US008460341B2

(12) **United States Patent**
Chin et al.

(10) **Patent No.: US 8,460,341 B2**
(45) **Date of Patent: Jun. 11, 2013**

(54) **DYNAMIC FACET REPLACEMENT SYSTEM**

(75) Inventors: **Kingsley Richard Chin**, West Palm Beach, FL (US); **Christopher A. Chang**, Beverly, MA (US); **Yani Deros**, Phoenix, AZ (US); **Matthew Ibarra**, Lakewood, CA (US); **Thomas Turner**, Nashua, NH (US)

(73) Assignee: **Spinefrontier Inc**, Beverly, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1030 days.

(21) Appl. No.: **12/146,623**

(22) Filed: **Jun. 26, 2008**

(65) **Prior Publication Data**

US 2009/0005818 A1 Jan. 1, 2009

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/852,379, filed on Sep. 10, 2007, now abandoned.

(60) Provisional application No. 60/946,422, filed on Jun. 27, 2007.

(51) **Int. Cl.**
A61B 17/70 (2006.01)

(52) **U.S. Cl.**
USPC **606/247**; 623/17.14

(58) **Field of Classification Search**
USPC 606/60, 246–249, 256–260; 623/17.11, 623/17.14, 17.16
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,092,893	A	3/1992	Smith	
6,565,605	B2	5/2003	Goble et al.	
6,579,319	B2	6/2003	Goble et al.	
7,087,084	B2	8/2006	Reiley	
7,147,664	B2	12/2006	Louis et al.	
7,351,261	B2	4/2008	Casey	
7,377,942	B2	5/2008	Berry	
2004/0186475	A1	9/2004	Falahee	
2005/0055096	A1	3/2005	Serham et al.	
2005/0080486	A1	4/2005	Fallin et al.	
2005/0119748	A1*	6/2005	Reiley et al.	623/17.11
2005/0131409	A1	6/2005	Chervitz et al.	
2005/0131537	A1	6/2005	Hoy et al.	
2005/0131538	A1	6/2005	Chervitz et al.	
2005/0131545	A1	6/2005	Chervitz et al.	
2005/0234551	A1	10/2005	Fallin et al.	
2005/0261770	A1*	11/2005	Kuiper et al.	623/17.11

(Continued)

FOREIGN PATENT DOCUMENTS

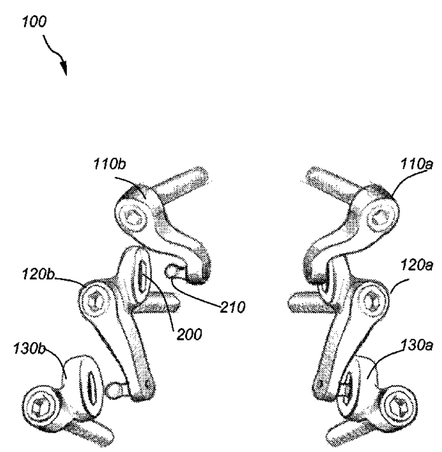
DE	10135771	A1	2/2003
WO	2007068469	A1	6/2007
WO	W02007067547	A2	6/2007

Primary Examiner — Eduardo C Robert
Assistant Examiner — Lynnsy Schneider
(74) *Attorney, Agent, or Firm* — AKC Patents LLC; Aliki K. Collins

(57) **ABSTRACT**

A system for a dynamic facet replacement includes first and second inferior facets, first and second pars and first and second superior facets. The first and second inferior facets are configured to replace left and right natural inferior facets and each facet comprises an articulating surface. The first and second superior facets are configured to replace left and right natural superior facets and each facet comprises an articulating surface. Each of the first and second pars includes first and second articulating surfaces and is configured to articulately connect the first and second articulating surfaces with the first articulating surfaces of the inferior and superior facets, respectively.

16 Claims, 31 Drawing Sheets



U.S. PATENT DOCUMENTS

2005/0267579 A1 12/2005 Reiley et al.
2006/0004449 A1 1/2006 Goble et al.
2006/0004451 A1 1/2006 Goble et al.
2006/0084987 A1* 4/2006 Kim 606/61
2006/0189983 A1 8/2006 Fallin et al.
2006/0189984 A1 8/2006 Fallin et al.
2006/0217718 A1* 9/2006 Chervitz et al. 606/61
2006/0229609 A1* 10/2006 Wang 606/61
2006/0265069 A1 11/2006 Goble et al.
2006/0271046 A1* 11/2006 Kwak et al. 606/61
2007/0168035 A1 7/2007 Koske
2007/0198014 A1* 8/2007 Graf et al. 606/61
2007/0233096 A1 10/2007 Garcia-Bengochea
2007/0233256 A1* 10/2007 Ohrt et al. 623/17.11
2007/0239159 A1 10/2007 Altarac et al.
2008/0015585 A1 1/2008 Berg et al.
2008/0103501 A1 5/2008 Ralph et al.
2008/0103600 A1 5/2008 Casey
2008/0125814 A1 5/2008 Yuan et al.

