

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
30 March 2006 (30.03.2006)

PCT

(10) International Publication Number
WO 2006/033659 A2

- (51) International Patent Classification: Not classified
- (21) International Application Number:
PCT/US2004/041539
- (22) International Filing Date:
10 December 2004 (10.12.2004)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
10/737,705 15 December 2003 (15.12.2003) US
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**
— without international search report and to be republished upon receipt of that report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: POLYAXIAL ADJUSTMENT OF FACET JOINT PROSTHESES

(57) Abstract: Prostheses, systems, and methods are provided for replacement of natural facet joints between adjacent vertebrae using polyaxial attachment mechanisms for securing the prostheses to the vertebrae. A cephalad prosthesis attached to a superior adjacent vertebra replaces the inferior half of a natural facet joint. A caudal prosthesis attached to an inferior adjacent vertebra replaces the superior half of a natural facet joint. Both the cephalad and caudal prostheses are configured with artificial facet joint structures that include articulating surfaces that cooperate and form an artificial articular configuration. The polyaxial attachment mechanism permits adjustment of the position of the artificial facet joint structure along more than one axis at or after the time the cephalad or caudal prosthesis is attached to a vertebra.



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POLYAXIAL ADJUSTMENT OF FACET JOINT PROSTHESES

FIELD OF THE INVENTION

5 [0001] This invention relates to prostheses, systems, and methods for treating various types of spinal pathologies, and in particular relates to attachment of prostheses to spinal vertebrae.

BACKGROUND OF THE INVENTION

10 [0002] The human spinal column 10, as shown in Figure 1, is comprised of a series of thirty-three stacked vertebrae 12 divided into five regions. The cervical region includes seven vertebrae, known as C1-C7. The thoracic region includes twelve vertebrae, known as T1-T12. The lumbar region contains five vertebrae, known as L1-L5. The sacral region is comprised of five vertebrae, known as S1-S5, while the
15 coccygeal region contains four vertebrae, known as Co1-Co4.

[0003] Figure 2 depicts a superior plan view of a normal human lumbar vertebra 12. Although human lumbar vertebrae vary somewhat according to location, they share many common features. Each vertebra 12 includes a vertebral body 14. Two short bones, the pedicles 16, extend backward from each side of the vertebral body 14 to
20 form a vertebral arch 18.

[0004] At the posterior end of each pedicle 16, the vertebral arch 18 flares out into broad plates of bone known as the laminae 20. The laminae 20 fuse with each other to form a spinous process 22. The spinous process 22 serves for muscle and ligamentous attachment. A smooth transition from the pedicles 16 to the laminae 20 is interrupted by
25 the formation of a series of processes.

[0005] Two transverse processes 24 thrust out laterally on each side from the junction of the pedicle 16 with the lamina 20. The transverse processes 24 serve as levers for the attachment of muscles to the vertebrae 12. Four articular processes, two superior 26 and two inferior 28, also rise from the junctions of the pedicles 16 and the
30 laminae 20. The superior articular processes 26 are sharp oval plates of bone rising upward on each side of the vertebrae, while the inferior processes 28 are oval plates of bone that jut downward on each side.

[0006] The superior and inferior articular processes 26 and 28 each have a natural bony structure known as a facet. The superior articular facet 30 faces upward, while the inferior articular facet 31 (see Figure 3) faces downward. When adjacent vertebrae 12 are aligned, the facets 30 and 31, capped with a smooth articular cartilage, interlock to form a facet joint 32, also known as a zygapophyseal joint.

[0007] The facet joint 32 is composed of a superior half and an inferior half. The superior half is formed by the vertebral level below the joint 32, and the inferior half is formed by the vertebral level above the joint 32. For example, in the L4-L5 facet joint, the superior half of the joint 32 is formed by bony structure on the L5 vertebra (i.e., a superior articular surface and supporting bone 26 on the L5 vertebra), and the inferior half of the joint 32 is formed by bony structure on the L4 vertebra (i.e., an inferior articular surface and supporting bone 28 on the L4 vertebra).

[0008] An intervertebral disc 34 between each adjacent vertebrae 12 permits gliding movement between the vertebrae 12. The structure and alignment of the vertebrae 12 thus permit a range of movement of the vertebrae 12 relative to each other.

[0009] Back pain, particularly in the "small of the back" or lumbosacral (L4-S1) region, is a common ailment. In many cases, the pain severely limits a person's functional ability and quality of life. Such pain can result from a variety of spinal pathologies.

[0010] Through disease or injury, the laminae, spinous process, articular processes, or facets of one or more vertebral bodies can become damaged, such that the vertebrae no longer articulate or properly align with each other. This can result in an undesired anatomy, loss of mobility, and pain or discomfort.

[0011] For example, the vertebral facet joints can be damaged by either traumatic injury or by various disease processes. These disease processes include osteoarthritis, ankylosing spondylolysis, and degenerative spondylolisthesis. The damage to the facet joints often results in pressure on nerves, also called "pinched" nerves, or nerve compression or impingement. The result is pain, misaligned anatomy, and a corresponding loss of mobility. Pressure on nerves can also occur without facet joint pathology, e.g., a herniated disc.

[0012] One type of conventional treatment of facet joint pathology is spinal stabilization, also known as intervertebral stabilization. Intervertebral stabilization

prevents relative motion between the vertebrae. By preventing movement, pain can be reduced. Stabilization can be accomplished by various methods.

5 [0013] One method of stabilization is spinal fusion. Another method of stabilization is fixation of any number of vertebrae to stabilize and prevent movement of the vertebrae.

[0014] Another type of conventional treatment is decompressive laminectomy. This procedure involves excision of the laminae to relieve compression of nerves.

10 [0015] These traditional treatments are subject to a variety of limitations and varying success rates. None of the described treatments, however, puts the spine in proper alignment or returns the spine to a desired anatomy. In addition, stabilization techniques, by holding the vertebrae in a fixed position, permanently limit a person's mobility.

[0016] There is, therefore, a need for prostheses, systems, and methods that overcome the problems and disadvantages associated with current strategies and designs
15 in various treatments for spine pathologies, and, particularly, a need for spinal prostheses with attachment mechanisms that facilitate positioning of the prostheses when attached to the vertebrae.

SUMMARY OF THE INVENTION

20 [0017] The present invention provides prostheses, systems, and methods designed to replace natural facet joints and possibly part of the lamina at virtually all spinal levels including L1-L2, L2-L3, L3-L4, L4-L5, L5-S1, T11-T12, and T12-L1, using polyaxial attachment mechanisms for securing the prostheses to the vertebrae. The prostheses, systems, and methods help establish a desired anatomy to a spine and return a desired
25 range of mobility to an individual. The prostheses, systems, and methods also help lessen or alleviate spinal pain by relieving the source nerve compression or impingement.

[0018] For the sake of description herein, the prostheses that embody features of the invention are identified as either "cephalad" or "caudal" with relation to the portion of a given natural facet joint they replace. As previously described, a natural facet joint,
30 such as facet joint 32 (Figure 3), has a superior half and an inferior half. In anatomical terms, the superior half of the joint is formed by the vertebral level below the joint, which can thus be called the "caudal" portion of the facet joint because it is closer to the feet of

the person. The inferior half of the facet joint is formed by the vertebral level above the joint, which can thus be called the “cephalad” portion of the facet joint because it is closer to the head of the person. Thus, a prosthesis that, in use, replaces the caudal portion of a natural facet joint (i.e., the superior half) will be called a “caudal” prosthesis.

5 Likewise, a prosthesis that, in use, replaces the cephalad portion of a natural facet joint (i.e., the inferior half) will be called a “cephalad” prosthesis.

[0019] In one aspect, the present invention provides a facet joint prosthesis including an artificial facet joint element connected to a fixation element by a polyaxially adjustable connection. In some embodiments the polyaxially adjustable connection is adapted and configured to permit the artificial facet joint element to be rotated with respect to the fixation element around more than one axis in order to tailor the prosthesis to the needs of the patient. The polyaxially adjustable connection may be further adapted and configured to permit the position of the artificial facet joint element to be continuously adjustable within an adjustability range with respect to the fixation element and may include a limit stop.

[0020] In various embodiments the artificial facet joint element is adapted to be movable medially, laterally, superiorly and/or inferiorly with respect to the fixation element. In some embodiments the polyaxially adjustable connection may be adapted and configured to permit the artificial facet joint element to be moved with respect to the fixation element after installation of the facet joint prosthesis in a patient. The invention may also include a fastener adapted and configured to prevent movement between the artificial facet joint element and the fixation element.

[0021] The artificial facet joint element in some embodiments may include a cephalad facet joint bearing surface and a cephalad facet joint bearing surface support. The cephalad facet joint bearing surface and the cephalad facet joint bearing surface support may be adapted and configured to be disposed laterally from a midline, or approximately at a midline, of a vertebra when the facet joint prosthesis is installed in a patient.

[0022] In some other embodiments the artificial facet joint element may include a caudal facet joint bearing surface and a caudal facet joint bearing surface support. The caudal facet joint bearing surface and the caudal facet joint bearing surface support may

be adapted and configured to be disposed laterally from a midline of a vertebra when the facet joint prosthesis is installed in a patient.

[0023] The facet joint prosthesis may also include a longitudinally adjustable connection between the artificial facet joint element and the fixation element. For example, in embodiments where the artificial facet joint element includes a facet joint bearing surface and a facet joint bearing surface support, the facet joint bearing surface support may be adapted and configured to be longitudinally movable with respect to the fixation element. The facet joint prosthesis may also include a fastener adapted and configured to prevent relative movement between the facet joint bearing surface support and the fixation element. The facet joint bearing surface support may also be further adapted and configured to be rotatable about a support longitudinal axis.

[0024] In some embodiments the polyaxially adjustable connection may include a facet joint element connection surface and a fixation element connection surface, with the facet joint element connection surface and fixation element connection surface being adapted and configured to be movable with respect to each other. In some embodiments the polyaxially adjustable connection may include a base member attached to the artificial facet joint element and movable with respect to the fixation element, and the base member may be further adapted and configured to be movable with respect to the artificial facet joint element.

[0025] Another aspect of the invention is a facet joint prosthesis including first and second artificial facet joint elements; a fixation element; and a polyaxially adjustable connection between at least one of the first or second facet joint elements and the fixation element. In some embodiments the first artificial facet joint element may include an artificial cephalad facet joint element, and the second artificial facet joint element may include an artificial caudal facet joint element. The fixation element may be a cephalad fixation element, and the polyaxially adjustable connection may include a cephalad polyaxially adjustable connection, with the facet joint prosthesis further including a caudal fixation element and a caudal polyaxially adjustable connection between the artificial caudal facet joint bearing element and the caudal fixation element. In some embodiments the artificial cephalad facet joint element includes a cephalad bearing surface and a cephalad bearing surface support, and in some embodiments the artificial

caudal facet joint element comprises a caudal bearing surface and a caudal bearing surface support.

