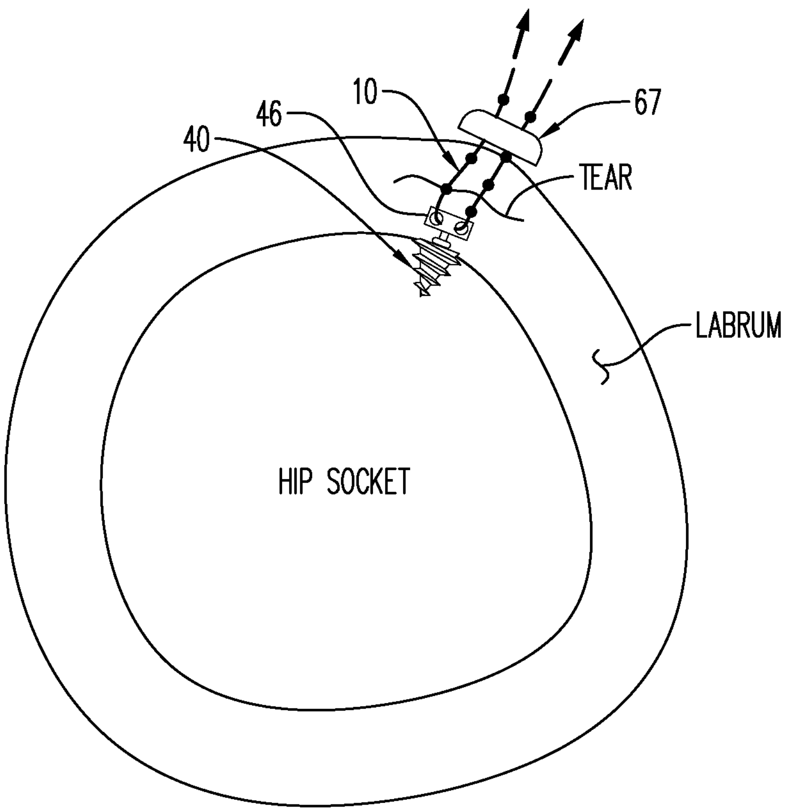



FIG. 15
HIP LABRAL REPAIR

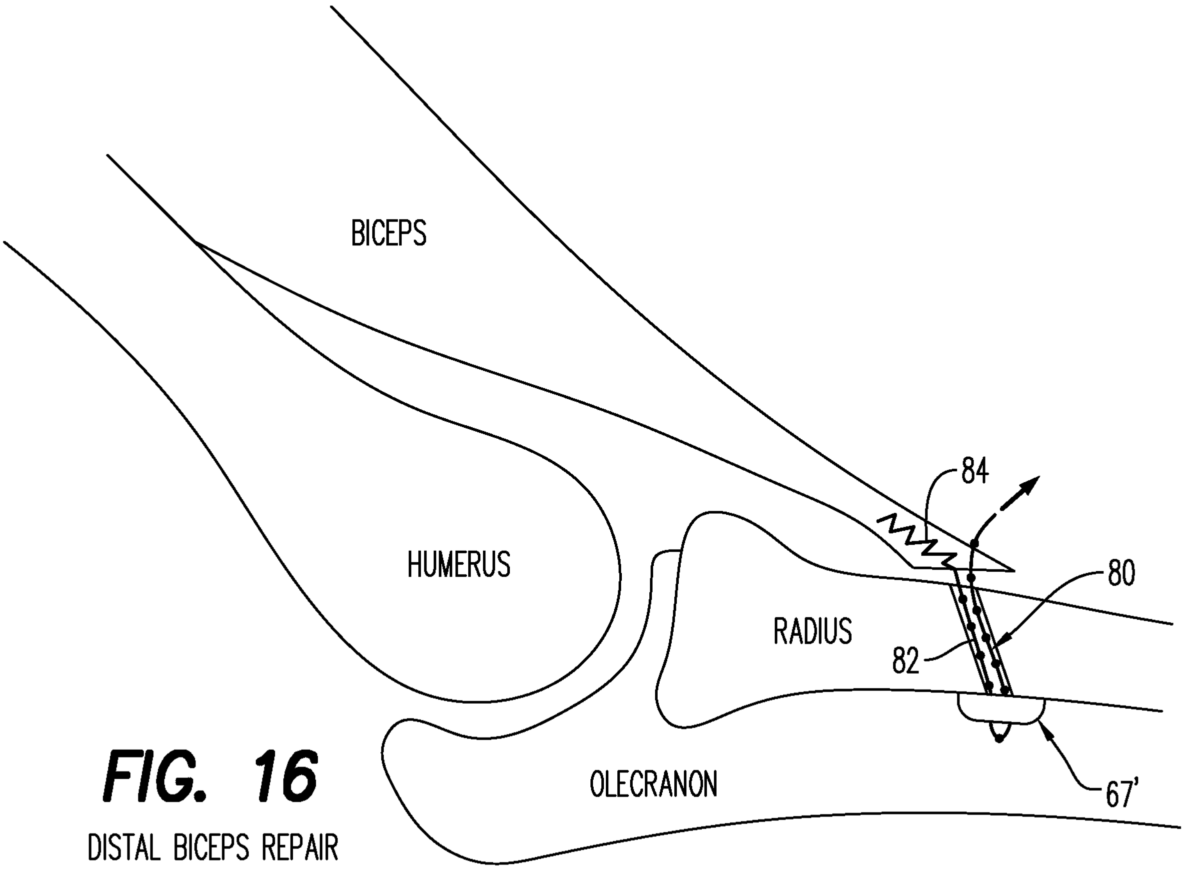



FIG. 16

DISTAL BICEPS REPAIR

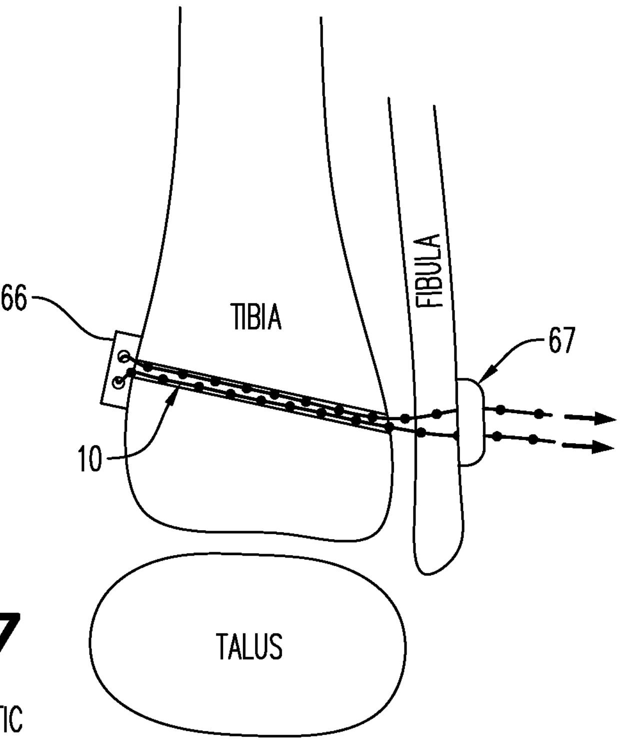



FIG. 17

ANKLE SYNDESMOTIC DISRUPTION

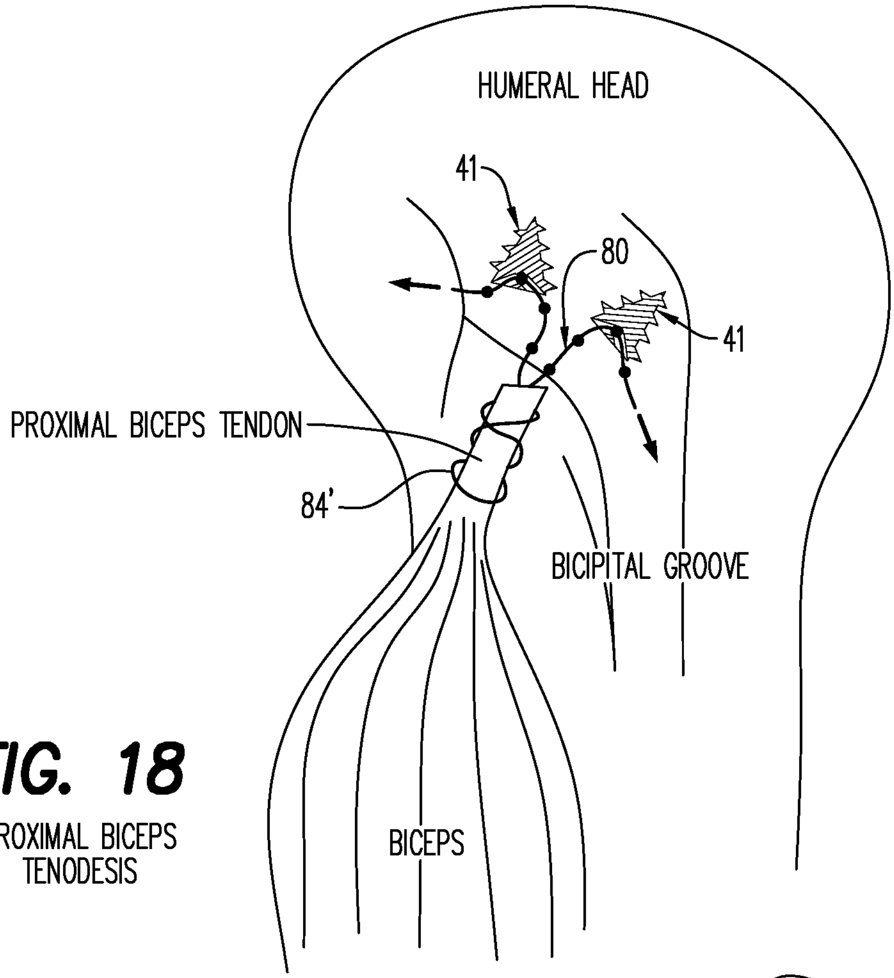



FIG. 18

PROXIMAL BICEPS TENODESIS

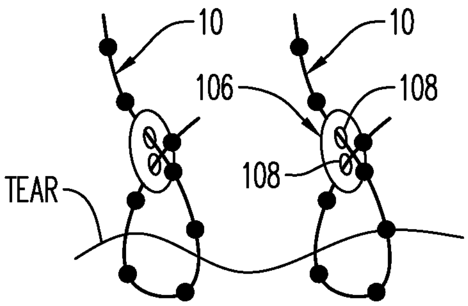



FIG. 20

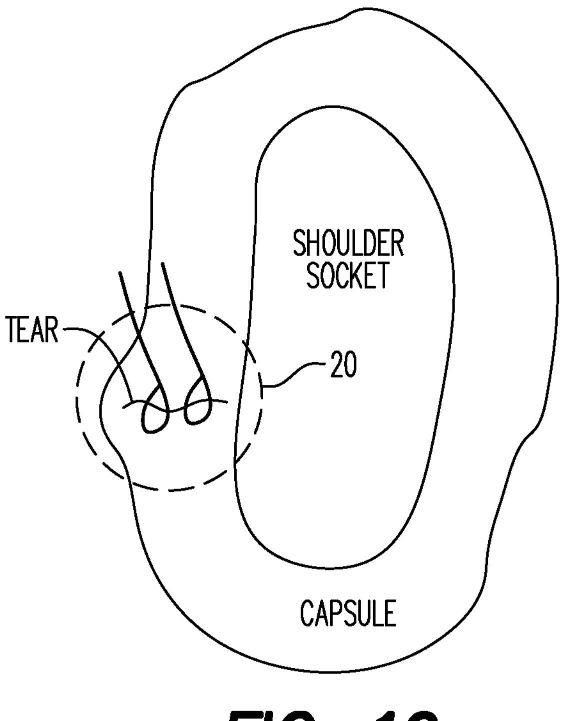



FIG. 19