* cited by examiner

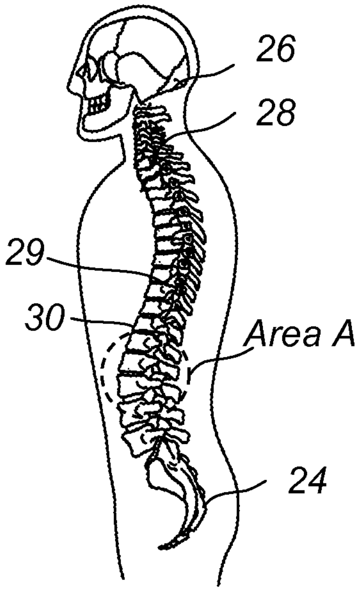


FIG. 1A

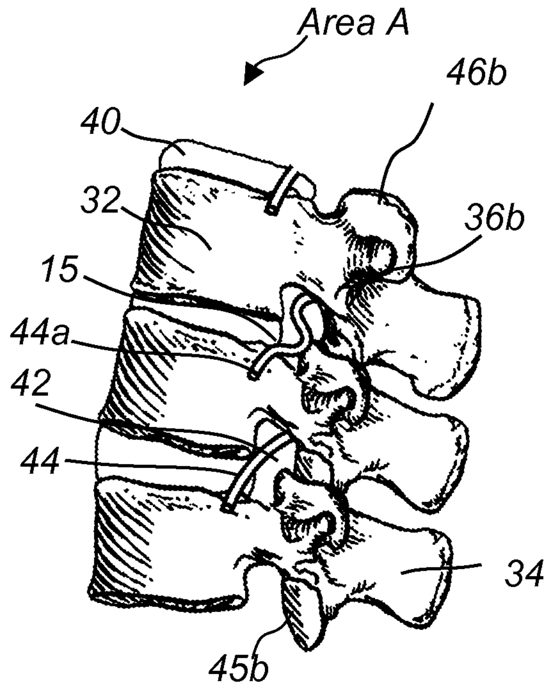


FIG. 1B

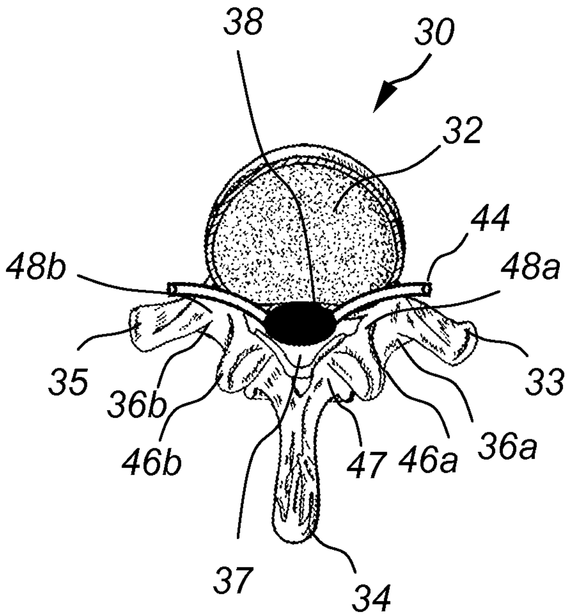


FIG. 1C

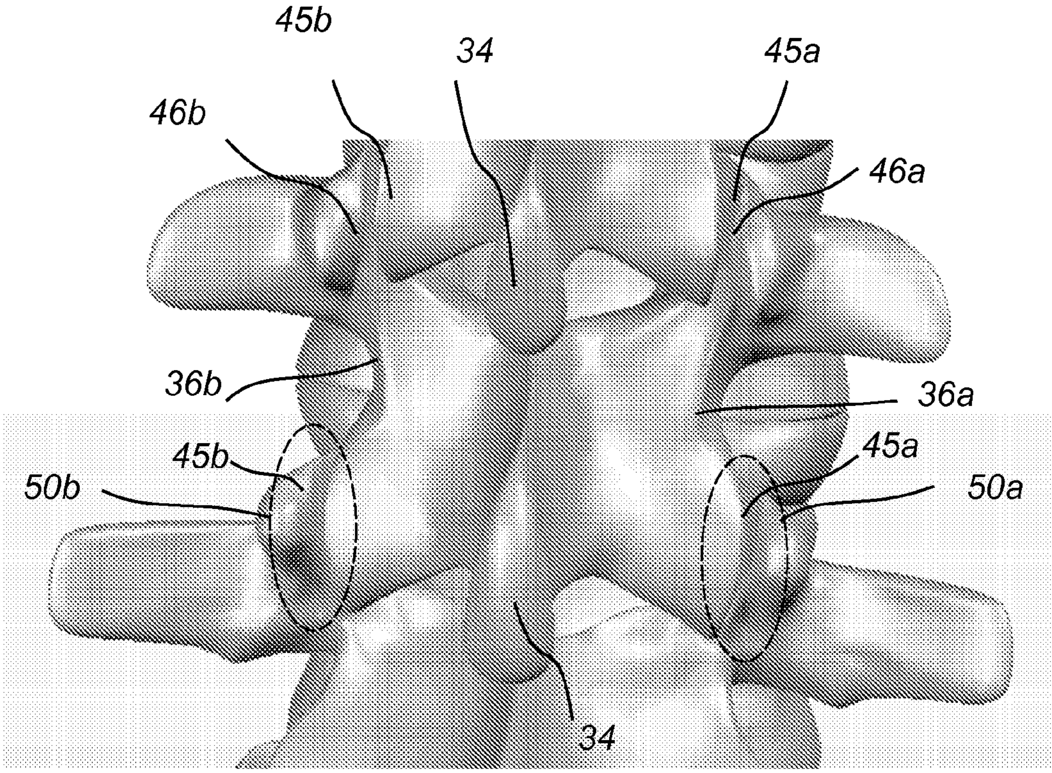

45b
34
45a
46b
46a
36b
36a
45b
45a
50b
50a
34

FIG. 2A

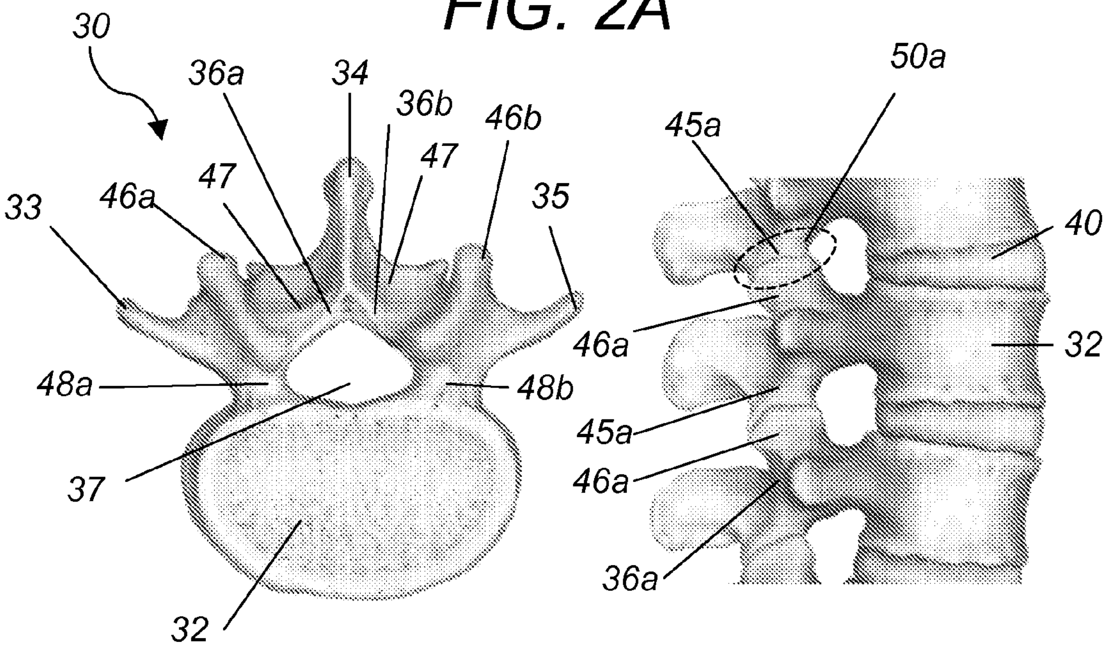

30
36a
34
36b
46b
47
47
46a
33
35
48a
48b
37
32
50a
45a
40
46a
32
45a
46a
36a

FIG. 2B

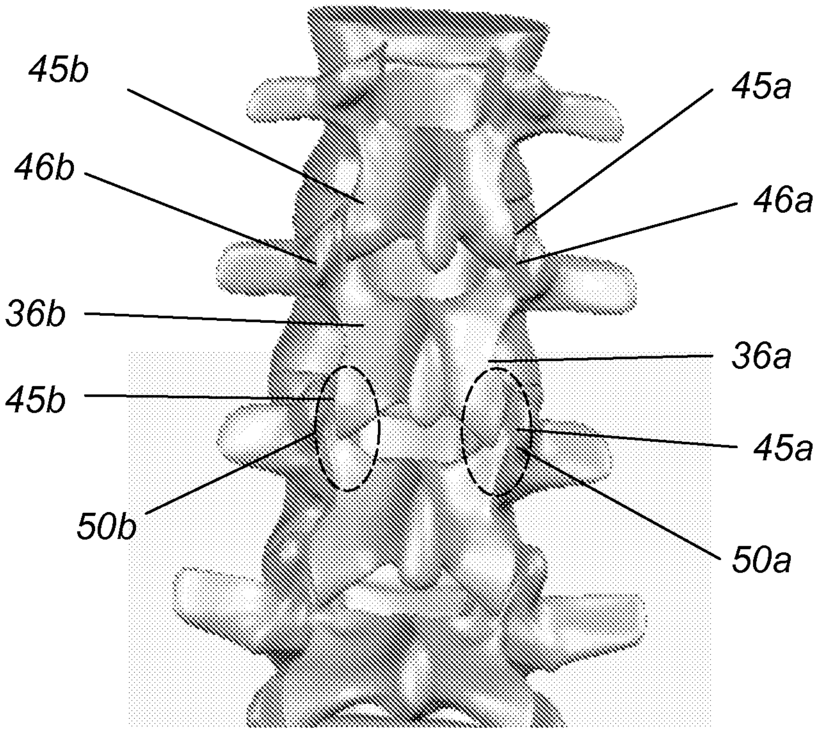


FIG. 3

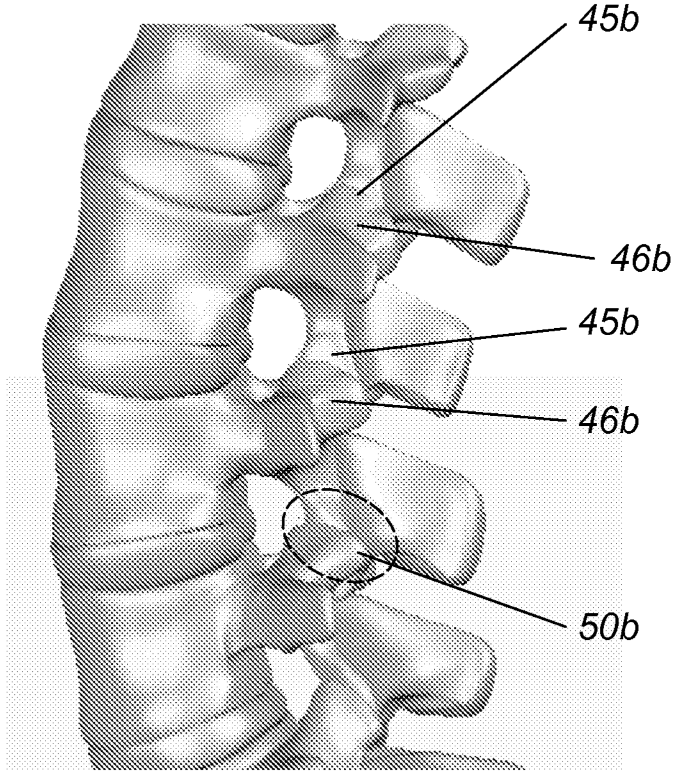