[0026] Under this aspect of the invention the first and second artificial facet joint elements may also include first and second artificial cephalad facet joint elements, respectively. The fixation element may be a first cephalad fixation element and the polyaxially adjustable connection may include a first cephalad polyaxially adjustable connection, with the facet joint prosthesis further including a second cephalad fixation element and a second cephalad polyaxially adjustable connection between the second artificial cephalad facet joint element and the second cephalad fixation element. In some embodiments the first and second artificial cephalad facet joint elements may include first and second cephalad bearing surfaces, respectively. In some embodiments the first and second artificial facet joint elements may include first and second support arms, respectively, and at least one cephalad bearing surface supported by at least one of the first and second support arms. In those embodiments the cephalad bearing surface may be disposed approximately at a midline of a vertebra when the prosthesis is installed in a patient, and the prosthesis may also include an artificial caudal facet joint element comprising a caudal bearing surface adapted and configured to mate with the cephalad bearing surface. The cephalad bearing surface may also be adapted to rotate about the support arm or arms by which it is supported.

[0027] Also according to this aspect of the invention the polyaxially adjustable connection may be adapted and configured to permit at least one of the artificial facet joint elements to be rotated with respect to the fixation element around more than one axis. The polyaxially adjustable connection may also be further adapted and configured to permit the position of at least one of the artificial facet joint elements to be continuously adjustable within an adjustability range with respect to the fixation element and may include a limit stop. The polyaxially adjustable connection may also be adapted and configured to permit at least one of the artificial facet joint elements to be moved with respect to the fixation element after installation of the facet joint prosthesis in a patient. In some embodiments the facet joint prosthesis further includes a fastener adapted and configured to prevent relative movement between at least one of the artificial facet joint elements and the fixation element.

[0028] Also according to this aspect of the invention the facet joint prosthesis may further include a longitudinally adjustable connection between at least one of the artificial facet joint elements and the fixation element. In some embodiments, at least one of the artificial facet joint elements includes a facet joint bearing surface and a facet joint bearing surface support, with the facet joint bearing surface support being adapted and configured to be longitudinally movable with respect to the fixation element. The facet joint prosthesis may further include a fastener adapted and configured to prevent relative movement between the facet joint bearing surface support and the fixation element. In some embodiments the facet joint bearing surface support may be further adapted and configured to be rotatable about a support longitudinal axis.

[0029] Further according to this aspect of the invention the polyaxially adjustable connection may include a facet joint element connection surface and a fixation element connection surface, with the facet joint element connection surface and fixation element connection surface being adapted and configured to be movable with respect to each other. The polyaxially adjustable connection may include a base member attached to at least one of the artificial facet joint elements and movable with respect to the fixation element, with the base member possibly being further adapted and configured to be movable with respect to at least one of the artificial facet joint elements.

[0030] Yet another aspect of the invention provides a facet joint prosthesis including first and second fixation elements; an artificial facet joint bearing surface (such as a cephalad bearing surface) adapted and configured to be disposed approximately at a midline of a vertebra when the facet joint prosthesis is installed in a patient; and first and second polyaxially adjustable connections between the facet joint bearing surface and the first and second fixation elements, respectively. In some embodiments the first and second polyaxially adjustable connections may each be adapted and configured to permit the first and second fixation elements to be rotated with respect to the artificial facet joint bearing surface around more than one axis. The facet joint prosthesis may also further include first and second fasteners adapted and configured to prevent relative movement between the artificial facet joint bearing surface and the first and second fixation elements, respectively.

[0031] The facet joint prosthesis according to this aspect of the invention may also include first and second longitudinally adjustable connections between the artificial

facet joint bearing surface and the first and second fixation elements, respectively. In some embodiments the facet joint prosthesis may include a first support arm disposed between the first fixation element and the artificial facet joint bearing surface and a second support arm disposed between the second fixation element and the artificial facet joint bearing surface, with the first and second support arms each being adapted and configured to support the artificial facet joint bearing surface and to be longitudinally movable with respect to the first and second fixation elements, respectively. The facet joint prosthesis may also further include first and second fasteners each adapted and configured to prevent relative movement between the facet joint bearing surface support and the fixation element. In some embodiments, the first support arm may be further adapted and configured to be rotatable about a first support arm longitudinal axis and the second support arm is further adapted and configured to be rotatable about a second support arm longitudinal axis. The first and second support arms may be two separate pieces, or they may be one integral piece. In some embodiments, third and fourth polyaxially adjustable connections between the facet joint bearing surface and the first and second fixation elements, respectively, may be employed.

[0032] Yet another aspect of the invention provides a facet joint prosthesis including an artificial facet joint bearing surface supported by first and second support arms adapted and configured to dispose the artificial facet joint bearing surface approximately at a midline of a vertebra when the facet joint prosthesis is installed in a patient; and first and second fixation elements adapted and configured to attach the first and second support arms, respectively, to a vertebra. The first and second support arms and the artificial facet joint bearing surface may be one integral piece. In some embodiments the facet joint prosthesis further includes first and second polyaxially adjustable connections between the first and second arms and the first and second fixation elements, respectively. In some embodiments, third and fourth polyaxially adjustable connections between the facet joint bearing surface and the first and second fixation elements, respectively, may be employed.

[0033] Another aspect of the invention provides a method of installing an artificial facet joint prosthesis, where the prosthesis includes a facet joint element and a fixation element, the method including the steps of attaching the prosthesis to a vertebra with the fixation element; and adjusting positions of the facet joint element and the

fixation element to a relative orientation. The adjusting step could include the step of moving the facet joint element medially, laterally, superiorly and/or inferiorly with respect to the fixation element. In some embodiments the attaching step is performed prior to the adjusting step, and in some embodiments the attaching step is performed after the adjusting step.

[0034] In some embodiments the adjusting step includes rotating the facet joint element with respect to the fixation element around more than one axis. The method may also include the step of preventing further rotation of the facet joint element after the rotating step.

10 [0035] In embodiments of the method where the facet joint element includes a facet joint bearing surface, the adjusting step may include the step of positioning the facet joint bearing surface laterally from a vertebra midline or approximately at a vertebra midline, and may include the step of positioning the facet joint bearing surface to face caudad or to face cephalad.

15 [0036] The adjusting step may also include the step of moving the facet joint element longitudinally with respect to the fixation element. In some embodiments the method may also include the step of preventing further longitudinal movement of the facet joint element after the moving step. The adjusting step may also include the step of rotating the facet joint element about a facet joint element longitudinal axis.

20 [0037] Other features and advantages of the invention are set forth in the following description and drawings, as well as in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0038] Figure 1 is a lateral elevation view of a normal human spinal column;
- 25 [0039] Figure 2 is a superior plan view of a normal human lumbar vertebra;
- [0040] Figure 3 is a lateral elevation view of adjoining normal human lumbar vertebrae L4 and L5;
- [0041] Figure 4 is a perspective view of one embodiment of a cephalad prosthesis constructed in accordance with the present invention for replacing the inferior half of a
- 30 natural facet joint on a superior vertebral body;
- [0042] Figure 5 is a top plan view of the cephalad prosthesis shown in Figure 4;

- [0043] Figure 6 is a front elevation view of the cephalad prosthesis shown in Figure 4;
- [0044] Figure 7 is a side elevation view of the cephalad prosthesis shown in Figure 4;
- 5 [0045] Figure 8 is a front section view of the cephalad prosthesis shown in Figure 4;
- [0046] Figure 9 is an exploded perspective view depicting various components of the cephalad prosthesis shown in Figure 4, including a set screw, a fixing nut, an artificial facet joint structure, a fixing insert, a base member, and a polyaxial screw member;
- 10 [0047] Figures 10A and 10B provide a top plan view and side section view, respectively, of the set screw shown in Figure 9;
- [0048] Figures 11A and 11B provide a top plan view and side elevation view, respectively, of the fixing nut shown in Figure 9;
- [0049] Figures 12A through 12D provide a top plan view, a front elevation view, a front section view, and a side elevation view, respectively, of the fixing insert shown in Figure 9;
- 15 [0050] Figures 13A through 13C provide a top plan view, a front elevation view, and a front section view, respectively, of the base member shown in Figure 9;
- [0051] Figures 14A through 14D provide a side elevation view, a top plan view, a bottom plan view, and a side section view, respectively, of the polyaxial screw member shown in Figure 9;
- 20 [0052] Figure 15 is a perspective view of one embodiment of a caudal prosthesis constructed in accordance with the present invention for replacing the superior half of a natural facet joint on an inferior vertebral body;
- 25 [0053] Figure 16 is a top plan view of the caudal prosthesis shown in Figure 15;
- [0054] Figure 17 is a side elevation view of the caudal prosthesis shown in Figure 15;
- [0055] Figure 18 is a front elevation view of the caudal prosthesis shown in Figure 15;
- 30 [0056] Figure 19 is a front section view of the caudal prosthesis shown in Figure 15;

[0057] Figure 20 is a posterior elevation view of two pairs of cephalad and caudal prostheses of this invention as installed in a patient;

[0058] Figure 21 is a posterior perspective view of the two pairs of installed cephalad and caudal prostheses of Figure 20;

5 [0059] Figure 22 is a posterior perspective view of installed cephalad and caudal prostheses according to another embodiment of the invention;

[0060] Figure 23 is a posterior elevation view of the prostheses shown in Figure 22;

[0061] Figure 24 is a side elevation view of the prostheses shown in Figures 22
10 and 23;

[0062] Figure 25 is a posterior elevation view of installed cephalad and caudal prostheses according to yet another embodiment of the invention;

[0063] Figure 26 is a side elevation view of the prostheses of Figure 25;

[0064] Figure 27 is a perspective view of the prostheses of Figures 25 and 26;

15 [0065] Figure 28 is a partial sectional view taken along the line A-A shown in Figure 25;

[0066] Figure 29 is a perspective view of a portion of the cephalad prosthesis of Figures 25-27;

[0067] Figure 30 is a partial sectional view taken along the line A-A shown in
20 Figure 29;

[0068] Figure 31 is a perspective view of the caudal prosthesis of Figures 25-27;
and

[0069] Figure 32 is a partial sectional view taken along the line A-A shown in
Figure 31.

25

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0070] Although the disclosure presented herein provides details to enable those skilled in the art to practice various embodiments of the invention, the physical embodiments disclosed herein merely exemplify the invention which may be embodied in
30 other specific structure. Accordingly, while preferred embodiments of the invention are described below, details of the preferred embodiments may be altered without departing

from the invention. All embodiments that fall within the meaning and scope of the appended claims, and equivalents thereto, are intended to be embraced by the claims.