JOINT CAPSULE REPAIR WITH FREE CAPTURE WITHOUT ANCHOR

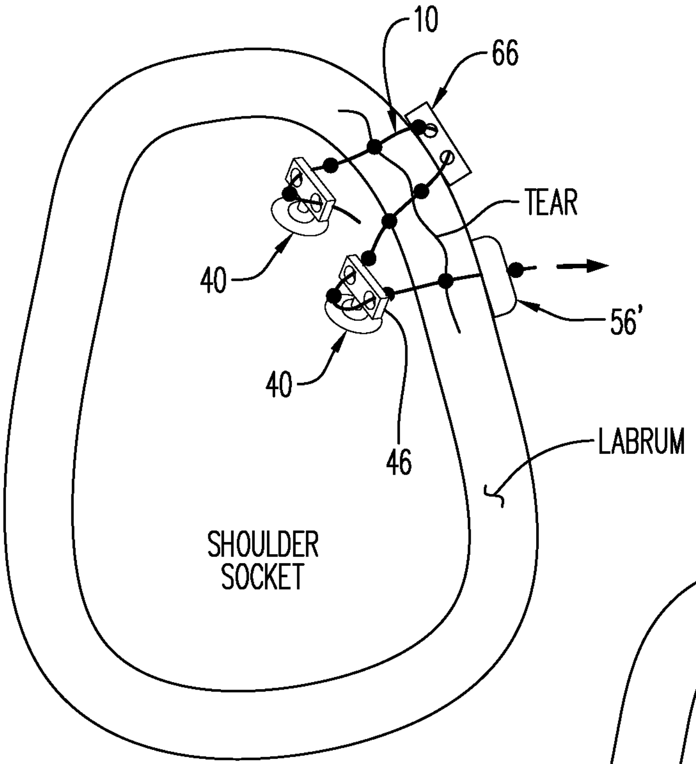



FIG. 21
SHOULDER
LABRAL REPAIR

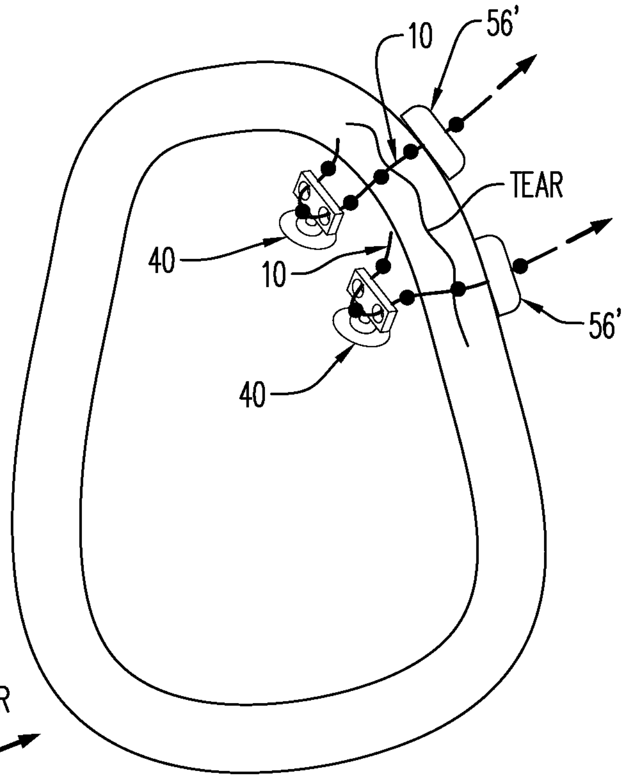



FIG. 22

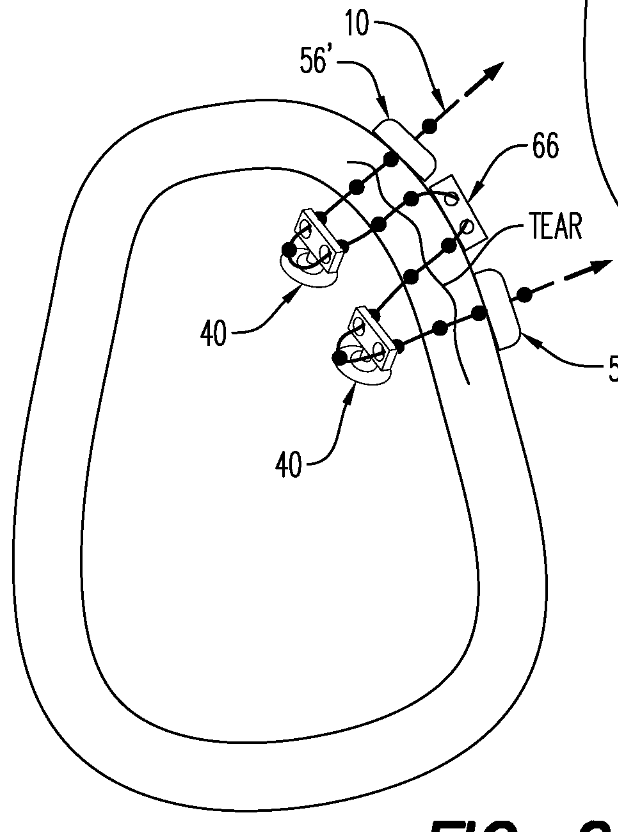



FIG. 23

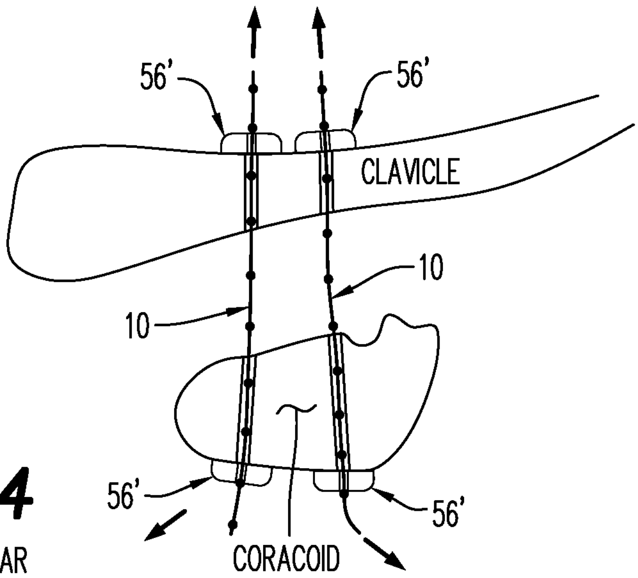



FIG. 24

CORACOCLAVICULAR LIGAMENT REPAIR

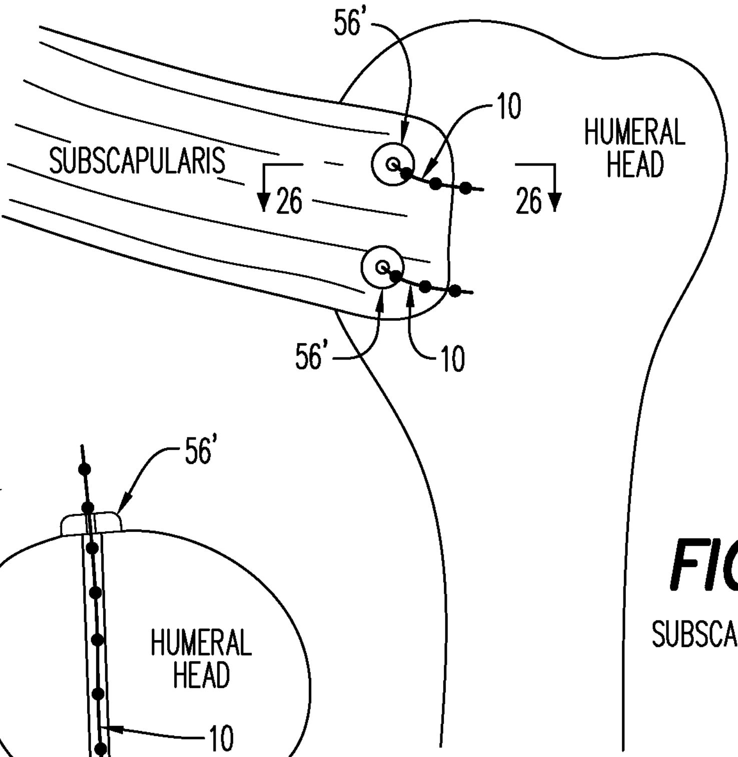



FIG. 25

SUBSCAPULARIS REPAIR

