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Suddaby

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(54) **FACET JOINT FIXATION DEVICE**
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This patent is subject to a terminal disclaimer.

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A61F 2/44 (2006.01)

(52) **U.S. Cl.**
USPC **623/17.11**

(58) **Field of Classification Search**
USPC 623/17.11-17.19
See application file for complete search history.

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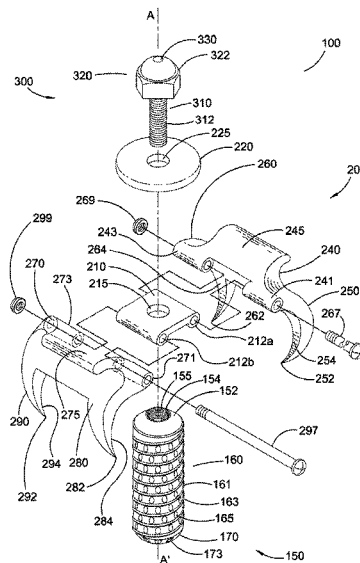
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(57) **ABSTRACT**

A device for fixing the positions of proximate bone elements including an inter-bone implant adapted to be implanted between suitably prepared proximate bone elements, the inter-bone implant having an internally threaded aperture, a bone fixation apparatus including a base having an eyelet and a means connected to the base for mechanically fixing the positions of the proximate bone elements relative to each other, the eyelet being substantially aligned with the internally threaded aperture, and a screw having a head and a threaded shaft extending therefrom, wherein the shaft is operatively arranged to extend through the eyelet and threadingly engage the internally threaded aperture, and the screw is operatively arranged to secure the bone fixation apparatus to the inter-bone implant.