[0071] Figures 4-14 show one embodiment of an artificial cephalad facet joint prosthesis 40 configured to replace the inferior portion of a natural facet joint, such as
5 after the surgical removal of the articulating process forming the inferior portion of the facet joint. When the cephalad prosthesis 40 is attached to a vertebra, the artificial facet joint structure 44 articulates with the superior half of the facet joint 32. The superior half of the facet joint 32 can comprise the natural superior half of the facet joint (i.e., the natural superior articulating surface 30 and supporting bony structure 26) on the vertebral
10 body below the facet joint 32. Alternatively, the superior half of the facet joint 32 may be comprised of an artificial facet joint prosthesis, such as the caudal prosthesis 100 as shown in Figures 15-19.

[0072] Prosthesis 40 includes an artificial facet joint element 44 connected to a fixation element 52 via a polyaxial connection 41 that permits facet joint element 44 and
15 fixation element 52 to be rotated with respect to each other around more than one axis. As will be seen from a detailed discussion of its structure, the embodiment of Figures 4-14 permits continuous adjustment through relative rotation of the facet joint element and the fixation element around many different axes through an adjustability range, up to a motion limit provided by a limit stop. In other embodiments, however, the number of
20 axes of rotation may be limited, and the movement may be permitted only in discrete increments. In various embodiments the facet joint element may be moved medially, laterally, superiorly and/or inferiorly with respect to the fixation element.

[0073] The relative positions of facet joint element 44 and fixation element 52 may be set prior to implant, after implant, or both before and after implant. After implant
25 and adjustment, the facet joint bearing surface 74 of facet joint element 44 may be in an anatomically correct position within the patient's body or in a non-anatomically correct position, depending on the requirements of the situation. For example, Figure 20 shows facet joint prosthesis 40 implanted and adjusted to place the facet joint bearing surface 74 laterally from the midline 119 of vertebrae 115 and 117.

30 [0074] In alternative embodiments, other convex or concave shapes may be used for the facet joint bearing surface. Bearing surface 74 may be formed from biocompatible metals (such as cobalt chromium steel, surgical steels, titanium, titanium

alloys, tantalum, tantalum alloys, aluminum, etc.), ceramics, polyethylene, biocompatible polymers, and other materials known in the prosthetic arts.

[0075] Fixation element 52 may be a screw, stem, corkscrew, wire, staple, adhesive, bone, and other materials known in the prosthetic arts. In the embodiment
5 shown in Figures 4-14, fixation element is a screw with a head 54 and a securing portion 56. A well 58 with an outer periphery shaped to mate with a driver tool is formed in head 54. The bottom tip 57 of fixation element 52 may include cutting edges 59 that facilitate insertion of fixation element 52 into the pedicle or other portion of a vertebra.

[0076] The invention may employ any suitable polyaxial connection structure,
10 such as the structure disclosed in U.S. Patent No. 5,360,431, the disclosure of which is incorporated by reference. In the embodiment of Figures 4-14, the polyaxial connection 41 of cephalad prosthesis 40 includes a base 42 connected to a support arm 72 of facet joint element 44. In alternative embodiments, base 42 may be integral with facet joint element 44. As shown in Figures 8, 13C and 14A, base 42 has a concave inside surface
15 91 that corresponds to and mates with a corresponding convex surface 53 formed on the head 54 of fixation element 52. A fixing insert 50 within base 42 also has a concave surface 78 corresponding to and mating with fixation element head 54 as shown. Concave surfaces 91 and 78 slide along convex surface 53 to permit continuous adjustment through relative rotation between facet joint element 44 and fixation element
20 52 along any axis desired. A limit stop surface 93 formed on the inside of base 42 interacts with fixation element 52 to limit the range of relative rotational motion between base 42 and fixation element 52 to be within an adjustability range.

[0077] In some embodiments, the facet joint prosthesis may also provide for longitudinal adjustment of the facet joint bearing surface location. For example, in the
25 embodiment shown in Figures 4-14, a longitudinally adjustable connection 71 permits support arm 72 to be moved along its longitudinal axis with respect to fixation element 52. In this embodiment, longitudinally adjustable connection 71 is formed from the interaction between the rod-like support arm 72 and a U-shaped channel 76 formed on fixing insert 50. The relative positions of support arm 76 and fixation element 52 may be
30 set prior to implant, after implant, or both before and after implant to adjust the position of the facet joint bearing surface.

[0078] Support arm 72 may also be rotated about its longitudinal axis if desired. While the embodiment shown in Figures 4-14 has a substantially spherical facet joint bearing surface 74, other facet joint bearing surface shapes may be used as well, and rotation of support arm 72 can help adjust the orientation of the facet joint bearing surface. Once again, the relative positions of support arm 72, facet joint bearing surface 74 and fixation element 52 may be set prior to implant, after implant, or both before and after implant.

[0079] One preferred method of installation, assembly and use of the cephalad facet joint prosthesis 40 is as follows. Fixation element 52 is inserted through the interior bore of base 42 until its head 54 rests against surface 91 of base 42. A neck 92 formed within base 42 has a diameter smaller than the diameter of head 54 to prevent fixation element 52 from passing through base 42. A driver tool (not shown) is then placed in well 58 to screw fixation element 52 into the pedicle or other portion of the vertebra. In some embodiments, an insertion hole may be formed in the vertebra prior to screwing in fixation element 52. Bone cement may also be used to hold fixation element 52 in place after insertion.

[0080] Next, the fixing insert 50 is placed within base 42 to rest on fixation element head 54. The U-shaped channel defining the upper surface 76 of the fixing insert 50 is aligned with a U-shaped opening 84 of the base member 42. Support arm 72 of the artificial facet joint element 44 is placed within the U-shaped opening 84 of base 42 and fixing insert 50.

[0081] A fixing nut 48 is threadably engaged with the outer periphery of base 42 above the artificial facet joint element 44. Similarly, a set screw 46 is threadably engaged with the inner periphery of base 42 above the artificial facet joint element 44. The center of set screw 46 is defined by an aperture 64 having a circumference shaped to mate with a corresponding driver tool (not shown).

[0082] Before the set screw 46 and fixing nut 48 are tightened, the position of base 42 is adjusted by rotating the artificial facet joint element 44, fixing insert 50 and base 42 around the outer surface of fixation element head 54. As discussed above, the sliding interaction of fixing insert 50 and base 42 with head 54 permit relative rotation of facet joint element 54 around more than one axis with respect to fixation element 52. The artificial facet joint element 44 is also adjustable along and about its longitudinal axis

within base 42 to place facet joint bearing surface 74 at its desired location. When tightened, fixing nut 48 and set screw 46 act as fasteners to prevent further relative movement between artificial facet joint element 44 and fixation element 52. Other fasteners may be used, of course, as known in the art.

5 [0083] Figures 15-19 show one embodiment of an artificial caudal facet joint prosthesis 100 configured to replace the superior portion of a natural facet joint, such as after the surgical removal of the articulating process forming the superior portion of the facet joint. When the caudal prosthesis 100 is attached to a vertebra, the artificial facet joint structure 104 articulates with the inferior half of the facet joint. The inferior half of
10 the facet joint can comprise the natural inferior half of the facet joint (i.e., the natural inferior articulating surface 31 and supporting bony structure 28 shown in Figures 2 and 3) on the vertebral body below the facet joint. Alternatively, the inferior half of the facet joint may be comprised of an artificial facet joint structure 44, such as the cephalad prosthesis shown in Figures 4-14.

15 [0084] Prosthesis 100 includes an artificial facet joint element 104 connected to a fixation element 116 via a polyaxial connection 115 that permits facet joint element 104 and fixation element 116 to be rotated with respect to each other around more than one axis. Like the embodiment shown in Figures 4-14, the embodiment of Figures 15-19 permits continuous adjustment through relative rotation of the facet joint element and the
20 fixation element around many different axes through an adjustability range, up to a motion limit provided by a limit stop. In other embodiments, however, the number of axes of rotation may be limited, and the movement may be permitted only in discreet increments.

[0085] The relative positions of facet joint element 104 and fixation element 116
25 may be set prior to implant, after implant, or both before and after implant. After implant and adjustment, the facet joint bearing surface 118 of facet joint element 104 may be in an anatomically correct position within the patient's body or in a non-anatomically correct position, depending on the requirements of the situation. For example, Figure 20 shows facet joint prosthesis 104 implanted and adjusted to place the facet joint bearing
30 surface 118 laterally from the midline 119 of vertebrae 115 and 117.

[0086] In alternative embodiments, other convex or concave shapes may be used for the facet joint bearing surface. Bearing surface 118 may be formed from

biocompatible metals (such as cobalt chromium steel, surgical steels, titanium, titanium alloys, tantalum, tantalum alloys, aluminum, etc.), ceramics, polyethylene, biocompatible polymers, and other materials known in the prosthetic arts.

[0087] Fixation element 116 may be a screw, stem, corkscrew, wire, staple, adhesive, bone, and other materials known in the prosthetic arts. As in the embodiment shown in Figures 4-14, fixation element 116 in this embodiment is a screw with a head 114 and a securing portion. A well with an outer periphery shaped to mate with a driver tool is formed in head 114, and the bottom tip of fixation element 116 may include cutting edges that facilitate insertion of fixation element 116 into the pedicle or other portion of a vertebra.

[0088] Many aspects of the caudal prosthesis of this embodiment are similar to aspects of the cephalad prosthesis described above. As shown in Figures 15-19, the polyaxial connection 115 of caudal prosthesis 100 includes a base 112 connected to a support arm 102 of facet joint element 104. In alternative embodiments, base 112 may be integral with facet joint element 104. Base 112 has a concave inside surface that corresponds to and mates with a corresponding convex surface formed on the head 114 of fixation element 116. A fixing insert 110 within base 112 also has a concave surface corresponding to and mating with fixation element head 114 as shown. The concave surfaces of the base and fixing insert slide along the convex surface of the fixation element head 114 to permit continuous adjustment through relative rotation between facet joint element 104 and fixation element 116 along any axis desired. A limit stop surface 120 formed on the inside of base 112 interacts with fixation element 116 to limit the range of relative rotational motion between base 112 and fixation element 116 to be within an adjustability range.

[0089] In some embodiments, the facet joint prosthesis may also provide for longitudinal adjustment of the facet joint bearing surface location. For example, in the embodiment shown in Figures 15-19, a longitudinally adjustable connection 111 permits support arm 102 to be moved along its longitudinal axis with respect to fixation element 116. In this embodiment, longitudinally adjustable connection 111 is formed from the interaction between the rod-like support arm 102 and a U-shaped channel formed on fixing insert 110. The relative positions of support arm 102 and fixation element 116

may be set prior to implant, after implant, or both before and after implant to adjust the position of the facet joint bearing surface.