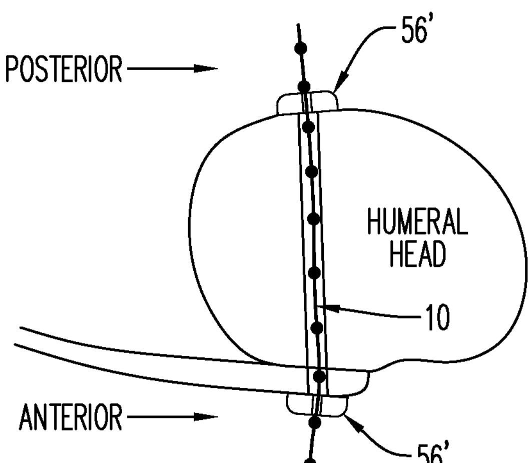



FIG. 26

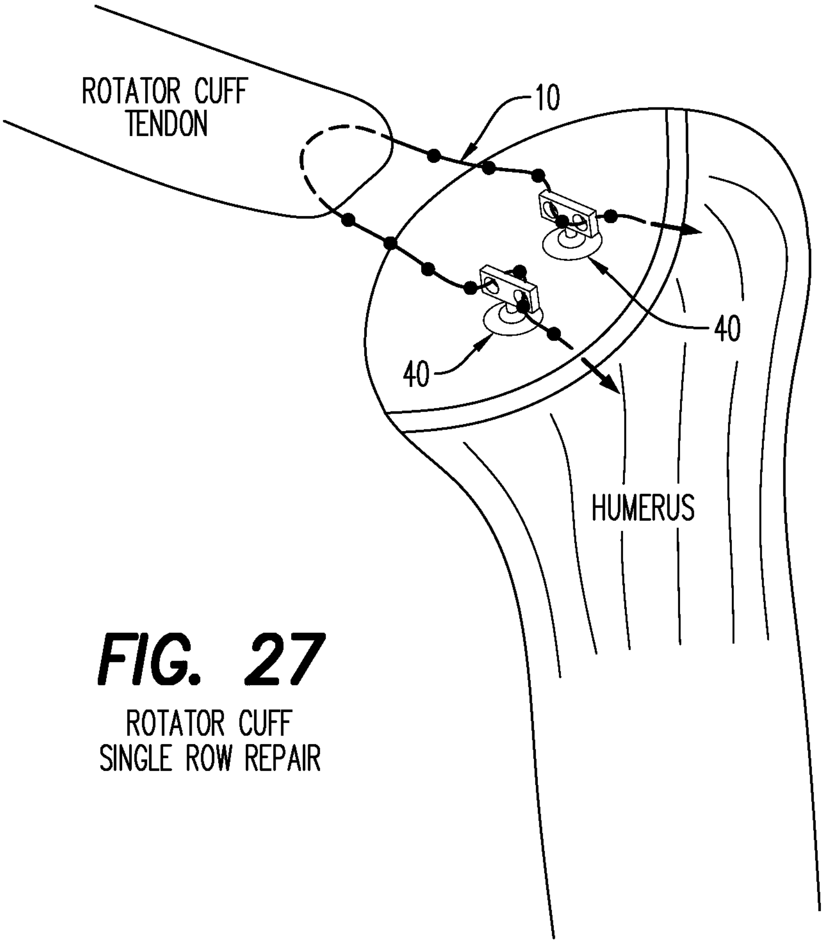



FIG. 27

ROTATOR CUFF
SINGLE ROW REPAIR

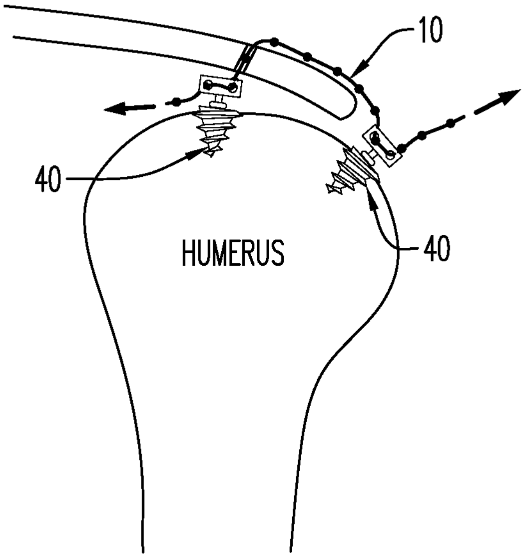



FIG. 28

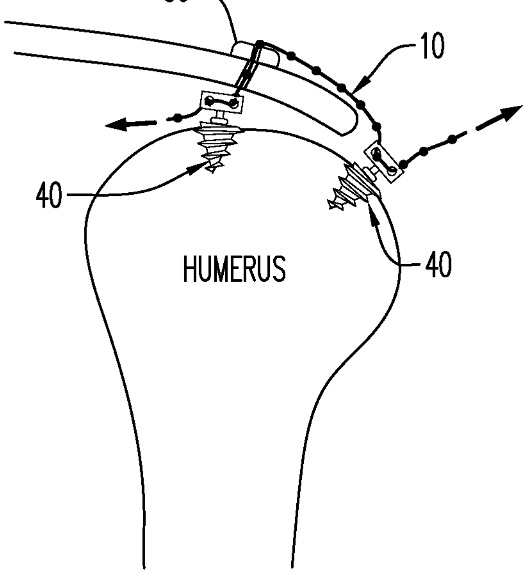



FIG. 29

DOUBLE ROW
REPAIR

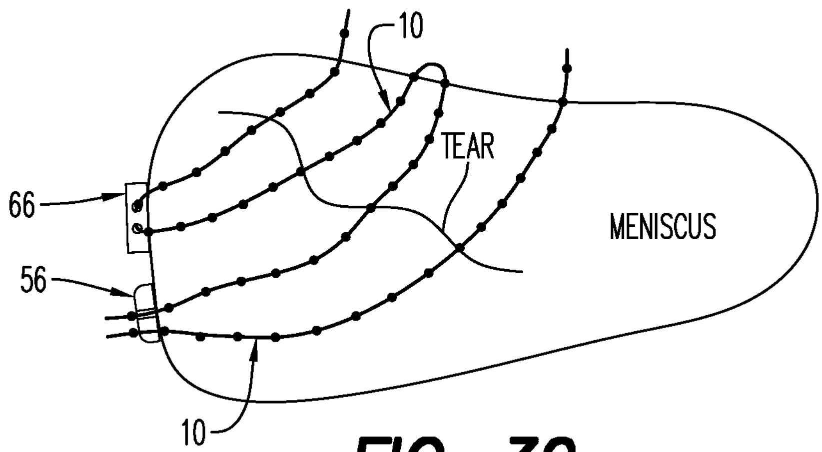



FIG. 30

MENISCAL REPAIR
SAGITTAL VIEW

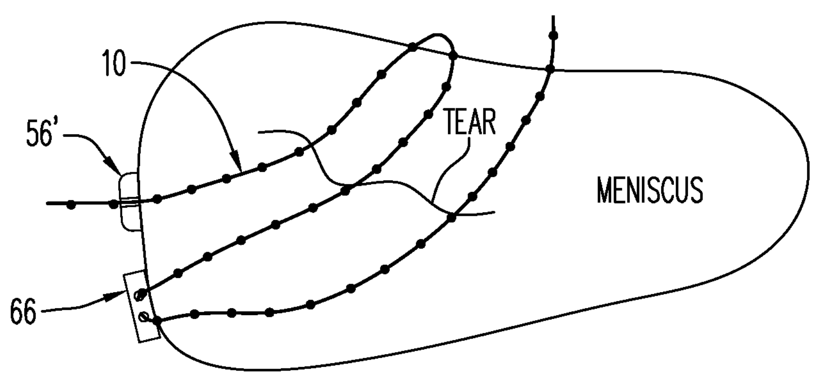



FIG. 31