6 Claims, 18 Drawing Sheets



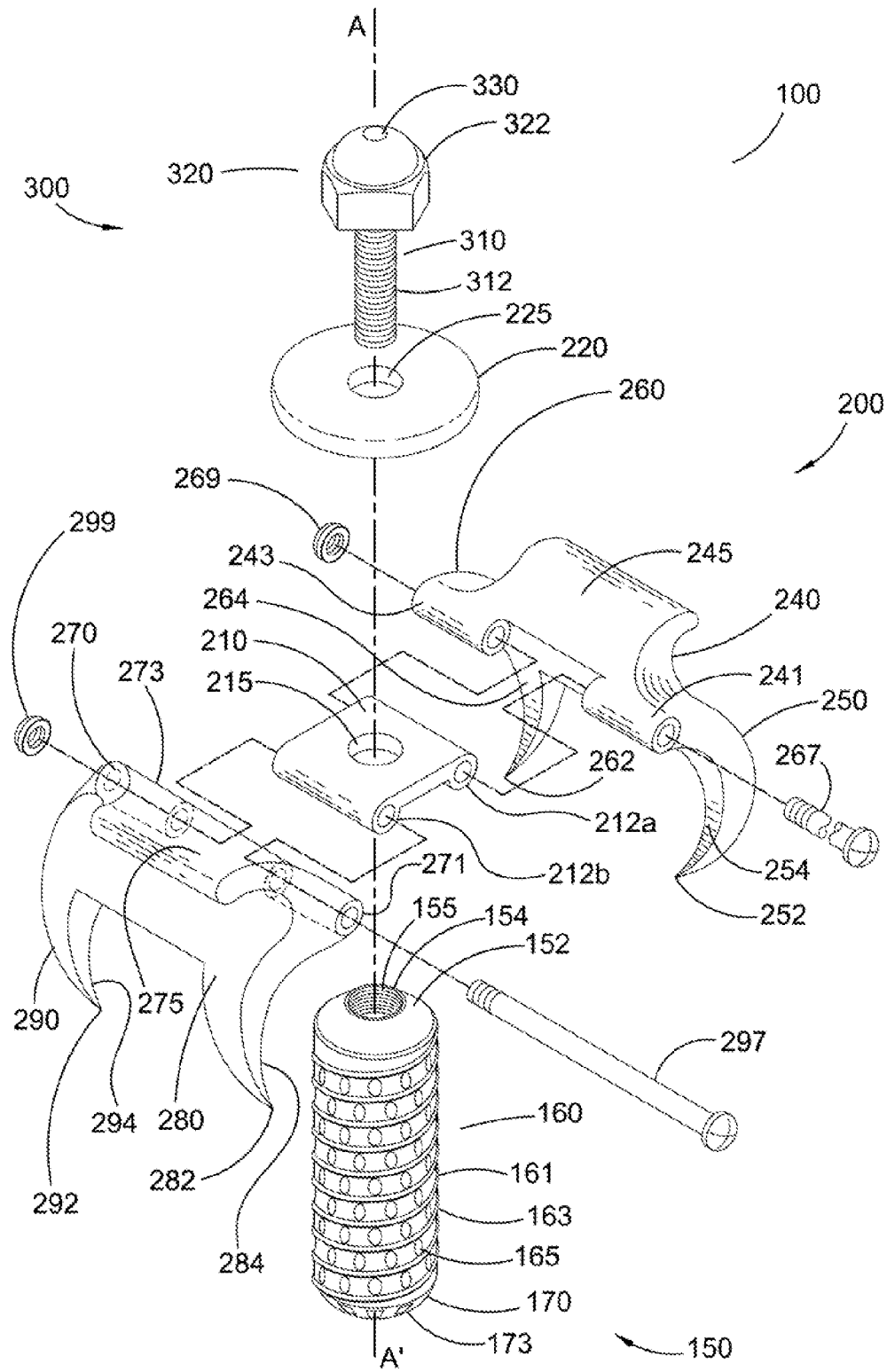


Fig. 1

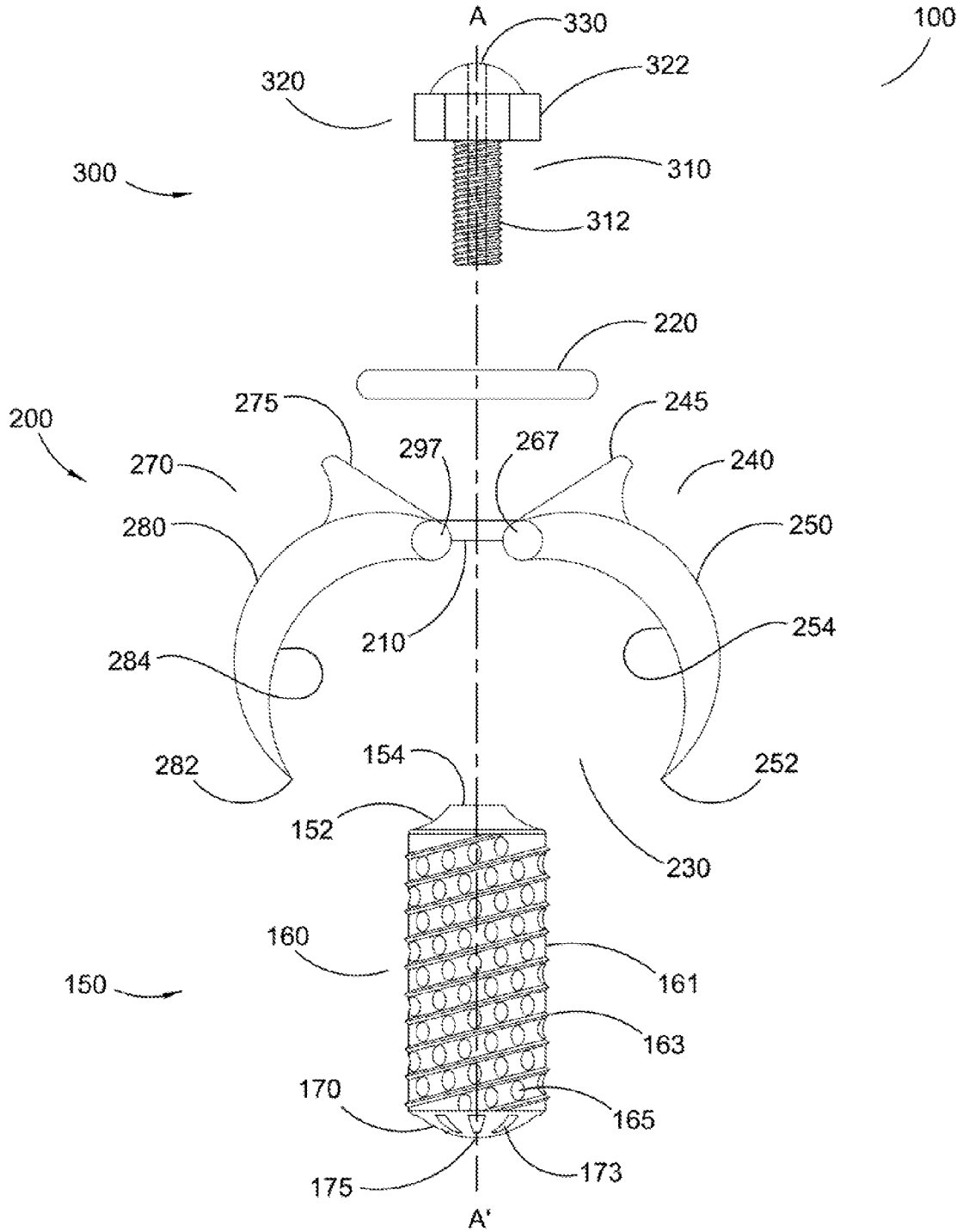


Fig. 2

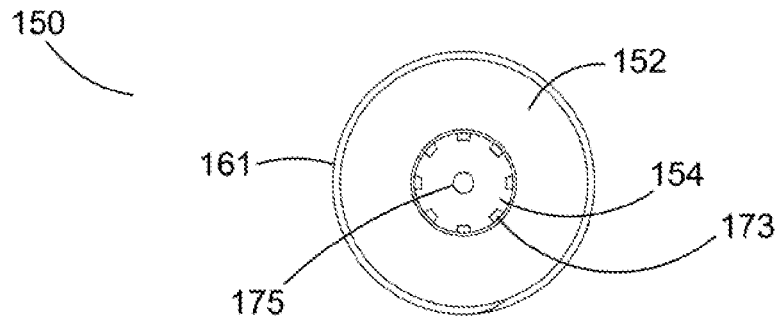


Fig. 3

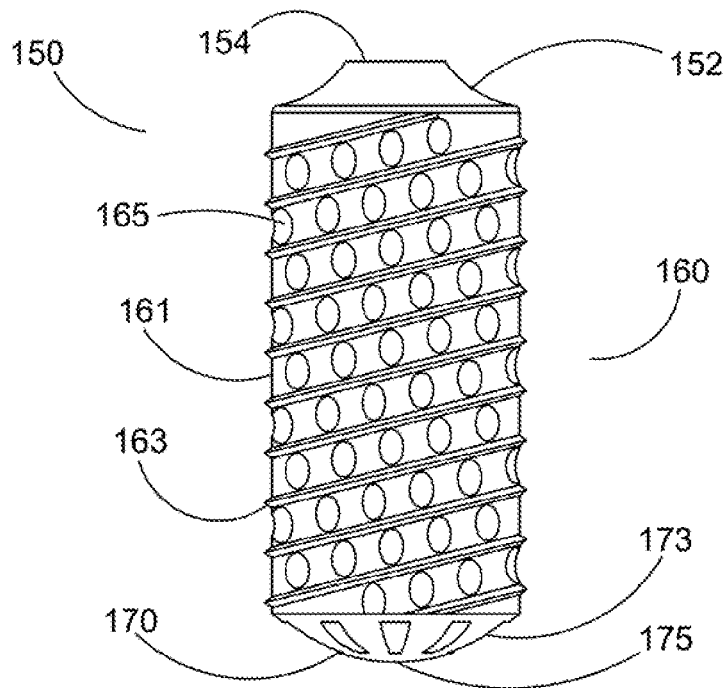


Fig. 4

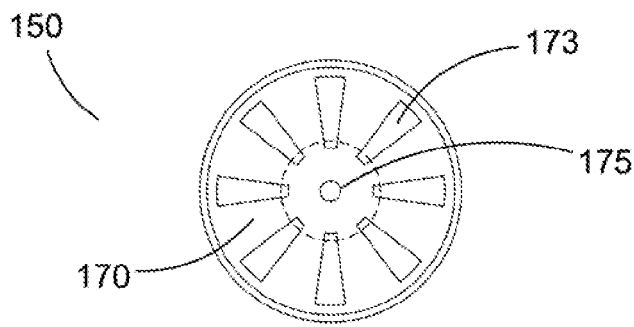


Fig. 5

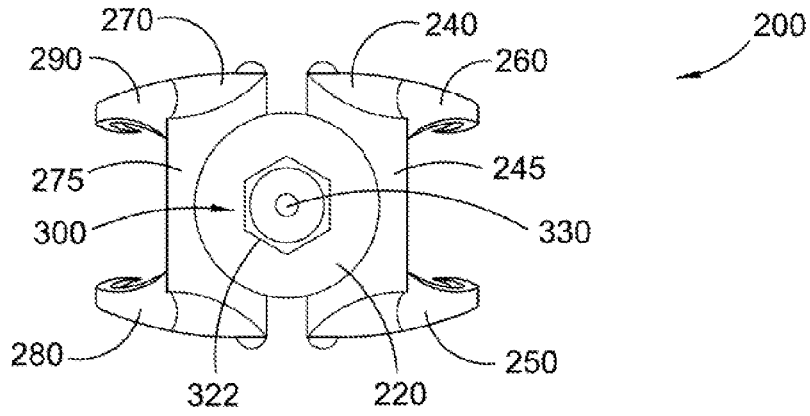


Fig. 6

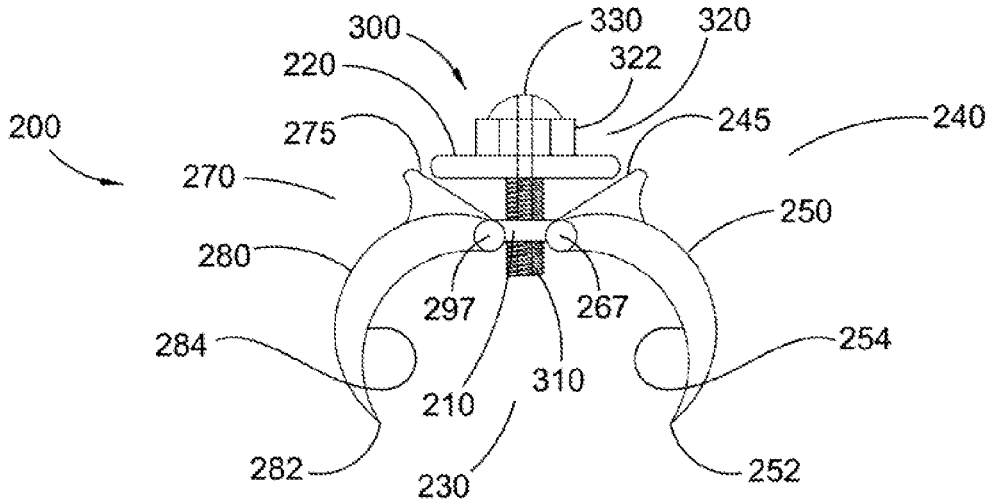