[0090] Caudal facet joint bearing surface 118 is shaped to mate with a corresponding artificial cephalad facet joint bearing surface that is spherically shaped. In this embodiment, bearing surface 118 is generally concave with a length along one axis 126 greater than the length along a perpendicular axis 128. Other bearing surface shapes may be used, of course. Support arm 102 may be rotated about its longitudinal axis to adjust the orientation of bearing surface 118, and the relative positions of support arm 102, facet joint bearing surface 118 and fixation element 116 may be set prior to implant, after implant, or both before and after implant.

[0091] One preferred method of installation, assembly and use of the caudal facet joint prosthesis 100 is as follows. Fixation element 116 is inserted through the interior bore of base 112 until its head 114 rests against the interior surface 91 of base 112. A neck 122 formed within base 112 has a diameter smaller than the diameter of fixation element head 114 to prevent fixation element 116 from passing through base 112. A driver tool (not shown) is then used to screw fixation element 116 into the pedicle or other portion of the vertebra. In some embodiments, an insertion hole may be formed in the vertebra prior to screwing in fixation element 116. Bone cement may also be used to hold fixation element 116 in place after insertion.

[0092] Next, the fixing insert 100 is placed within base 112 to rest on fixation element head 114. A U-shaped channel in the upper surface of the fixing insert 100 is aligned with a U-shaped opening of the base member 112. Support arm 102 of the artificial facet joint element 104 is placed within the U-shaped opening of base 112 and fixing insert 100.

[0093] A fixing nut 108 is threadably engaged with the outer periphery of base 112 above the artificial facet joint element 104. Similarly, a set screw 106 is threadably engaged with the inner periphery of base 112 above the artificial facet joint element 104. The center of set screw 106 is defined by an aperture having a circumference shaped to mate with a corresponding driver tool (not shown).

[0094] Before the set screw 106 and fixing nut 108 are tightened, the position of base 112 is adjusted by rotating the artificial facet joint element 104, fixing insert 100 and base 112 around the outer surface of fixation element head 114. As discussed above, the

sliding interaction of fixing insert 100 and base 112 with head 114 permit relative rotation of facet joint element 104 around more than one axis with respect to fixation element 116. The artificial facet joint element 104 is also adjustable along and about its longitudinal axis within base 112 to place facet joint bearing surface 118 at its desired location. When
5 tightened, fixing nut 108 and set screw 106 act as fasteners to prevent further relative movement between artificial facet joint element 104 and fixation element 116. Other fasteners may be used, of course, as known in the art.

[0095] From the description herein, it should be understood that either the cephalad prosthesis 40 or the caudal prosthesis 100 may be used for unilateral facet joint
10 replacement (one side of a given vertebral body). The prostheses 40 and 100 may also be used to provide bilateral facet joint replacement (i.e., on both the left and right sides of a given vertebral body).

[0096] Furthermore, as shown in Figures 20 and 21, a system comprised of both prostheses 40 and 100 may be used to provide complete (i.e., superior and inferior) facet
15 joint replacement of one or more natural facet joints. The cephalad prostheses 40 and caudal prosthesis 100 are desirably positioned to form an articulated system that replaces a natural facet joint. Cephalad prostheses 40 are attached to the superior adjoining vertebra and replace the articulating function of the cephalad portion of the natural facet joints. Likewise, caudal prostheses 100 are attached to the inferior adjoining vertebra and
20 replace the articulating function of the caudal portion of the natural facet joints. The facet joint bearing surfaces of prostheses 40 and 100 thus cooperate to provide an artificial articular configuration. The complete facet joint replacement can be unilateral or bilateral, as desired. A bilateral facet joint replacement is shown in Figures 20 and 21.

[0097] Figure 20 provides a posterior elevation view of two adjacent lumbar
25 vertebrae after removal of the inferior and superior halves of the natural facet joints on both the left and right sides of the adjacent vertebrae. Since the inferior and superior halves of the natural facet joint are removed, the artificial articular configuration need not be constrained by, and can be unlike, the preexisting articulation of the natural facet joint prior to its removal.

30 [0098] Preferably, a polyaxial attachment mechanism is configured to attach either the cephalad prostheses 40 to the superior adjoining vertebra, or the caudal prostheses 100 to the inferior adjoining vertebra, or both. As described earlier, the

polyaxial attachment mechanism permits the position of the artificial facet joint structure of the cephalad and/or caudal prosthesis 40, 100 (as the case may be) to be adjusted along more than one axis after the polyaxial attachment mechanism has been attached to the superior and/or inferior vertebra. The systems 130 depicted in Figures 20 and 21 include
5 polyaxial attachment mechanisms for both the cephalad prostheses and the caudal prostheses. Accordingly, a physician is provided maximum flexibility to position the articulating surfaces of the prostheses 40 and 100 when the prostheses are attached to the vertebrae. The position of the artificial facet joint structures can be fully adjusted to obtain an optimal articulation between the adjoining vertebrae, and together create a
10 desired lordotic angle between the vertebral bodies of the vertebrae.

[0099] Figures 22-24 show cephalad and caudal facet joint prostheses according to another embodiment of the invention providing an artificial facet joint located approximately at the center or midline of the vertebrae to which the prostheses are attached. Cephalad prosthesis 200 has a facet joint element 201 including two support
15 arms or rods 202 and 204 supporting a cephalad bearing surface element 206. While other materials may be used, support arms 202 and 204 are preferably formed from titanium, and bearing surface element 206 is preferably formed from biocompatible metals (such as cobalt chromium steel, surgical steels, titanium, titanium alloys, tantalum, tantalum alloys, aluminum, etc.), ceramics, polyethylene, biocompatible polymers, and
20 other materials known in the prosthetic arts. In this embodiment, support arms 202 and 204 and bearing surface element 206 are separate elements and may be selected from a kit containing different size elements to meet the needs of the patient. For example, support arms ranging in size from 10 mm to 25 mm in length may be used for cephalad prostheses attached to the L4 vertebra.

25 [00100] In alternative embodiments, support arms 202 and 204 may be formed as a single element and may also be integral with bearing surface 206. In other alternative embodiments, one or more bushings (not shown) are disposed between bearing surface element 206 and the support arms 202 and 204 to enable bearing surface element 206 to rotate about support arms 202 and 204.

30 [00101] Support arms 202 and 204 are each attached to superior vertebra 208 via fixation elements such as screw, stem, corkscrew, wire, staple, adhesive, bone, and other materials known in the prosthetic arts. As shown, the fixation elements attach prosthesis

200 to pedicle portions of vertebra 208. Attachment to other portions of vertebra 208 are possible as well.

[00102] Polyaxial connections 210 and 212 between support arms 202 and 204 and their respective fixation elements permit support arms 202 and 204, and thereby cephalad
5 facet joint element 201, to be rotated about the fixation elements around more than one axis. In fact, polyaxial connections 210 and 212 permit continuous adjustment between support arms 202 and 204 and their fixation elements around many axes, up to a motion limit provided by a limit stop. In this embodiment, polyaxial connections 210 and 212 are substantially the same as those shown in the embodiments of Figures 4-19. In other
10 embodiments, however, other polyaxial connections may be used; the number of axes of rotation may also be limited, and movement may be permitted only in discrete increments.

[00103] The relative positions of cephalad facet joint element 201 and the fixation elements may be set prior to implant, after implant, or both before and after implant. In
15 addition, this embodiment provides for longitudinal adjustment between the facet joint element 201 and the fixation elements. The longitudinally adjustable connections 214 and 216 permits arms 202 and 204, respectively, to be moved along longitudinal axes with respect to their fixation elements. Once again, the longitudinally adjustable connections of this embodiment are substantially similar to the longitudinally adjustable
20 connections described above with respect to the embodiments shown in Figures 4-19. In this embodiment, support arms 202 and 204 may also be rotated about longitudinal axes, if desired. The relative longitudinal and rotational positions of support arms 202 and 204 and their fixation elements may be set prior to implant, after implant, or both before and after implant to adjust the position of the cephalad facet joint bearing surface 206.

[00104] Figures 22-24 also show a caudal facet joint prosthesis 300 with an artificial facet joint bearing surface 302 supported by support arms 304 and 306. In this
25 embodiment, artificial facet bearing surface 302 is disposed substantially at the midline of vertebra 308 so as to meet and interact with the facet bearing surface 206 of cephalad prosthesis 200, as shown. Fixation elements 310 and 312 attach support arms 304 and
30 306, respectively, to vertebra 308, such as at pedicle portions of the vertebra. Fixation elements 310 and 312 may be a screw, stem, corkscrew, wire, staple, adhesive, bone, and other materials known in the prosthetic arts. In this embodiment, support arms 304 and

306 and facet bearing surface 302 are formed as a integral piece. In other embodiments, these elements may be formed as separate pieces. In use, caudal prosthesis 300 may be selected from a kit containing caudal prostheses of different sizes, such as between 32 mm and 60 mm wide prostheses for the L5 vertebra.

5 [00105] Figures 25-30 show yet another embodiment of the invention providing another artificial facet joint located approximately at the midline of the vertebrae. Cephalad prosthesis 400 has a facet joint element including two support arms or rods 402 and 404 supporting a cephalad bearing element 406. In this embodiment, facet joint element 406 includes a facet joint bearing surface element 414 with a facet joint bearing
10 surface 416 formed on one side thereof. As shown, facet joint bearing surface element 414 has a plate 418 extending from its posterior side. In this embodiment, plate 418 attaches to facet joint bearing surface element 414 via a force fit connection at the crossbar's centerpoint 420. Plate 418 connects to support arms 402 and 404 via polyaxial connections 422 and 424, respectively. The appropriate size of the prosthesis, such as the
15 width of plate 418 and the size of bearing surface 416, may be determined by a sizing tool and selected appropriately.

[00106] Support arms 402 and 404 are each attached to superior vertebra 408 via fixation elements such as screw, stem, corkscrew, wire, staple, adhesive, bone, and other materials known in the prosthetic arts. As shown, the fixation elements are screws 403
20 which attach prosthesis 400 to pedicle portions of vertebra 408. Attachment to other portions of vertebra 408 are possible as well.

[00107] Polyaxial connections 410 and 412 between support arms 402 and 404 and their respective fixation elements permit support arms 402 and 404, and thereby cephalad facet joint element 406, to be rotated about the pedicle fixation elements around more
25 than one axis. In fact, polyaxial connections 410 and 412 permit continuous adjustment between support arms 402 and 404 and their fixation elements around many axes, up to a motion limit provided by a limit stop. In this embodiment, polyaxial connections 410 and 412 are substantially the same as those shown in the embodiments of Figures 4-19. In other embodiments, however, other polyaxial connections may be used; the number of
30 axes of rotation may also be limited, and movement may be permitted only in discrete increments.