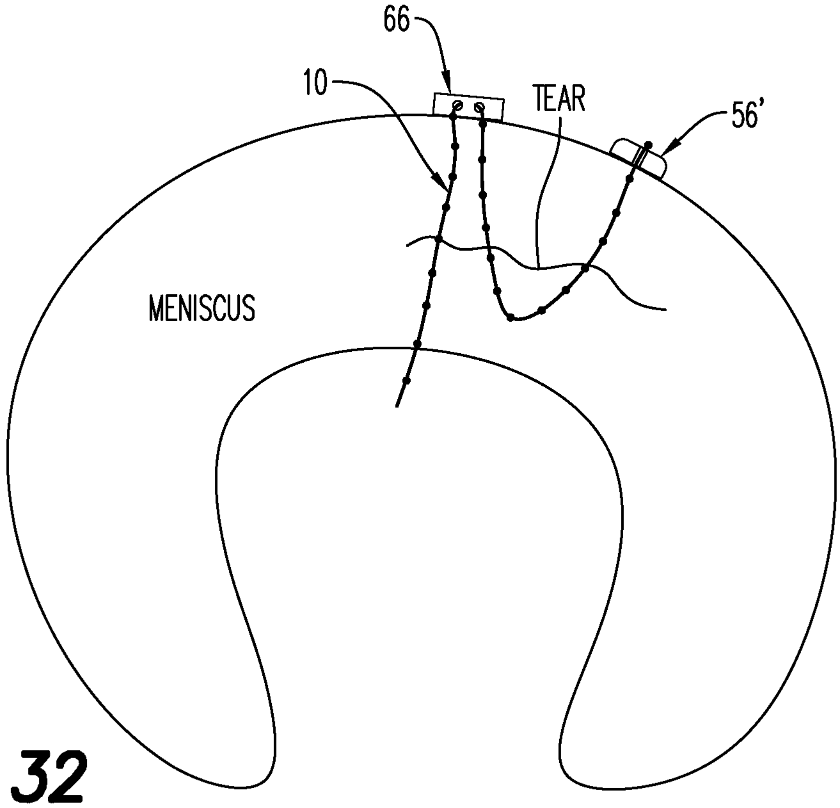



FIG. 32

MENISCAL REPAIR
FIXED OR WITH
INTERFACE

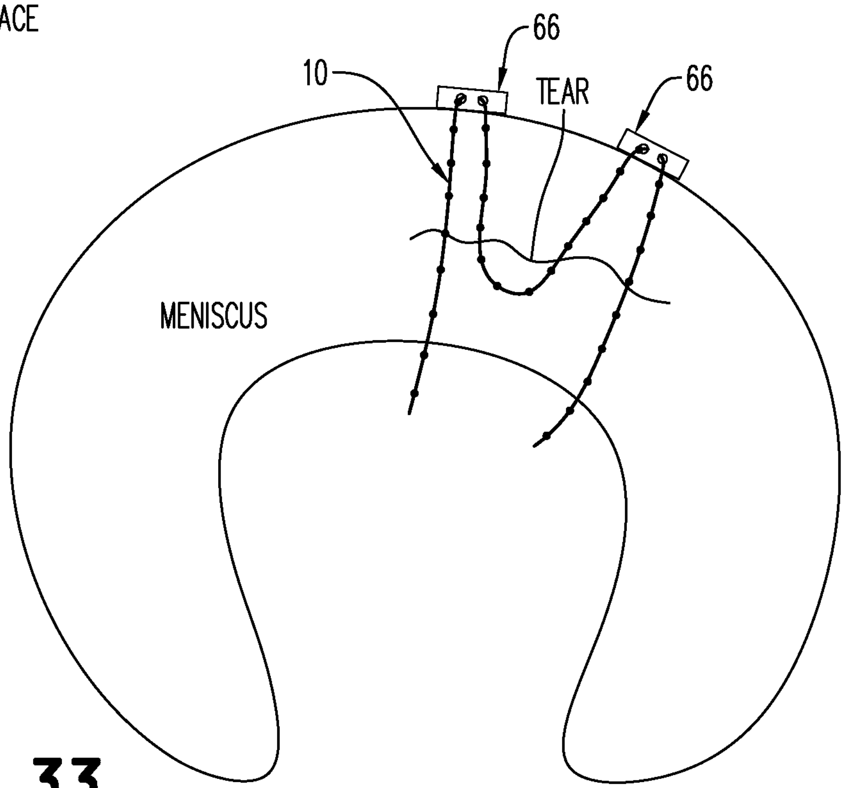



FIG. 33

MENISCAL REPAIR
MULTIPLE REPAIRS

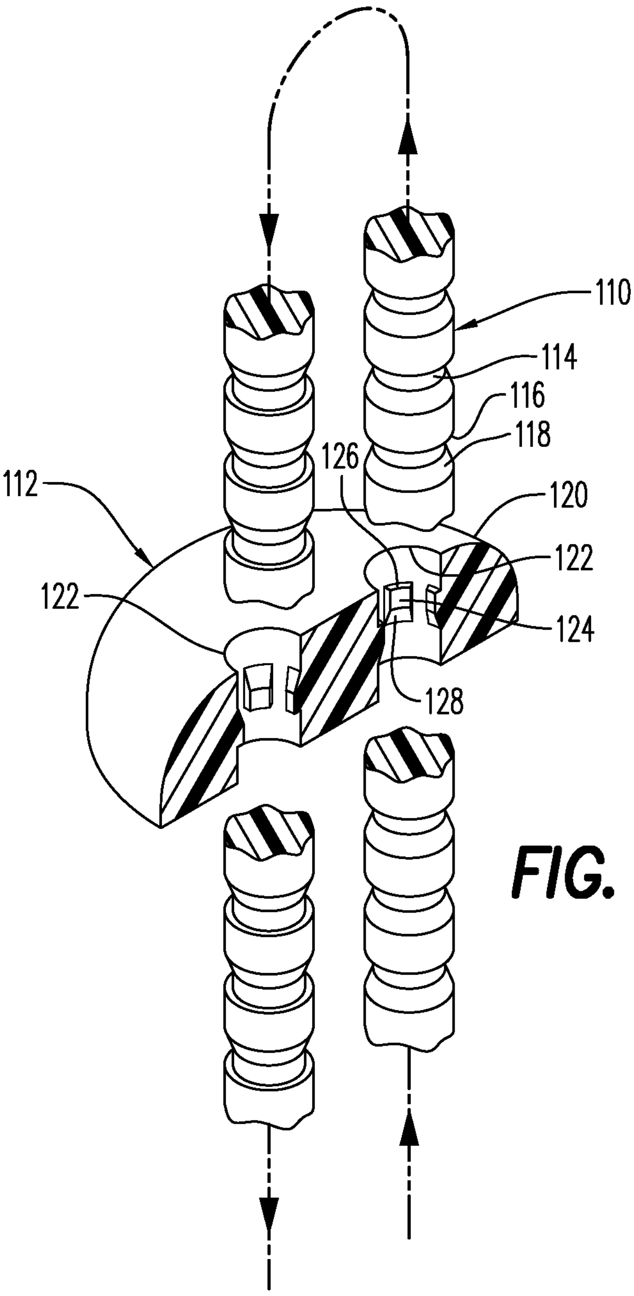



FIG. 34

FIG. 35

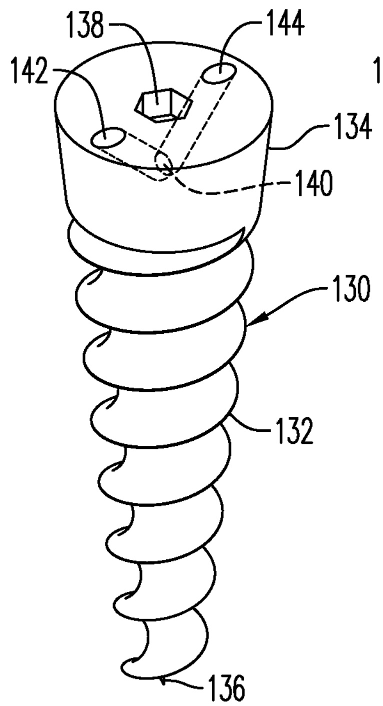



FIG. 36

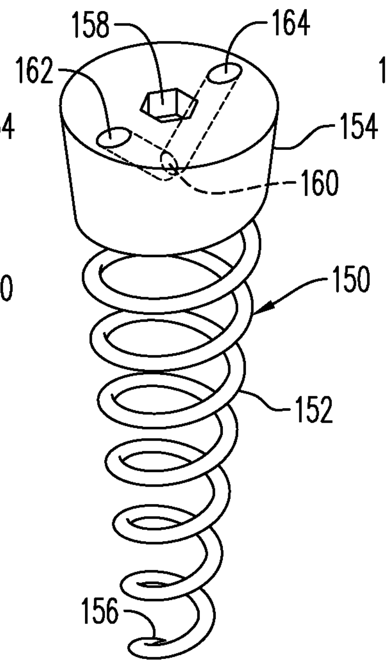



FIG. 37

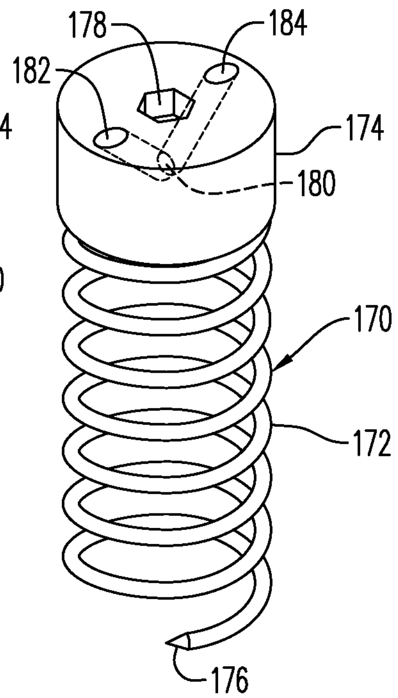
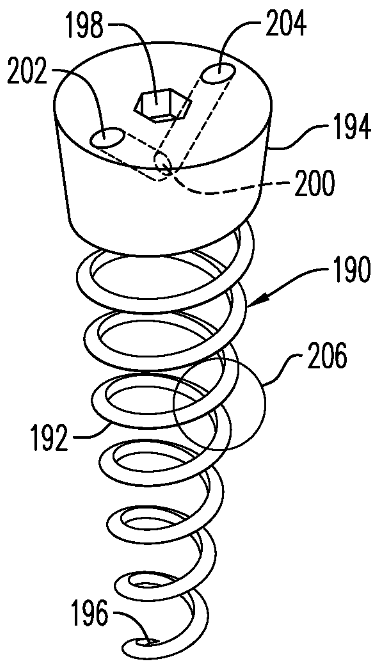