Fig. 7

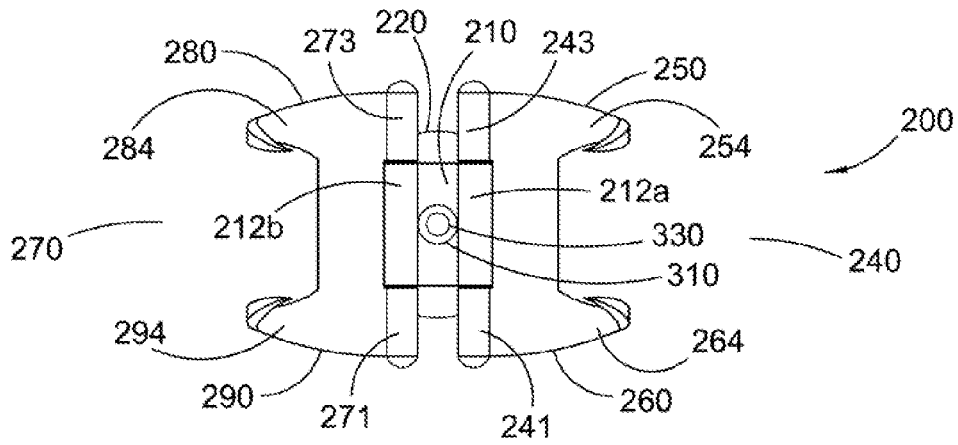


Fig. 8

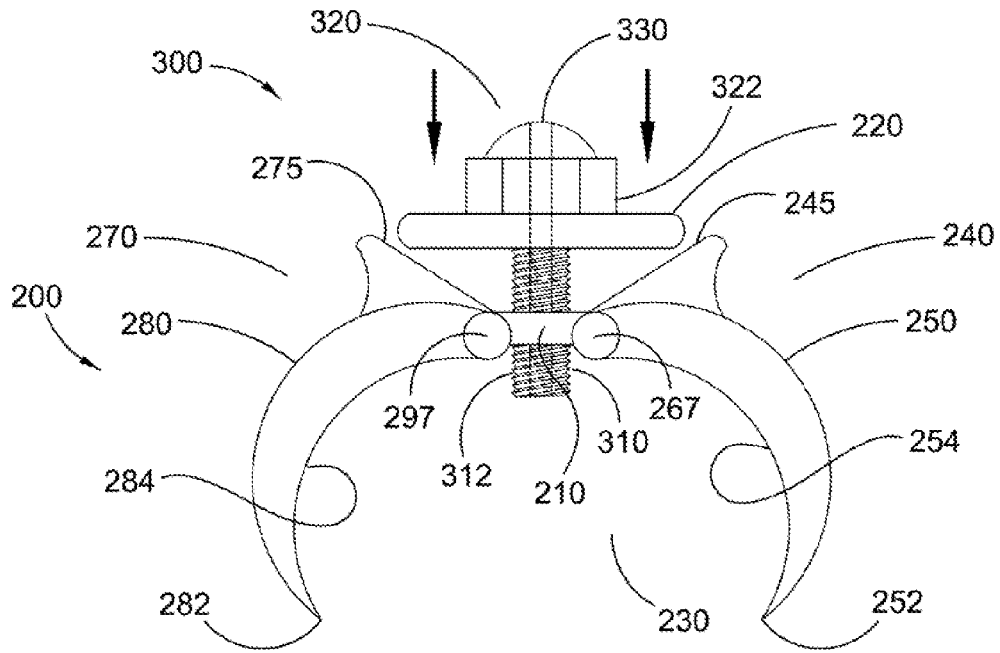


Fig. 8a

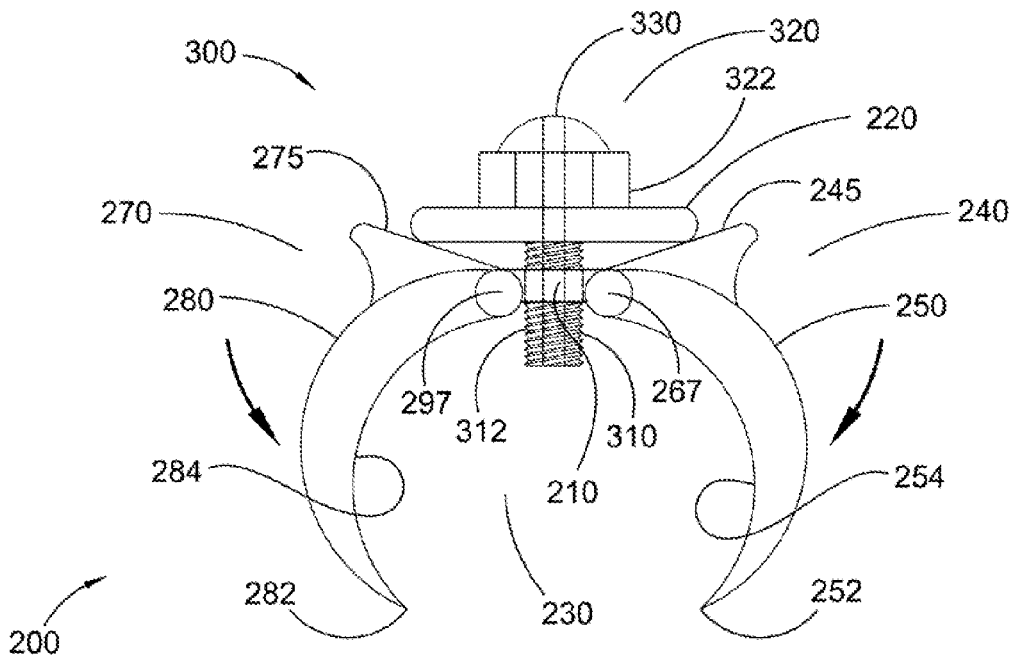


Fig. 8b

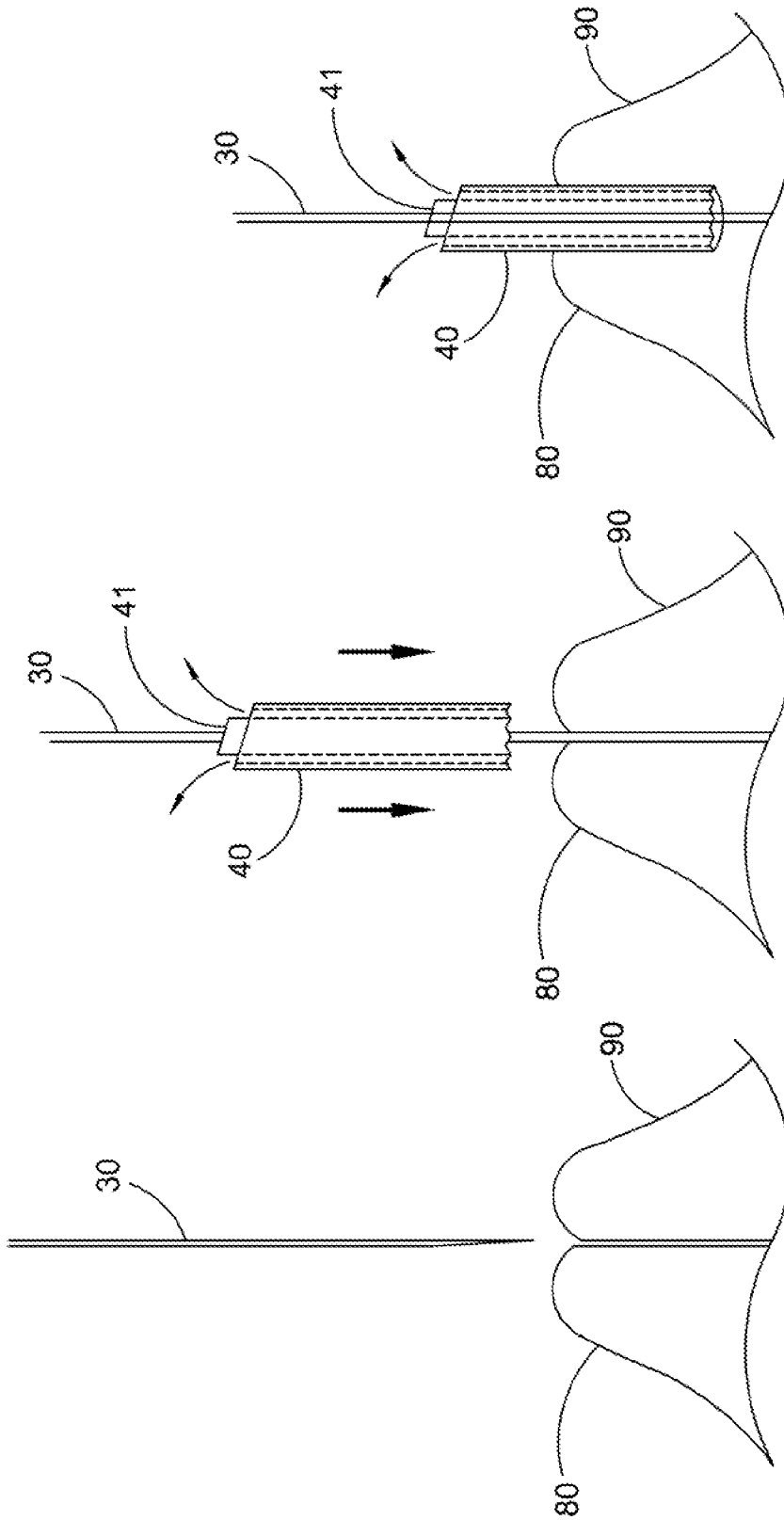


Fig. 9a

Fig. 9b

Fig. 9c

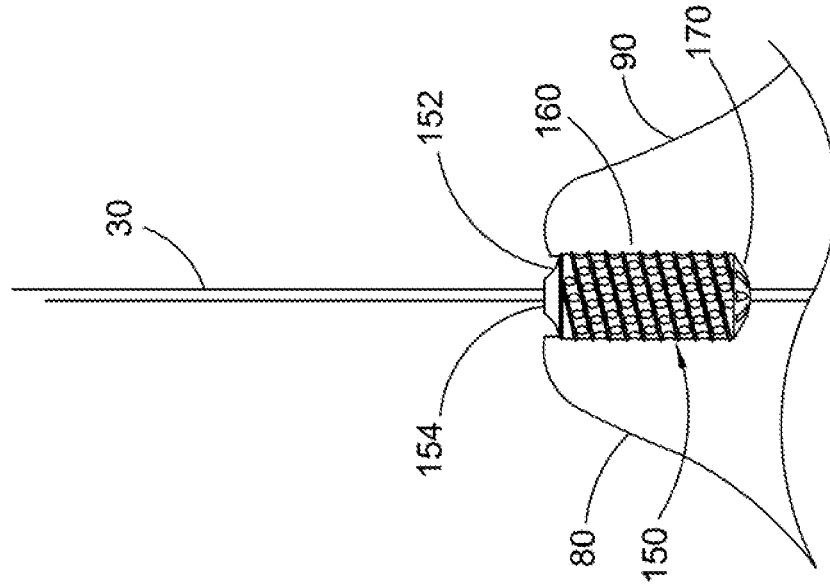


Fig. 9d

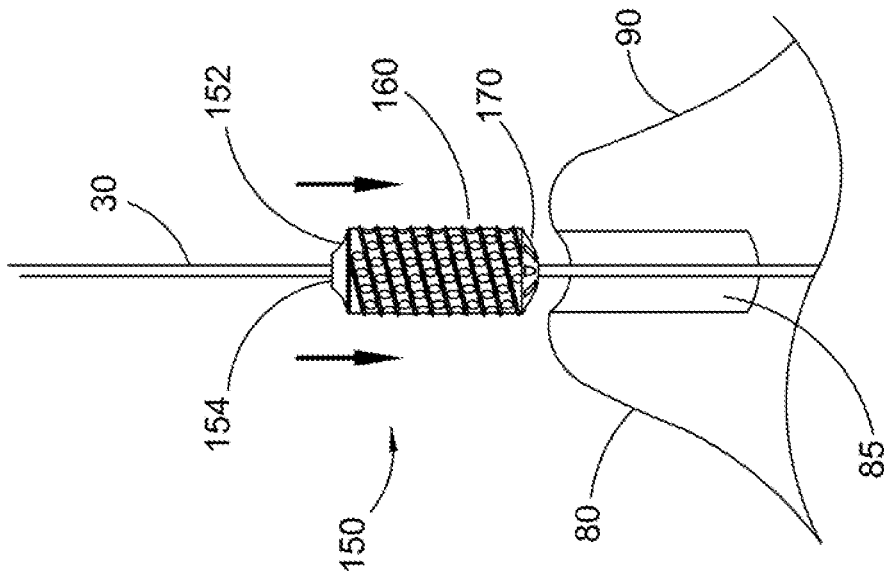


Fig. 9e

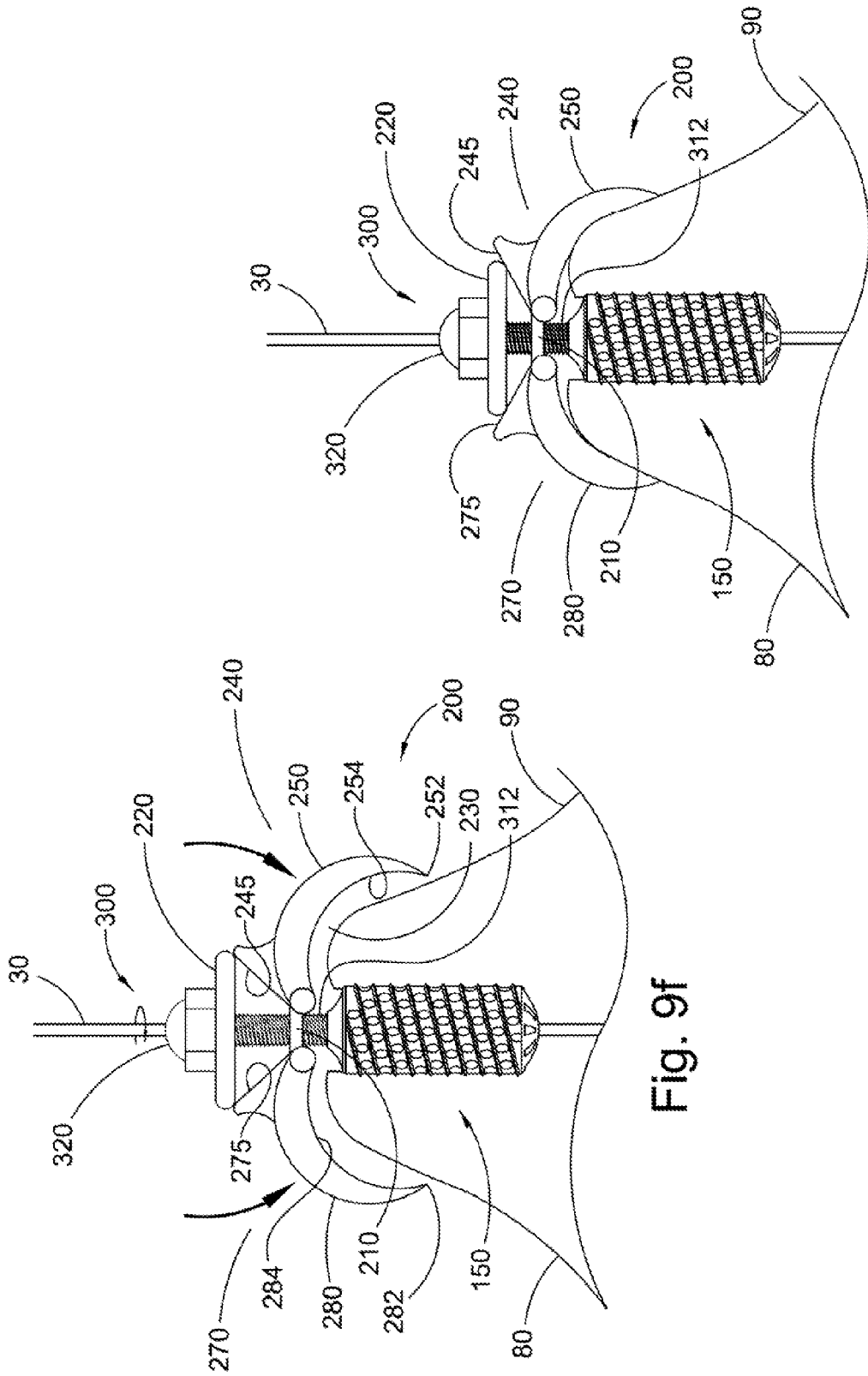