FIG. 4

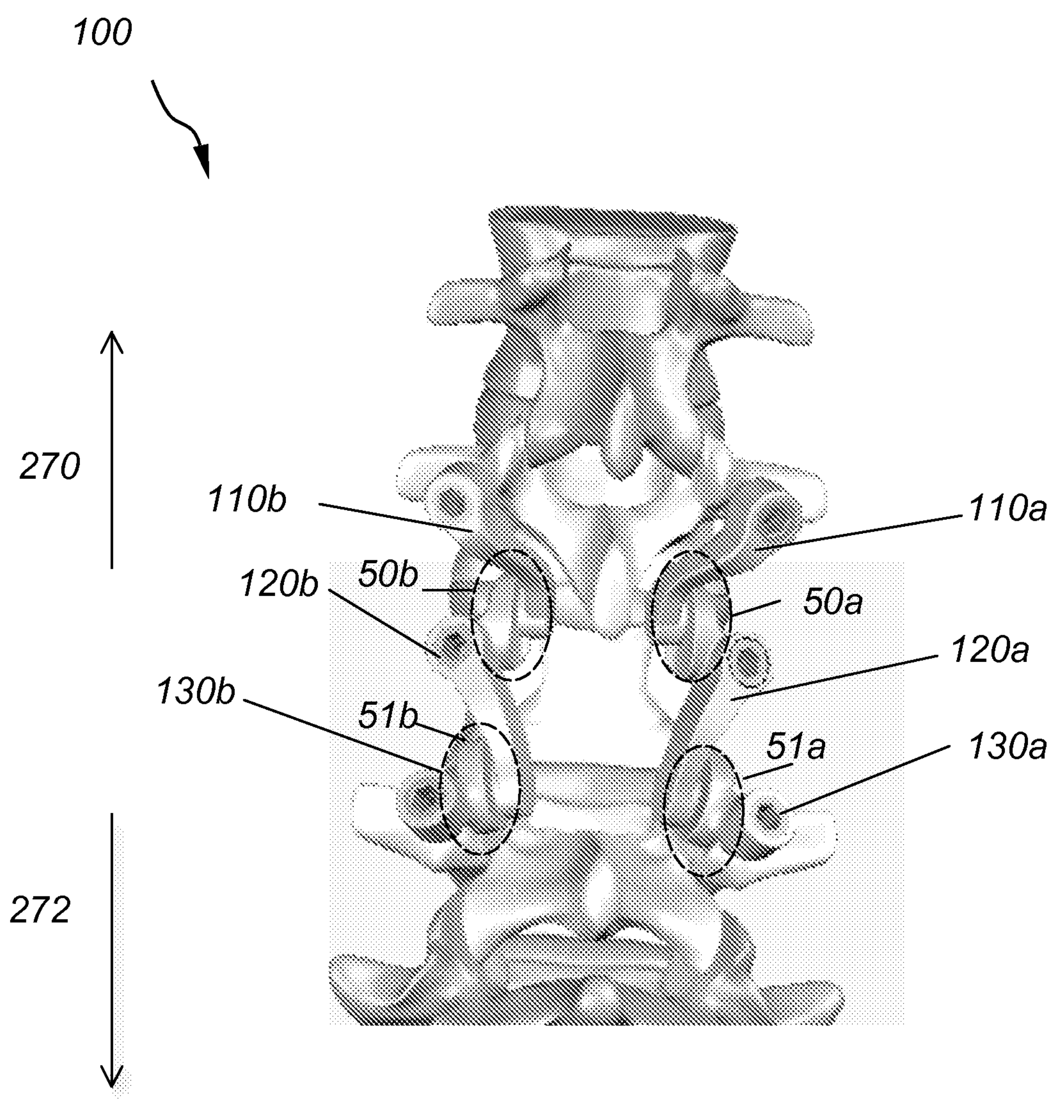


FIG. 5

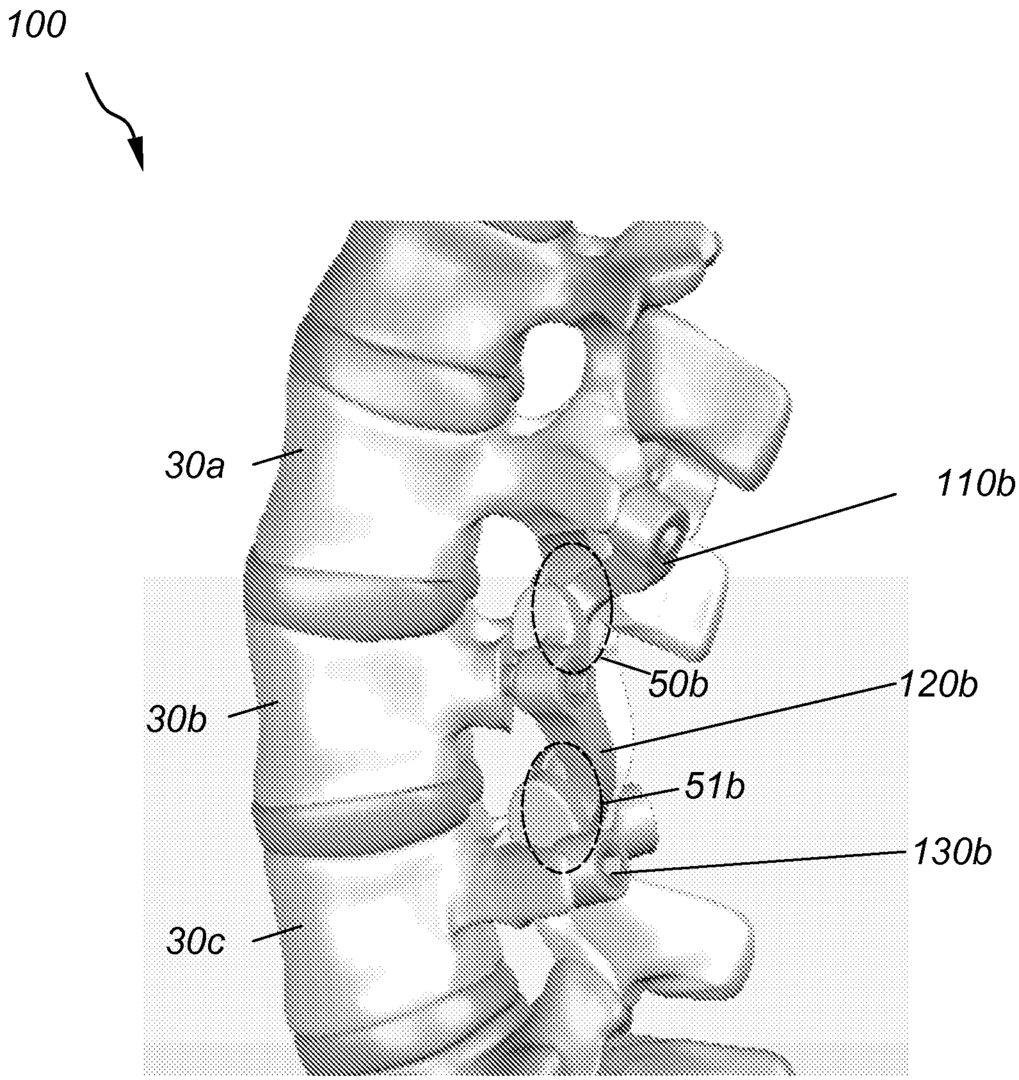


FIG. 6

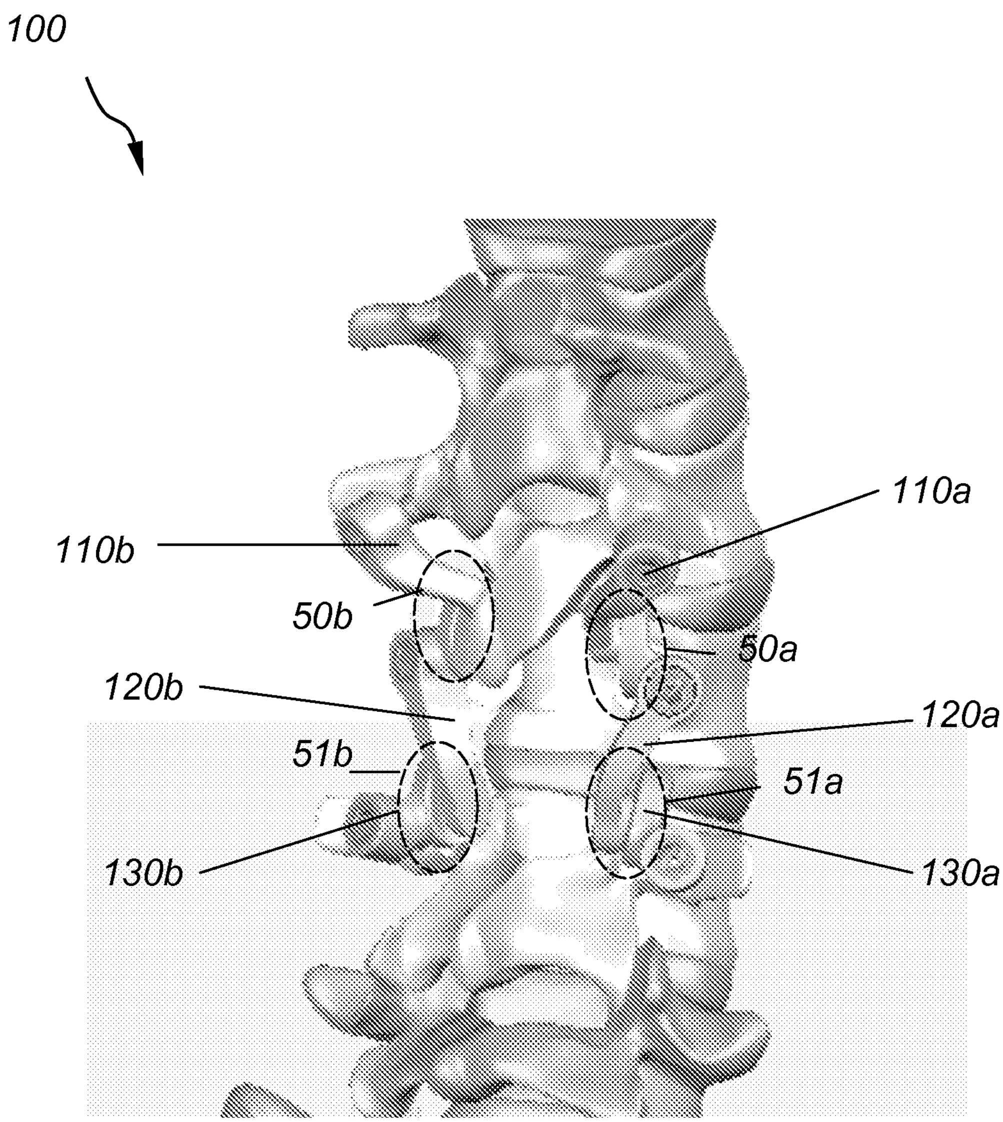


FIG. 7

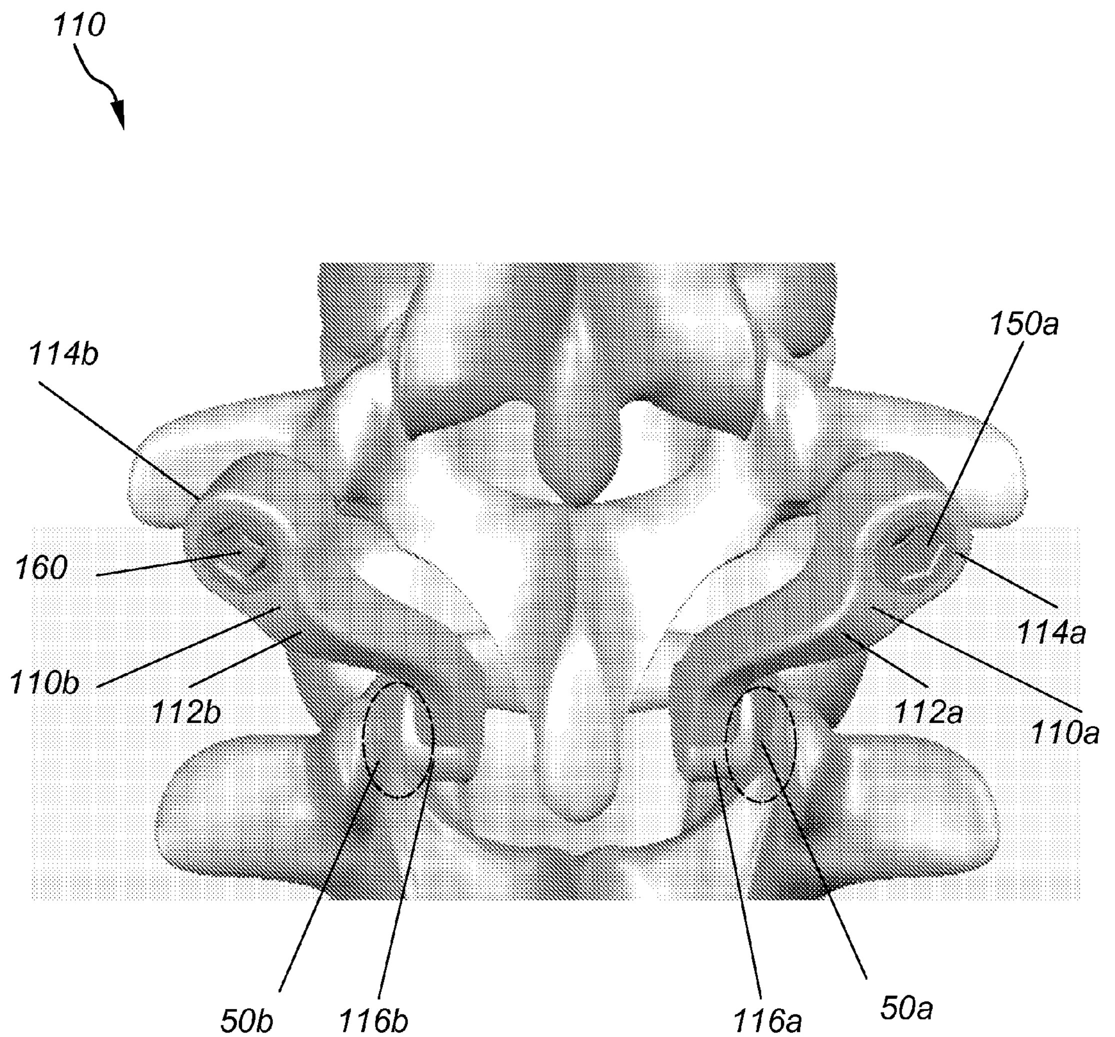


FIG. 8

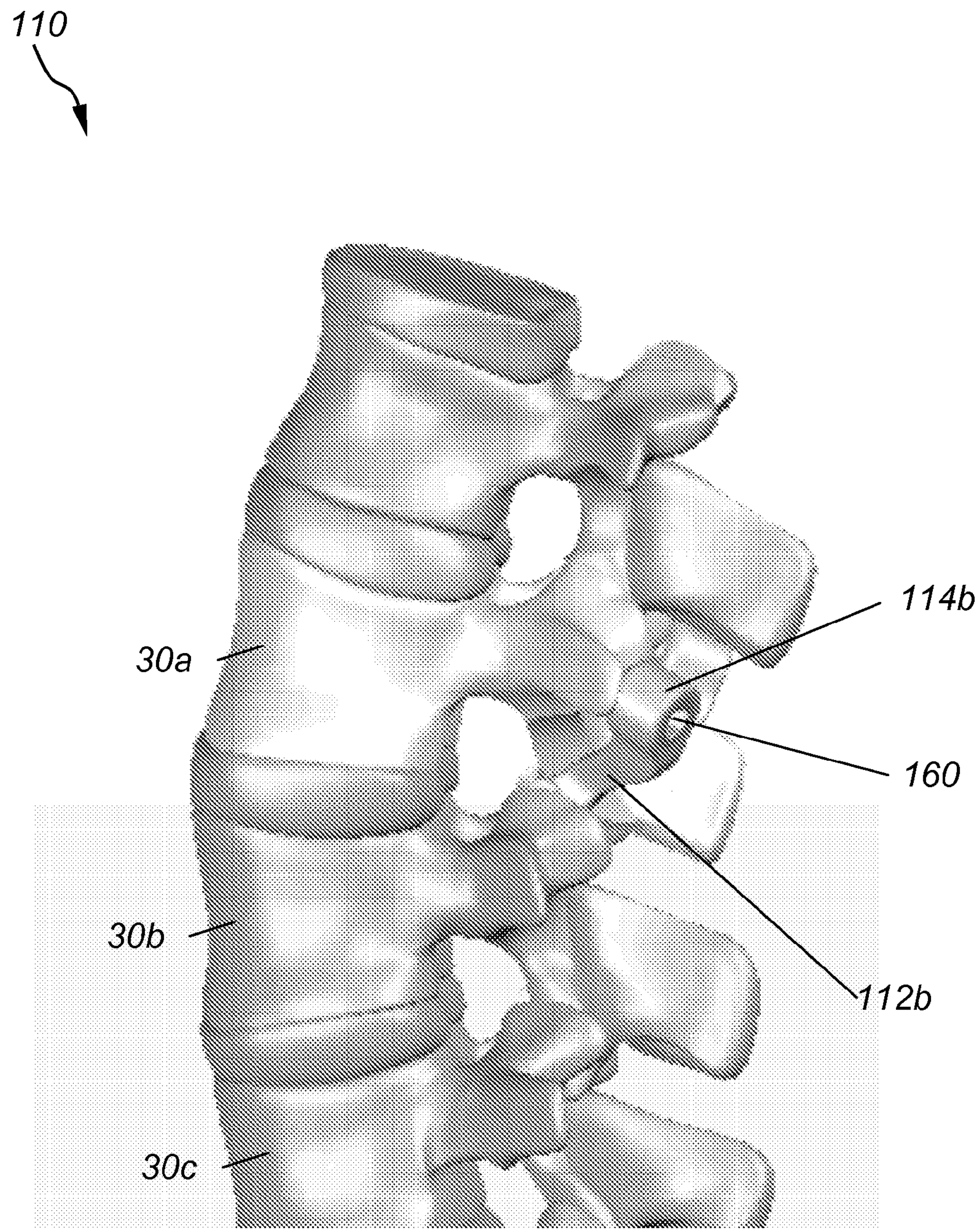


FIG. 9

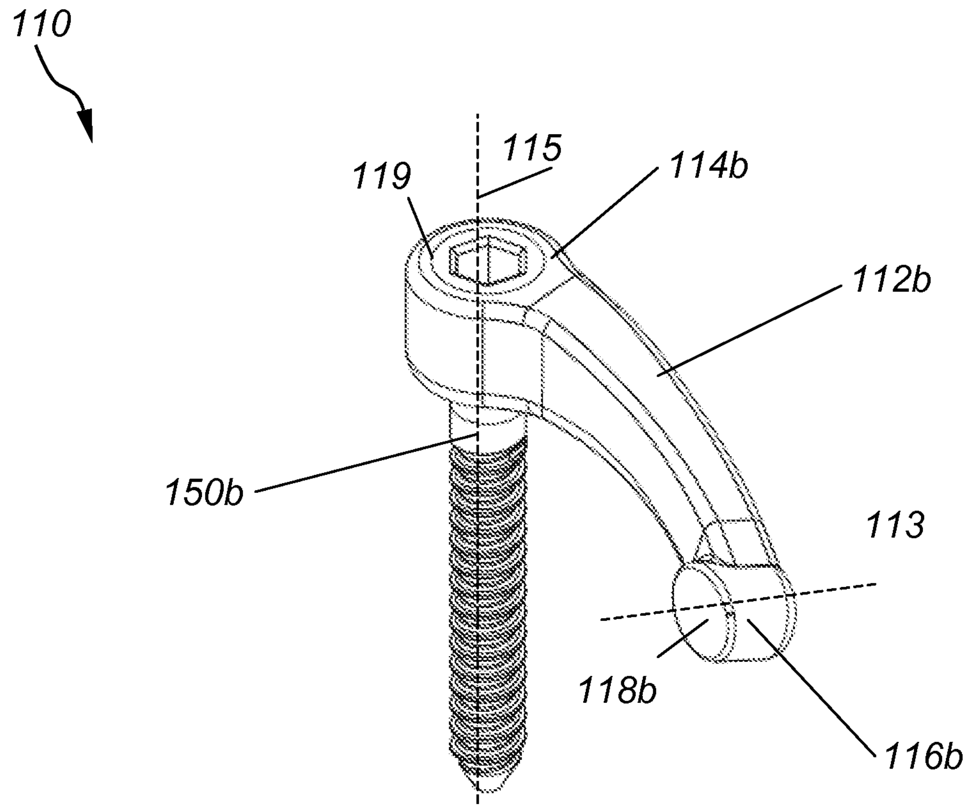


FIG. 10A

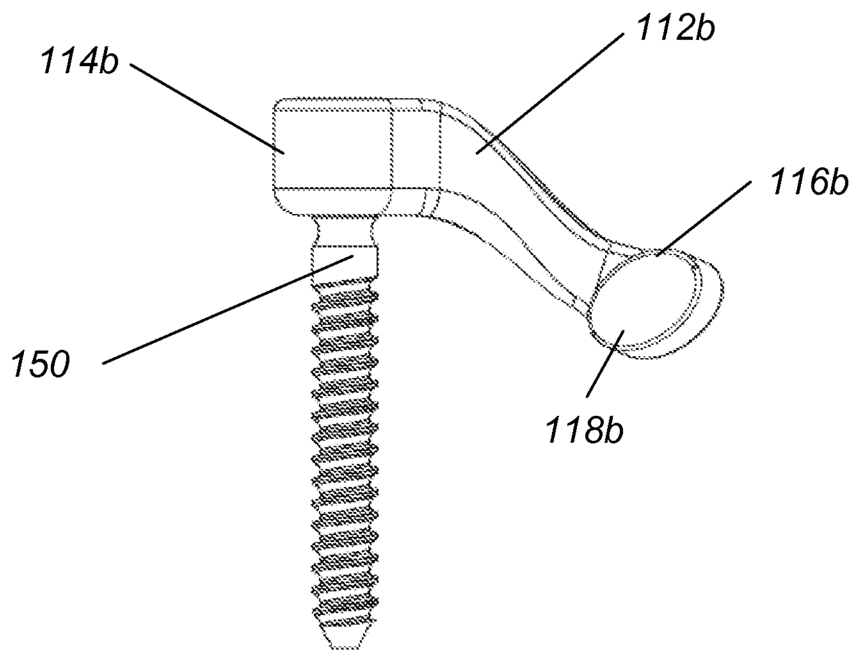


FIG. 10B

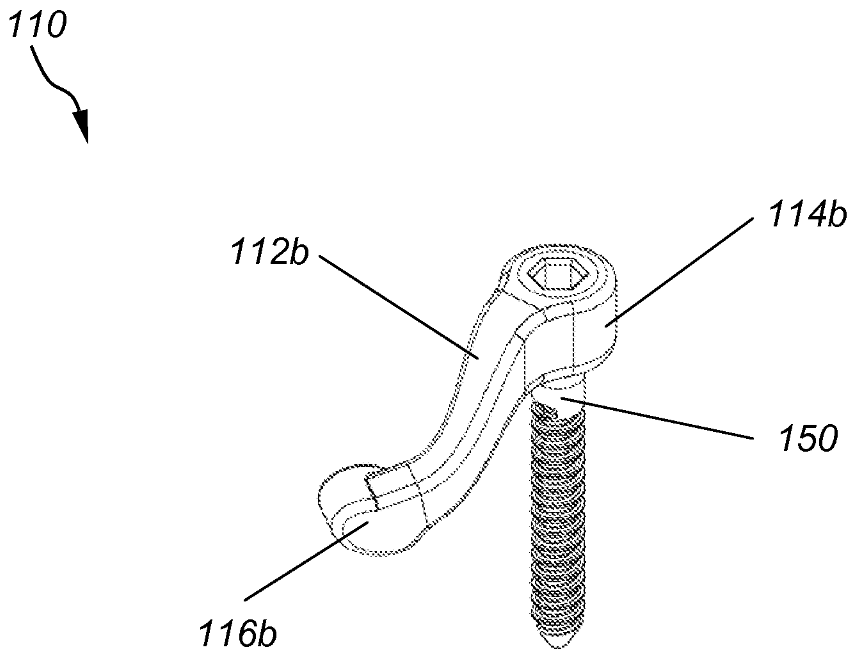


FIG. 11A

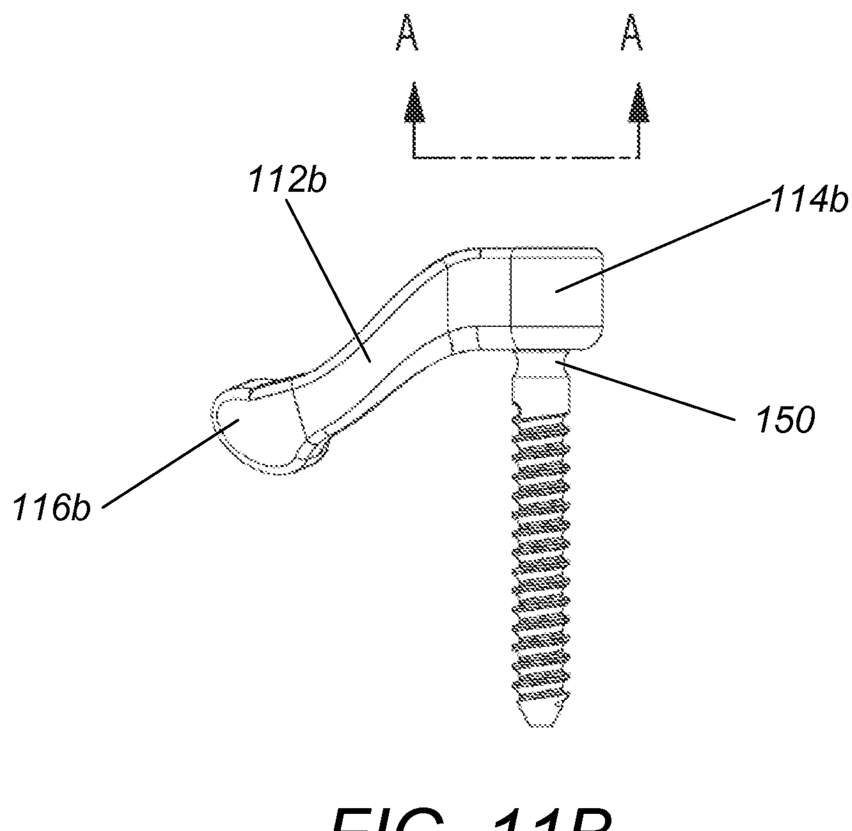