FIG. 38



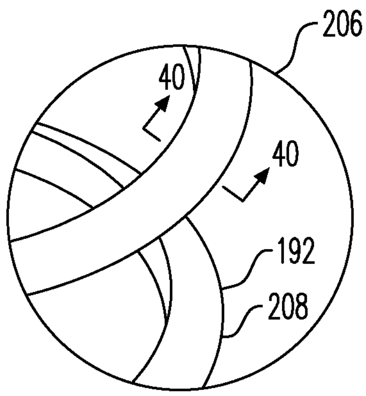




FIG. 39

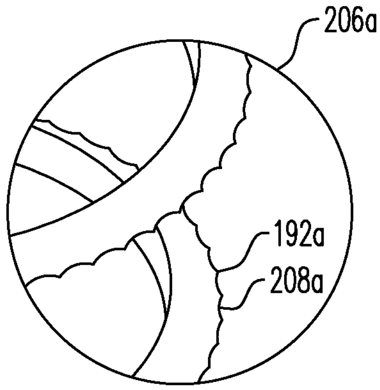



FIG. 39A

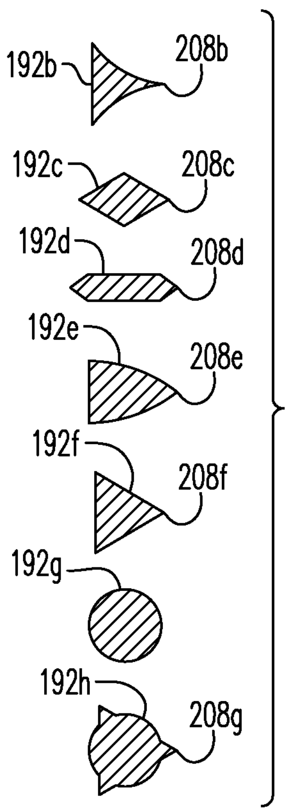



FIG. 40

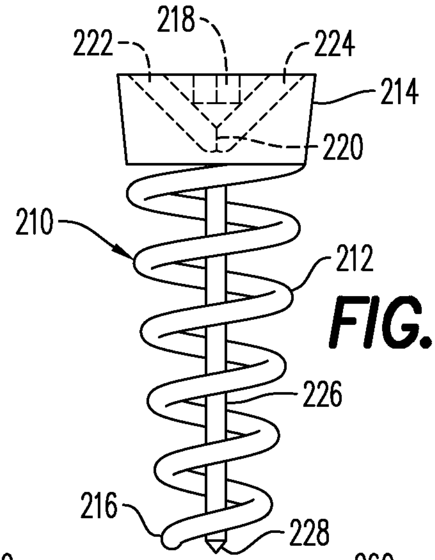



FIG. 41

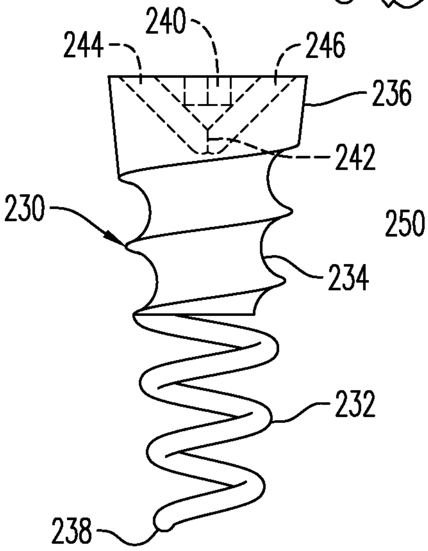



FIG. 42

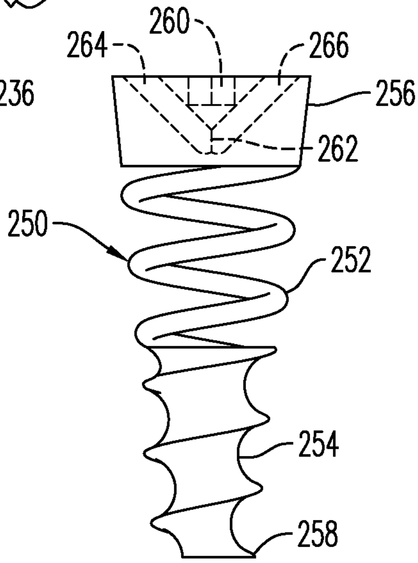



FIG. 43

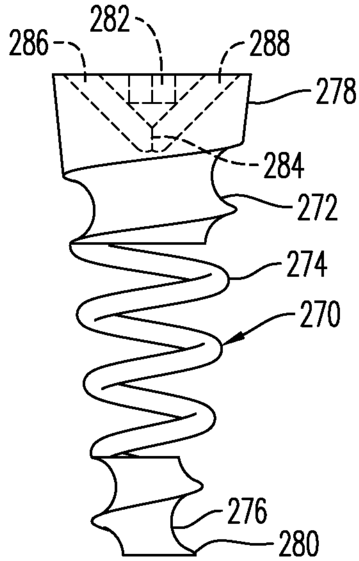



FIG. 44

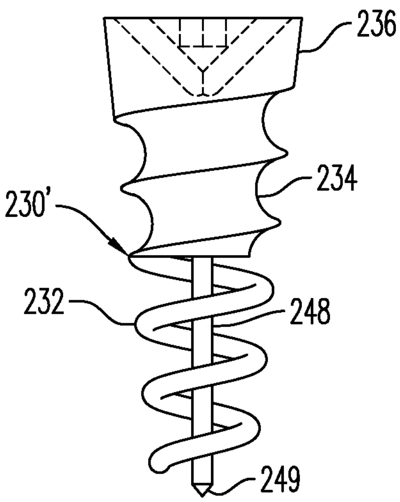



FIG. 45

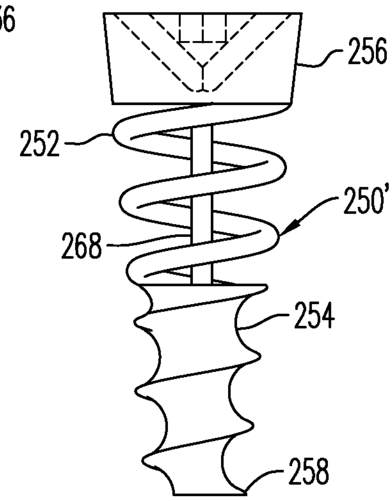



FIG. 46

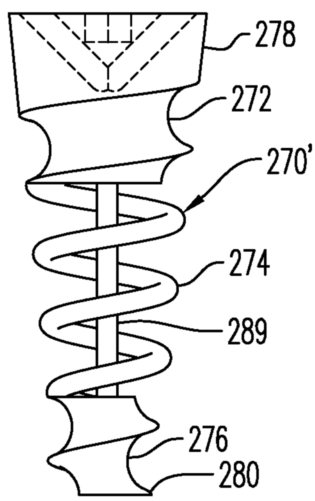



FIG. 47

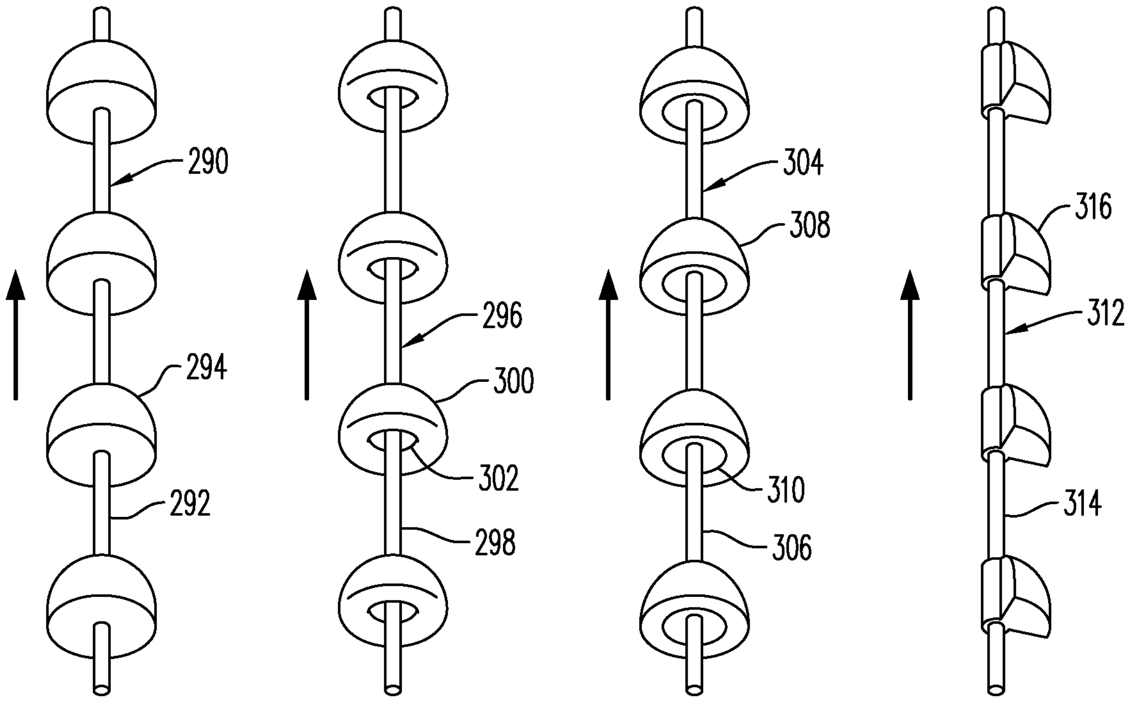



FIG. 48 FIG. 49 FIG. 50 FIG. 51

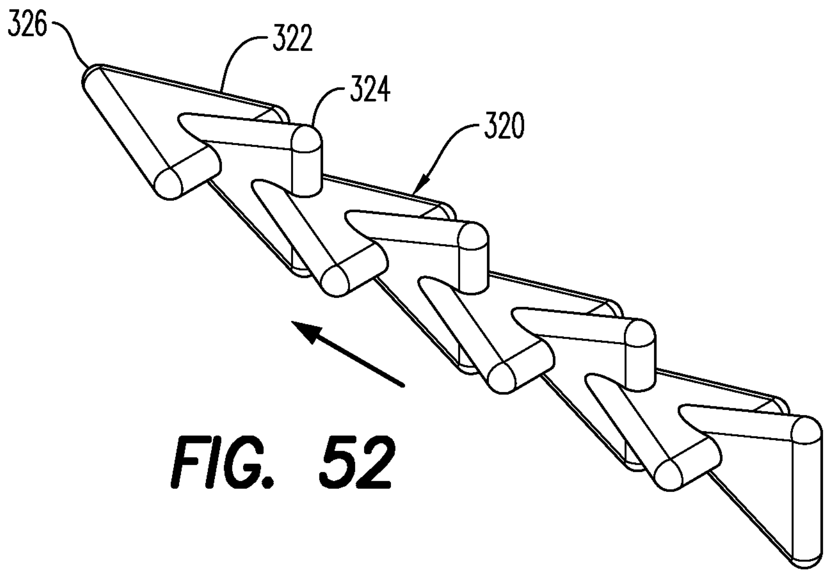



FIG. 52

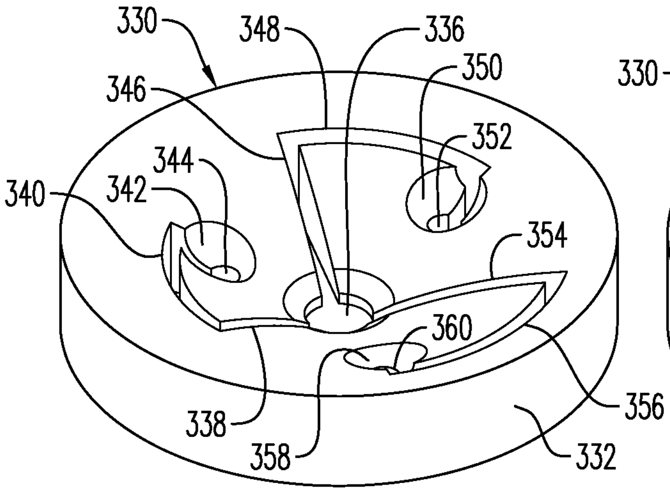



FIG. 53

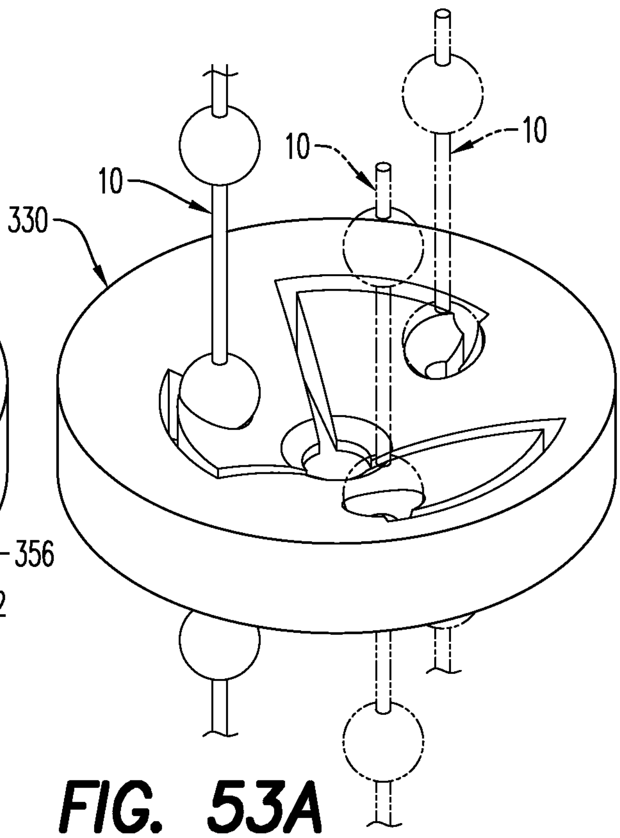



FIG. 53A

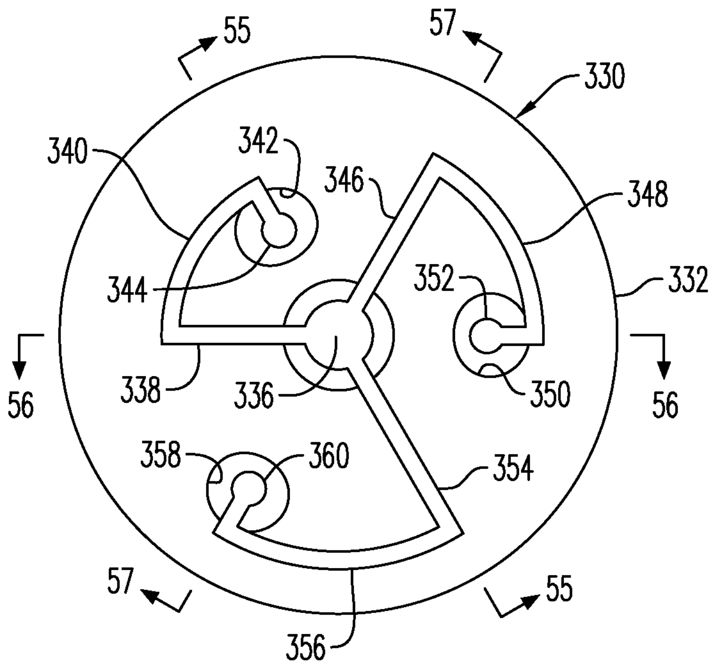



FIG. 54

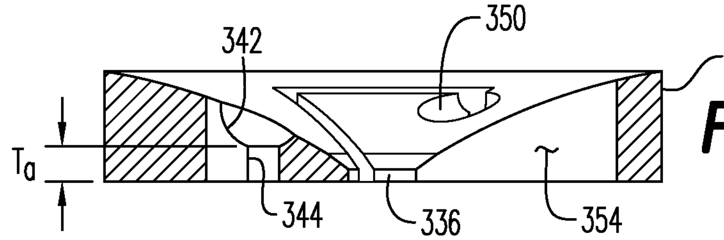



FIG. 55

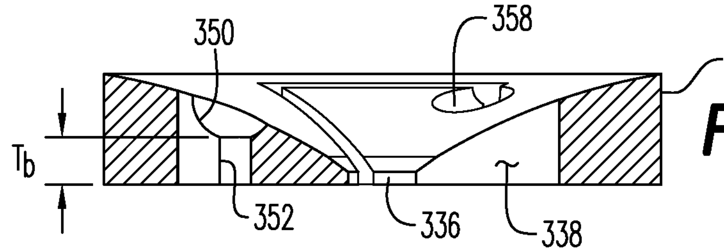



FIG. 56

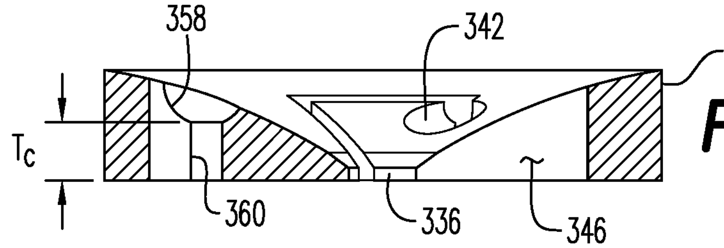



FIG. 57