Fig. 9f

Fig. 9g

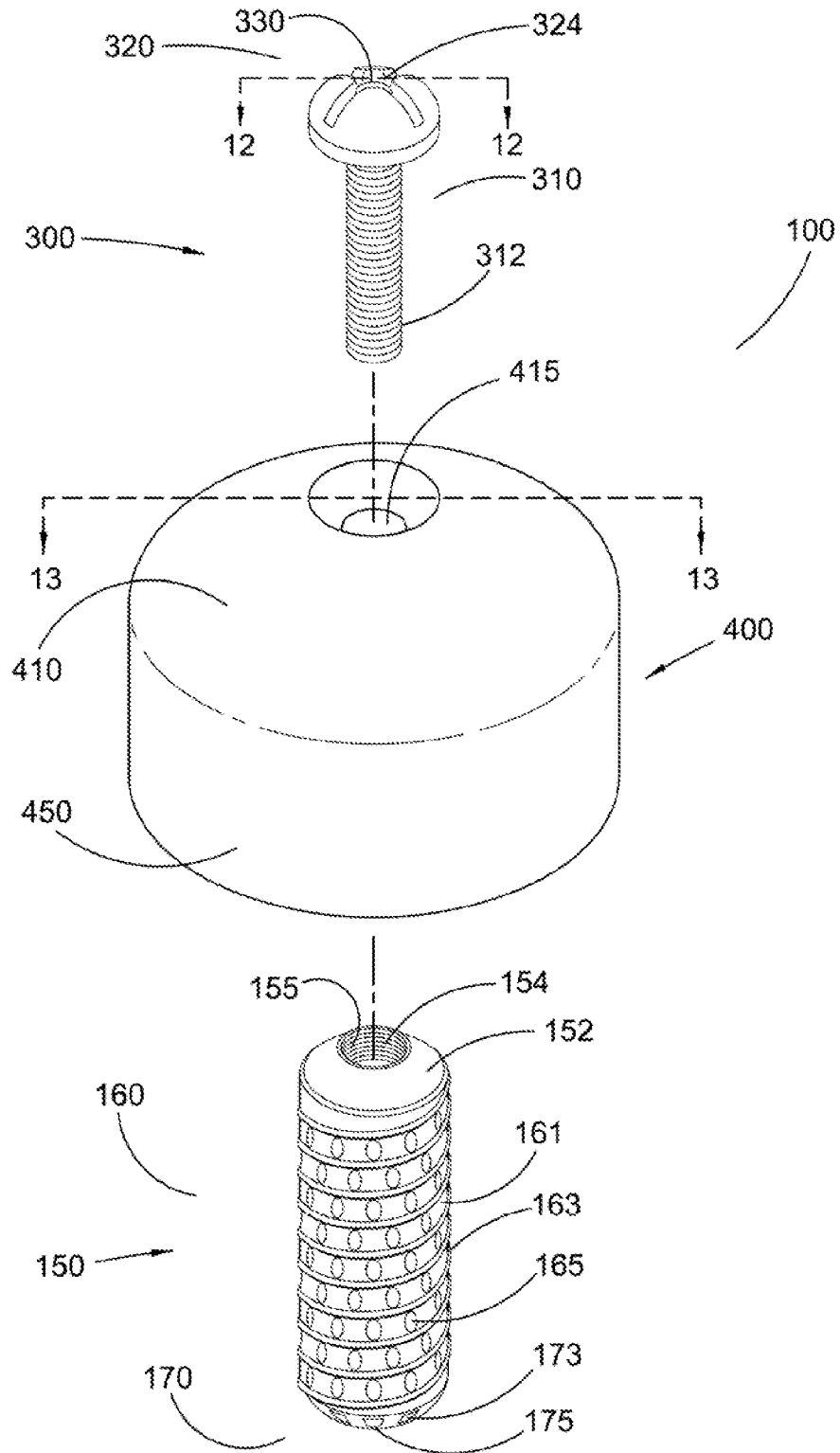


Fig. 10

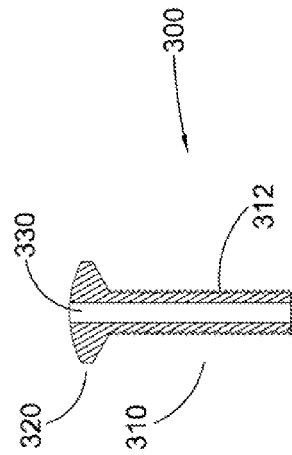


Fig. 12

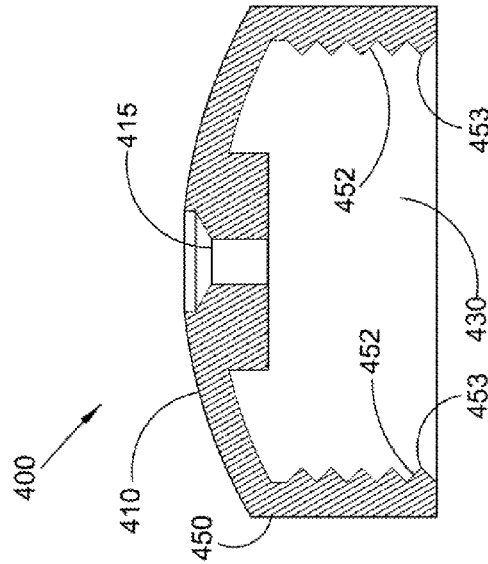


Fig. 13

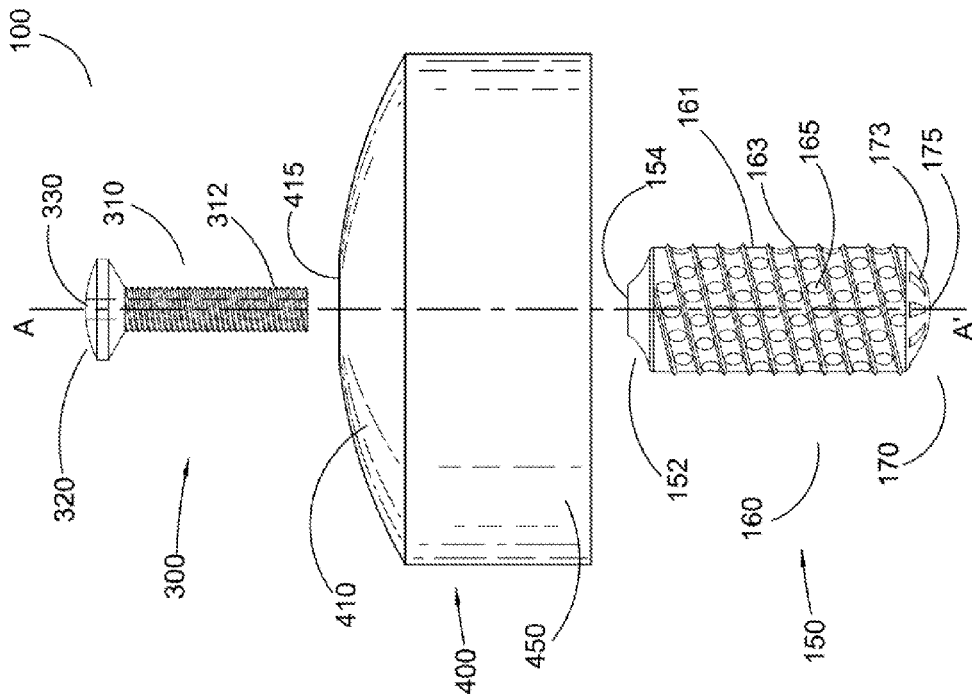


Fig. 11

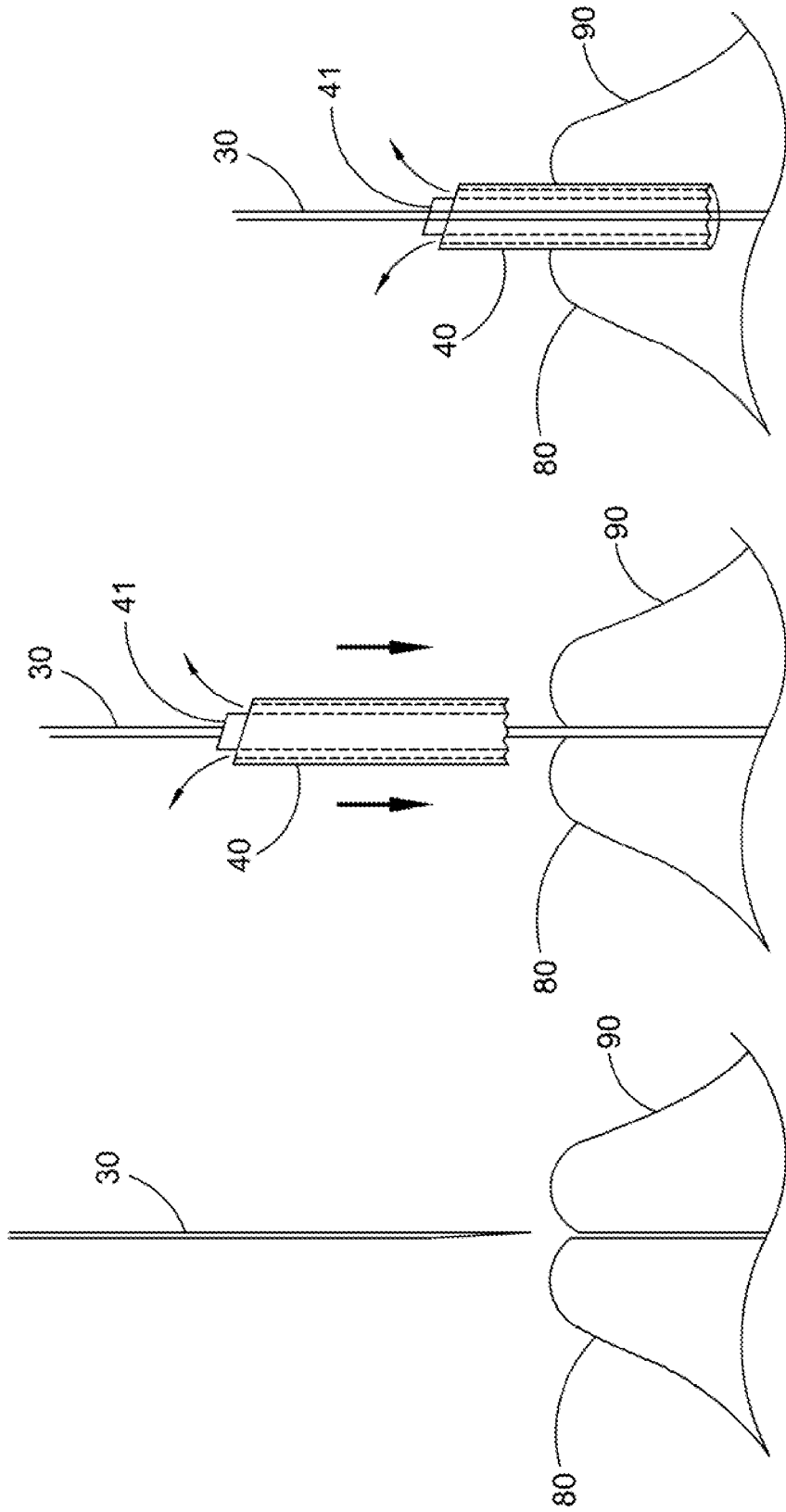


Fig. 14c

Fig. 14b

Fig. 14a

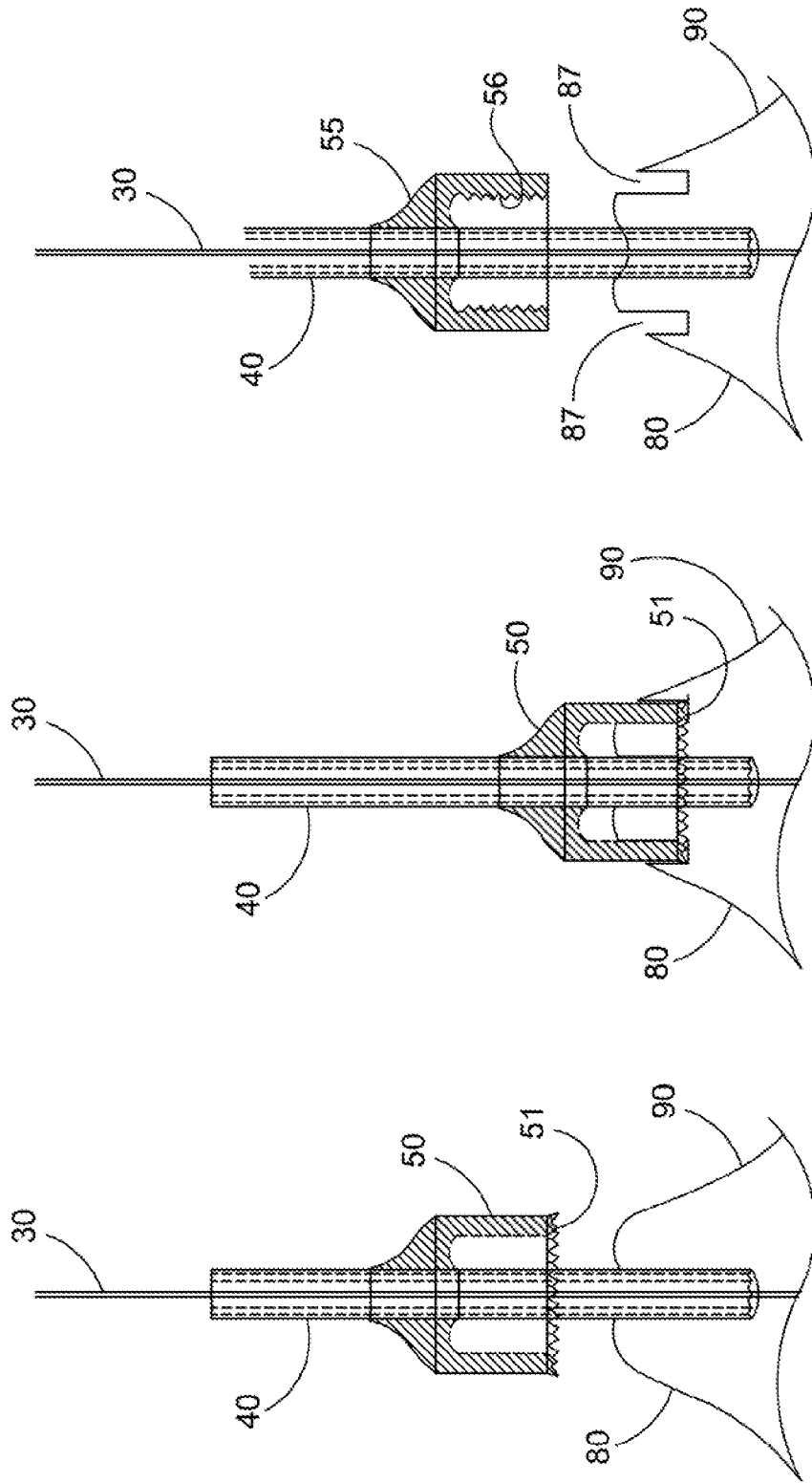


Fig. 14f

Fig. 14e

Fig. 14d