FIG. 11B

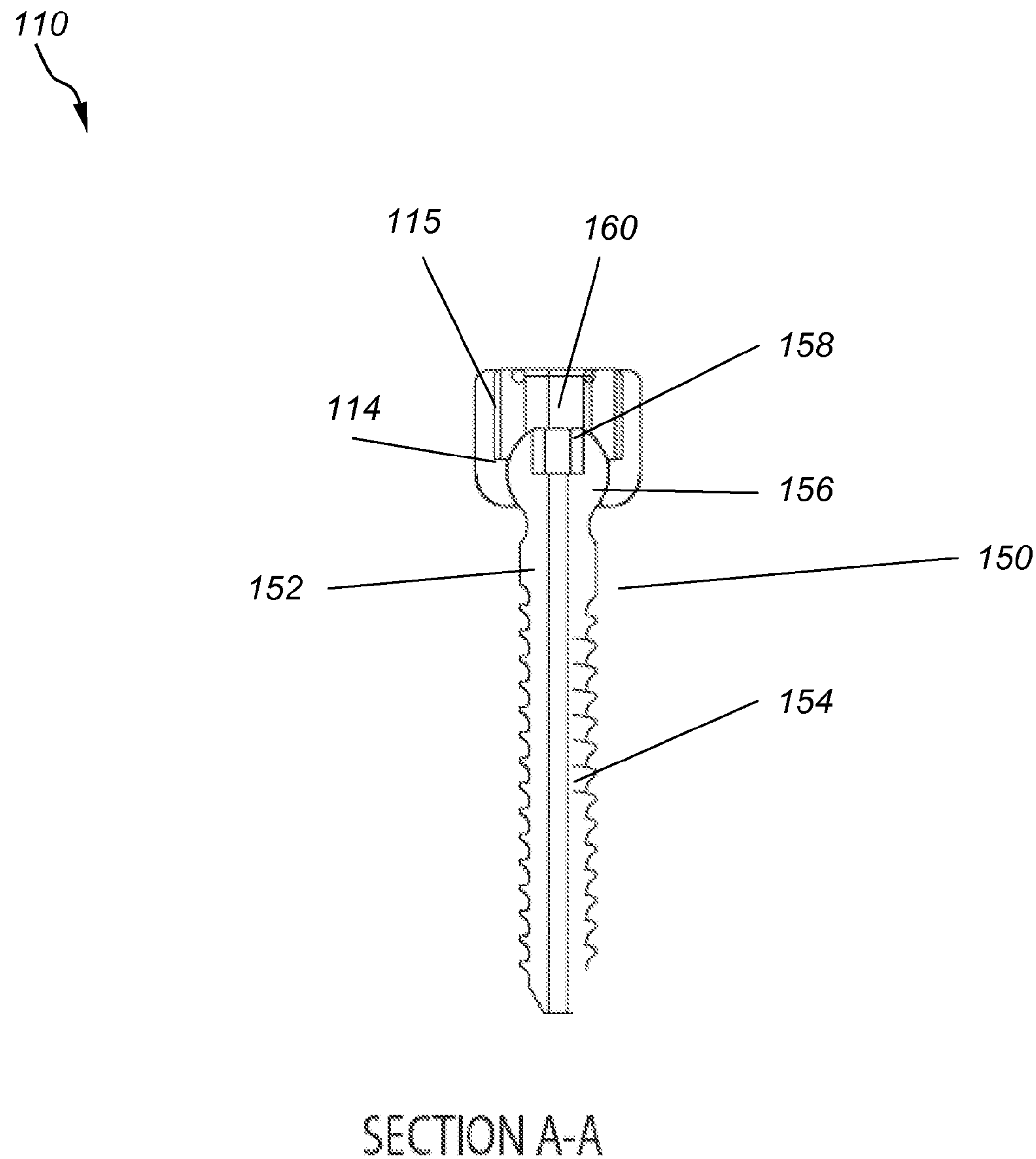


FIG. 12

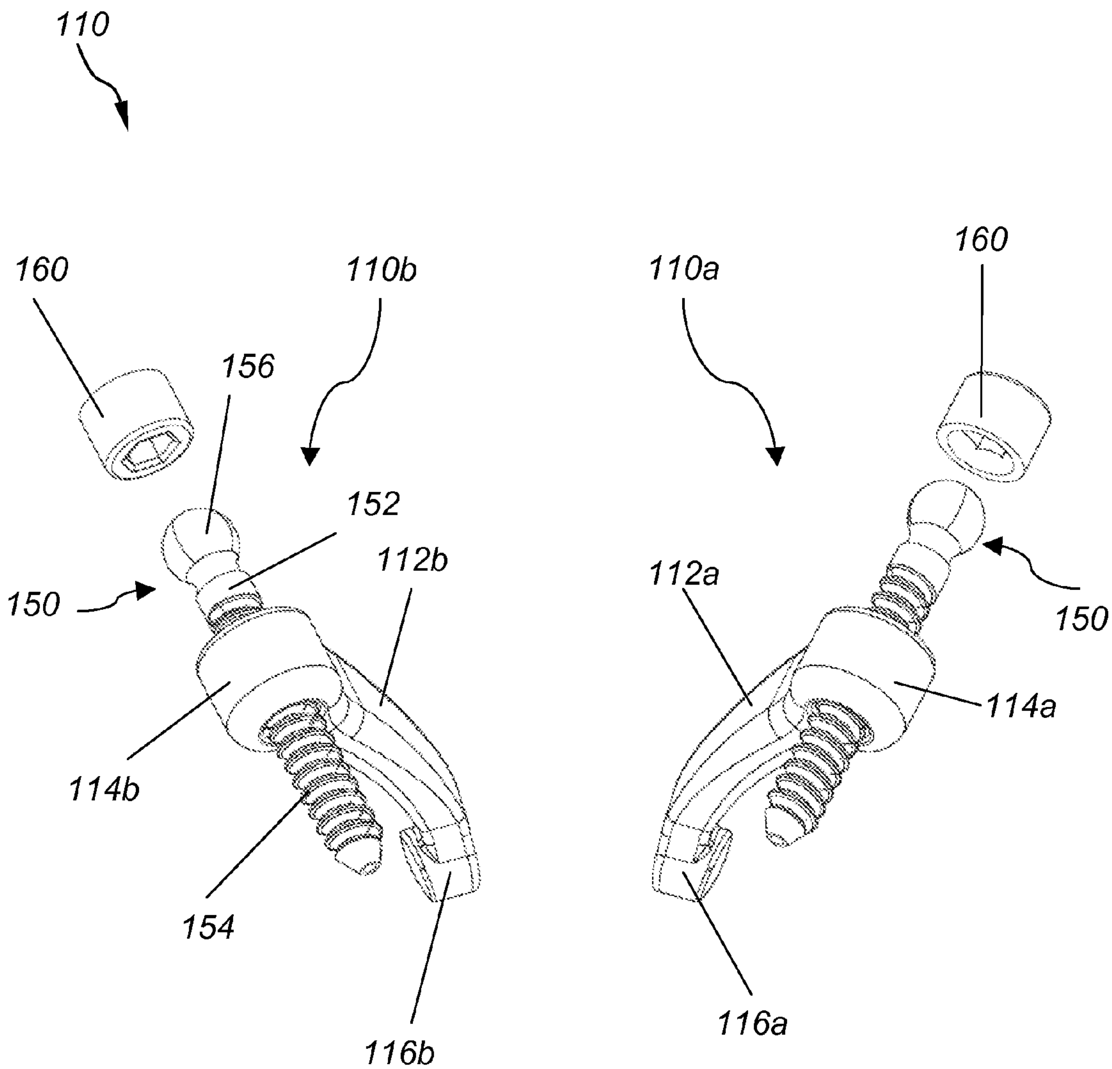

110
160
110b
110a
160
156
152
112b
112a
150
150
114b
114a
154
116b
116a

FIG. 13

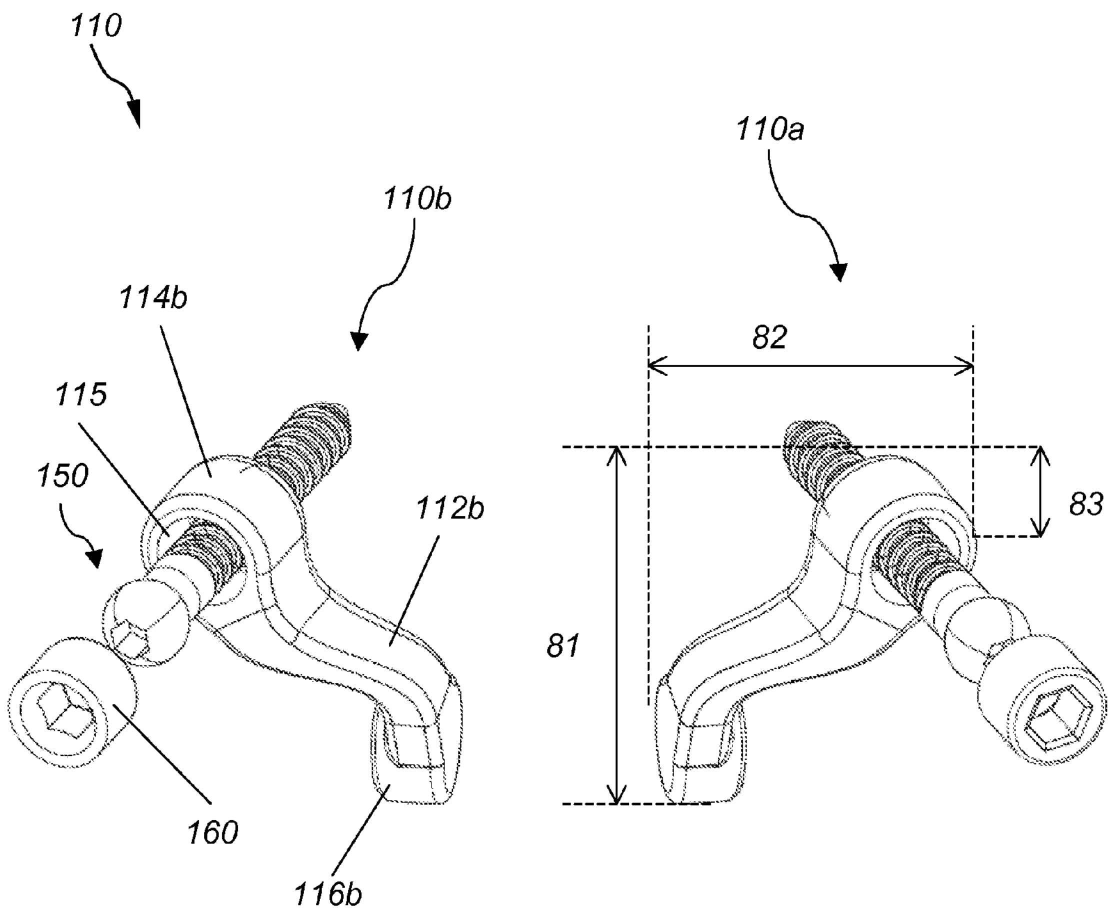


FIG. 14

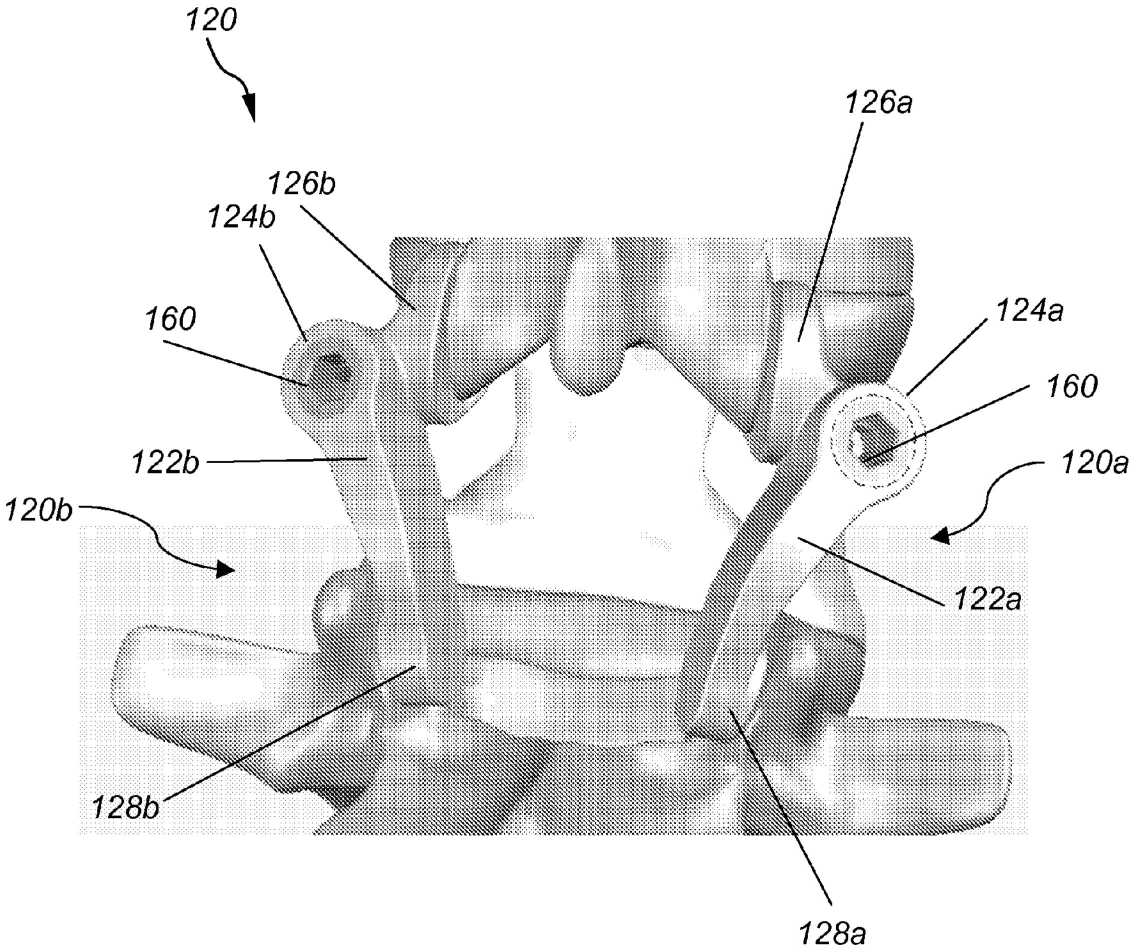


FIG. 15

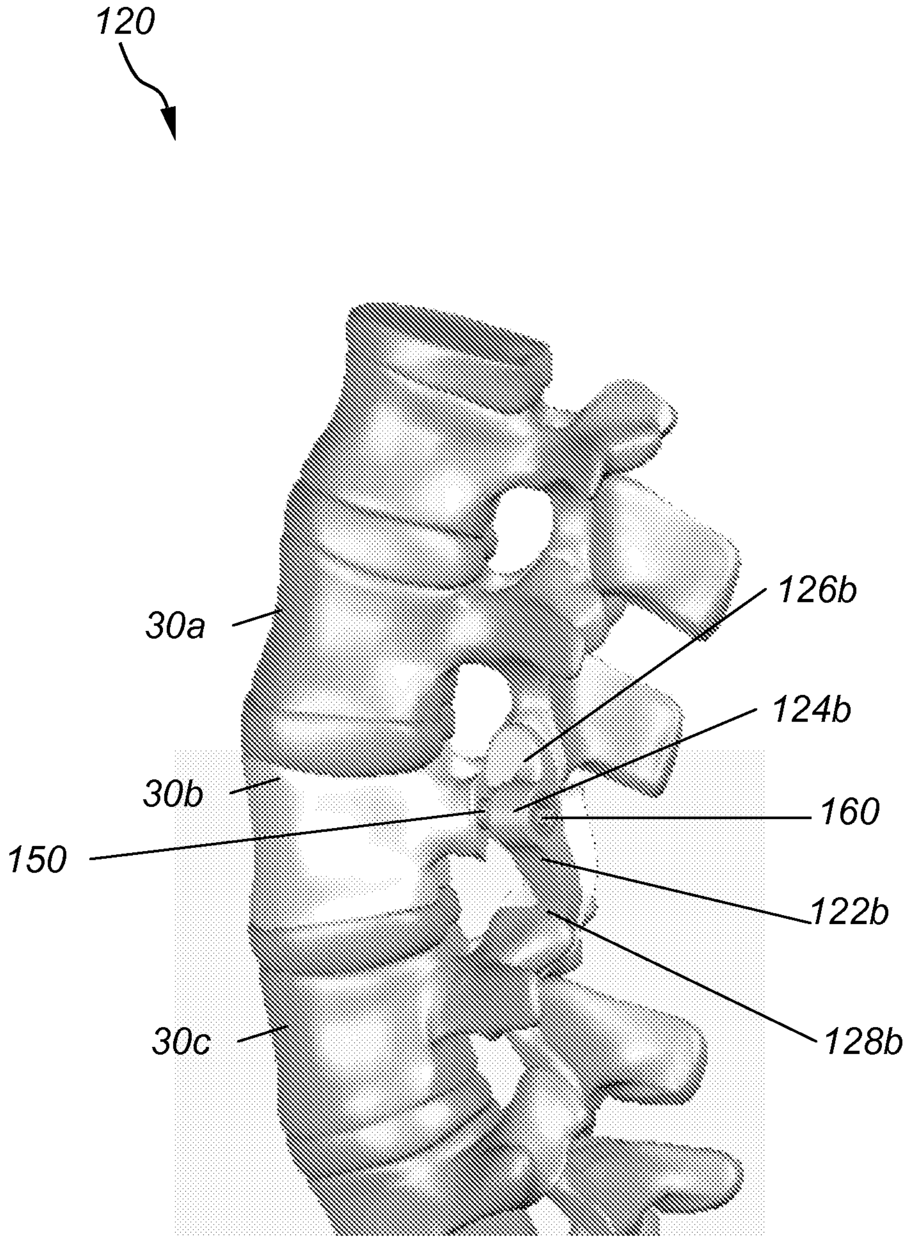


FIG. 16

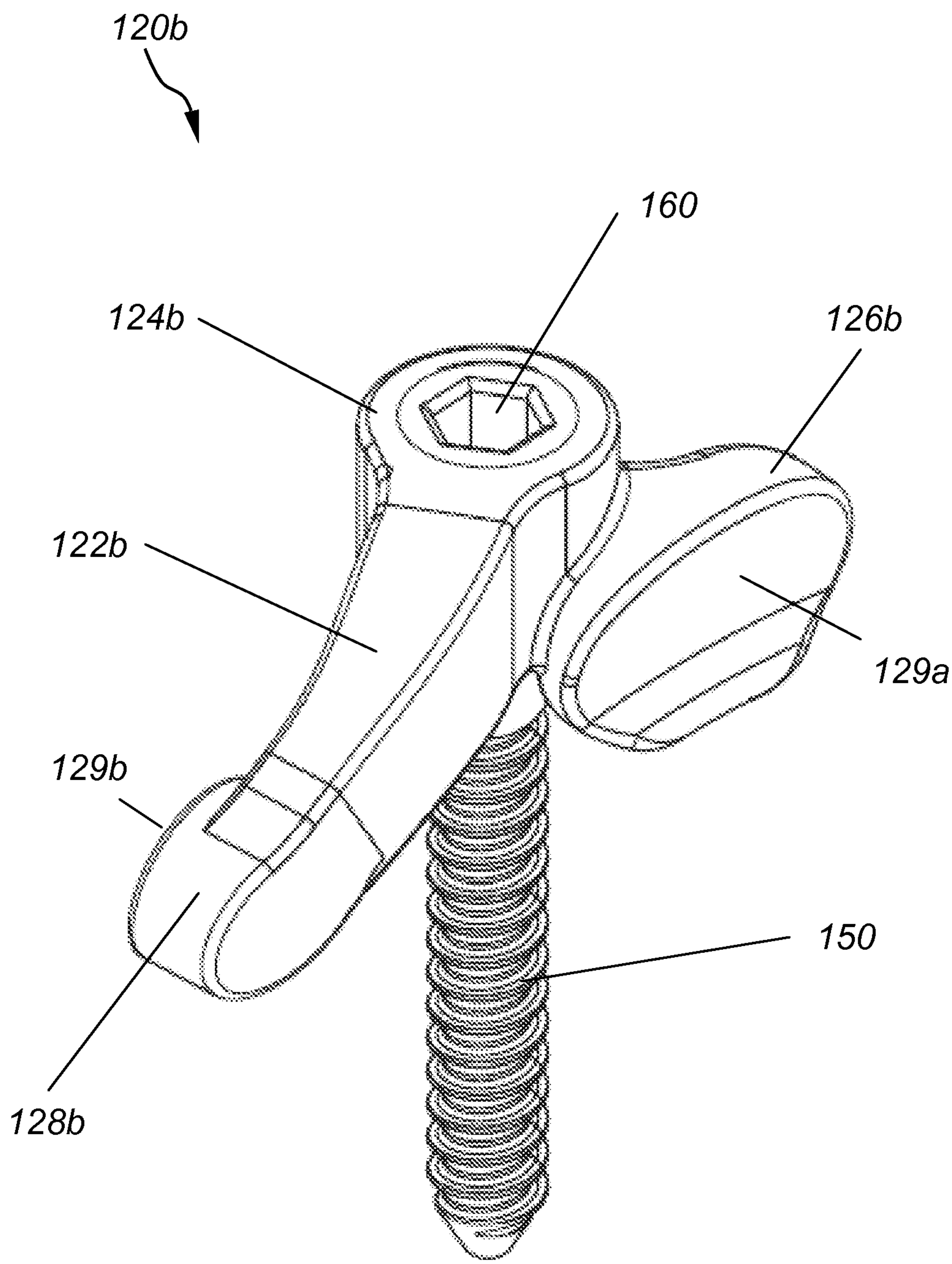


FIG. 17

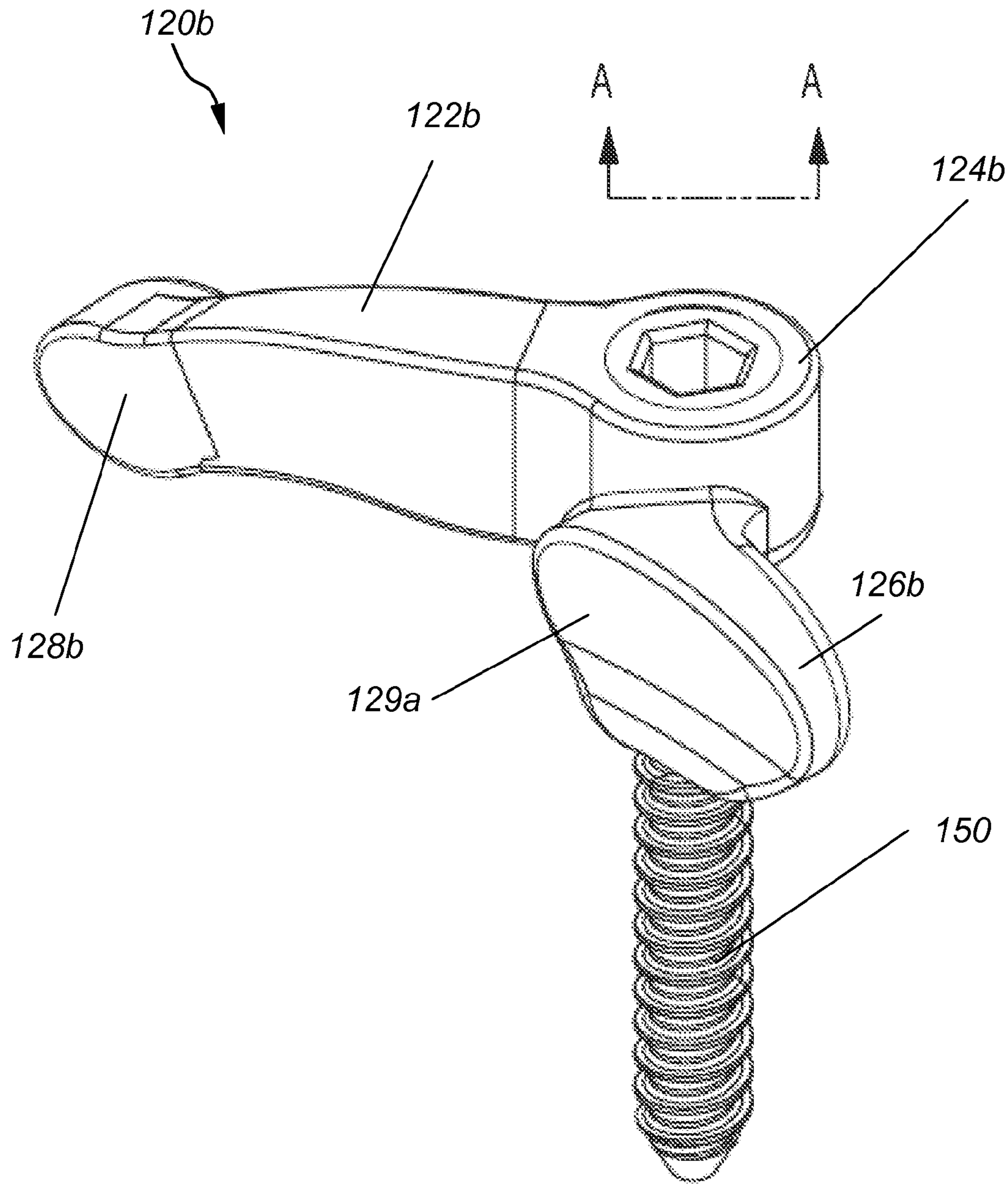
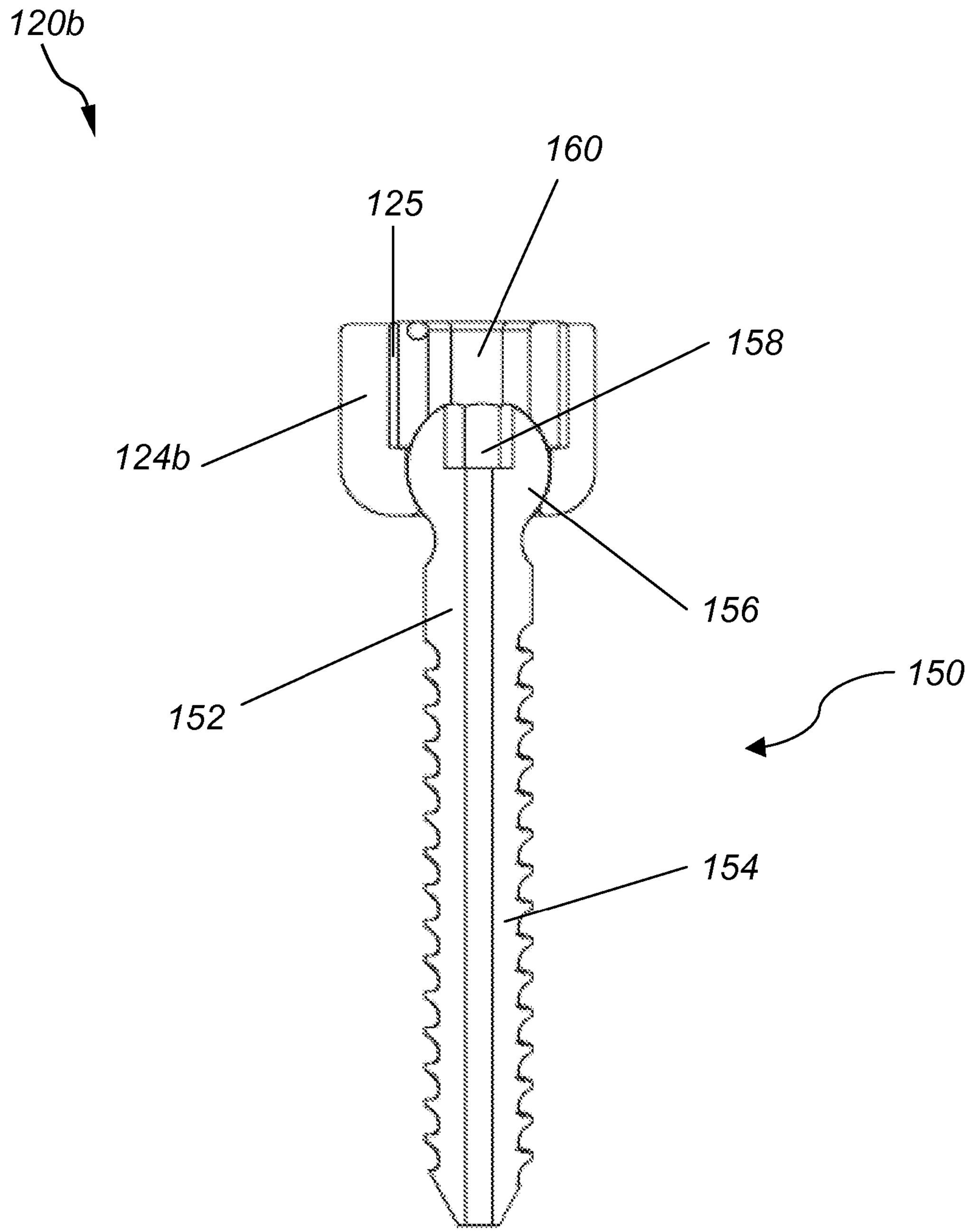