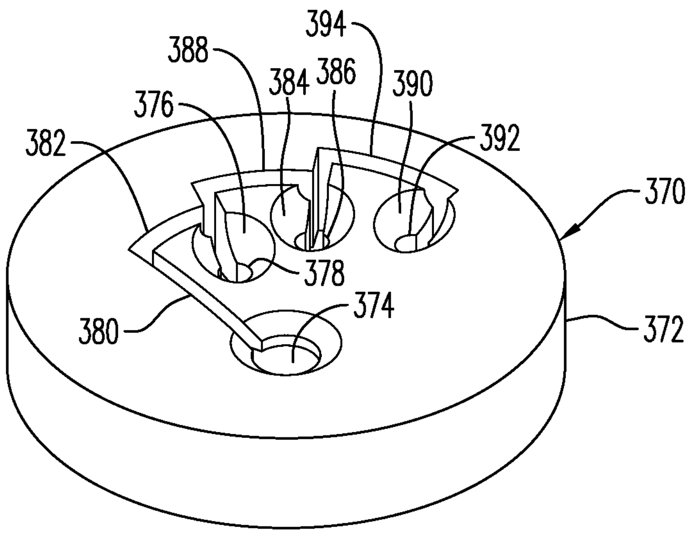



FIG. 58

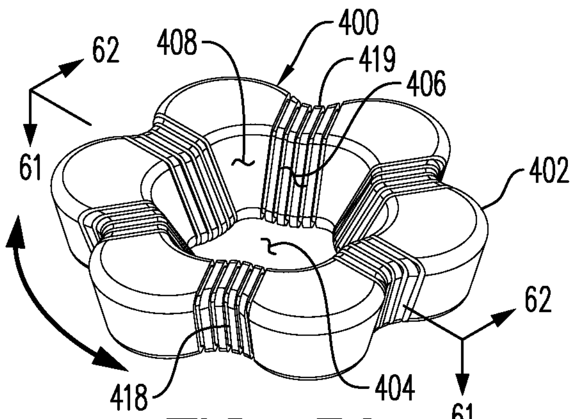



FIG. 59

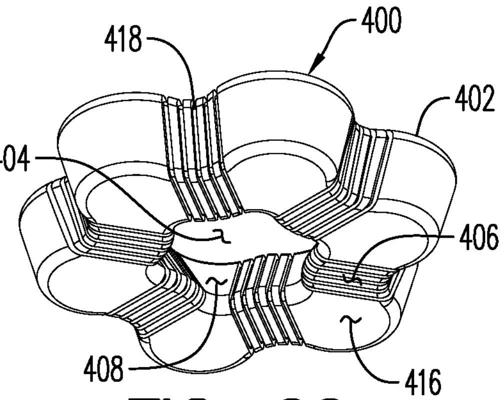



FIG. 60

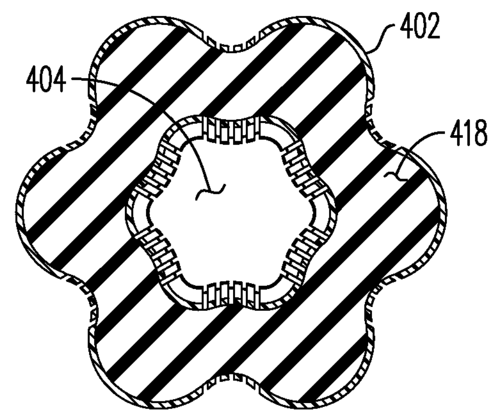



FIG. 61

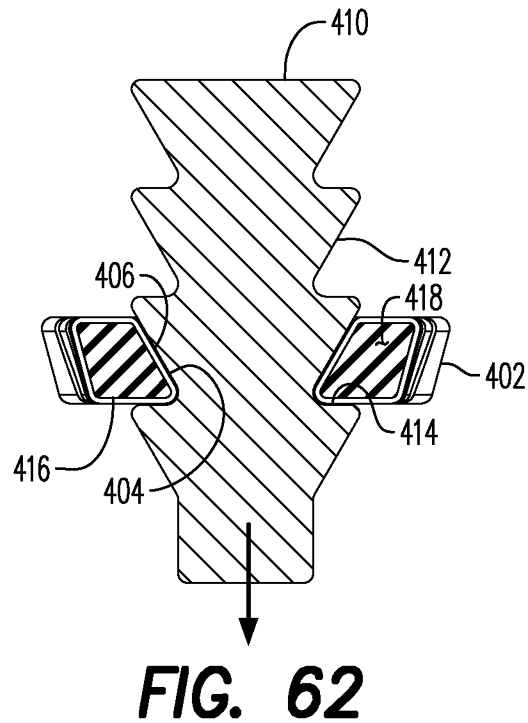



FIG. 62

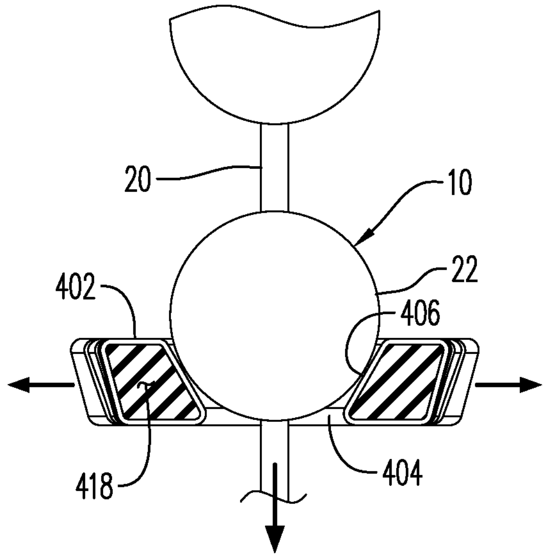



FIG. 63

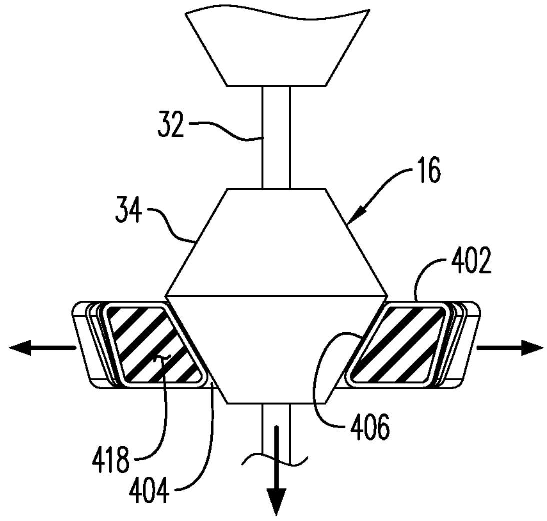



FIG. 64

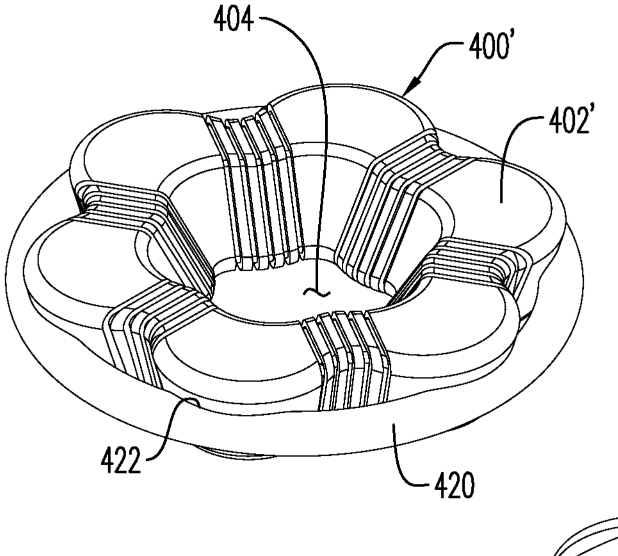



FIG. 65

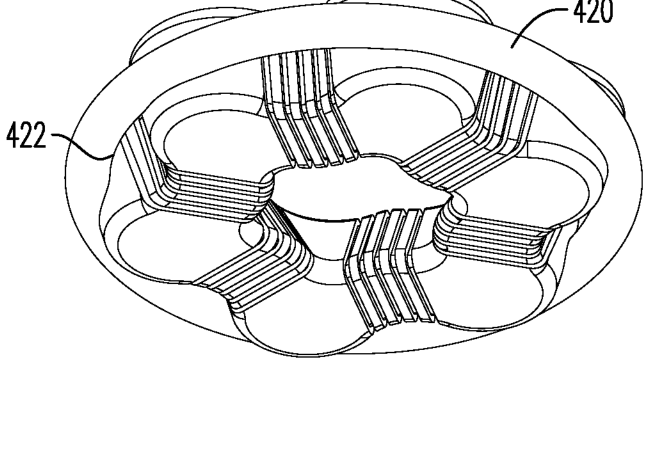



FIG. 66

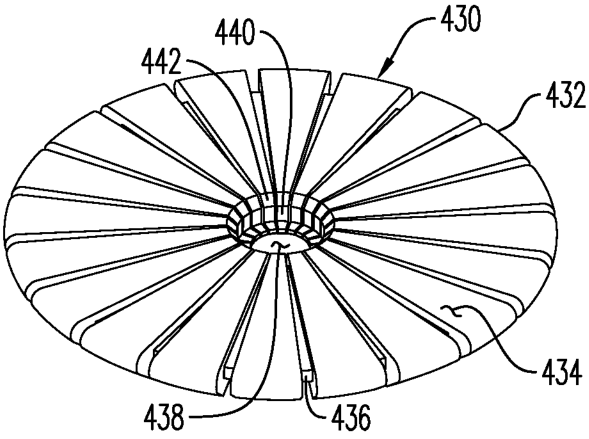



FIG. 67

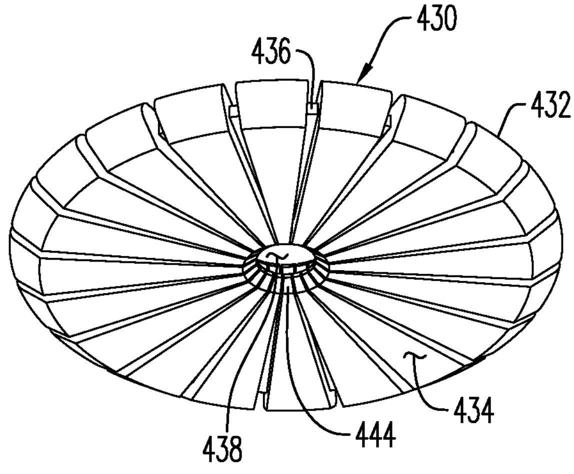



FIG. 68

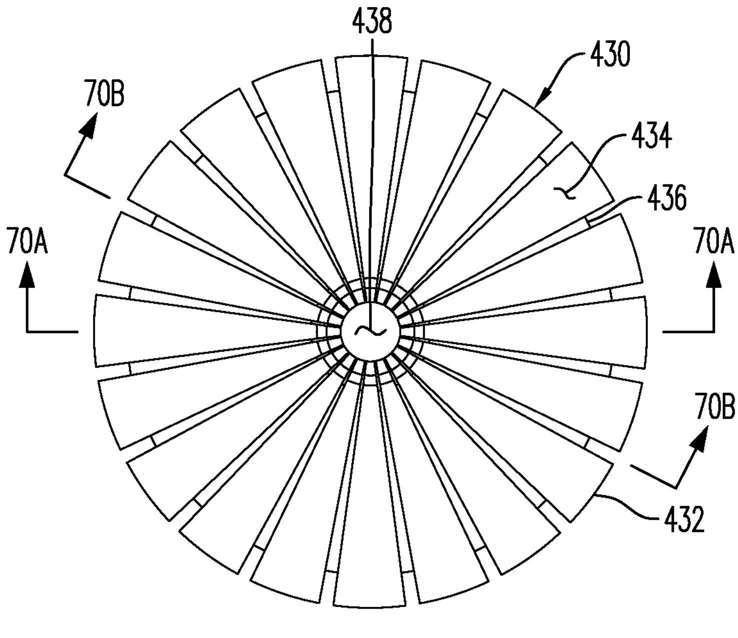



FIG. 69

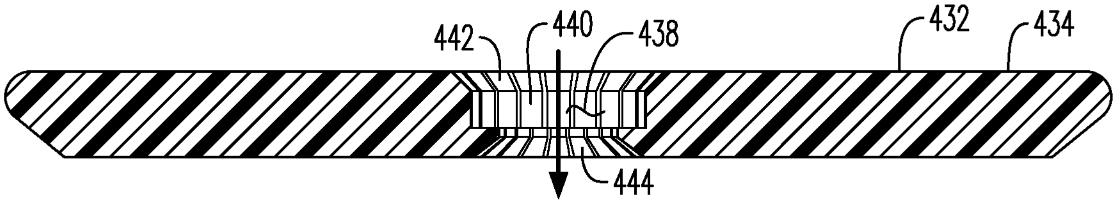



FIG. 70A

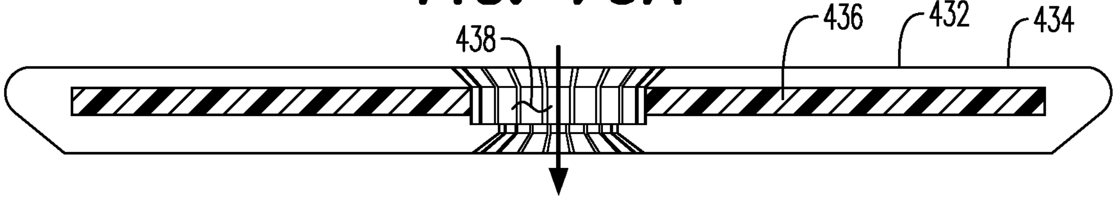



FIG. 70B

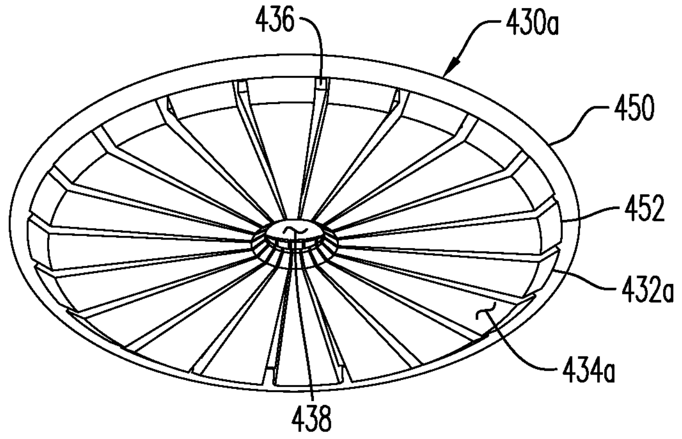



FIG. 71

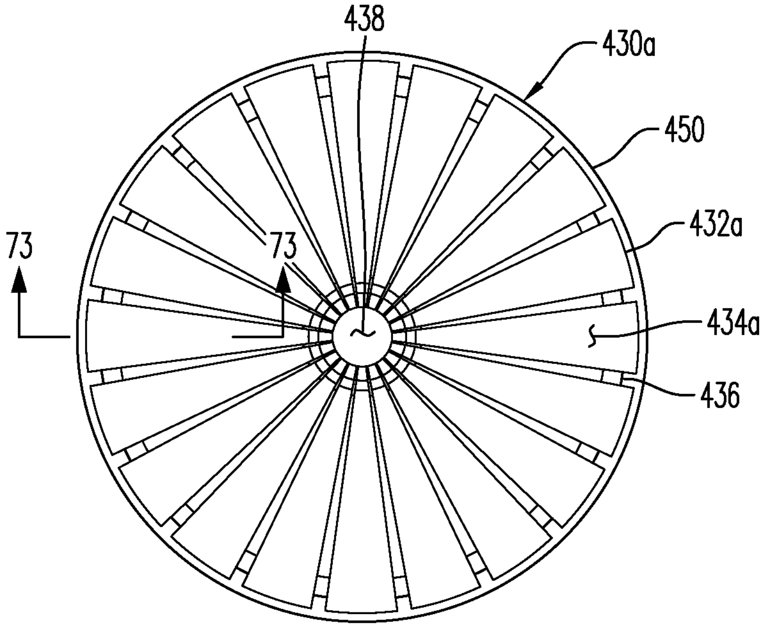



FIG. 72

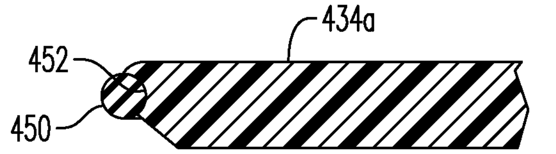



FIG. 73

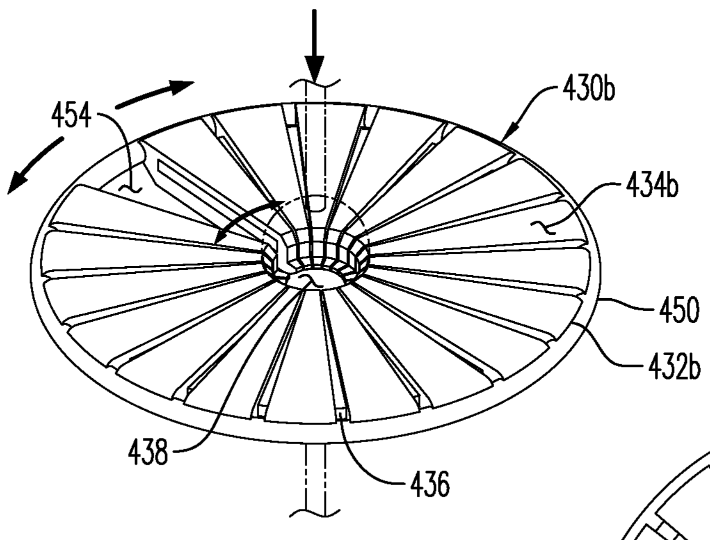



FIG. 74

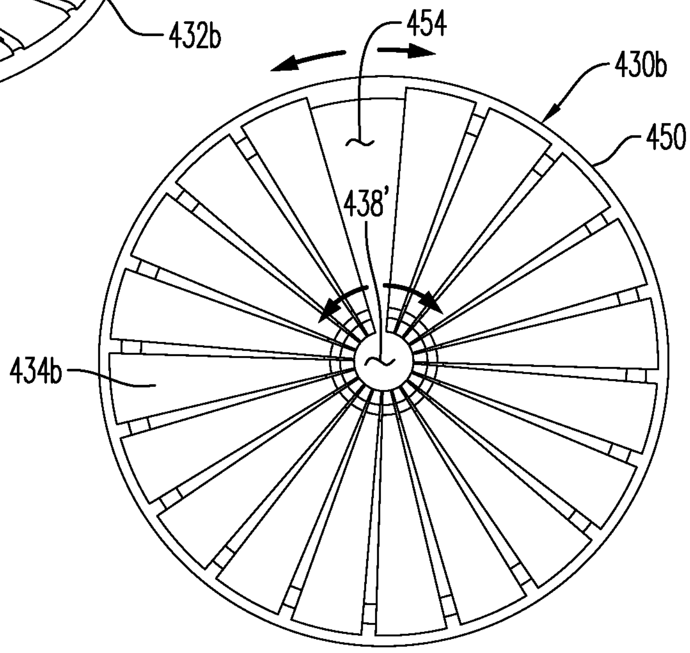



FIG. 75

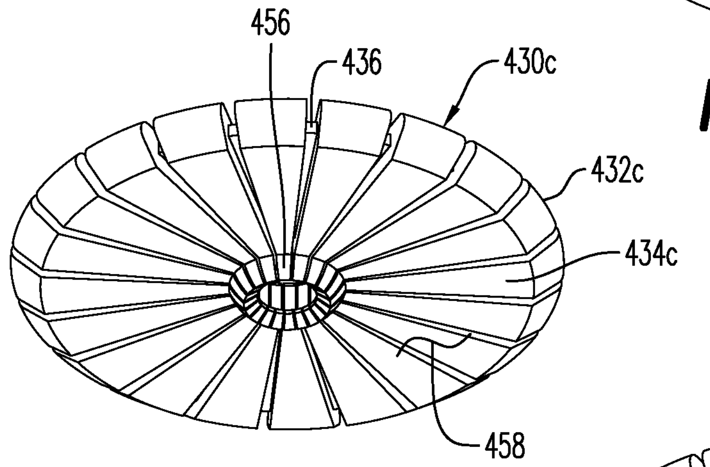