[00108] The structure of polyaxial connections 422 and 424 in this embodiment is shown in Figure 30. As shown, support arm 404 has a head 426 with a substantially spherical surface 428 disposed in a spherical pocket 430 formed in plate 418. Support arm 404 extends through an opening 432 in plate 418 that is wider than the arm portion of support arm 404 but narrower than the support arm head 426. As can be seen from Figure 30, the connection between support arm 404 and plate 418 permits support arm 404 and plate 418 to be rotated with respect to each other about more than one axis. Once the proper relative orientation has been achieved, a nut 434 mounted on a threaded portion 436 of support arm 404 is tightened against plate 418. The concave face of nut 434 matches the convex shape of the underside of plate 418 to enable nut 434 to be tightened against plate 418 to maintain the relative orientation of support arm 404 and plate 418. Polyaxial connection 422 has a substantially similar construction.

[00109] While other materials may be used, support arms 402 and 404 and plate 418 are preferably formed from titanium, and facet joint element 406 is preferably formed from biocompatible metals (such as cobalt chromium steel, surgical steels, titanium, titanium alloys, tantalum, tantalum alloys, aluminum, etc.), ceramics, polyethylene, biocompatible polymers, and other materials known in the prosthetic arts.

[00110] Caudal prosthesis 500 has an artificial facet joint bearing surface 502 supported by support arms 504 and 506. In this embodiment, artificial facet joint bearing surface 502 is disposed substantially at the midline of vertebra 508 so as to meet and interact with the facet joint bearing surface 416 of the cephalad prosthesis 400, as shown in Figure 28. When installed in the patient, support arms 504 and 506 elevate facet joint bearing surface 502 above the dura portion of the vertebra.

[00111] Fixation elements 510 and 512 attach caudal prosthesis 500 to vertebra 508, such as at pedicle portions of the vertebra as shown. Fixation elements 510 and 512 may be a screw, stem, corkscrew, wire, staple, adhesive, bone, and other materials known in the prosthetic arts. In the embodiment shown in Figures 25-30, fixation elements 510 and 512 are self-tapping screws.

[00112] The appropriate size of caudal prosthesis 500 may be determined by using a sizing tool. To attach caudal prosthesis 500 to vertebra 508, a probe is used to determine the appropriate screw length to be used, as known in the art. The probe makes a pilot hole for the screw. As shown in Figure 30, the screws 510 and 512 are inserted

into caudal screw housings 514 and 516, respectively, which have substantially conical inside surfaces, such as surface 518 of housing 514. The screws have substantially spherical heads, such as screw head 520 of screw 510. The interaction of the spherical screw heads with the conical screw housing surfaces enables the screws to be inserted at angles other than 90°. After insertion, set screws 522 and 524 with substantially spherically concave bottom surfaces are inserted into screw housings 514 and 516, respectively, to hold support arms 504 and 506 against their respective screws.

5 [00113] The interaction between the cephalad and caudal bearing surfaces governs how the vertebrae to which they are attached move with respect to each other. The bearing surface shapes can provide motion limit stops and can help replace the function of removed ligaments. For example, the cephalad and caudal bearing surfaces of some preferred embodiments of the invention provide for ranges of motion of 0 to 20 degrees in flexion, 0 to 10 degrees in extension, 0 to 15 degrees in axial rotation, and 0 to 4 degrees in lateral bending.

10 [00114] The relative shapes of the cephalad and caudal bearing surfaces also govern the quality of the relative movement between the vertebrae to which they are attached. For example, the quality of the relative movement provided by the movable cephalad bearing surface described above with reference to Figures 22-24 is different than the sliding point of contact connection between the concave cephalad bearing surface and convex caudal bearing surface of the embodiment shown in Figures 25-30.

15 [00115] While preferred embodiments of the invention have been illustrated and described, it will be appreciated that various changes can be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A facet joint prosthesis comprising an artificial facet joint element connected to a fixation element by a polyaxially adjustable connection.
2. The facet joint prosthesis of claim 1 wherein the polyaxially adjustable connection is adapted and configured to permit the artificial facet joint element to be rotated with respect to the fixation element around more than one axis.
3. The facet joint prosthesis of claim 2 wherein the polyaxially adjustable connection is further adapted and configured to permit the position of the artificial facet joint element to be continuously adjustable within an adjustability range with respect to the fixation element.
4. The facet joint prosthesis of claim 2 wherein the polyaxially adjustable connection comprises a limit stop.
5. The facet joint prosthesis of claim 1 wherein the artificial facet joint element is adapted to be movable medially with respect to the fixation element.
6. The facet joint prosthesis of claim 1 wherein the artificial facet joint element is adapted to be movable laterally with respect to the fixation element.
7. The facet joint prosthesis of claim 1 wherein the artificial facet joint element is adapted to be movable superiorly with respect to the fixation element.
8. The facet joint prosthesis of claim 1 wherein the artificial facet joint element is adapted to be movable inferiorly with respect to the fixation element.
9. The facet joint prosthesis of claim 1 wherein the polyaxially adjustable connection is adapted and configured to permit the artificial facet joint element to be moved with respect to the fixation element after installation of the facet joint prosthesis in a patient.
10. The facet joint prosthesis of claim 1 further comprising a fastener adapted and configured to prevent movement between the artificial facet joint element and the fixation element.
11. The facet joint prosthesis of claim 1 wherein the artificial facet joint element comprises a cephalad facet joint bearing surface and a cephalad facet joint bearing surface support.
12. The facet joint prosthesis of claim 11 wherein the cephalad facet joint bearing surface and the cephalad facet joint bearing surface support are adapted and

configured to be disposed laterally from a midline of a vertebra when the facet joint prosthesis is installed in a patient.

13. The facet joint prosthesis of claim 11 wherein the cephalad facet joint bearing surface and the cephalad facet joint bearing surface support are adapted and configured to be disposed approximately at a midline of a vertebra when the facet joint prosthesis is installed in a patient.

14. The facet joint prosthesis of claim 1 wherein the artificial facet joint element comprises a caudal facet joint bearing surface and a caudal facet joint bearing surface support.

15. The facet joint prosthesis of claim 14 wherein the caudal facet joint bearing surface and the caudal facet joint bearing surface support are adapted and configured to be disposed laterally from a midline of a vertebra when the facet joint prosthesis is installed in a patient.

16. The facet joint prosthesis of claim 1 further comprising a longitudinally adjustable connection between the artificial facet joint element and the fixation element.

17. The facet joint prosthesis of claim 16 wherein the artificial facet joint element comprises a facet joint bearing surface and a facet joint bearing surface support, the facet joint bearing surface support being adapted and configured to be longitudinally movable with respect to the fixation element.

18. The facet joint prosthesis of claim 17 further comprising a fastener adapted and configured to prevent relative movement between the facet joint bearing surface support and the fixation element.

19. The facet joint prosthesis of claim 17 wherein the facet joint bearing surface support is further adapted and configured to be rotatable about a support longitudinal axis.

20. The facet joint prosthesis of claim 1 wherein the polyaxially adjustable connection comprises a facet joint element connection surface and a fixation element connection surface, the facet joint element connection surface and fixation element connection surface being adapted and configured to be movable with respect to each other.

21. The facet joint prosthesis of claim 1 wherein the polyaxially adjustable connection comprises a base member attached to the artificial facet joint element and movable with respect to the fixation element.

22. The facet joint prosthesis of claim 21 wherein the base member is further adapted and configured to be movable with respect to the artificial facet joint element.

23. A facet joint prosthesis comprising:
first and second artificial facet joint elements;
a fixation element; and
a polyaxially adjustable connection between at least one of the first or second facet joint elements and the fixation element.

24. The facet joint prosthesis of claim 23 wherein the first artificial facet joint element comprises an artificial cephalad facet joint element and the second artificial facet joint element comprises an artificial caudal facet joint element.

25. The facet joint prosthesis of claim 24 wherein the fixation element comprises a cephalad fixation element and the polyaxially adjustable connection comprises a cephalad polyaxially adjustable connection, the facet joint prosthesis further comprising a caudal fixation element and a caudal polyaxially adjustable connection between the artificial caudal facet joint bearing element and the caudal fixation element.

26. The facet joint prosthesis of claim 25 wherein the artificial cephalad facet joint element comprises a cephalad bearing surface and a cephalad bearing surface support.

27. The facet joint prosthesis of claim 25 wherein the artificial caudal facet joint element comprises a caudal bearing surface and a caudal bearing surface support.

28. The facet joint prosthesis of claim 23 wherein the first and second artificial facet joint elements comprise first and second artificial cephalad facet joint elements, respectively.

29. The facet joint prosthesis of claim 28 wherein the fixation element comprises a first cephalad fixation element and the polyaxially adjustable connection comprises a first cephalad polyaxially adjustable connection, the facet joint prosthesis further comprising a second cephalad fixation element and a second cephalad polyaxially adjustable connection between the second artificial cephalad facet joint element and the second cephalad fixation element.

30. The facet joint prosthesis of claim 28 wherein the first and second artificial cephalad facet joint elements comprise first and second cephalad bearing surfaces, respectively.

5 31. The facet joint prosthesis of claim 28 wherein the first and second artificial facet joint elements comprise first and second support arms, respectively, and at least one cephalad bearing surface supported by at least one of the first and second support arms.

32. The facet joint prosthesis of claim 31 wherein the cephalad bearing surface is disposed approximately at a midline of a vertebra when the prosthesis is installed in a patient.

10 33. The facet joint prosthesis of claim 32 wherein the cephalad bearing surface is adapted to rotate about the support arm or arms by which it is supported.

34. The facet joint prosthesis of claim 32 further comprising an artificial caudal facet joint element comprising a caudal bearing surface adapted and configured to mate with the cephalad bearing surface.

15 35. The facet joint prosthesis of claim 34 wherein the polyaxially adjustable connection is adapted and configured to permit at least one of the artificial facet joint elements to be rotated with respect to the fixation element around more than one axis.

36. The facet joint prosthesis of claim 35 wherein the polyaxially adjustable connection is further adapted and configured to permit the position of at least one of the artificial facet joint elements to be continuously adjustable within an adjustability range with respect to the fixation element.

37. The facet joint prosthesis of claim 35 wherein the polyaxially adjustable connection comprises a limit stop.

25 38. The facet joint prosthesis of claim 23 wherein the polyaxially adjustable connection is adapted and configured to permit at least one of the artificial facet joint elements to be moved with respect to the fixation element after installation of the facet joint prosthesis in a patient.