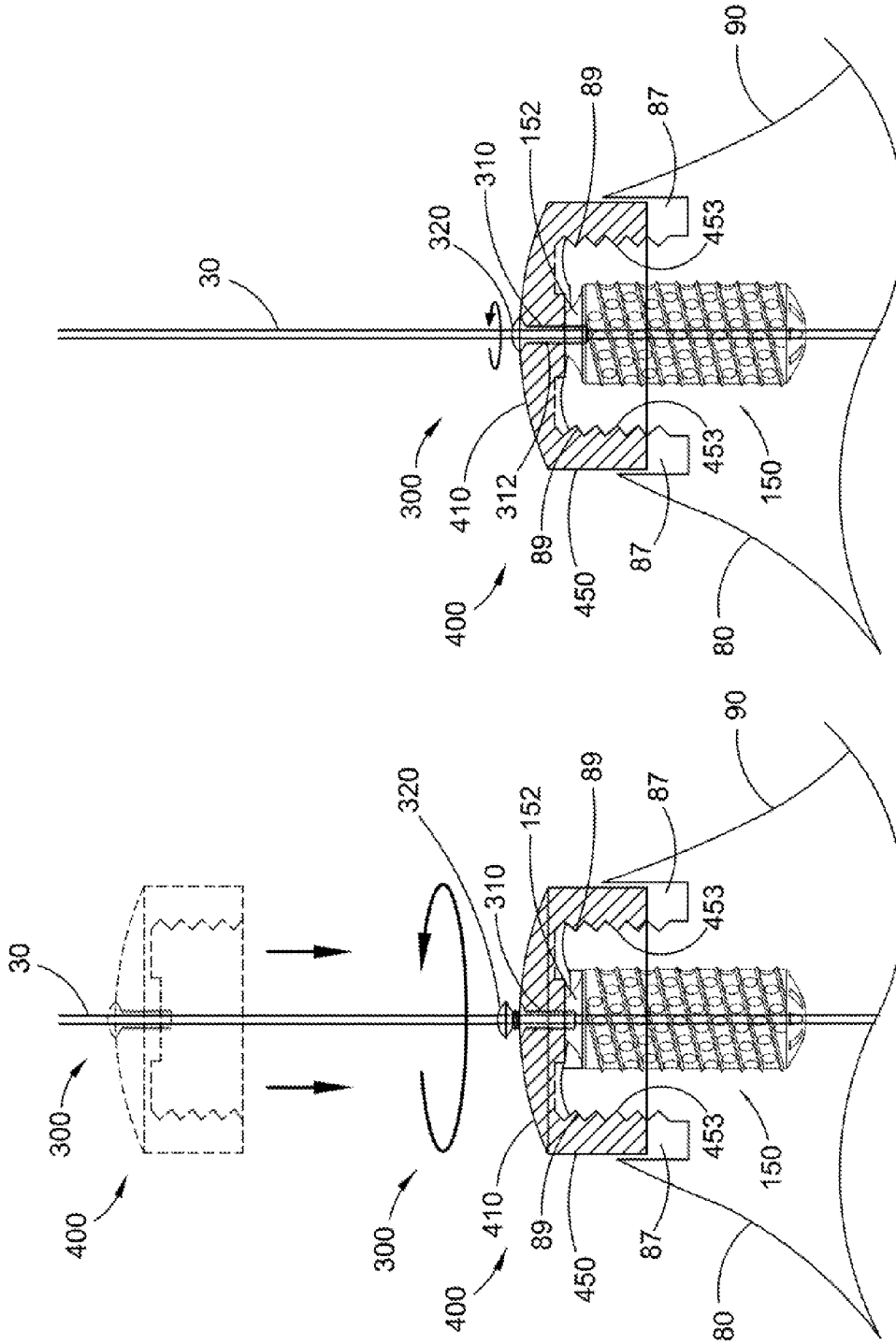
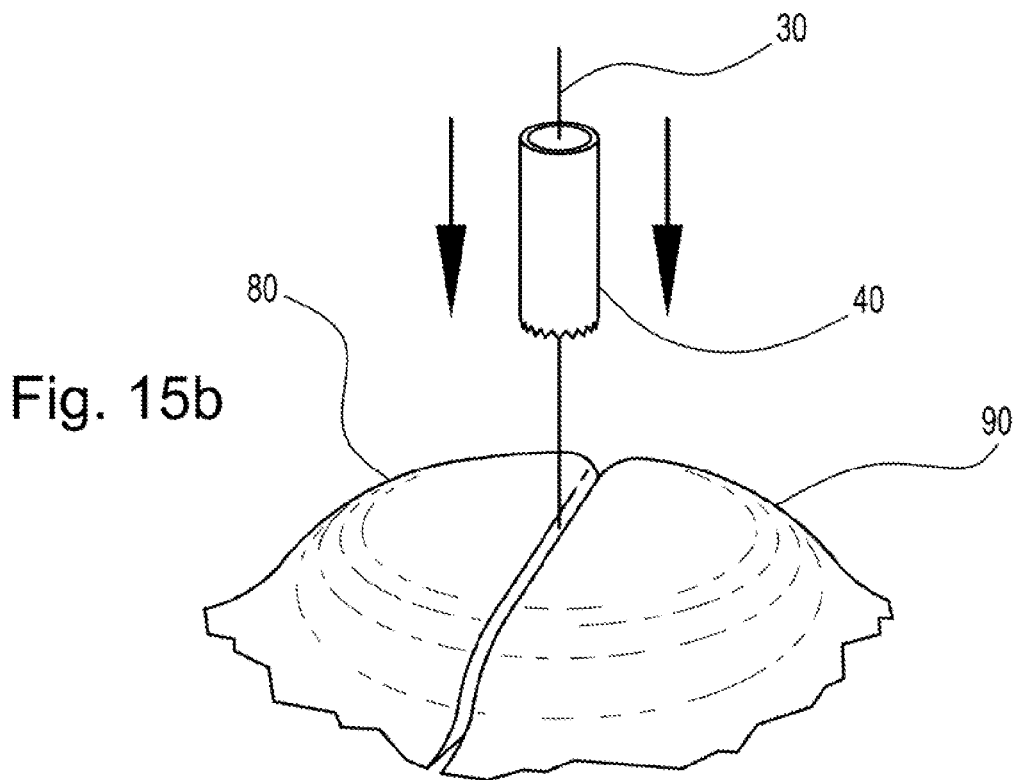
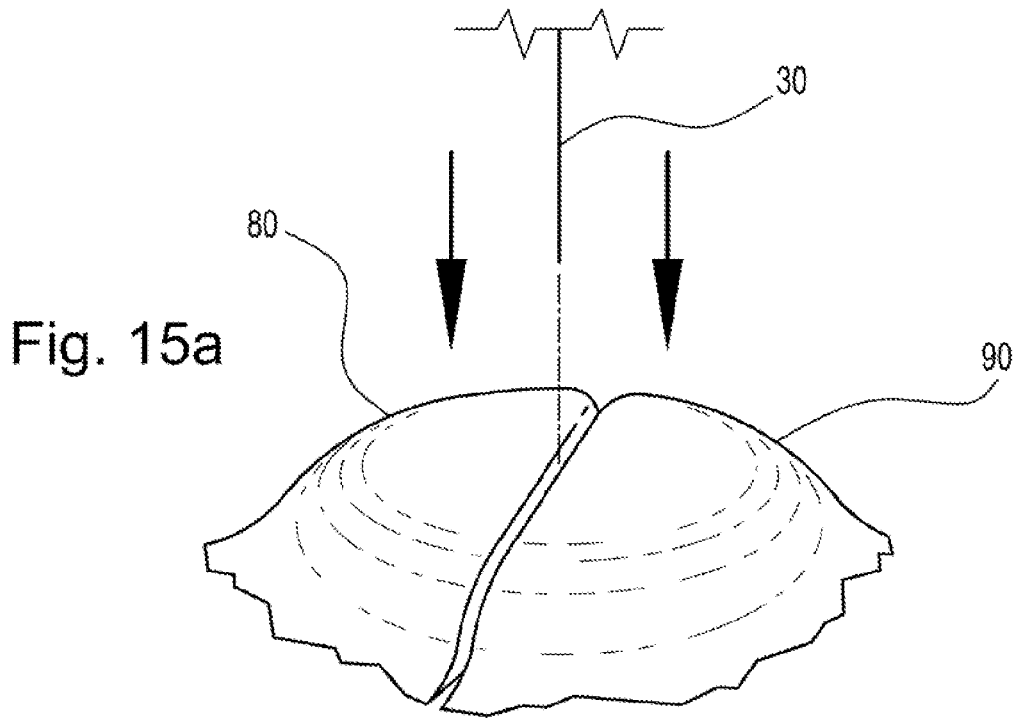
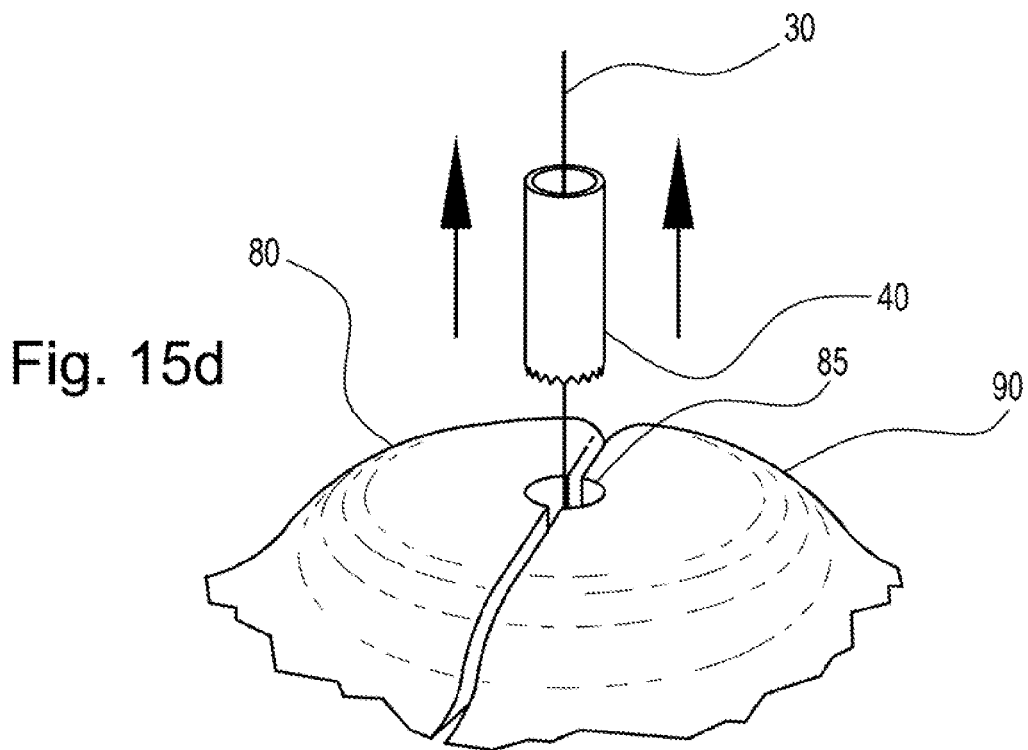
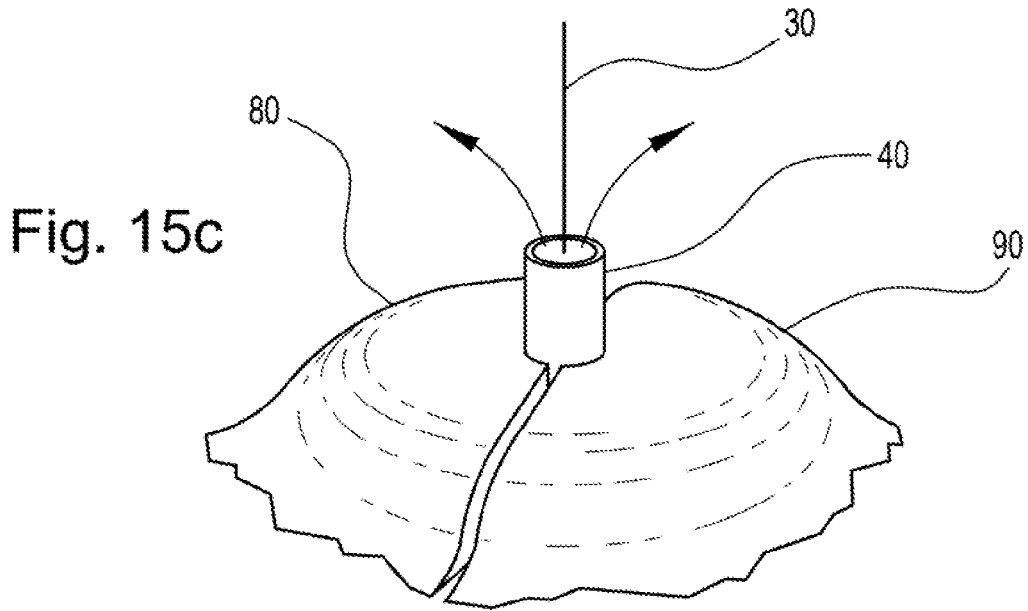
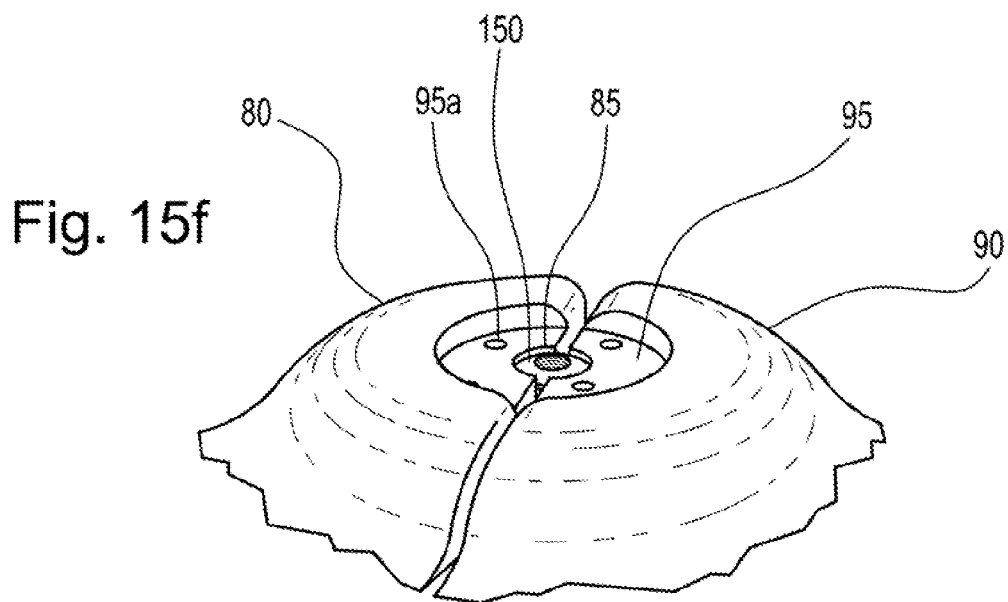
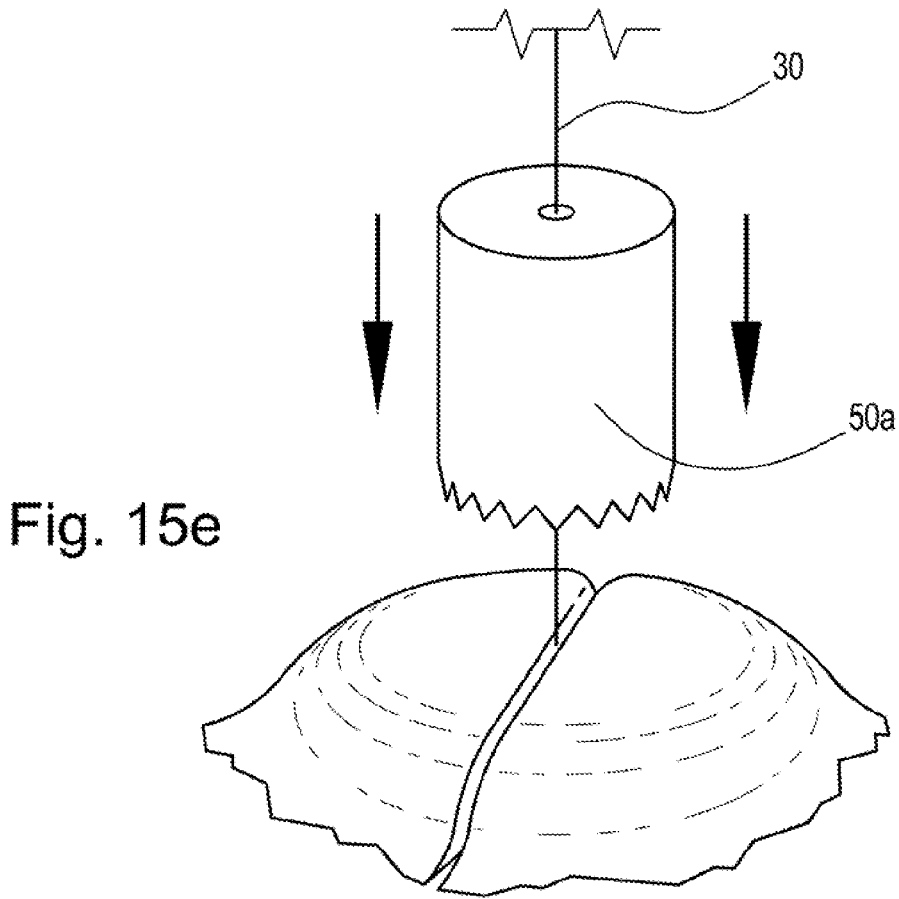


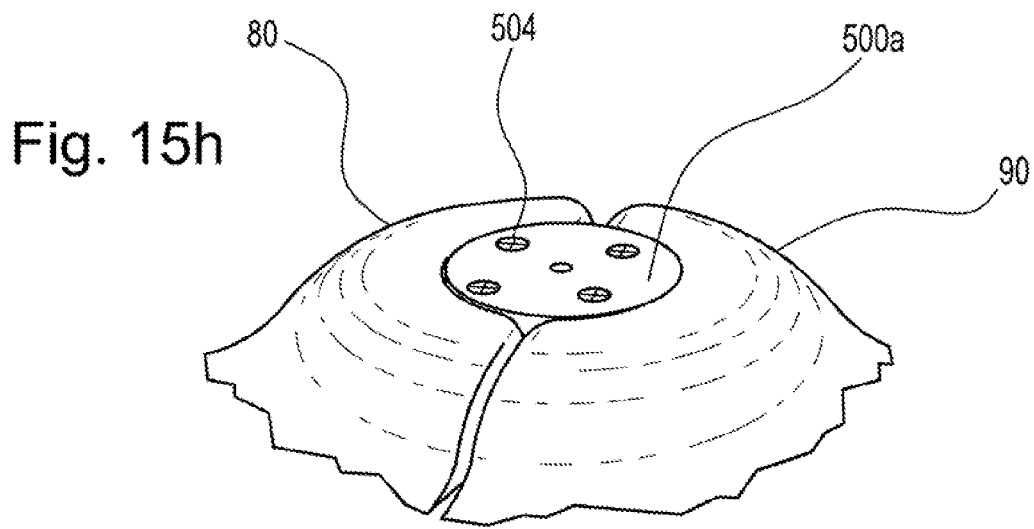
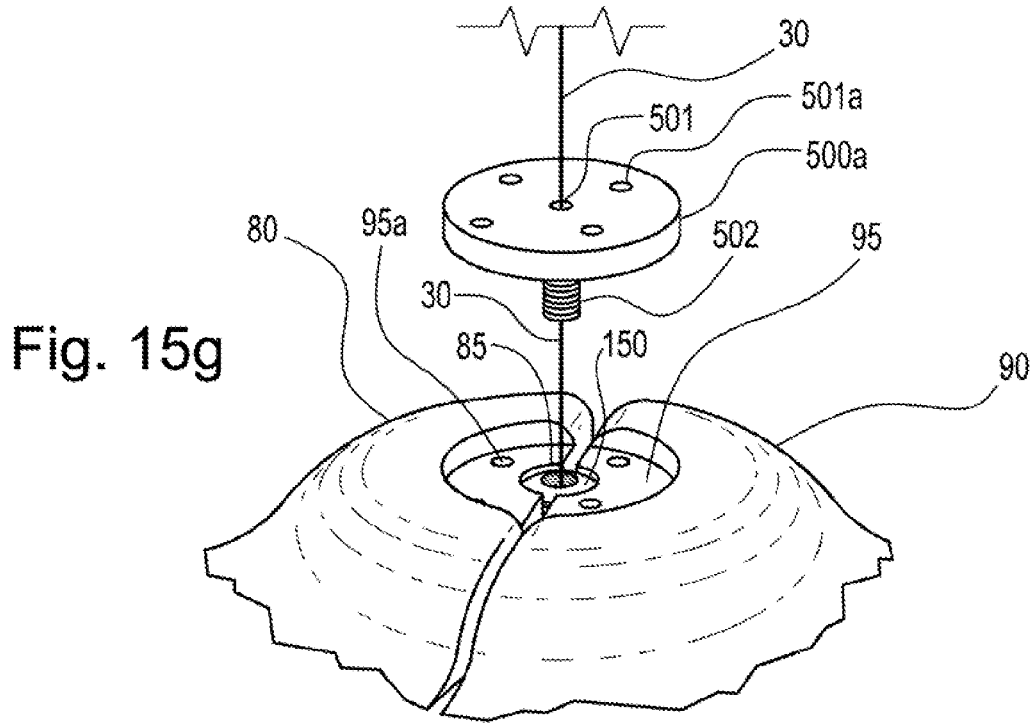
Fig. 14h