FIG. 18



SECTION A-A

FIG. 19

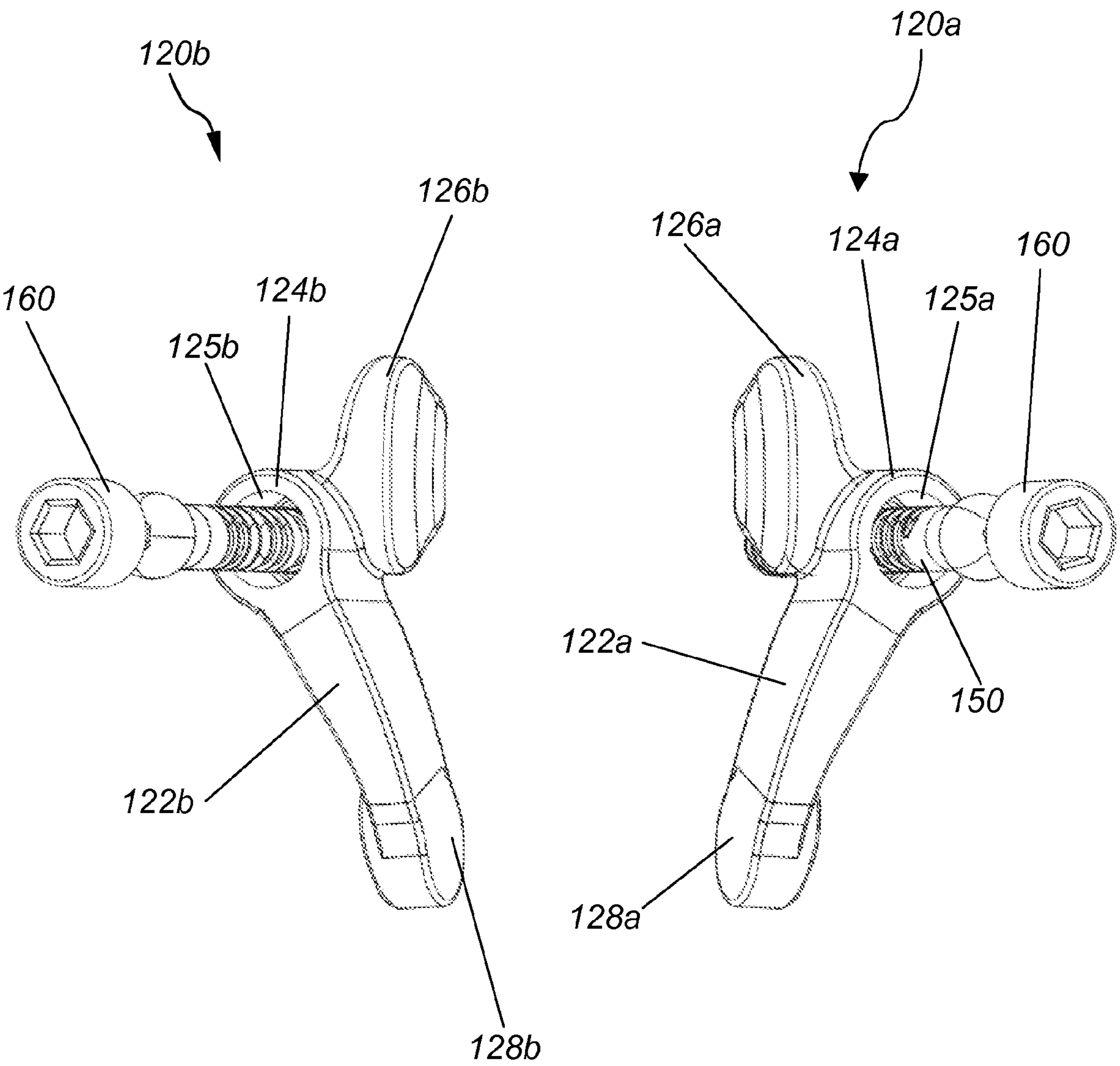

120b
120a
126b
126a
124a
160
160
124b
125a
125b
122a
150
122b
128a
128b

FIG. 20

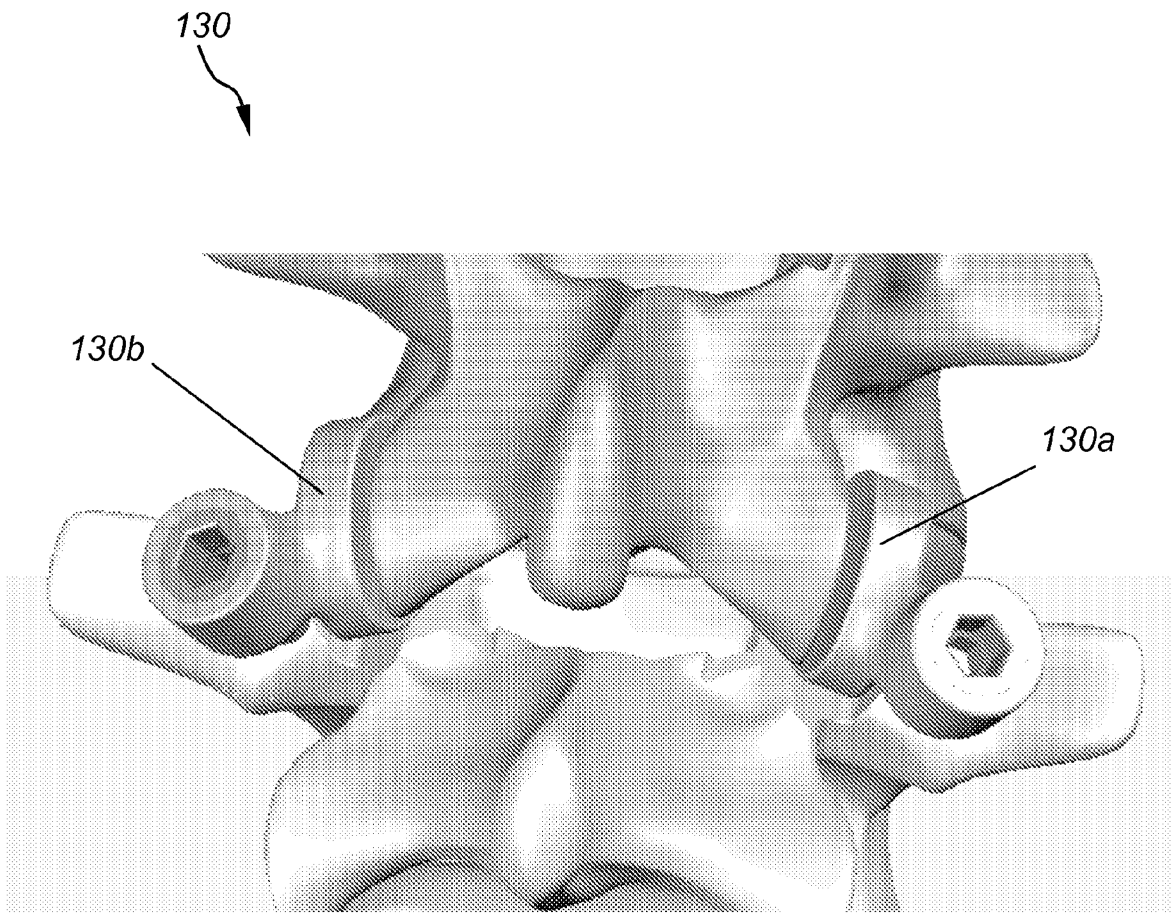


FIG. 21

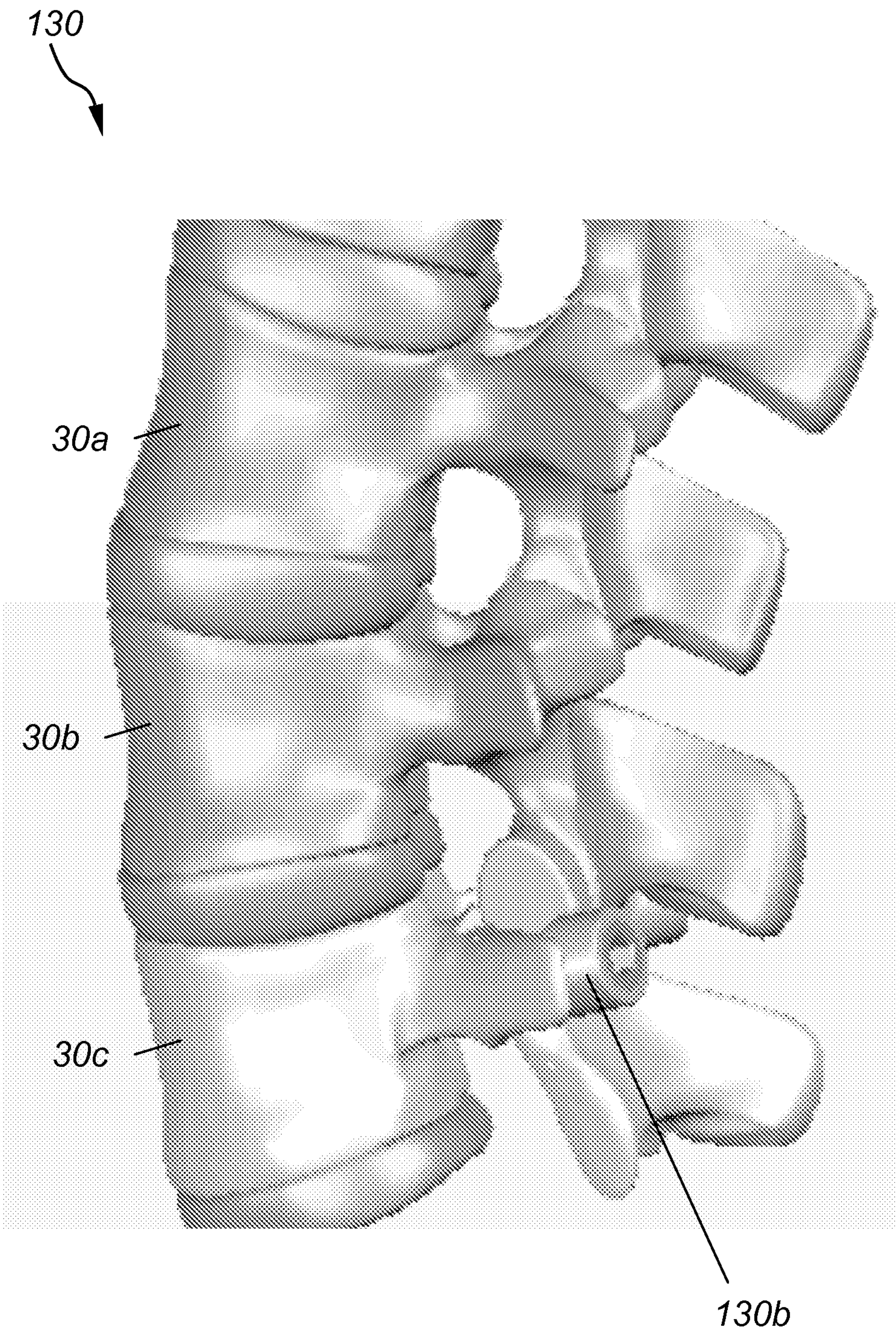


FIG. 22

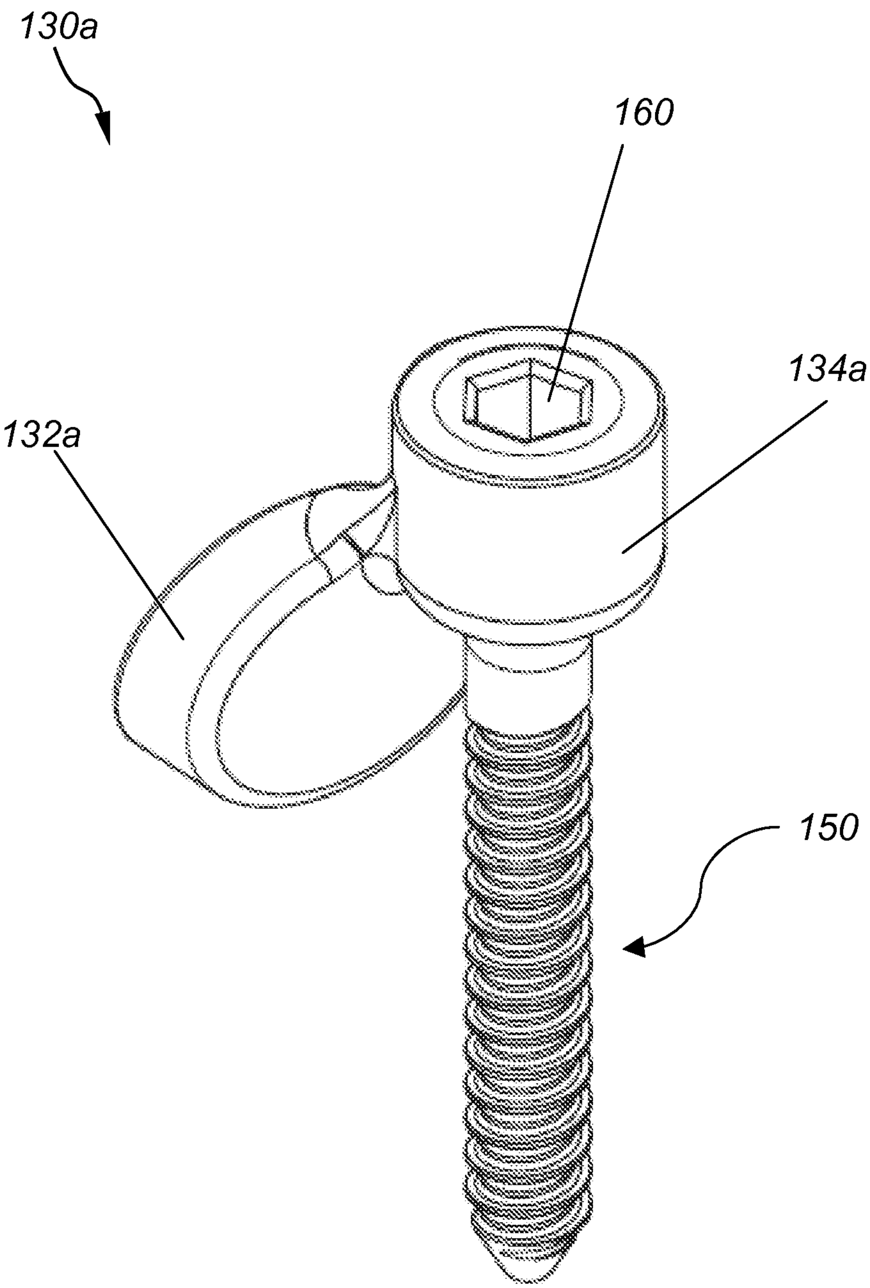


FIG. 23

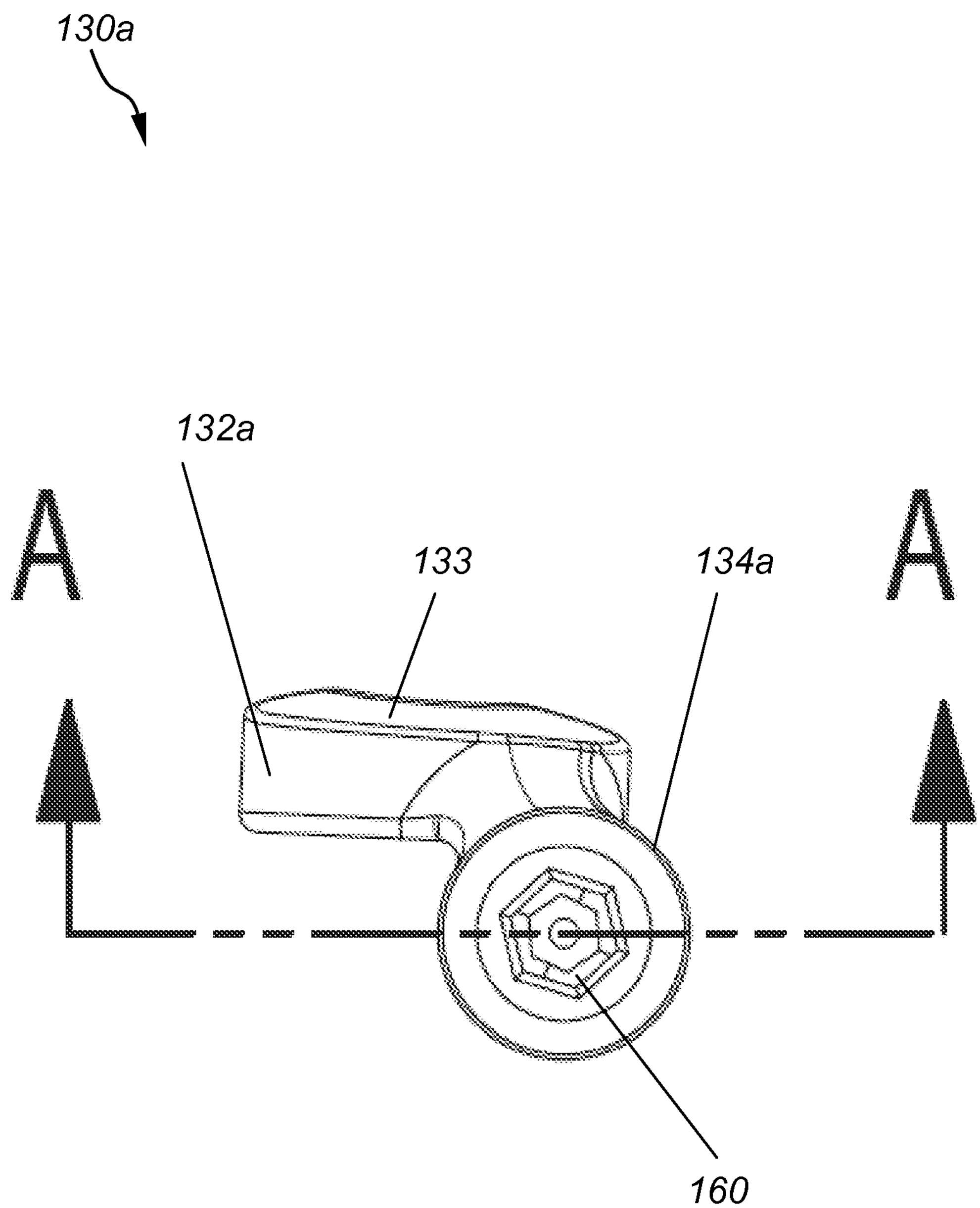


FIG. 24

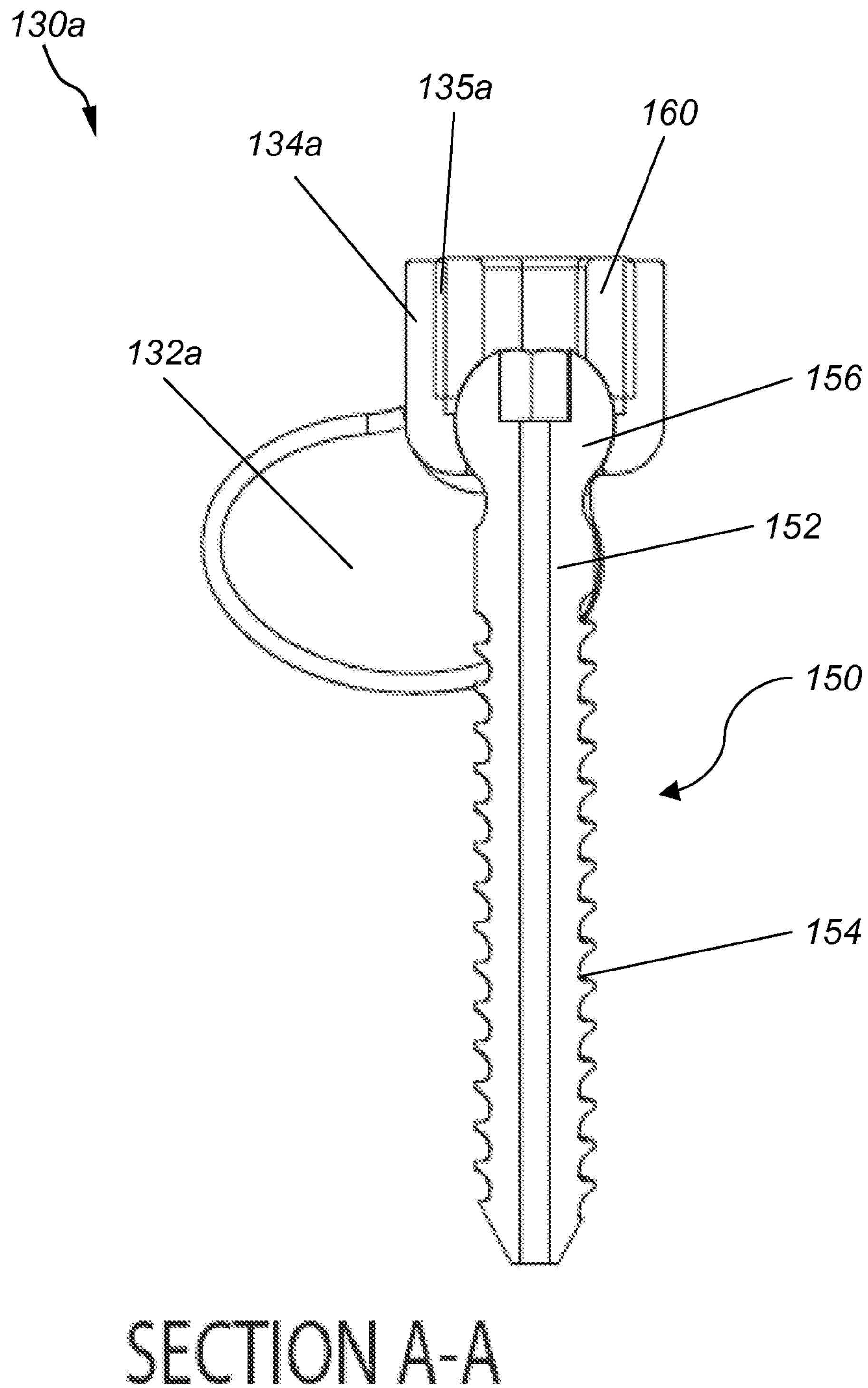


FIG. 25

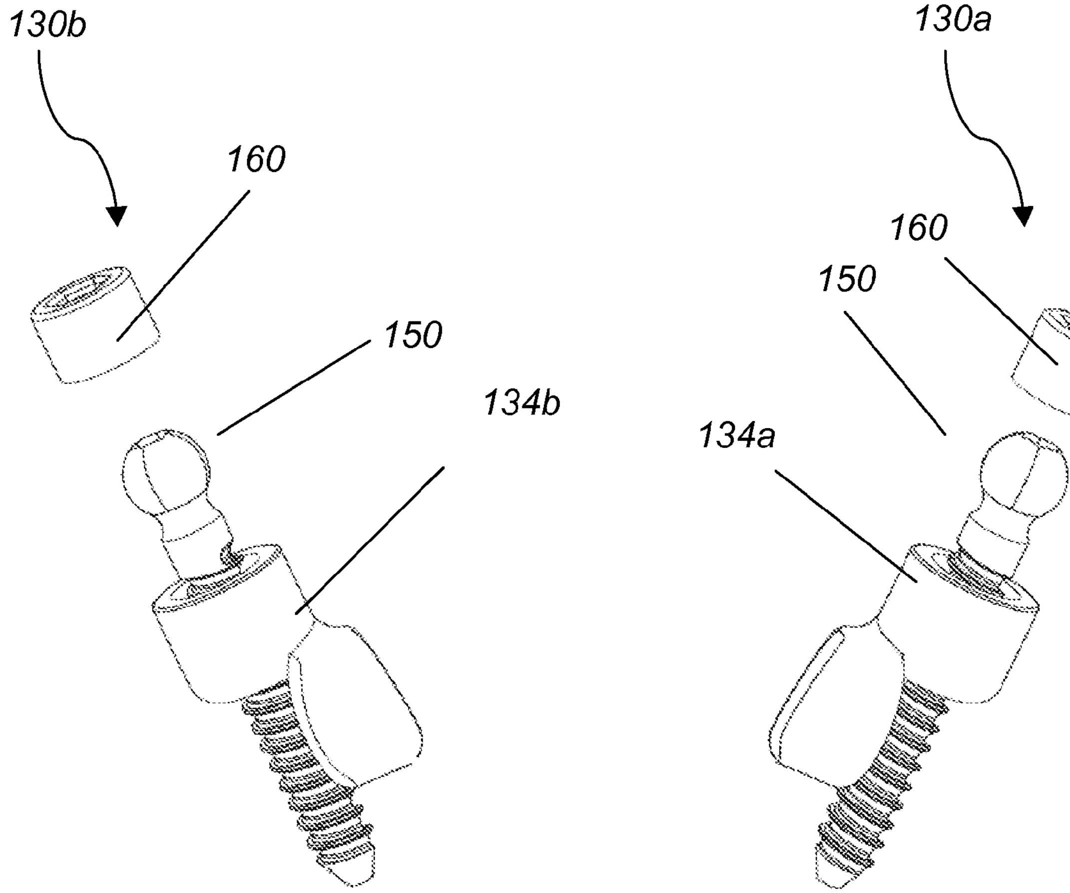


FIG. 26

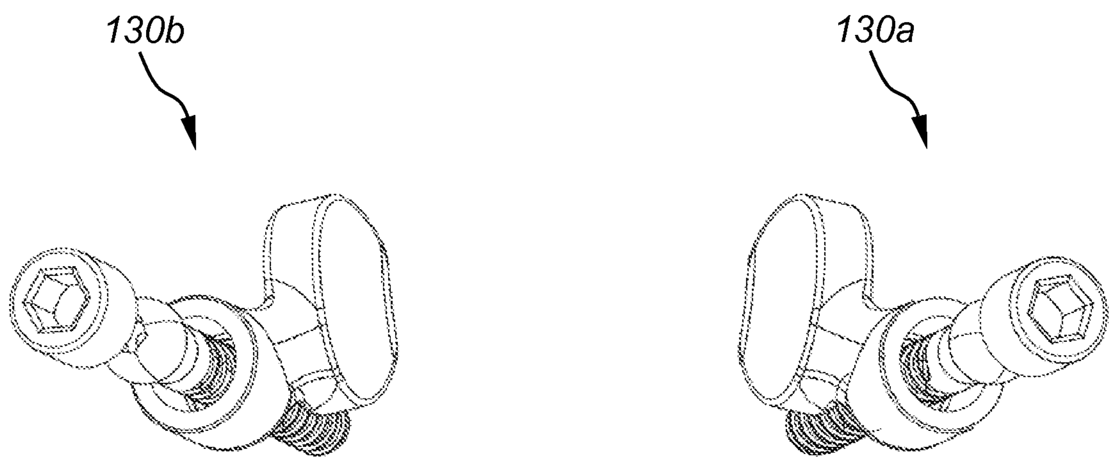


FIG. 27

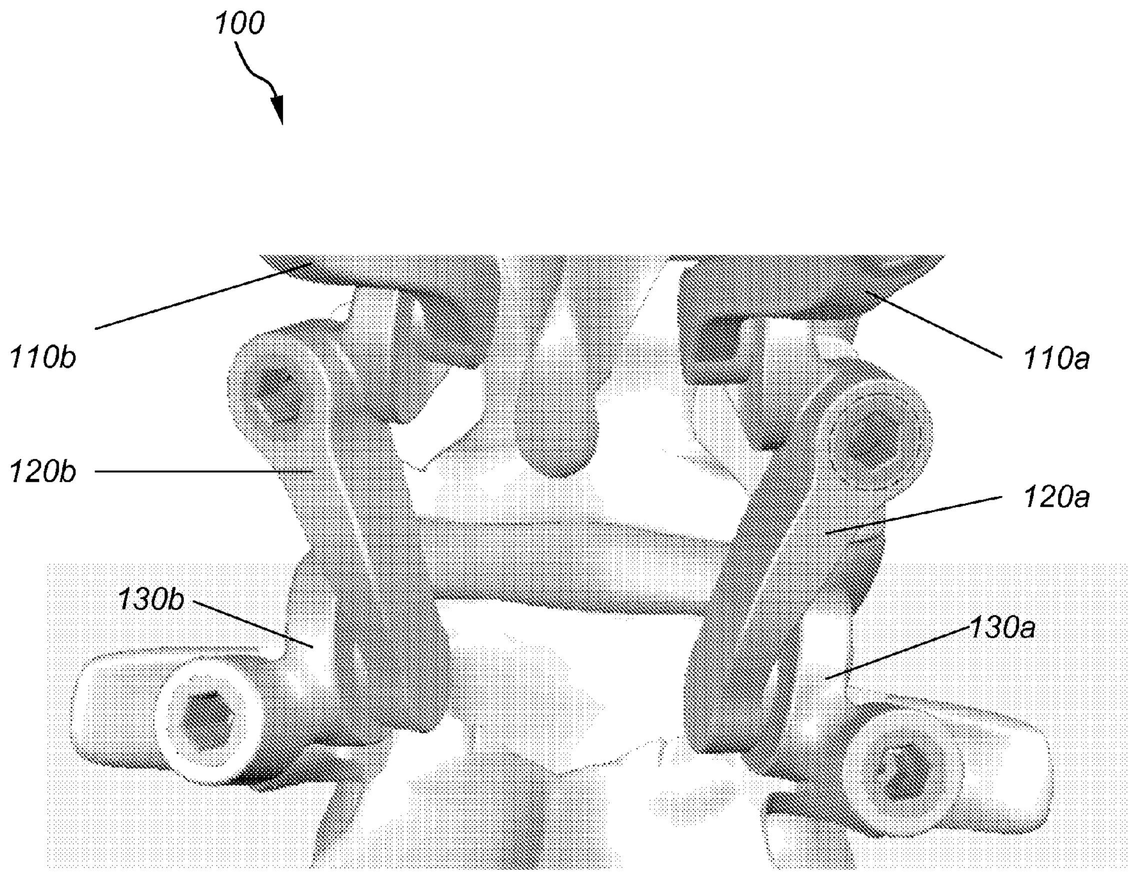


FIG. 28

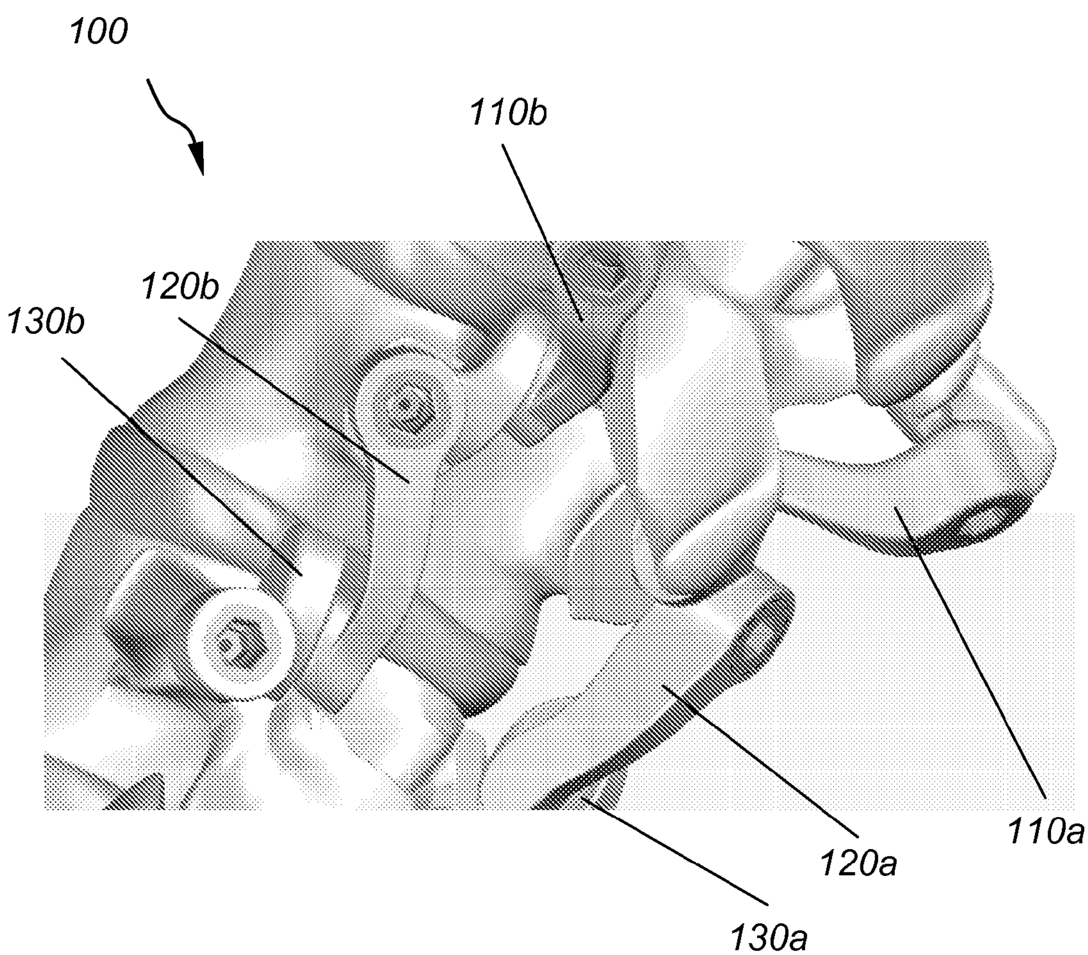


FIG. 29

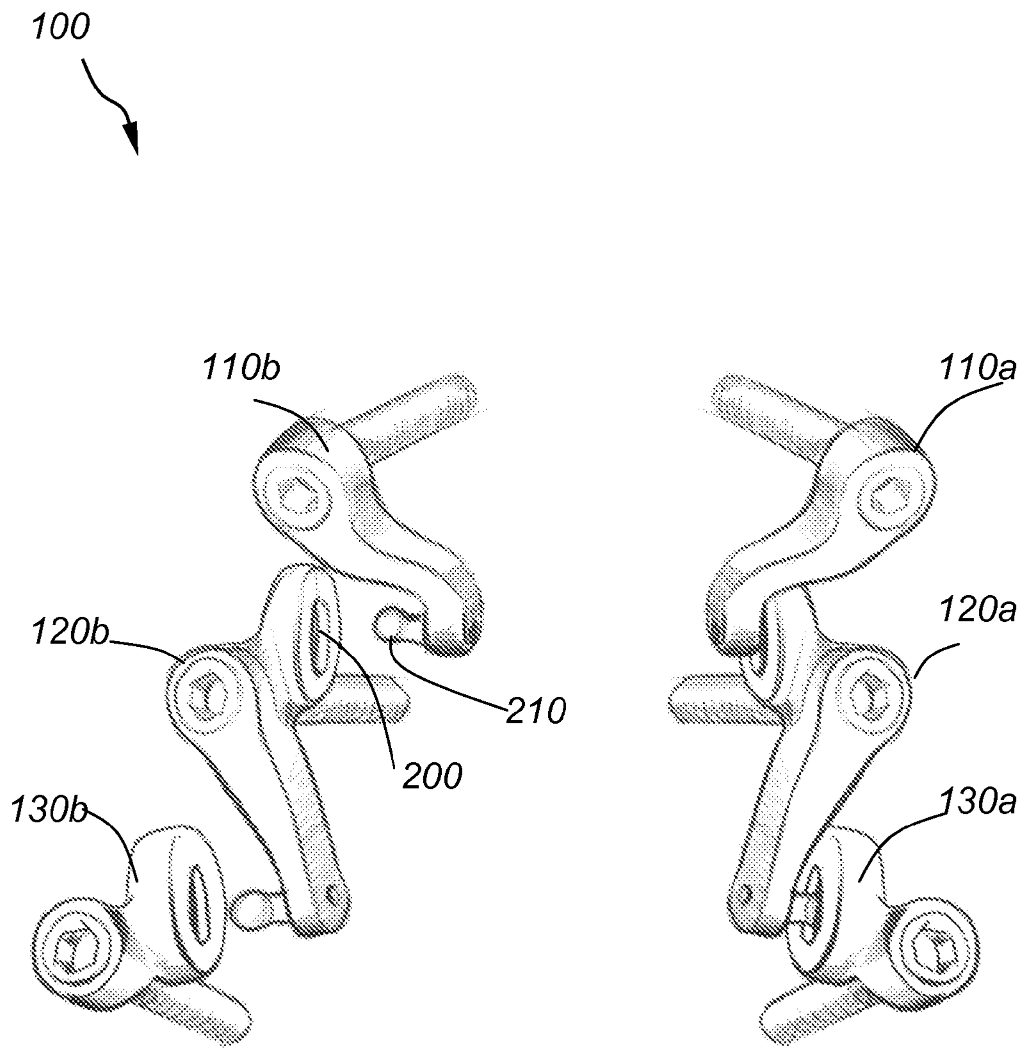


FIG. 30

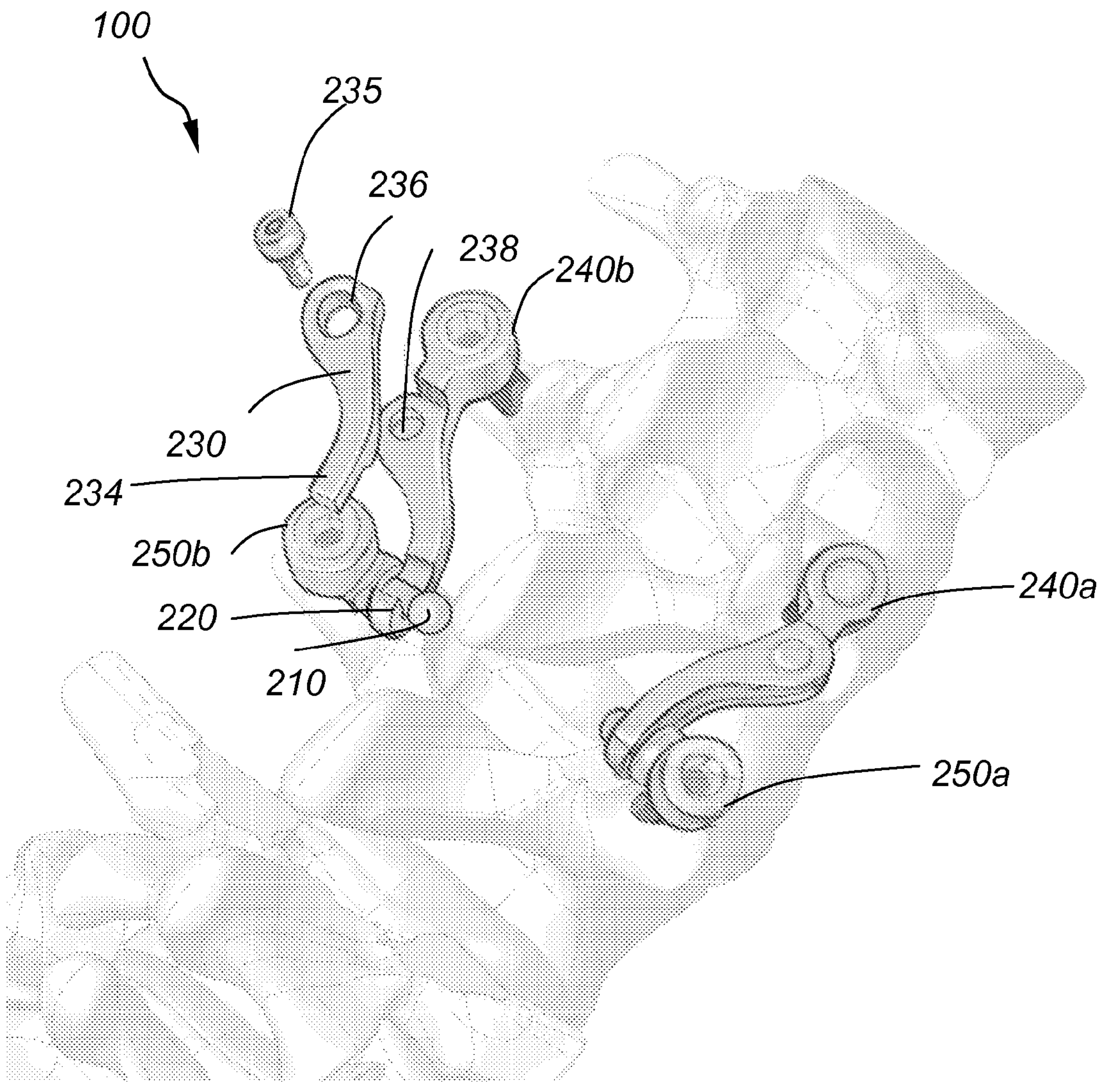


FIG. 31

DYNAMIC FACET REPLACEMENT SYSTEM

CROSS REFERENCE TO RELATED CO-PENDING APPLICATIONS

This application claims the benefit of U.S. provisional application Ser. No. 60/946,422 filed Jun. 27, 2007 and entitled "DYNAMIC FACET REPLACEMENT SYSTEM", the contents of which are expressly incorporated herein by reference.

This application is also a continuation in part of U.S. application Ser. No. 11/852,379 filed on Sep. 10, 2007 and entitled "APPARATUS AND METHOD FOR CONNECTING SPINAL VERTEBRAE" the contents of which are expressly incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a system and method for dynamic facet replacement, and in particular to a facet joint replacement that connects adjacent spinal vertebrae while preserving spinal stability and mobility.

BACKGROUND OF THE INVENTION

The human spine **29** comprises individual vertebrae **30** that interlock with each other to form a spinal column, shown in FIG. **1**A. Referring to FIGS. **1**B, **1**C, **2**A, **2**B, **3** and **4**, each vertebra **30** has a cylindrical bony body (vertebral body) **32**, two pedicles **48***a*, **48***b* extending from the vertebral body **32**, a lamina **47** extending from the pedicles **48***a*, **48***b*, three winglike projections (two transverse processes **33**, **35** extending from the pedicles **48***a*, **48***b*, respectively, and one spinous process **34** extending from the lamina **47**), pars interarticularis **36***a*, **36***b*, two superior facets **46***a*, **46***b* extending from the pedicles **48***a*, **48***b*, respectively, and two inferior facets **45***a*, **45***b* extending from the lamina **47**. The pars interarticularis **36***a*, **36***b* connect the superior **46***a*, **46***b* and inferior **45***a*, **45***b* facets of the vertebra, respectively, on either side of the spinous process **34**. The bodies of the vertebrae **32** are stacked one on top of the other and form the strong but flexible spinal column. The spinous process **34**, lamina **47**, pars interarticularis **36***a*, **36***b*, superior facets **46***a*, **46***b*, inferior facets **45***a*, **45***b*, transverse processes **33**, **35**, and pedicles **48***a*, **48***b* are positioned so that the space they enclose forms a tube, i.e., the spinal canal **37**. The spinal canal **37** houses and protects the spinal cord and other neural elements. A fluid filled protective membrane, the dura **38**, covers the contents of the spinal canal. The spinal column is flexible enough to allow the body to twist and bend, but sturdy enough to support and protect the spinal cord and the other neural elements. The inferior facets **45***a*, **45***b* of one vertebra fit perfectly into the superior facets **46***a*, **46***b* of the vertebra below it, thereby forming left and right facet joints **50***a*, **50***b*. The facet joints **50***a*, **50***b* provide stability and guide motion in the spine. Like the bones that form other joints in the human body, such as the hip, knee, or elbow, the articular surfaces of the facet joints are covered by a layer of smooth cartilage, surrounded by a strong capsule of ligaments, and lubricated by synovial fluid.

The vertebrae **30** are separated and cushioned by thin pads of tough, resilient fiber known as inter-vertebral discs **40**. Inter-vertebral discs **40** provide flexibility to the spine and act as shock absorbers during activity. There is a small opening (foramen) **42** between each vertebra **30**, through which nerves **44** pass and go to different body parts. When the vertebrae are properly aligned the nerves **44** pass through without a problem. However, when the vertebrae are misaligned or a constriction **15** is formed in the spinal canal, the nerves get compressed **44***a* and may cause back pain, leg pain or other neurological disorders. Disorders of the spine that may cause misalignment of the vertebrae or constriction of the spinal canal include spinal injuries, infections, tumor formation, herniation of the inter-vertebral discs (i.e., slippage or protrusion), arthritic disorders, and scoliosis. In these pathologic circumstances, surgery may be tried to either decompress the neural elements and/or fuse adjacent vertebral segments. Decompression may involve laminectomy, discectomy, or corpectomy. Laminectomy