39. The facet joint prosthesis of claim 23 further comprising a fastener adapted and configured to prevent relative movement between at least one of the artificial facet joint elements and the fixation element.

30

40. The facet joint prosthesis of claim 23 further comprising a longitudinally adjustable connection between at least one of the artificial facet joint elements and the fixation element.

41. The facet joint prosthesis of claim 40 wherein at least one of the artificial
5 facet joint elements comprises a facet joint bearing surface and a facet joint bearing surface support, the facet joint bearing surface support being adapted and configured to be longitudinally movable with respect to the fixation element.

42. The facet joint prosthesis of claim 41 further comprising a fastener adapted and configured to prevent relative movement between the facet joint bearing
10 surface support and the fixation element.

43. The facet joint prosthesis of claim 41 wherein the facet joint bearing surface support is further adapted and configured to be rotatable about a support longitudinal axis.

44. The facet joint prosthesis of claim 23 wherein the polyaxially adjustable
15 connection comprises a facet joint element connection surface and a fixation element connection surface, the facet joint element connection surface and fixation element connection surface being adapted and configured to be movable with respect to each other.

45. The facet joint prosthesis of claim 23 wherein the polyaxially adjustable
20 connection comprises a base member attached to at least one of the artificial facet joint elements and movable with respect to the fixation element.

46. The facet joint prosthesis of claim 45 wherein the base member is further adapted and configured to be movable with respect to at least one of the artificial facet joint elements.

25 47. A facet joint prosthesis comprising:

first and second fixation elements;

an artificial facet joint bearing surface adapted and configured to be disposed approximately at a midline of a vertebra when the facet joint prosthesis is installed in a patient; and

30 first and second polyaxially adjustable connections between the facet joint bearing surface and the first and second fixation elements, respectively.

48. The facet joint prosthesis of claim 47 wherein the first and second polyaxially adjustable connections are each adapted and configured to permit the first and second fixation elements to be rotated with respect to the artificial facet joint bearing surface around more than one axis.

5 49. The facet joint prosthesis of claim 47 further comprising first and second fasteners adapted and configured to prevent relative movement between the artificial facet joint bearing surface and the first and second fixation elements, respectively.

50. The facet joint prosthesis of claim 47 further comprising first and second longitudinally adjustable connections between the artificial facet joint bearing surface and
10 the first and second fixation elements, respectively.

51. The facet joint prosthesis of claim 50 further comprising a first support arm disposed between the first fixation element and the artificial facet joint bearing surface and a second support arm disposed between the second fixation element and the artificial facet joint bearing surface, the first and second support arms each being adapted
15 and configured to support the artificial facet joint bearing surface and to be longitudinally movable with respect to the first and second fixation elements, respectively.

52. The facet joint prosthesis of claim 51 further comprising first and second fasteners each adapted and configured to prevent relative movement between the facet joint bearing surface support and the fixation element.

20 53. The facet joint prosthesis of claim 51 wherein the first support arm is further adapted and configured to be rotatable about a first support arm longitudinal axis and the second support arm is further adapted and configured to be rotatable about a second support arm longitudinal axis.

54. The facet joint prosthesis of claim 51 wherein the first and second support
25 arms comprise two separate pieces.

55. The facet joint prosthesis of claim 51 wherein the first and second support arms comprise one integral piece.

56. The facet joint prosthesis of claim 47 wherein the artificial facet joint bearing surface is adapted and configured to be a cephalad facet joint bearing surface.

30 57. The facet joint prosthesis of claim 47 further comprising third and fourth polyaxially adjustable connections between the facet joint bearing surface and the first and second fixation elements, respectively.

58. A facet joint prosthesis comprising:

an artificial facet joint bearing surface supported by first and second support arms adapted and configured to dispose the artificial facet joint bearing surface approximately at a midline of a vertebra when the facet joint prosthesis is installed in a patient; and

5 first and second fixation elements adapted and configured to attach the first and second support arms, respectively, to a vertebra.

59. The facet joint prosthesis of claim 58 wherein the first and second support arms and the artificial facet joint bearing surface comprise one integral piece.

60. The facet joint prosthesis of claim 58 further comprising first and second
10 polyaxially adjustable connections between the first and second arms and the first and second fixation elements, respectively.

61. The facet joint prosthesis of claim 60 further comprising third and fourth polyaxially adjustable connections between the facet joint bearing surface and the first and second fixation elements, respectively.

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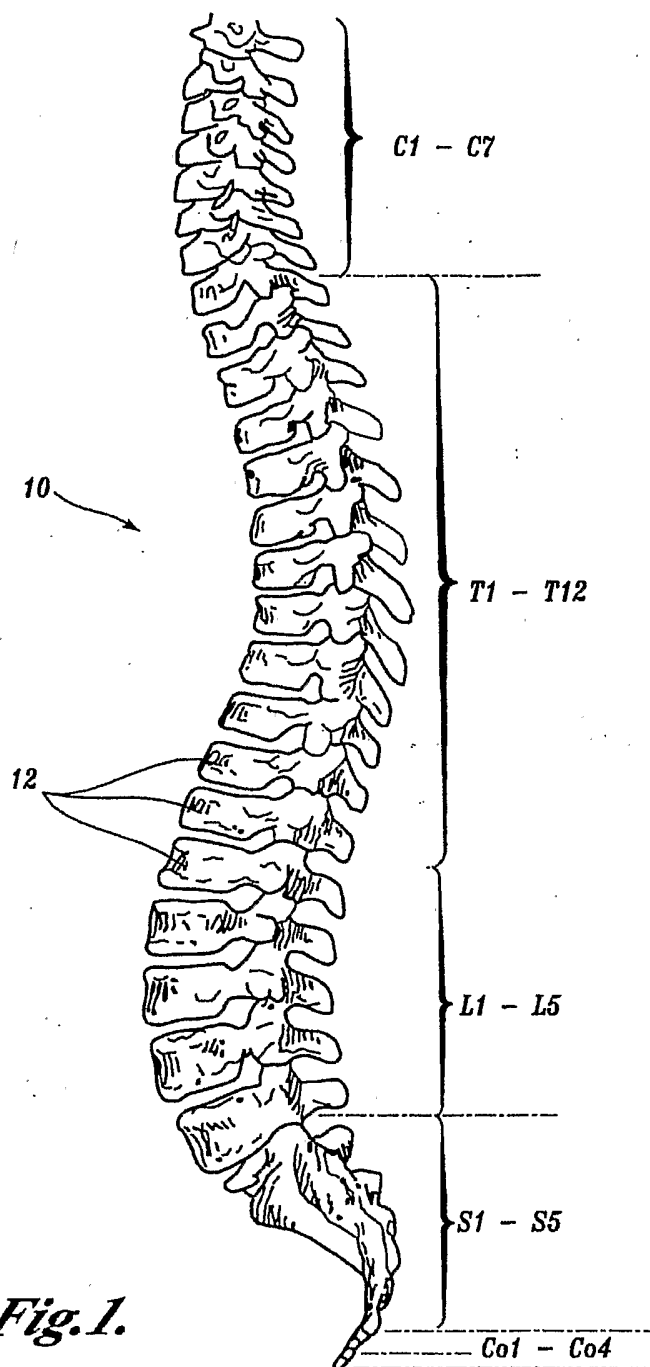
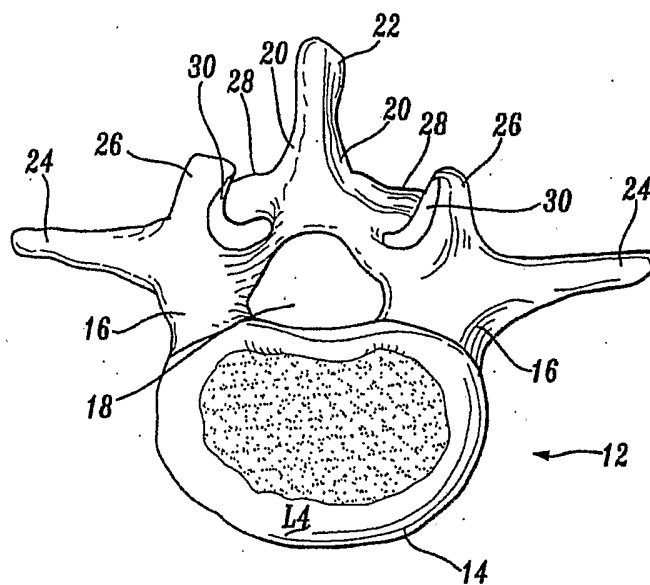
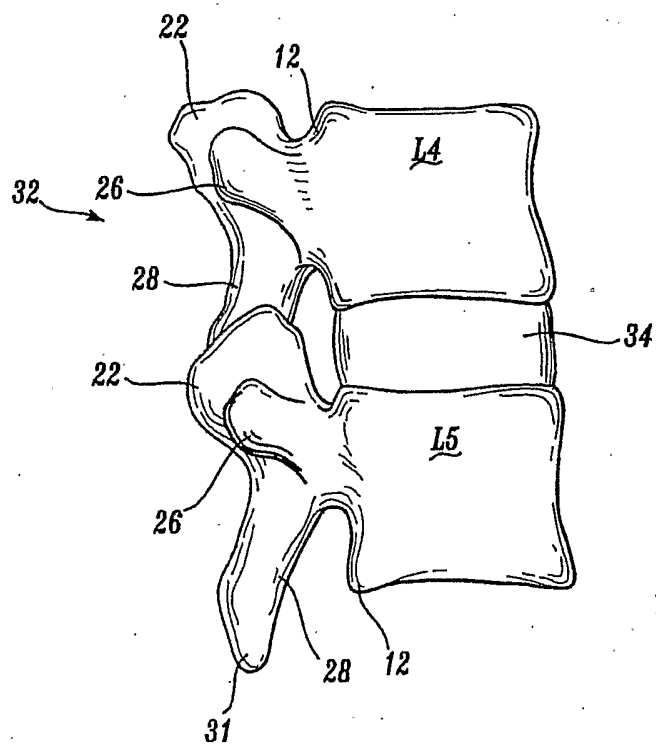


Fig.1.

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*Fig. 2.**Fig. 3.*

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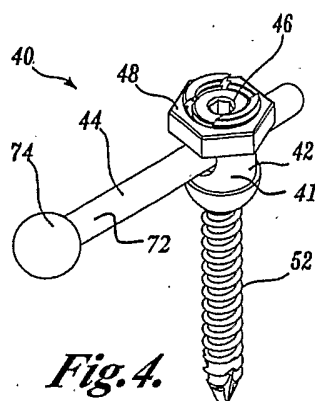


Fig. 4.