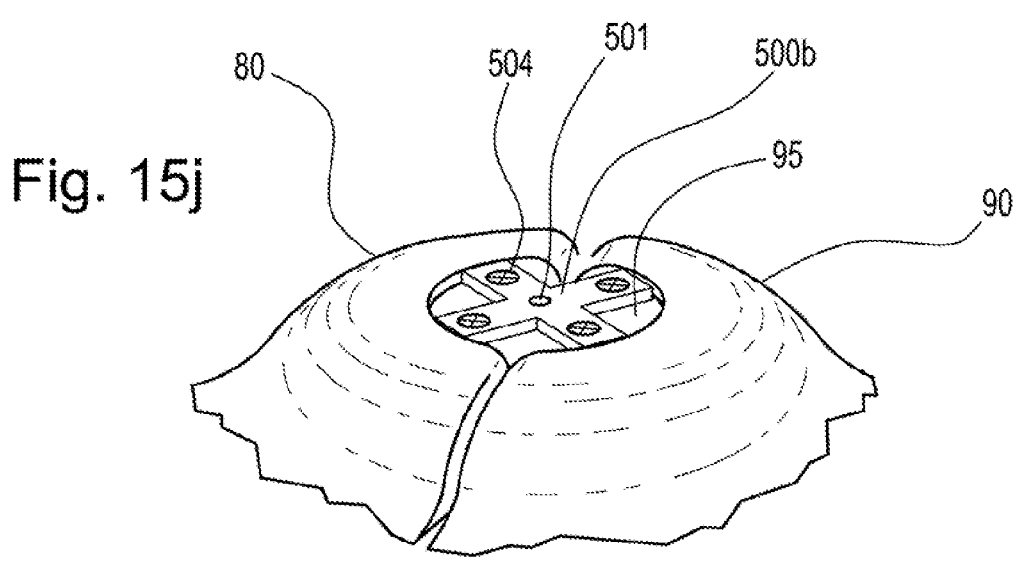
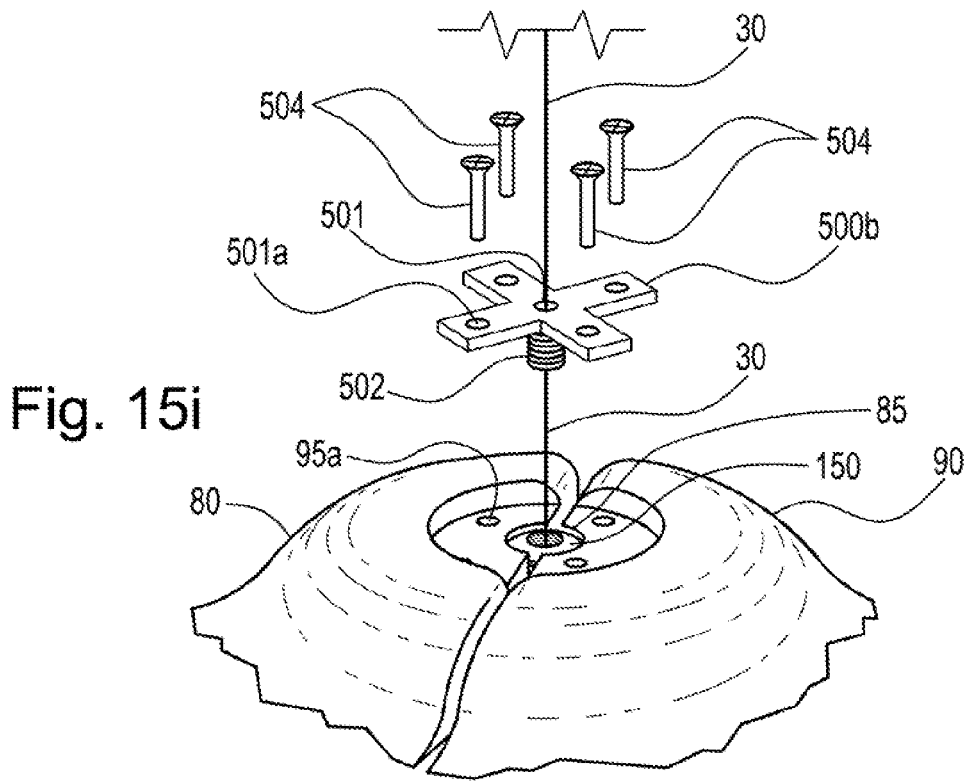
Fig. 14g











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FACET JOINT FIXATION DEVICE**CROSS REFERENCE TO RELATED APPLICATIONS**

This application is filed under 35 U.S.C. §120 as a continuation-in-part patent application of U.S. patent application Ser. No. 12/148,986, now U.S. Pat. No. 8,080,046, filed Apr. 24, 2008, which application is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

This invention relates to the field of orthopedic surgery and, particularly, to inter-bone fixation and fusion devices and, even more particularly, to interarticular facet joint fixation and fusion devices.

BACKGROUND OF THE INVENTION

The intervertebral discs of the human spine are prone to degeneration. In particular, the intervertebral discs located in highly mobile regions of the spine are disproportionately prone to degeneration, primarily due to overt and covert trauma to the tissue that occurs in the course of repetitive activities. Such trauma tends to disrupt the internal architecture of the disc and leads to bulging, herniation or protrusion of pieces of the disc, and the eventual collapse of the disc space. The resultant mechanical and/or chemical irritation of the surrounding neural elements, such as the spinal cord and nerves, may cause pain, inflammation and varying degrees of osteoarthritis and disability. Additionally, the loss of disc space height relaxes tension on the longitudinal spinal ligaments, thereby contributing to varying degrees of spinal instability.

Various treatments have been developed to treat such intervertebral disc degeneration. Many of these treatments involve the fusion of adjacent vertebra in order to limit their ability to move independently from each other, as such independent movement tends to exacerbate the degeneration of the interposed disc. These prior spinal fusion operations often involve either the passive grafting of bone between the surfaces of proximate articular processes in a facet joint that is denuded of synovium, or they involve the mechanical fixation of the facet joint with a simple screw.

These prior treatments, while fairly adequate for their purpose, suffer from a number of drawbacks. For example, operations that involve the passive grafting of bone require additional instrumented fixation of the spine to prevent dislodgement of the bone grafts from between the articular surfaces of the joint. Operations involving the mechanical fixation with a simple screw are largely adjunctive, that is, the screw alone is not sufficient as a means for fixing the facet joint. The long term success of this procedure is usually dependent upon bony union occurring elsewhere between the adjacent vertebral elements being fused, i.e., interbody or inter-transverse postero-lateral fusions.

Thus, there is a longfelt need for a facet fixation device that can be utilized either directly in a stand alone facet fusion procedure or as an adjunctive fixator to be utilized when other forms of spinal fusion are employed, e.g., as back up for an anterior fusion. There is also a longfelt need for such a device that may be deployed radiographically or through endoscopically-assisted minimally invasive approaches.

BRIEF SUMMARY OF THE INVENTION

The present invention is a device for fixing the positions of proximate bone elements, which is particularly adapted for

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the fixation of proximate articular processes in a facet joint (hereinafter referred to as the "facet fixation device" or, simply, the "device"). The device broadly comprises: an inter-bone implant adapted to be implanted between suitably prepared proximate bone elements, the inter-bone implant comprising an internally threaded aperture; a bone fixation apparatus comprising a base having an eyelet and a means connected to the base for mechanically fixing the positions of the proximate bone elements relative to each other, the eyelet being substantially aligned with the internally threaded aperture; and, a screw comprising a head and a threaded shaft extending therefrom, wherein the shaft is operatively arranged to extend through the eyelet and threadingly engage the internally threaded aperture, and the screw is operatively arranged to secure the bone fixation apparatus to the inter-bone implant.

The means for mechanically fixing the positions of the proximate bone elements relative to each other generally comprises substantially opposed surfaces, between which at least a portion of each of the proximate bone elements is immovably secured. The substantially opposed surfaces may be provided by an integral form, such as the inner annular surface of an annular wall, or by separate structures, such as the inner surfaces of opposed jaws.

In an alternate embodiment, the bone fixation device includes a cap that is placed within a recess common to both of the proximate bones. In this embodiment, holes in the cap are aligned with pilot holes within the common recess that are drilled into each of the proximate bones. Screws are inserted through the cap holes into the pilot holes. In this embodiment, the cap fixes the proximate bones by acting as a bridge holding the bones together until the bones grow together through the implant.

It is a general object of the present invention to provide a facet fixation device that can be utilized either directly in a stand alone facet fusion procedure or as an adjunctive fixator to be utilized when other forms of spinal fusion are employed, e.g., as back up for an anterior fusion. It is also the object of this invention to provide for deployment of the device either radiographically or through endoscopically assisted minimally invasive approaches.

These and other objects and advantages of the present invention will be readily appreciable from the following description of preferred embodiments of the invention and from the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The nature and mode of operation of the present invention will now be more fully described in the following detailed description of the invention taken with the accompanying drawing figures, in which:

FIG. 1 is an exploded perspective view of a first embodiment of the present invention facet fixation device;

FIG. 2 is an exploded, side elevational view of a first embodiment facet fixation device;

FIG. 3 is a top plan view of an inter-bone implant of the facet fixation device;

FIG. 4 is a side elevational view of the inter-bone implant;

FIG. 5 is a bottom plan view of the inter-bone implant;

FIG. 6 is a top plan view of the first embodiment bone fixation apparatus;

FIG. 7 is a side elevational view of the first embodiment bone fixation apparatus;

FIG. 8 is a bottom plan view the first embodiment bone fixation apparatus;

FIG. 8a is a side elevational view of a screw and the first embodiment bone fixation apparatus illustrating the screw moving downwardly;

FIG. 8b is a side elevational view of the screw and bone fixation apparatus shown in FIG. 8a illustrating the actuation of the bone fixation apparatus by the screw;

FIG. 9a is a side view showing a first step in the implementation of the first embodiment facet fixation device;

FIG. 9b is a side view showing a second step in the implementation of the first embodiment facet fixation device;

FIG. 9c is a side view showing a third step in the implementation of the first embodiment facet fixation device;

FIG. 9d is a side view showing a fourth step in the implementation of the first embodiment facet fixation device;

FIG. 9e is a side view showing a fifth step in the implementation of the first embodiment facet fixation device;

FIG. 9f is a side view showing a sixth step in the implementation of the first embodiment facet fixation device;

FIG. 9g is a side view showing a seventh step in the implementation of the first embodiment facet fixation device;

FIG. 10 is an exploded perspective view of a second embodiment of the present invention facet fixation device;

FIG. 11 is an exploded, side elevational view of the second embodiment facet fixation device;

FIG. 12 is a cross-sectional view taken generally along line 12-12 in FIG. 10;

FIG. 13 is a cross-sectional view taken generally along line 13-13 in FIG. 10;

FIG. 14a is a side view showing a first step in the implementation of the second embodiment facet fixation device;

FIG. 14b is a side view showing a second step in the implementation of the second embodiment facet fixation device;

FIG. 14c is a side view showing a third step in the implementation of the second embodiment facet fixation device;

FIG. 14d is a side view showing a fourth step in the implementation of the second embodiment facet fixation device;

FIG. 14e is a side view showing a fifth step in the implementation of the second embodiment facet fixation device;

FIG. 14f is a side view showing a sixth step in the implementation of the second embodiment facet fixation device;

FIG. 14g is a side view showing a seventh step in the implementation of the second embodiment facet fixation device;

FIG. 14h is a side view showing an eighth step in the implementation of the second embodiment facet fixation device for the fixation of proximate bone elements;

FIG. 15a is a side perspective view showing a first step in the implementation of the third embodiment facet fixation device;

FIG. 15b is a side perspective view showing a second step in the implementation of the third embodiment facet fixation device;

FIG. 15c is a side perspective view showing a third step in the implementation of the third embodiment facet fixation device;

FIG. 15d is a side perspective view showing the hole prepared for the implant after drilling is completed;

FIG. 15e is a side perspective view illustrating a fourth step wherein a fluted flat bottom end mill is moved toward the proximate bone elements;

FIG. 15f is a side perspective view showing drilled pilot holes in the recess formed by the flat bottom end mill and the interbone implant positioned in the bore between the proximate bone elements;

FIG. 15g is a side perspective exploded view depicting the suitably prepared recess with pilot holes with one embodiment of the fixation cap in the form of a circular cap screw;

FIG. 15h is a side perspective view showing the circular cap screw fastened in place in the recess between the proximate bone elements;

FIG. 15i is a side perspective exploded view depicting the suitably prepared recess with pilot holes with a second embodiment of the fixation cap in the form of a cross or x-shaped cap screw; and,

FIG. 15j is a side perspective exploded view depicting the circular cap screwed in place in recess 95.