involves the removal of part of the lamina **47**, i.e., the bony roof of the spinal canal. Discectomy involves removal of the inter-vertebral discs **40**. Corpectomy involves removal of the vertebral body **32** as well as the adjacent disc spaces **40**. Laminectomy and corpectomy result in central exposure of the dura **38** and its contents. An exposed dura **38** puts the neural elements and spinal cord at risk from direct mechanical injury or scarring from overlying soft tissues. Scarring is considered a major cause for failed back syndrome in which patients continue to have back and leg pain after spinal surgery. Current methods to decrease the risk of developing this syndrome include covering the dura with fat harvested from the patient's subcutaneous tissues or using a synthetic material. However, no material as yet has been used that completely or significantly prevents scarring of the dura and nerve roots after spine surgery in humans.

Furthermore, laminectomy predisposes the patient to instability through the facet joints and may lead to post-laminectomy kyphosis (abnormal forward curvature of the spine), pain, and neurological dysfunction. Therefore the surgeon needs to stabilize the spine after laminectomy procedures and after corpectomy. One spine stabilization method is fusion. Fusion involves the fixation of two or more vertebrae. Fusion works well because it stops pain due to movement of the intervertebral discs **40** or facets **45***a*, **45***b*, **46***a*, **46***b*, immobilizes the spine, and prevents instability and or deformity of the spine after laminectomy or corpectomy. However, spinal fusion limits spinal mobility. Maintaining spinal mobility may be preferred over fusion in some cases to allow more flexibility of the spine and to decrease the risk of junction problems above and below the level of the fixation due to increased stress.

An arthritic facet joint may also cause back pain (facet arthropathy). Since the majority of the motion along the spine occurs at the facet joints, fusing the diseased facet would often relieve pain but again at a high cost of fusing across at least one spinal segment thus preventing motion and effectively increasing stresses at the adjacent facet joints. Increased stresses predispose facet joints to accelerated arthritis, pain, and instability requiring additional surgery to fuse these levels. This cyclic process results in an overall decreased mobility of the spine. Therefore, it is an attractive alternative to attempt to replace the diseased facet without resorting to fusion, thus avoiding significant limitation in mobility of the spine. The obvious solution would be to replace the opposing surfaces of each facet to preserve motion between the surfaces. However, any efforts to replace the facets at their natural location necessitate destroying the facet capsule and risks producing an unstable joint. Therefore, it is desirable to achieve spine stabilization that preserves mobility, and does not cause tissue scarring or destroy the facet capsule. It is also desirable to be able to implant the stabilization device percutaneously utilizing minimally invasive surgery.

SUMMARY OF THE INVENTION

The present invention relates to a system and method for dynamic facet replacement, and in particular to a facet joint replacement that connects adjacent spinal vertebrae while preserving spinal stability and mobility.

In general in one aspect the invention features a dynamic facet replacement system articulately connecting a first spinal vertebra to an adjacent second spinal vertebra and the second spinal vertebra to an adjacent third spinal vertebra, along the natural facet joints. The facet replacement system includes first and second inferior facet components configured to replace left and right natural inferior facets of the first vertebra, respectively, first and second par components configured to replace left and right natural pars of a second vertebra, respectively, and first and second superior facet components configured to replace left and right natural facets of a third vertebra, respectively. Each of the inferior and superior facet components comprises a facet articulating surface and each of the par components comprises first and second par articulating surfaces. The first and second par components are shaped and dimensioned to be inserted between the first and second inferior and superior facet components, respectively, and to articulately connect the first and second inferior facet components to the first and second superior facet components, respectively, by connecting the first and second par articulating surfaces to the facet articulating surfaces of the inferior and superior facet components, respectively.