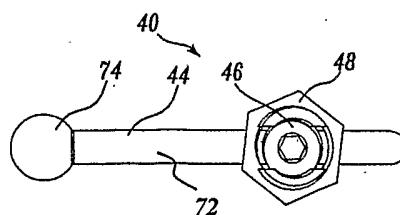


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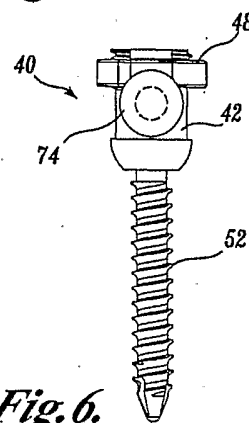


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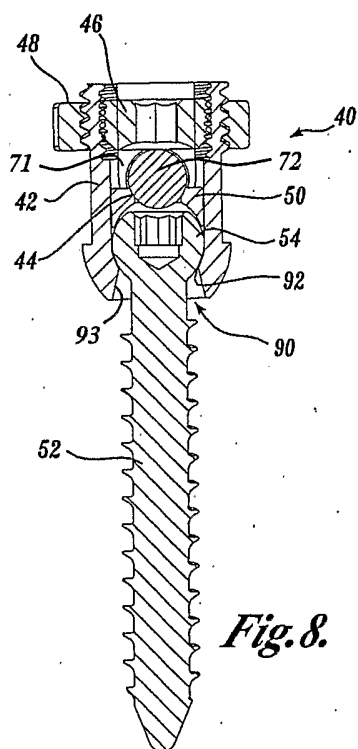


Fig. 8.

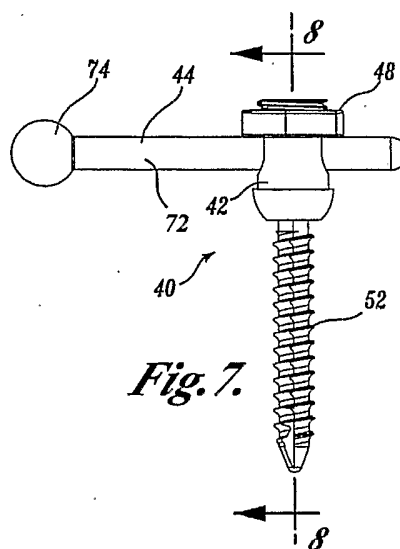


Fig. 7.

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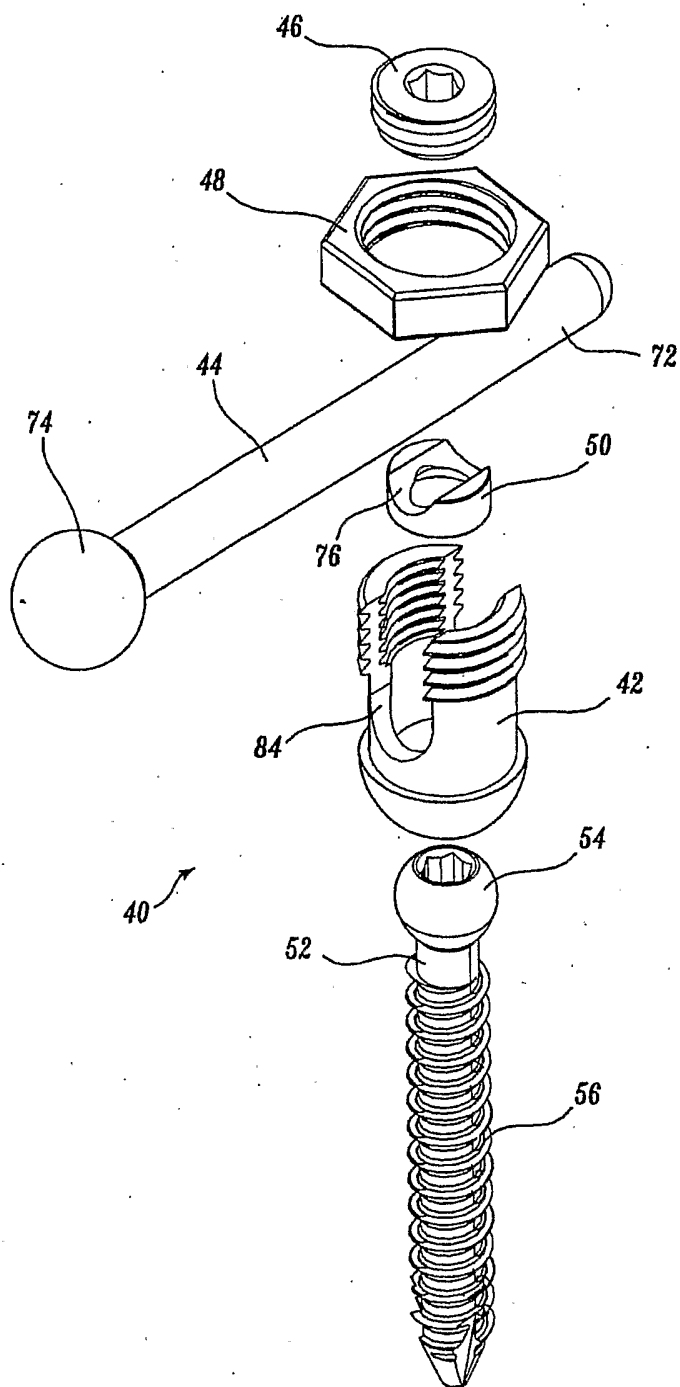


Fig. 9.

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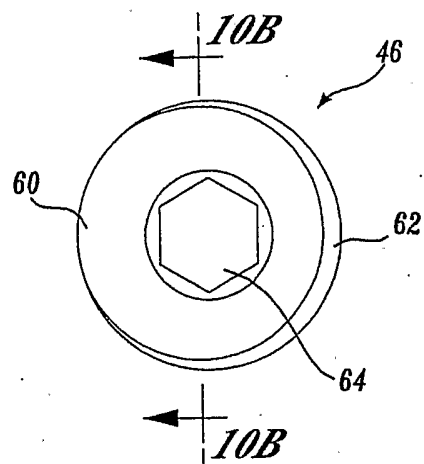


Fig. 10A.

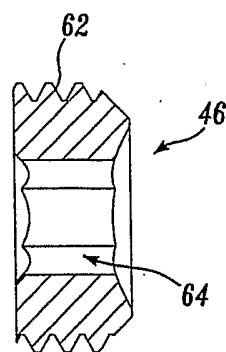


Fig. 10B.

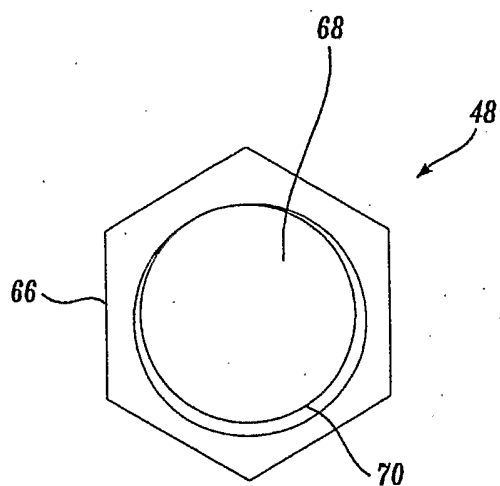


Fig. 11A.

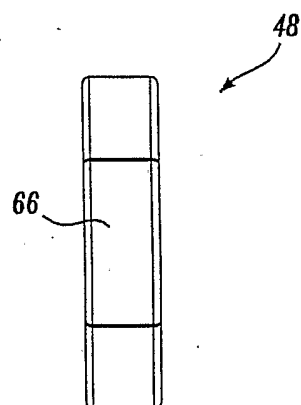


Fig. 11B.

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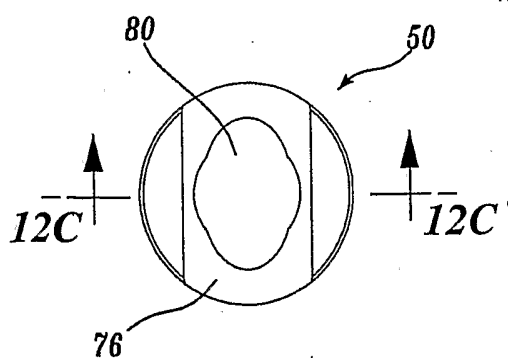


Fig. 12A.

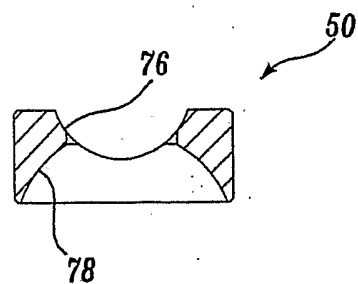


Fig. 12C.

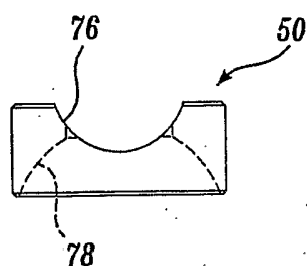


Fig. 12B.

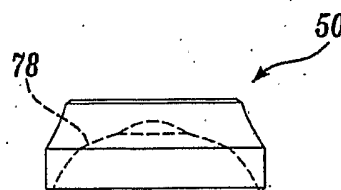


Fig. 12D.

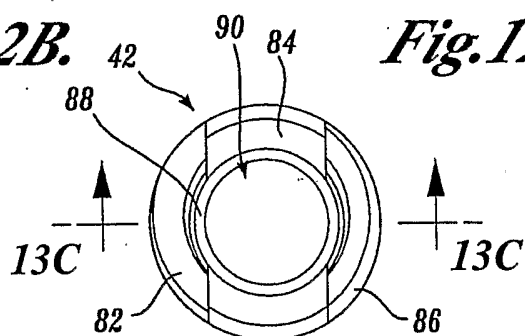


Fig. 13A.

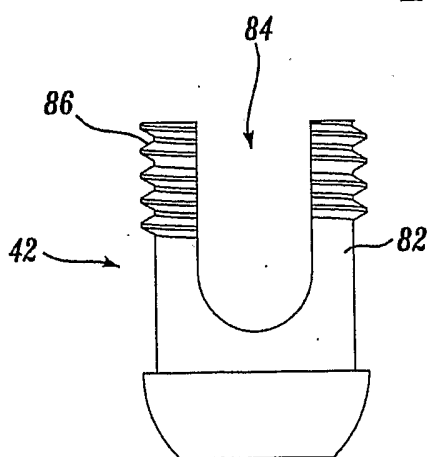


Fig. 13B.