DETAILED DESCRIPTION OF THE INVENTION

At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements of the invention. While the present invention is described with respect to what is presently considered to be the preferred aspects, it is to be understood that the invention as claimed is not limited to the disclosed aspects.

Furthermore, it should be understood that this invention is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It should also be understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present invention, which is limited only by the appended claims.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs. Although any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods, devices, and materials are now described.

As stated supra, the present invention device broadly comprises: an inter-bone implant adapted to be implanted between suitably prepared proximate bone elements, the implant having a threaded aperture; a bone fixation apparatus adapted to mechanically fix the position of the proximate bone elements relative to each other and to the inter-bone implant, the bone fixation apparatus including a base having an eyelet substantially aligned with the internally threaded aperture; and, a screw comprising a head and a threaded shaft extending therefrom, the shaft being arranged through the eyelet and threadingly engaged in the internally threaded aperture, and the screw is operatively arranged to fixedly secure the bone fixation apparatus to the inter-bone implant.

The inter-bone implant is operatively arranged to promote the fusion or bony union of the proximate bone elements, and the bone fixation apparatus is operatively arranged to fix the respective position of the proximate bone elements relative to each other and, possibly to the implant, in order to enhance the efficacy of the inter-bone implant. It should be noted that the bone fixation apparatus is not merely supplementary to the inter-bone implant, but is operatively arranged to independently fix the positions of the proximate bone element relative to each other, which may be advantageous in situations where an inter-bone implant is not necessary, not feasible, or simply unwanted due to the nature of the treatment.

Multiple embodiments of the bone fixation apparatus have been contemplated, two of which are shown and described in detail herein. Regardless of the particular embodiment, the bone fixation apparatus comprises a base and a means connected thereto for mechanically fixing the positions of the proximate bone elements relative to each other and, when

applicable, to the inter-bone implant. When used in conjunction with the inter-bone implant, the base is preferably in the form of an arcuate or planar plate which includes an eyelet. The eyelet is arranged to receive the shaft of the screw there-through and allow at least portion of the shaft to reach and threadingly engage the internally threaded aperture of the inter-bone implant.

The means for mechanically fixing the positions of the proximate bone elements relative to each other generally comprises at least two substantially opposed surfaces, between which at least a portion of each of the proximate bone elements is immovably secured. The substantially opposed surfaces may be provided by an integral form, such as the inner annular surface of an annular wall, or by separate structures, such as the inner surfaces of opposed jaws.

The following provides a detailed description of two embodiments of the present invention, which are differentiated from each other primarily by the particular bone fixation apparatus employed. The first embodiment bone fixation apparatus comprises a plurality of opposed jaws, which are operatively arranged to provide the at least two substantially opposed surfaces. The second embodiment bone fixation apparatus comprises an annular wall having an inner annular surface, which is operatively arranged to provide the at least two substantially opposed surfaces.

The first embodiment facet fixation device **100** is best understood in view of FIGS. 1-9g. FIG. 1 is a perspective view of facet fixation device **100** broadly comprising inter-bone implant **150**, screw **300**, and bone fixation apparatus **200**, hereinafter referred to as clamp **200**.

Screw **300**, which may be any suitable screw, broadly includes head **320**, shaft **310** having threads **312**, and, preferably, through-bore **330**. The screw drive of screw **300** may be of any type, but is preferably hex cap screw **322** when used in combination with clamp **200**. Screw **300** may further include plate **220**, the function of which is described in detail infra. Plate **220** may be a separate component, as shown in the figures, or integrally formed with head **320**.

As shown in FIGS. 3-5, inter-bone implant **150** comprises body **160**, which is preferably hollow and either cylindrical or frustoconical, first end **152**, and second end **170**. First end **152** includes aperture **154** having internal threads **155**, which are operatively arranged to threadingly engage threads **312** of screw **300**. Second end **170** preferably includes one or more apertures **173**, which are arranged to accept residual bone material into hollow body **160**, and central aperture **175**.

Residual bone material is often produced when preparing proximate bone elements for the implantation of inter-bone implant **150** therebetween, as described in detail infra. The residual bone material often contains viable osteocytes, which can help rebuild bony matrix and enable the proximate bone elements to form a bony union therebetween and, ultimately, fuse. Implant **150** may also include bone morphogenic proteins, such as BMP-2 and BMP-7, which serve to induce such bony union. Outer surface **161** of body portion **160** is preferably irregular and includes at least one, but preferably a plurality, of apertures **165**. The irregularity of outer surface **161** may be in the form of protuberances, for example, threads **163** as shown in the figures. The irregularity of outer surface **161** helps secure implant **150** between proximate bone elements by creating a frictional engagement between implant **150** and the bone elements. Apertures **165** are also arranged to receive residual bone material into body **160**.

Clamp **200** comprises: base **210**, which is preferably in the form of a substantially planar plate, and includes eyelet **215** operatively arranged to receive shaft **310** therethrough; and, a

pair of opposed jaws, **240** and **270**, pivotally connected to base **210**. Jaws **240** and **270** may comprise any number of teeth, the shape and structure of which may be adapted for particular bone elements, such as, a superior articular process and an inferior articular process of a facet joint. Additionally, clamp **200** may comprise more than the two jaws shown and described herein, and may also comprise as few as one pivotally connected jaw. Regardless of the particular adaptation, the teeth of the jaws comprise substantially opposed surfaces, between which at least a portion of each of the proximate bone elements is immovably secured, as described in further detail infra.

In the particular embodiment shown and described herein, jaw **240** preferably comprises two teeth, namely, first tooth **250** and second tooth **260**. First tooth **250** comprises first inner surface **254** and terminates at first pointed tip **252**. Second tooth **260** comprises second inner surface **264** and terminates second pointed tip **262**. First and second pointed tips **252** and **262**, respectively, are arranged to frictionally engage and/or pierce the surface of the proximate bone elements.

Likewise, jaw **270** preferably comprises two teeth, namely, third tooth **280** and fourth tooth **290**. Third tooth **280** comprises third inner surface **284** and terminates at third pointed tip **282**. Fourth tooth **290** comprises fourth inner surface **294** and terminates fourth pointed tip **292**. Third and fourth pointed tips **282** and **292**, respectively, are arranged to frictionally engage and/or pierce the surface of the proximate bone elements.

Jaws **240** and **270** may be pivotally connected to base **210** by any means known in the art. In the particular embodiment shown and described herein, base **210** includes barrels **212a** and **212b**. Barrel **212a** is operatively arranged to fit between, and align with, barrels **241** and **243** of jaw **240**, and pivot pin **267** is operatively arranged to extend through barrels **241**, **212a**, and **243**. Together, barrels **241**, **212a**, **243**, and pivot pin **267** form a hinge bearing which provides a pivotable connection between jaw **240** and base **210**. Pivot pin **267** may include cap **269** affixed to one end to prevent it from sliding out of the barrels.

Likewise, barrel **212b** is operatively arranged to fit between, and align with, barrels **271** and **273** of jaw **270**, and pivot pin **297** is operatively arranged to extend through barrels **271**, **212b**, and **273**. Together, barrels **271**, **212b**, **273**, and pivot pin **297** form a hinge bearing which provides a pivotable connection between jaw **270** and base **210**. Pivot pin **297** may include cap **299** affixed to one end to prevent it from sliding out of the barrels.

Jaw **240** is arranged substantially opposed to jaw **270**, such that first and second inner surfaces **254** and **264**, respectively, of jaw **240** are arranged substantially opposed to third and fourth inner surfaces **284** and **294**, respectively, of jaw **270**, thereby defining mouth **230**. It is between these opposed surfaces that at least a portion of each of the proximate bone elements is immovably secured, as described in further detail infra. Jaws **240** and **270** are also arranged to pivot toward and/or away from each other.

In a preferred embodiment, jaws **240** and **270** further comprise actuators **245** and **275**, respectively. Jaw **240** is operatively arranged to pivot toward jaw **270** when a force is applied to actuator **245**. Likewise, jaw **270** is operatively arranged to pivot toward jaw **240** when a force is applied to actuator **275**. In one embodiment, head **320** is operatively arranged to apply mechanical force to actuator **245** and/or actuator **275** as head **320** moves toward base **210**. In a further embodiment, head **320** applies such mechanical force simul-

taneously to actuators **245** and **275**, thereby causing each actuator to simultaneously pivot toward each other.

In a preferred embodiment, device **100** includes plate **220**, which is arranged between head **320** and base **210**. Plate **220** is operatively arranged to provide a mechanical connection between head **320** and actuators **245** and **275**, i.e., head **320** is operatively arranged to apply mechanical force to plate **220**, which, in turn, is operatively arranged to apply mechanical force to actuators **245** and **275**, as head **320** moves toward base **210**. Plate **220** preferably includes aperture **225**, which is substantially aligned with eyelet **215** and internally threaded aperture **154**, and is arranged to receive shaft **310** therethrough. As shown in the figures, plate **220** may be embodied as a simple washer.

The arrows in FIG. **8a** illustrate head **320** moving toward base **210** in order to apply mechanical force to plate **220**, and the arrows in FIG. **8b** illustrate the pivoting of jaws **240** and **270** pivoting toward each other in response to the application of mechanical force on actuators **245** and **275** by plate **220**.

Broadly, FIGS. **9a-9g** illustrate the preferred method or procedure by which device **100** is implemented. Particularly: FIGS. **9a-9c** illustrate the method by which proximate bone elements **80** and **90** are suitably prepared for the implementation of device **100**; FIGS. **9d-9e** illustrate the method by which inter-bone implant **150** is implanted between the suitably prepared proximate bone elements **80** and **90**; and, FIGS. **9f-9g** illustrate the method by which the bone fixation apparatus, specifically, clamp **200**, is arranged to mechanically fix the positions of proximate bone elements **80** and **90** relative to each other, and the method by which screw **300** is operatively arranged to secure clamp **200** to inter-bone implant **150**.

As shown in FIG. **9a**, the initial step in the procedure includes inserting a Kirschner wire, hereinafter referred to as K-wire **30**, between proximate bone elements **80** and **90**. K-wire **30** is operatively arranged to guide the tools involved in suitably preparing proximate bone elements **80** and **90**, as well as, the various components of device **100**, toward proximate bone elements **80** and **90**. FIG. **9b** illustrates the second step in the procedure wherein first drill **40** is guided by K-wire **30** toward bone elements **80** and **90**, as indicated by the arrows. First drill **40** is preferably hollow so that K-wire **30** can be arranged in its interior, in order to guide it toward proximate bone elements **80** and **90**. Additionally, first drill **40** may include suction channel **41**, which is operatively arranged to remove excess bone material created by the drilling process, as is illustrated by the arrows proximate to channel **41** in FIGS. **9b** and **9c**. FIG. **9c** illustrates the third step in the procedure wherein first drill **40** removes bone material from both proximate bone elements **80** and **90**.

As shown in FIG. **9d**, first drill **40** is operatively arranged to remove bone material from bone elements **80** and **90**, thereby generating cavity **85**, which is defined by bone elements **80** and **90**. Cavity **85** is arranged to receive inter-bone implant **150** therein. FIG. **9d** illustrates the fourth step in the procedure wherein inter-bone implant **150** is guided by K-wire **30** toward cavity **85**. Since implant **150** includes apertures **154** and **175** at opposite ends, and body portion **160** is preferably hollow, K-wire **30** can be arranged inside implant **150** in order to guide it toward cavity **85**, as indicated by the arrows in FIG. **9d**.

FIG. **9e** illustrates the fifth step in the procedure wherein implant **150** is arranged between suitably prepared bone elements **80** and **90**. Implant **150** is preferably arranged such that outer surface **161** is in contact with proximate bone elements **80** and **90**, particularly by means of a frictional engagement of threads **163** with bone elements **80** and **90**, thereby mitigating any movement of implant **150** within cavity **85**.

Clamp **200** and screw **300** are arranged to be guided by K-wire **30** toward implant **150** and proximate bone elements **80** and **90**. Particularly, K-wire **30** can be threaded through eyelet **215** in order to guide clamp **200** toward implant **150** and proximate bone elements **80** and **90**. In a preferred embodiment, screw **300** includes through-bore **330**, through which K-wire **30** can be threaded in order to guide screw **300** toward eyelet **215** and internally threaded aperture **154**.

FIG. **9f** illustrates the sixth step in the procedure wherein shaft **310** is arranged through eyelet **215** and is threadingly engaging internally threaded aperture **154**, as illustrated by the semicircular arrow around K-wire **30**. As threads **312** of shaft **310** positively engage internally threaded aperture **154**, head **320** is drawn toward base **210** and applies mechanical force to plate **220**. Plate **220**, in turn, applies mechanical force to actuators **245** and **275**, which cause jaws **240** and **270** to pivot toward each other, as illustrated by the arrows proximate the jaws.