FIG. 76

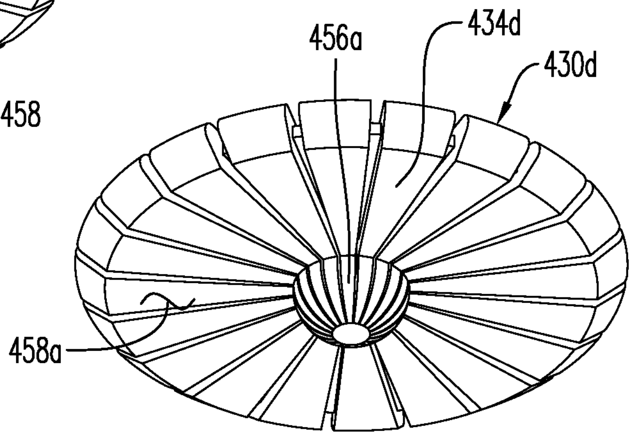



FIG. 76A

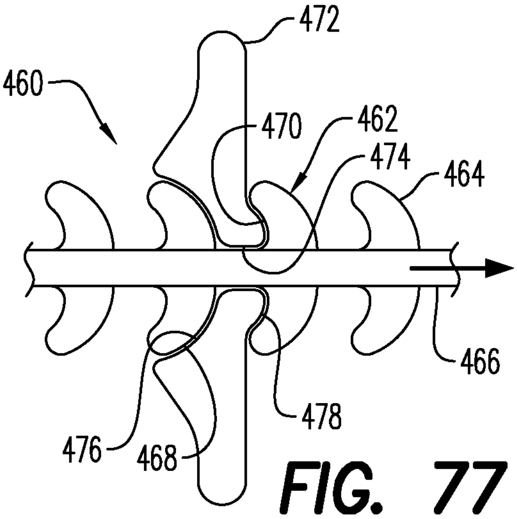



FIG. 77

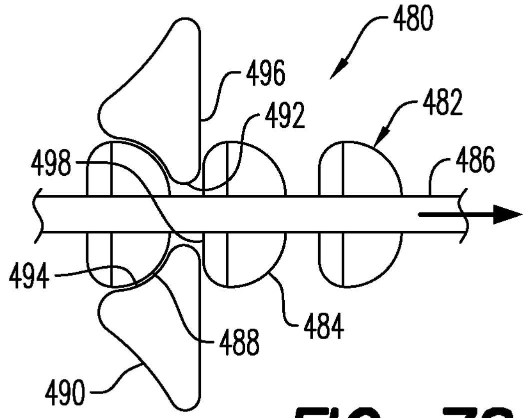



FIG. 78

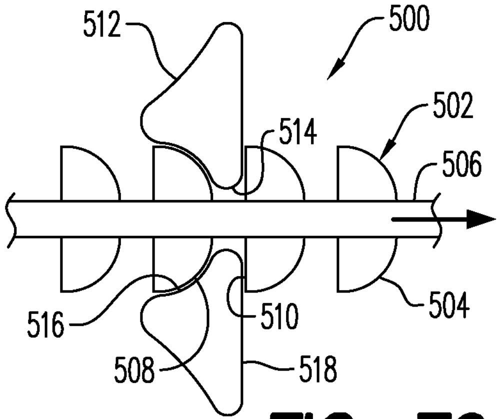



FIG. 79

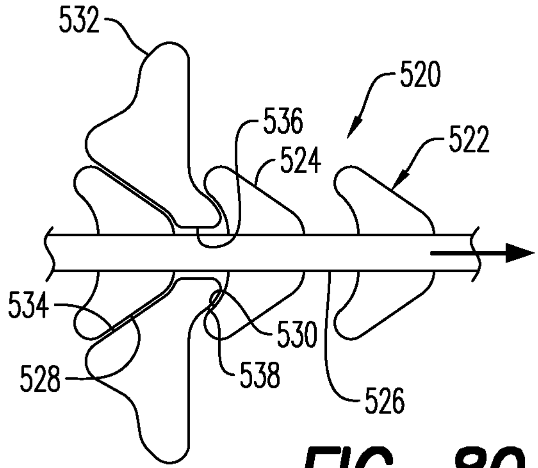



FIG. 80

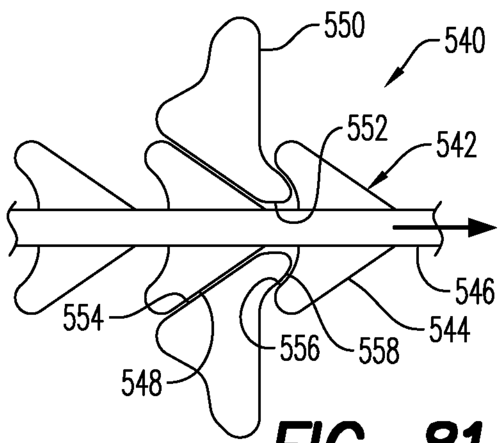



FIG. 81

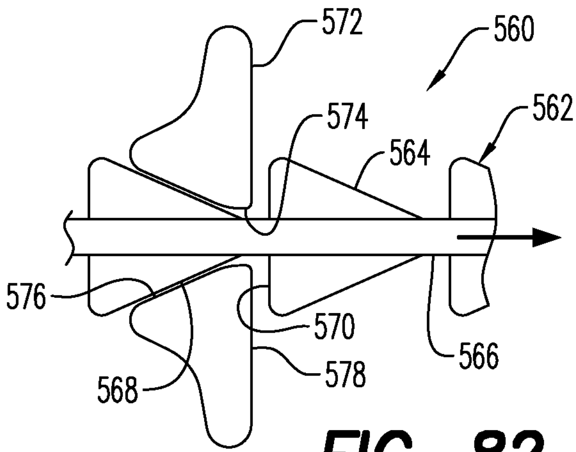



FIG. 82

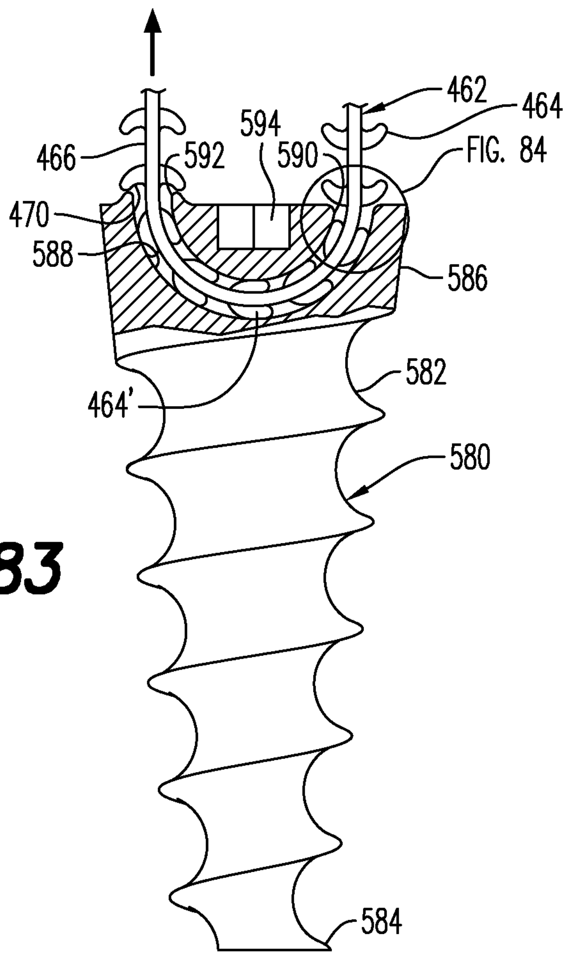

462
464
594
466
592
590
FIG. 84
470
588
586
582
464'
580
584

FIG. 83

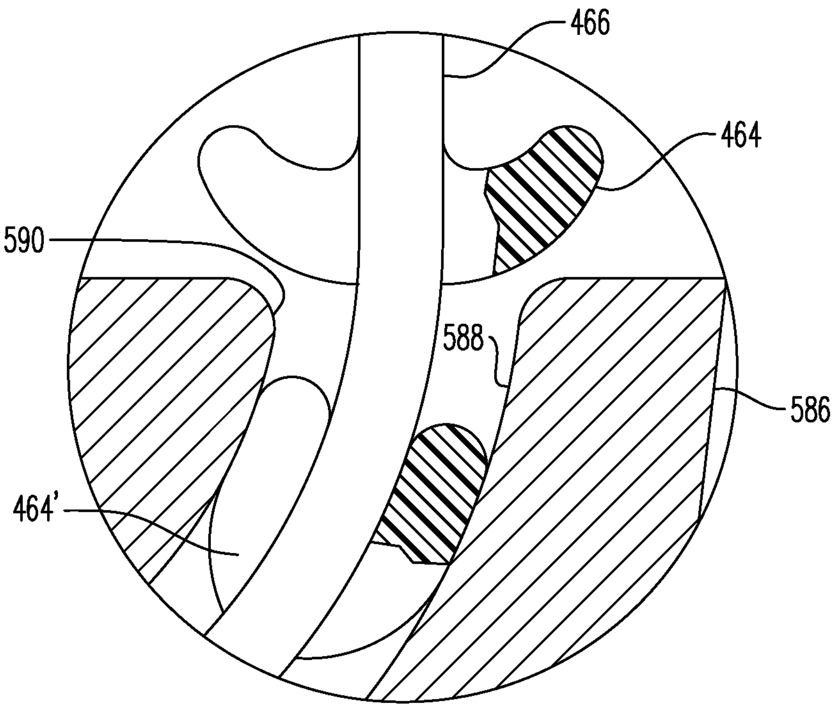

466
464
590
588
586
464'

FIG. 84

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/057872

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC(8) - A61B 17/04 (2012.01)
USPC - 606/232
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - A61B 17/04 (2012.01)
USPC - 606/232, 326

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

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2006/0106423 A1 (WEISEL et al) 18 May 2006 (18.05.2006) entire document | 1-21 |
| Y | US 2008/0082113 A1 (BISHOP et al) 03 April 2008 (03.04.2008) entire document | 1-21 |
| Y | US 2006/0106422 A1 (DEL RIO et al) 18 May 2006 (18.05.2006) entire document | 3, 9 |
| Y | US 6,015,410 A (TORMALA et al) 18 January 2000 (18.01.2000) entire document | 4, 5, 10, 11, 17 |
| Y | US 2007/0282375 A1 (HINDRICHS et al) 06 December 2007 (06.12.2007) entire document | 13, 19 |
| Y | US 2007/0156151 A1 (GUAN et al) 05 July 2007 (05.07.2007) entire document | 21 |
| A | US 5,413,585 A (PAGEDAS) 09 May 1995 (09.05.1995) entire document | 1-21 |
| A | US 5,370,661 A (BRANCH) 06 December 1994 (06.12.1994) entire document | 1-21 |

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"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 18 January 2012 | 30 JAN 2012 |

| Name and mailing address of the ISA/US | Authorized officer: |
|---|---|
| Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-3201 | Blaine R. Copenheaver<br>PCT Helpdesk: 571-272-4300<br>PCT OSP: 571-272-7774 |