Implementations of this aspect of the invention may include one or more of the following features. The connection of the par components to the inferior and superior facet components comprises a surface-to-surface articulation mechanism or a constrained articulation mechanism. The constrained articulation mechanism comprises a male articulation component engaging a female articulation component. Each of the inferior facet components comprises a first extension member protruding from the inferior facet articulating surface and each of the par components comprises a first groove formed in the first par articulating surface and wherein the first groove is shaped and dimensioned to receive the first extension member and thereby to articulately connect the inferior facet component to the par component. Each of the par components further comprises a second extension member protruding from the second par articulating surface and wherein the superior facet component comprises a second groove formed in the superior facet articulating surface and wherein the second groove is shaped and dimensioned to receive the second extension member and thereby to articulately connect the superior facet component to the par component. Each of the inferior facet components comprises an elongated curved body and the body comprises a first cylindrical shaped end, configured to be attached to a location of the first vertebra and a second cylindrical shaped end comprising the inferior facet articulating surface. In each of the inferior facet components, the first cylindrically shaped end's axis is oriented perpendicular to the second cylindrical shaped end's axis. Each of the par components comprises an elongated curved body and the body comprises a first cylindrical shaped end, configured to be attached to a location of the second vertebra, a second cylindrical shaped end comprising the second par articulating surface, and wherein the first cylindrically shaped end further comprises a wing extension comprising the first par articulating surface. In each of the par components the first cylindrically shaped end's axis is oriented perpendicular to the second cylindrical shaped end's axis. Each of the superior facet components comprises a cylindrically shaped end, configured to be attached to a location of the third vertebra and wherein the cylindrically shaped end further comprises a wing extension comprising the superior facet articulating surface. Any of the cylindrically shaped ends is attached to the vertebral locations via a poly-axial screw. Any of the vertebral locations comprise one of a pedicle, transverse processes, facets, pars interarticularis, intervertebral disc, lamina, or vertebral body. The dynamic facet replacement system comprises at least one of metal, plastic, ceramic, bone, polymers, composites, absorbable material, biodegradable material, or combinations thereof. The vertebras comprise one of cervical, thoracic, lumbar or sacrum vertebras. The male articulation component comprises an extension member and the female articulation member comprises a slot shaped and dimensioned to receive the extension member. The constrained articulation mechanism further comprises a locking member configured to fit over the slot and to lock the extension member within the slot.

In general in one aspect the invention features a method for articulately connecting a first spinal vertebra to an adjacent second spinal vertebra and the second spinal vertebra to an adjacent third spinal vertebra, along the natural facet joints. The method includes providing first and second inferior facet components configured to replace left and right natural inferior facets of a first vertebra, respectively, and attaching the first and second inferior facet components to first and second locations of the first vertebra, respectively. Each of the inferior facet components comprises an articulating surface. Next, providing first and second par components configured to replace left and right natural pars of a second vertebra, respectively, and attaching the first and second par components to first and second locations of the second vertebra, respectively. Each of the par components comprises first and second par articulating surfaces. Next, providing first and second superior facet components configured to replace left and right natural facets of a third vertebra, respectively, and attaching the first and second superior facet components to first and second locations of the third vertebra, respectively. Each of the superior facet components comprises an articulating surface. Finally, articulately connecting the first and second par articulating surfaces to the articulating surfaces of the inferior and superior facet components, respectively. The connection of the par components to the inferior and superior facet components comprises a constrained articulation mechanism and the constrained articulation mechanism comprises a male articulation component engaging a female articulation component. The male articulation component comprises an extension member and the female articulation member comprises a slot shaped and dimensioned to receive the extension member, and wherein the constrained articulation mechanism further comprises a locking member configured to fit over the slot and to lock the extension member within the slot.