FIG. **9g** illustrates the seventh, and relatively final, step in the procedure wherein inter-bone implant **150** is arranged between suitably prepared proximate bone elements **80** and **90**; clamp **200**, is fixing the positions of proximate bone elements **80** and **90** relative to each other by immovably securing at least a portion of bone elements **80** and **90** between substantially opposed surfaces **254** and **284**, eyelet **215** is substantially aligned with internally threaded aperture **154**, and screw **300** is securing clamp **200** to inter-bone implant **150**.

The second embodiment facet fixation device **100**, is best understood in view of FIGS. **10-14h**. FIG. **10** is a perspective view of device **100** broadly comprising inter-bone implant **150**, screw **300**, and bone fixation apparatus **400**, hereinafter referred to as cap **400**.

Screw **300**, which may be any suitable screw, broadly includes head **320**, shaft **310** having threads **312**, and, preferably, through-bore **330**, as shown in FIGS. **11** and **12**. The screw drive of screw **300** may be of any type, but is preferably cruciform screw drive **324** when used in combination with cap **400**.

As in the first embodiment, inter-bone implant **150** includes body **160**, which is preferably hollow and either cylindrical or frustoconical, first end **152**, and second end **170**. First end **152** includes aperture **154** having internal threads **155**, which are operatively arranged to threadingly engage threads **312** of screw **300**. Second end **170** preferably includes one or more apertures **173**, which are arranged to accept residual bone material into hollow body **160**, and central aperture **175**. Outer surface **161** of body portion **160** is preferably irregular and includes at least one, but preferably a plurality, of apertures **165**. The irregularity of outer surface **161** may be in the form of protuberances, for example, threads **163** as shown in the figures. The irregularity of outer surface **161** helps secure implant **150** between proximate bone elements by creating a frictional engagement between implant **150** and the bone elements. Apertures **165** are also arranged to receive residual bone material into body **160**.

Cap **400** comprises: base **410**, which is preferably in the form of a substantially arcuate plate, and includes eyelet **415** operatively arranged to receive shaft **310** therethrough; and, annular wall **450** extending from base **410**, which, in conjunction with base **410**, defines inner chamber **430**. Eyelet **415** is preferably recessed so that head **320** fits substantially flush with the surface of base **410** when assembled together. Annular wall **450** may be a cylindrical form, as shown and described, but may also be adapted for different proximate

bone elements, the particular structure of which may necessitate a different shape for annular wall 450, such as, a frustoconical form.

Regardless of the particular adaptation, annular wall 450 comprises inner annular surface 452, which preferably includes threads 453, as shown in FIG. 13. Inner annular surface 452 provides a continuum of substantially opposed surfaces, since any location on inner annular surface 452 has a complimentary location, diametrically opposed across chamber 430, on surface 452. Thus, inner annular surface 452 provides a continuum of diametrically opposed surfaces, between which at least a portion of each of the proximate bone elements is immovably secured, as described in further detail infra.

Broadly, FIGS. 14a-14h illustrate the preferred method or procedure by which device 100 is implemented. Particularly: FIGS. 14a-14f illustrate the method by which proximate bone elements 80 and 90 are suitably prepared for the implementation of device 100; FIGS. 14g-14h illustrate the method by which the bone fixation apparatus, namely, cap 400, is arranged to mechanically fix the positions of proximate bone elements 80 and 90 relative to each other, and the method by which screw 300 is operatively arranged to secure cap 400 to inter-bone implant 150. The method by which inter-bone implant 150 is implanted between the suitably prepared proximate bone elements 80 and 90 is not shown in these figures as it is substantially identical to steps described supra and shown in FIGS. 9d-9e.

The first three steps for suitably preparing proximate bone elements 80 and 90 are illustrated in FIGS. 14a-14c, and are substantially identical to the first three respective steps for implementing the first embodiment, as described supra and shown in FIGS. 9a-9c. Particularly, FIG. 14a shows the initial step wherein K-wire 30 is inserted between proximate bone elements 80 and 90. K-wire 30 is operatively arranged to guide the tools involved in suitably preparing proximate bone elements 80 and 90, as well as, the various components of device 100, toward proximate bone elements 80 and 90. FIG. 14b illustrates the second step in the procedure wherein first drill 40 is guided by K-wire 30 toward bone elements 80 and 90, as indicated by the arrows. First drill 40 is preferably hollow so that K-wire 30 can be arranged in its interior, in order to guide it toward proximate bone elements 80 and 90. Additionally, first drill 40 may include suction channel 41, which is operatively arranged to remove excess bone material created by the drilling process, as is illustrated by the arrows proximate to channel 41 in FIGS. 14b and 14c. FIG. 14c illustrates the third step in the procedure wherein first drill 40 removes bone material from both proximate bone elements 80 and 90, thereby generating cavity 85.

To suitably prepare proximate bone elements 80 and 90 for the implantation of second embodiment device 100, the additional steps shown in FIGS. 14d-14f are required. FIG. 14d illustrates a fourth step wherein second drill 50 is guided by K-wire 30 toward proximate bone elements 80 and 90. Second drill 50 comprises an annular wall having a ring of teeth 51 along its circular leading edge. As shown in FIGS. 14e and 14f, second drill 50 is operatively arranged to carve annular recess 87 into bone elements 80 and 90.

FIG. 14f shows the next step wherein third drill 55 is guided by K-wire 30 toward proximate bone elements 80 and 90, particularly toward annular recess 87. Third drill 55 is a threading tool comprising an annular wall having threaded inner annular surface 56, which is operatively arranged to carve threads 89 into bone elements 80 and 90 within annular recess 87, as shown in FIGS. 14g and 14h. Annular recess 87 is arranged to fittingly receive annular wall 450 of cap 400.

Additionally, 89 threads are operatively arranged to threadingly engage threads 453 of inner annular surface 452.

FIGS. 14g-14h show inter-bone implant 150 already implanted between proximate bone elements 80 and 90 within cavity 85. Cap 400 and screw 300 are arranged to be guided by K-wire 30 toward implant 150 and proximate bone elements 80 and 90, as illustrated with the parallel arrows shown in FIG. 14g. Particularly, K-wire 30 can be threaded through eyelet 415 in order to guide cap 400 toward implant 150 and proximate bone elements 80 and 90, as shown in FIG. 14g. In a preferred embodiment, screw 300 includes through-bore 330, through which K-wire 30 can be threaded in order to guide screw 300 toward eyelet 415 and internally threaded aperture 154.

FIG. 14g further illustrates how threads 453 of inner annular surface 452 threadingly engage threads 89 of annular recess 87, as indicated by the large semicircular arrow around K-wire 30. As threads 453 threadingly engage threads 89, proximate bone elements 80 and 90 are immovably secured between the continuum of substantially opposed surfaces provided by inner annular surface 452, as described supra.

FIG. 14h illustrates the relatively final step in the procedure wherein shaft 310 is arranged through eyelet 415 and is threadingly engaging internally threaded aperture 154, as indicated by the small semicircular arrow around K-wire 30. As threads 312 of shaft 310 positively engage internally threaded aperture 154, head 320 is drawn toward base 410 until cap 400 is secured to inter-bone implant 150.

FIGS. 15a-15j illustrate an alternate preferred method or procedure by which device 100 is implemented. Person of skill in the art will recognize that the choice of method would depend on the individual circumstances of each surgical situation. Particularly, FIGS. 15a-15f illustrate the method by which proximate bone elements 80 and 90 are suitably prepared for the implantation of implant 150. FIGS. 15g-15j illustrate the method by which the bone fixation apparatus, namely, cap 500, is arranged to fix the positions of proximate bone elements 80 and 90 relative to each other and the method by which cap 500 is attached to inter-bone implant 150.

The first three steps for suitably preparing proximate bone elements 80 and 90 are illustrated in FIGS. 15a-15d, and are substantially identical to the first three respective steps for implementing the first embodiment, as described supra and shown in FIGS. 9a-9c. Particularly, FIG. 15a shows the preferred initial step wherein K-wire 30 is inserted between proximate bone elements 80 and 90. K-wire 30 is operatively arranged to guide the tools involved in suitably preparing proximate bone elements 80 and 90, as well as the fixation device 500 described below, toward proximate bone elements 80 and 90. FIG. 15b illustrates the second step in the procedure wherein first drill 40 is guided by K-wire 30 toward bone elements 80 and 90, as indicated by the arrows. First drill 40 is preferably hollow so that K-wire 30 can be arranged in its interior, in order to guide it toward proximate bone elements 80 and 90. Additionally, first drill 40 may include suction channel 41, seen in FIG. 9c, which is operatively arranged to remove excess bone material created by the drilling process, as is illustrated by the arrows proximate to channel 41 in FIG. 9c. FIG. 15c illustrates the third step in the procedure wherein first drill 40 removes bone material from both proximate bone elements 80 and 90, thereby generating cavity 85. FIG. 15d shows the cavity 85 prepared for implant 150 by first drill 40 after drilling is completed.

To suitably prepare proximate bone elements 80 and 90 for the implantation of implant 150 and the third embodiment of the fixation device, screw cap 500, the additional steps shown in FIGS. 15e-15f are required. FIGS. 15g and 15i show two

forms of screw cap **500**, circular screw cap **500a** ("cap **500a**") and cross or x-shaped screw cap **500b** ("cap **500b**") (collectively "cap **500**"), respectively. Cap **500a** includes a circular cap with a hollow externally threaded stem **502** and, preferably, central bore **501** that extends continuously through both the circular cap and hollow stem **502** to form a cap screw. Preferably, cap **500** also includes screw holes **501a** to accommodate screws **504** which are used to attach cap **500** to the bottom of recess **95**. Stem **502** is threaded to threadably attach cap **500a** to previously positioned implant **150** which has an internally threaded aperture **154** as described above.

FIG. **15e** illustrates a fourth step wherein drill **50a**, preferably guided by K-wire **30** is moved toward proximate bone elements **80** and **90**. Third drill **50a** is a flat bottom end mill having a flat bottom with flutes to bore a common recess **95** between proximate bone elements **80** and **90**. By common is meant that recess **95** spans each of the proximate bone elements, in this example proximate bone elements **80** and **90**. Within recess **95**, a pilot drill is used to drill at least one pilot hole **95a** into each proximate bone element **80** and **90**. FIG. **15f** shows the completed recess **95** with pilot holes **95a**. Pilot holes are holes with a diameter smaller than a screw that will be threaded into the pilot hole in order to allow the threading to be more easily started.

FIG. **15g** is a side perspective view depicting the suitably prepared recess **95** with pilot holes **95a** along with circular cap **500a**. Similarly, FIG. **15i** shows an x-shaped cap **500b** in an exploded view over recess **95** and pilot holes **95a**. Caps **500a** and **500b** each include at least one cap hole **501a** aligned with at least one pilot hole **95a** in each of proximate bone elements **80** and **90**. Center hole **501** is in the center of cap **500a** and at the center of the junction of the legs of cap **500b**. Center hole **501** allows the use of K-wire **30** to guide the placement of cap **500a** or **500b** into recess **95** to be threaded into implant **150**. Persons of skill in the art will recognize that caps having different shapes may also be effectively used. Also seen is implant **150** inserted into hole **85**.

FIG. **15h** shows cap **500a** screwed in place in recess **95**, while FIG. **15j** depicts cap **500b** screwed in place in recess **95**. It can be seen that by threading screws **504** through cap holes **501a** into pilot holes **95a**, proximate bone elements **80** and **90** are kept in a fixed position relative to each other allowing proximate bone elements **80** and **90** to fuse to each other through implant **85**.

Thus, it is seen that the objects of the present invention are efficiently obtained, although modifications and changes to the invention should be readily apparent to those having ordi-

nary skill in the art, which modifications are intended to be within the spirit and scope of the invention as claimed. It also is understood that the foregoing description is illustrative of the present invention and should not be considered as limiting. Therefore, other embodiments of the present invention are possible without departing from the spirit and scope of the present invention.

I claim:

1. A device for fixing the positions of proximate bone elements comprising:

an interbone implant adapted to be implanted between suitably prepared proximate bone elements and including an internally threaded bore;

a bone fixation apparatus comprising at least one hole wherein said bone fixation apparatus includes a cap sized to fit in a single recess common to each of said proximate bone elements, said cap having a plurality of cap holes extending through said cap and a threaded stem sized to threadably attach to said internally threaded bore to form a second threadable attachment; at least one screw inserted through said at least one hole and threadably attached to at least one of said proximate bone elements to form a first threadable attachment; and, wherein each of said proximate bone elements includes at least one pilot hole.

2. The device for fixing the positions of proximate bone elements as recited in claim 1 wherein said cap is a circular cap.

3. The device for fixing the positions of proximate bone elements as recited in claim 1 wherein said cap is an x-shaped cap.

4. The device for fixing the positions of proximate bone elements as recited in claim 1 wherein said at least one pilot hole is a plurality of pilot holes, and wherein at least one of said plurality of pilot holes is drilled into each of said bone elements, and wherein said first threadable attachment comprises each of said at least one screw threaded through at least one of said plurality of cap holes into one of said plurality of pilot holes.

5. The device for fixing the positions of proximate bone elements as recited in claim 1 wherein said interbone implant further comprises a body portion having an irregular outer surface.

6. The device for fixing the positions of proximate bone elements as recited in claim 1 wherein said bone fixation device further comprises a center hole.

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