Among the advantages of this invention may be one or more of the following. The implantable spinal stabilization device stabilizes the spine along the facet joints, while allowing the patient to retain spinal flexibility by preserving motion between adjacent vertebras. This spinal stabilization device may be implanted using minimally invasive surgery along lines left and right of the midline of the spinal column. The spinal stabilization device may be used for the treatment of a multitude of spinal disorders including facet arthritis and spinal stenosis. The implantable device has a compact structure and low profile. The implant can be inserted percutaneously along the sides of the spine without the need to make a large midline incision and stripping the erector spinal muscles laterally. There is no need to remove the posterior elements of the vertebras such as the spinous processes and lamina.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and description below. Other features, objects and advantages of the invention will be apparent from the following description of the preferred embodiments, the drawings and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the figures, wherein like numerals represent like parts throughout the several views:

FIG. **1**A is a side view of the human spinal column;

FIG. **1**B is an enlarged view of area A of FIG. **1**A;

FIG. **1**C is an axial cross-sectional view of a lumbar vertebra;

FIG. **2**A illustrates the facet joints of two adjacent vertebras;

FIG. **2**B illustrates another axial cross-sectional view of a lumbar vertebra and a side view of adjacent lumbar vertebras;

FIG. **3** is a front (posterior) perspective view of the lumbar section of the human spinal column;

FIG. **4** is a side view of the lumbar section of FIG. **3**;

FIG. **5** is a front (posterior) perspective view of an embodiment of the dynamic facet replacement system;

FIG. **6** is a side view of the dynamic facet replacement system of FIG. **5**

FIG. **7** is another front perspective view of the dynamic facet replacement system of FIG. **5**;

FIG. **8** is a front (posterior) perspective view of the inferior facet replacement assembly;

FIG. **9** is a side view of the inferior facet replacement assembly of FIG. **8**;

FIG. **10**A is a front perspective view of a facet replacement component of FIG. **8**;

FIG. **10**B is a side view of the facet replacement component of FIG. **10**A;

FIG. **11**A is another front perspective view of the facet replacement component of FIG. **8**;

FIG. **11**B is a side perspective view of the facet replacement component of FIG. **11**A;

FIG. **12** is a cross-sectional view of the facet replacement component of FIG. **11**B along the axis A-A;

FIG. **13** is a partially exploded anterior view of the inferior facet replacement assembly of FIG. **8**;

FIG. **14** is a partially exploded posterior view of the inferior facet replacement assembly of FIG. **8**;

FIG. **15** is a front (posterior) perspective view of the pars replacement assembly;

FIG. **16** is a side perspective view of the pars replacement assembly of FIG. **15**;

FIG. **17** is front perspective view of a pars replacement component of FIG. **15**;

FIG. **18** is side perspective view of the pars replacement component of FIG. **17**;

FIG. **19** is a cross-sectional view of the pars replacement component of FIG. **18** along the A-A axis;

FIG. **20** is a partially exploded posterior view of the pars replacement assembly of FIG. **15**;

FIG. **21** is a front (posterior) perspective view of the superior facet replacement assembly;

FIG. **22** is a side perspective view of the superior facet replacement assembly of FIG. **21**;

FIG. **23** is a front perspective view of a superior facet replacement component of FIG. **21**;

FIG. **24** is a top view of the superior facet replacement component of FIG. **23**;

FIG. **25** is a cross-sectional view of the superior facet replacement component of FIG. **24** along the A-A axis;

FIG. **26** is a partially exploded view of the superior facet replacement assembly of FIG. **21**;

FIG. **27** is a top view of the partially exploded superior facet replacement assembly of FIG. **26**;

FIG. **28** is a front (posterior) perspective view of the interfaces (joints) between the pars assembly with the superior facet replacement assembly and the pars assembly with the inferior facet replacement assembly;

FIG. **29** is a side perspective view of FIG. **28**;

FIG. **30** is detailed view of the facet articulation mechanism; and

FIG. **31** is another embodiment of a facet articulation mechanism.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a system and method for dynamic facet replacement, and in particular to a facet joint replacement that connects adjacent spinal vertebrae while preserving spinal stability and mobility.

Referring to FIG. **5**, FIG. **6** and FIG. **7** a dynamic facet replacement system **100** includes an inferior facet replacement assembly **110**, pars replacement assembly **120** and a superior facet replacement assembly **130**. The inferior facet replacement assembly **110** includes first and second inferior facet replacement components **110***a*, **110***b*. The pars replacement assembly **120** includes first and second pars replacement components **120***a*, **120***b*. The superior facet replacement assembly includes first and second superior facet replacement components **130**, **130***b*. In the embodiment of FIG. **5** the inferior facet replacement components **110***a*, **110***b* articulate with the pars replacement components **120***a*, **120***b*, respectively, and the pars replacement components **120***a*, **120***b*, articulate with the superior facet replacement components **130***a*, **130***b*, respectively, to dynamically stabilize the facet joints **50***a*, **50***b* and **51***a*, **51***b* between the adjacent vertebras **30***a*, **30***b* and **30***b*, **30***c*, respectively. In this embodiment the articulation between the inferior facet replacement components or the superior facet replacement components and the pars replacement components is surface to surface articulation. In other embodiments the articulation is a constrained articulation. In one embodiment the constrained articulation is by engaging a male articulation component with a female articulation component, as described in the co-pending patent application Ser. No. 10/660,927 entitled "Apparatus and method for connecting spinal vertebrae", the contents of which are incorporated herein by reference. In the embodiment of FIG. **30** the articulation mechanism is a tongue and groove type articulation. As shown in FIG. **30**, one surface includes a groove **240** and the opposite articulating surface includes an extension **210** that fits into the opposite groove to form a tongue and groove type connection. Extension **210** may be snapped in or slidably inserted into the groove **200**. In other embodiments, extension **210** is placed in a slot and then rotated to engage and lock into a groove communicating with the slot. Furthermore, in other embodiments any of the described replacement components articulate with the surfaces of the natural facets. In another embodiment of the articulation mechanism, shown in FIG. **31**, a first articulating member **250***b* includes and extension member **210** that fits into a slot **220** of an opposite second articulating member **240***b*. An elongated locking member **230** fits over the open end of the slot **220** and locks the extension member **210** in the slot **220**. The locking member **230** includes an elongated body having a portion **234** that fits over the slot **220** and a portion that includes a through opening **236**. Opening **236** is aligned with an opening **238** in the second articulating member **240***b* and a bolt or screw **235** is inserted into openings **236** and **238** to lock locking member **230** onto articulating member **240***b* and extension member **210** in the slot **220**.

Referring to FIG. **8** and FIG. **9**, the inferior facet replacement assembly **110** includes facet replacement components **110***a*, **110***b* that articulate with facet-like surfaces of the pars **120***a*, **120***b*, respectively, as shown in FIG. **5**, or with the natural superior facets **46***a*, **46***b* of the adjacent vertebra **30***b*. Each inferior facet replacement component **110***a*, **110***b*, includes an elongated curved body **112***a*, **112***b* having a cylindrical shaped first end **114***a*, **114***b* and cylindrical shaped second end **116***a*, **116***b*. The axis **113** of the cylindrical shaped second end **116***b* is oriented perpendicular to the axis **115** of the cylindrical shaped first end **114***a*, as shown in FIG. **10**A. The cylindrical second end **116***b* extends away from the main body **112***b* and has a portion that overhangs in the direction of **113***b*. The cylindrical second end **116***b* has an elliptical first surface **118***b* configured to articulate with the natural superior facet or any other facet-like surface. The cylindrical shaped first end **114***b* has a through opening **119** dimensioned to receive a fixation element **150***b*. In the example of FIG. **8** the fixation element **150** is an elongated poly-axial screw and is used to anchor the facet replacement component **110***b* to pedicle **48***b* of the vertebra **30***a*. The poly-axial screw **150** includes a spherical head **156** and an elongated body **152** having outer threads **154**. The spherical head **156** includes a cutout **158** on the top dimensioned and configured to receive a screwdriver, shown in FIG. **12**. Once the screw is anchored in the desired vertebral location, the cylindrical shaped first end **114***b* is rotated and oriented to position the main body **112***b* so that the elliptical surface **118***b* of the second cylindrical end **116** articulates with a facet-like surface of the replacement par or a natural facet. Once the desired orientation of the main body **112***b* is set, the first cylindrical shaped end **114***b* is secured onto the spherical screw head **156** with a set screw **160**, as shown in FIG. **12** and FIG. **13**. Other vertebral locations where the fixation element **150** may be anchored include the vertebral body, lamina or the processes.

Referring to FIG. **15** and FIG. **16**, the pars replacement assembly **120** includes pars replacement components **120***a*, **120***b* that articulate with facet-like surfaces of the superior and inferior facet replacement components **110***a*, **110***b*, and **130***a*, **130***b*, respectively, as shown in FIG. **5**, or with the natural superior facets **46***a*, **46***b* and inferior facets **45***a*, **45***b* of the adjacent vertebras **30***a*, **30***c*, respectively. Each par replacement component **120***a*, **120***b*, includes an elongated curved body **122***a*, **122***b* having a cylindrical shaped first end **124***a*, **124***b* and cylindrical shaped second end **128***a*, **128***b*. The axis **123** of the cylindrical shaped second end **128***b* is oriented perpendicular to the axis **125** of the cylindrical shaped first end **124***b*, as shown in FIG. **17**. The cylindrical first end **124***b* also includes a wing-like extension **126***b* having an elliptical surface **129***a* configured to articulate with a facet-like surface of an inferior facet replacement component or a natural inferior facet. The cylindrical second end **128***b* extends away from the main body **122***b* and has a portion that overhangs in the direction of **123***b*. The cylindrical second end **128***b* has an elliptical first surface **129***b* configured to articulate with a facet-like surface of the superior facet replacement component, shown in FIG. **5** or a natural superior facet. The cylindrical shaped first end **124***b* has a through opening **89** dimensioned to receive a fixation element **150**. In the example of FIG. **17** the fixation element **150** is an elongated poly-axial screw and is used to anchor the par replacement component **110***b* to pedicle **48***b* of the vertebra **30***b*. The poly-axial screw **150** includes a spherical head **156** and an elongated body **152** having outer threads **154**. The spherical head **156** includes a cutout on the top **158** dimensioned and configured to receive a screwdriver. Once the screw is anchored in the desired vertebral location, the cylindrical shaped first end **124***b* is rotated and oriented to position the main body **122***b* so that the elliptical surfaces **129***a* of the wing-like extension of the first end and **129***b* of the second cylindrical end **128***b* articulate with facet-like surfaces of the inferior facet replacement component and the superior facet replacement component, respectively, or the inferior and superior natural facets. Once the desired orientation of the main body **122***b* is set, the first cylindrical end is secured onto the spherical screw head **150** with a setscrew **160**, as shown in FIG. **20**.

Referring to FIG. **21** and FIG. **22**, the superior facet replacement assembly **130** includes superior facet replacement components **130***a*, **130***b* that articulate with facet-like surfaces of the pars **120***a*, **120***b*, respectively, as shown in FIG. **5** and FIG. **28**, or with the natural inferior facets **45***a*, **45***b* of the adjacent vertebra **30***b*. Each superior facet replacement component **130***a*, **130***b*, includes a cylindrical shaped first end **134***a*, **134***b* and a wing-like extension **132***a*, **132***b*, extending from the cylindrical shaped first end **134***a*, **134***b*, respectively. The wing-like extension **132***a* has an elliptical surface **133***a* configured to articulate with a facet-like surface of an inferior facet replacement component, or par replacement component or a natural inferior facet. The cylindrical shaped first end **134***a* has a through opening **139** dimensioned to receive a fixation element **150**. In the example of FIG. **23** the fixation element **150** is an elongated poly-axial screw and is used to anchor the facet replacement component **130***a* to pedicle **48***a* of the vertebra **30***c*. The poly-axial screw **150** includes a spherical head **156** and an elongated body **152** having outer threads **154**. The spherical head **156** includes a cutout on the top **158** dimensioned and configured to receive a screwdriver. Once the screw is anchored in the desired vertebral location, the cylindrical shaped first end **134***a* is rotated and oriented so that the elliptical surface **133***a* of the wing-like structure **132***a* articulates with a facet-like surface of the replacement par or a natural facet. Once the desired orientation of the elliptical surface **133***a* is set, the first cylindrical end is secured onto the spherical screw head **156** with a setscrew **160**, as shown in FIG. **26**.

The superior replacement components **130***a*, **130***b* articulate with the par replacement components **120***a*, **120***b*, respectively, to form facet joint **51***a*, **51***b* and the par replacement components **120***a*, **120***b* articulate with the inferior replacement components **110***a*, **11***b*, respectively, to form facet joints **50***a*, **50***b*, as shown in FIG. **5**, FIG. **28** and FIG. **29**.

Other embodiments are within the scope of the following claims. The facet replacement components and the par replacement components are made of metal, plastic, ceramic, bone, polymers, composites, absorbable material, biodegradable material, or combinations thereof. The articulating surfaces may be flat or slightly curved. The articulation may be a constrained articulation, as was described above. The facet replacement components may have adjustable lengths. The facet replacement system may be extended in either caudad **272** or cephalad **270** directions

Several embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A dynamic facet replacement system configured to articulately connect a first spinal vertebra to an adjacent second spinal vertebra and said second spinal vertebra to an adjacent third spinal vertebra, along the natural facet joints comprising:

first and second inferior facet components configured to replace left and right natural inferior facets of a first vertebra, respectively;

first and second par components configured to replace left and right natural pars of a second vertebra, respectively;

first and second superior facet components configured to replace left and right natural facets of a third vertebra, respectively;

wherein each of said inferior and superior facet components comprises a facet articulating surface and each of said par components comprises first and second par articulating surfaces, wherein said first and second par articulating surfaces are opposite to each other;

wherein said first and second par components are shaped and dimensioned to be inserted between said first and second inferior and superior facet components, respectively, and to articulately connect said first and second inferior facet components to said first and second superior facet components, respectively, by connecting said first and second par articulating surfaces to said facet articulating surfaces of the inferior and superior facet components, respectively;

wherein each of said inferior facet components comprises an elongated curved body extending along a first axis and said body comprises a first cylindrical shaped end, configured to be attached to a location of said first vertebra and a second cylindrical shaped end comprising said inferior facet articulating surface and extending from said elongated curved body perpendicular to said axis; and

wherein in each of said inferior facet components, said first cylindrically shaped end's axis is oriented perpendicular to said second cylindrical shaped end's axis and perpendicular to said elongated curved body's first axis.

2. The dynamic facet replacement system of claim **1** wherein said connection of said par components to said inferior and superior facet components comprises a surface-to-surface articulation mechanism.

3. The dynamic facet replacement system of claim **1** wherein said connection of said par components to said inferior and superior facet components comprises a constrained articulation mechanism.

4. The dynamic facet replacement system of claim **3** wherein said constrained articulation mechanism comprises a male articulation component engaging a female articulation component.

5. The dynamic facet replacement system of claim **4** wherein each of said inferior facet components comprises a first extension member protruding from said inferior facet articulating surface and each of said par components comprises a first groove formed in said first par articulating surface and wherein said first groove is shaped and dimensioned to receive said first extension member and thereby to articulately connect said inferior facet component to said par component.

6. The dynamic facet replacement system of claim **5** wherein each of said par components further comprises a second extension member protruding from said second par articulating surface and wherein said superior facet component comprises a second groove formed in said superior facet articulating surface and wherein said second groove is shaped and dimensioned to receive said second extension member and thereby to articulately connect said superior facet component to said par component.

7. The dynamic facet replacement system of claim **6** wherein each of said par components comprises an elongated curved body extending along a second axis and said body comprises a first cylindrical shaped end, configured to be attached to a location of said second vertebra, a second cylindrical shaped end comprising said second par articulating surface, and wherein said first cylindrically shaped end further comprises a wing extension comprising said first par articulating surface.

8. The dynamic facet replacement system of claim **7** wherein in each of said par components said first cylindrically shaped end's axis is oriented perpendicular to said second cylindrical shaped end's axis and perpendicular to said elongated curved body's second axis.

9. The dynamic facet replacement system of claim **8** wherein each of said superior facet components comprises a cylindrically shaped end, configured to be attached to a location of said third vertebra and wherein said cylindrically shaped end further comprises a wing extension comprising said superior facet articulating surface.

10. The dynamic facet replacement system of claim **9** wherein any of said cylindrically shaped ends is configured to be attached to said vertebral locations via a poly-axial screw.

11. The dynamic facet replacement system of claim **10** wherein any of said vertebral locations comprise one of a pedicle, transverse processes, facets, pars interarticularis, intervertebral disc, lamina, or vertebral body.

12. The dynamic facet replacement system of claim **4** wherein said male articulation component comprises an extension member and said female articulation member comprises a slot shaped and dimensioned to receive said extension member.

13. The dynamic facet replacement system of claim **1** comprising at least one of metal, plastic, ceramic, bone, polymers, composites, absorbable material, biodegradable material, or combinations thereof.

14. The dynamic facet replacement system of claim **1** wherein any of said vertebras comprises one of cervical, thoracic, lumbar or sacrum vertebras.

15. A method for articulately connecting a first spinal vertebra to an adjacent second spinal vertebra and said second spinal vertebra to an adjacent third spinal vertebra, along the natural facet joints comprising:

providing first and second inferior facet components configured to replace left and right natural inferior facets of a first vertebra, respectively, and wherein each of said inferior facet components comprises an articulating surface;

attaching said first and second inferior facet components to first and second locations of said first vertebra, respectively;

providing first and second par components configured to replace left and right natural pars of a second vertebra, respectively, and wherein each of said par components comprises first and second par articulating surfaces, and wherein said first and second par articulating surfaces are opposite to each other;

attaching said first and second par components to first and second locations of said second vertebra, respectively;

providing first and second superior facet components configured to replace left and right natural facets of a third vertebra, respectively, and wherein each of said superior facet components comprises an articulating surface;

attaching said first and second superior facet components to first and second locations of said third vertebra, respectively;

articulately connecting said first and second par articulating surfaces to the articulating surfaces of the inferior and superior facet components, respectively; and

wherein each of said inferior facet components comprises an elongated curved body extending along a first axis and said body comprises a first cylindrical shaped end, configured to be attached to a location of said first vertebra and a second cylindrical shaped end comprising said inferior facet articulating surface and extending from said elongated curved body perpendicular to said first axis; and

wherein in each of said inferior fact components, said first cylindrically shaped end's axis is oriented perpendicular to said second cylindrical end's axis and perpendicular to said elongated curved body's first axis.

16. The method of claim **15** wherein said connection of said par components to said inferior and superior facet components comprises a constrained articulation mechanism and wherein said constrained articulation mechanism comprises a male articulation component engaging a female articulation component.

* * * * *