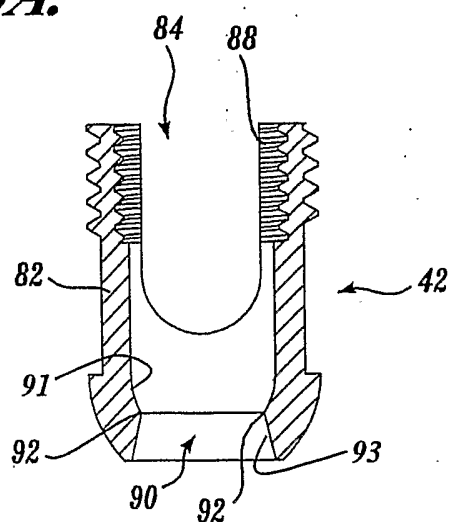
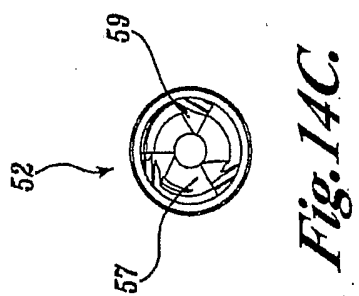
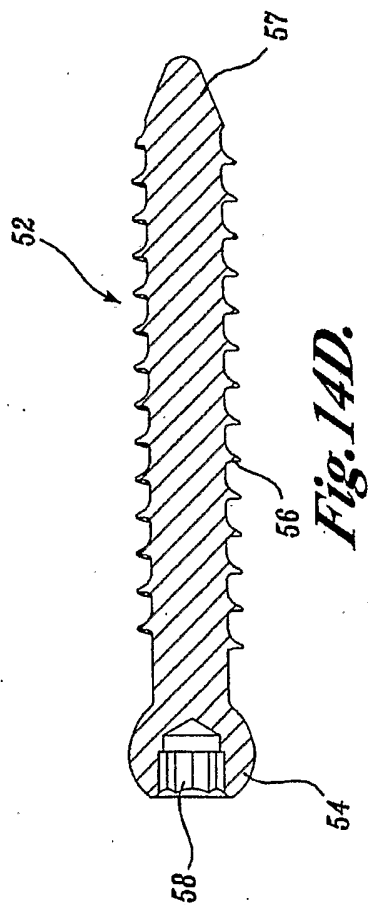
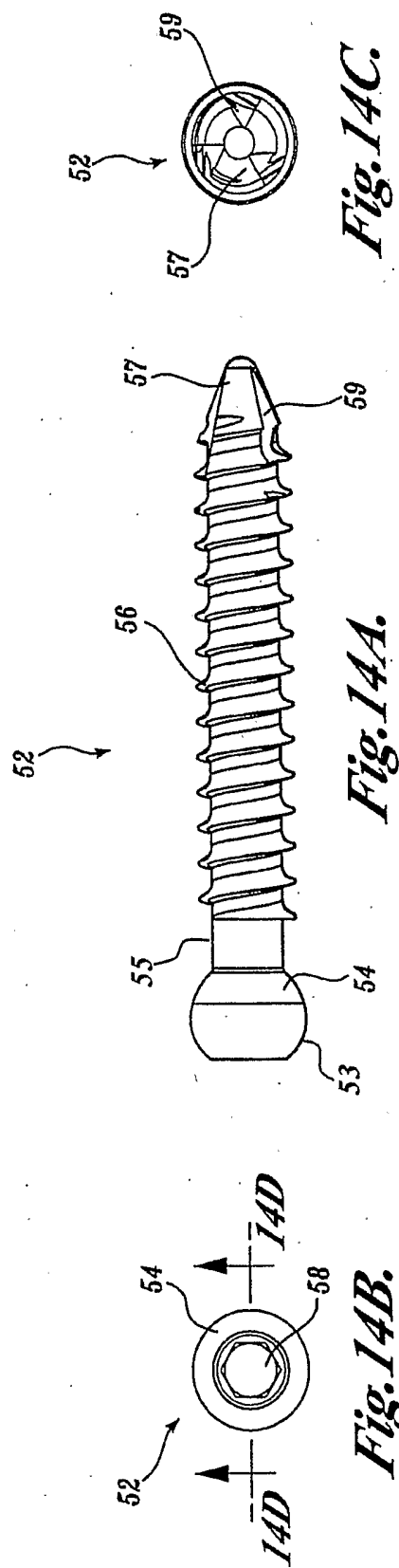


Fig. 13C.

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Fig.15.

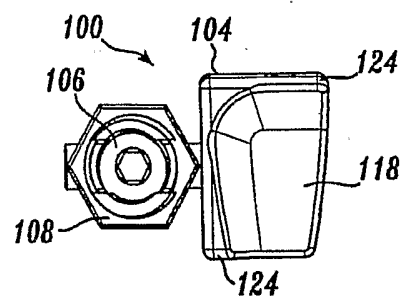
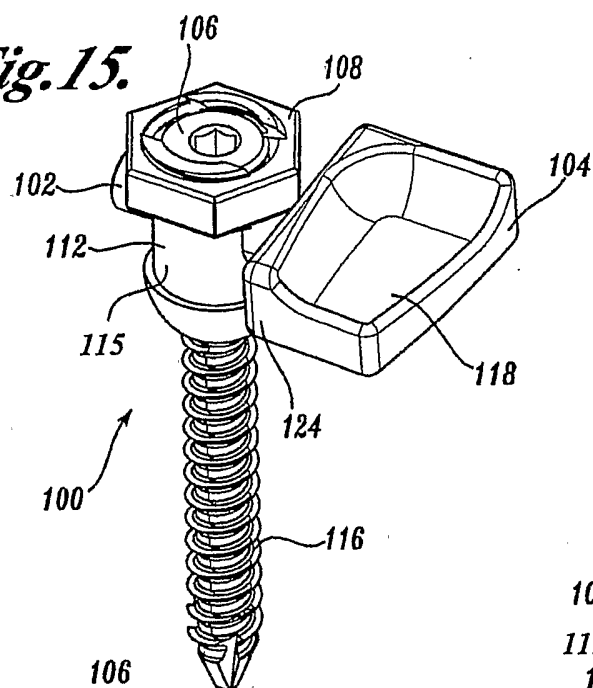


Fig.16.

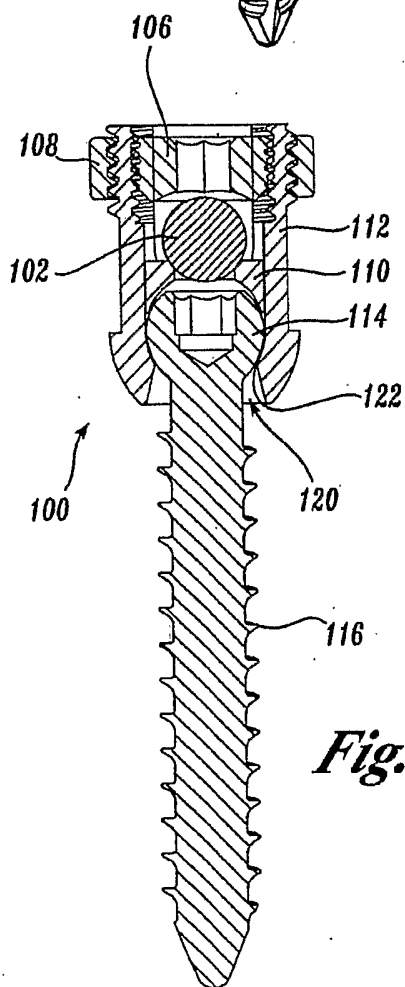


Fig.19.

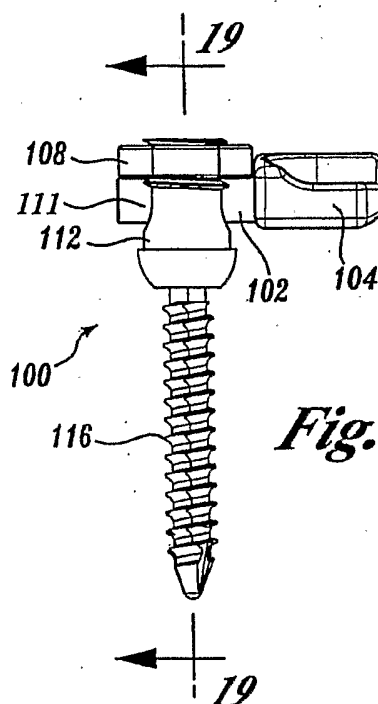


Fig.17.

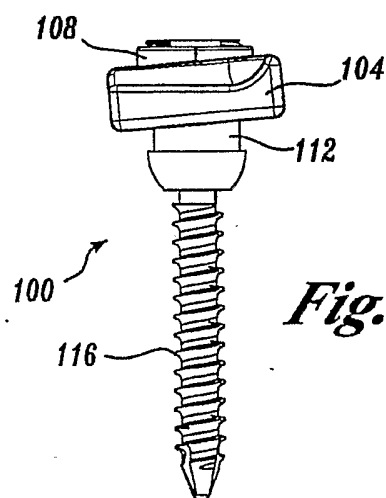


Fig.18.

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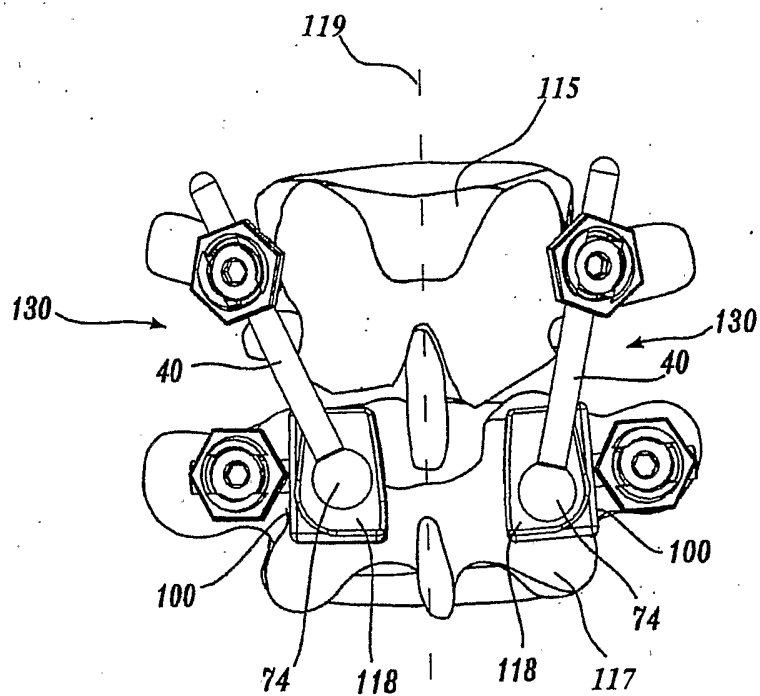


Fig. 20.

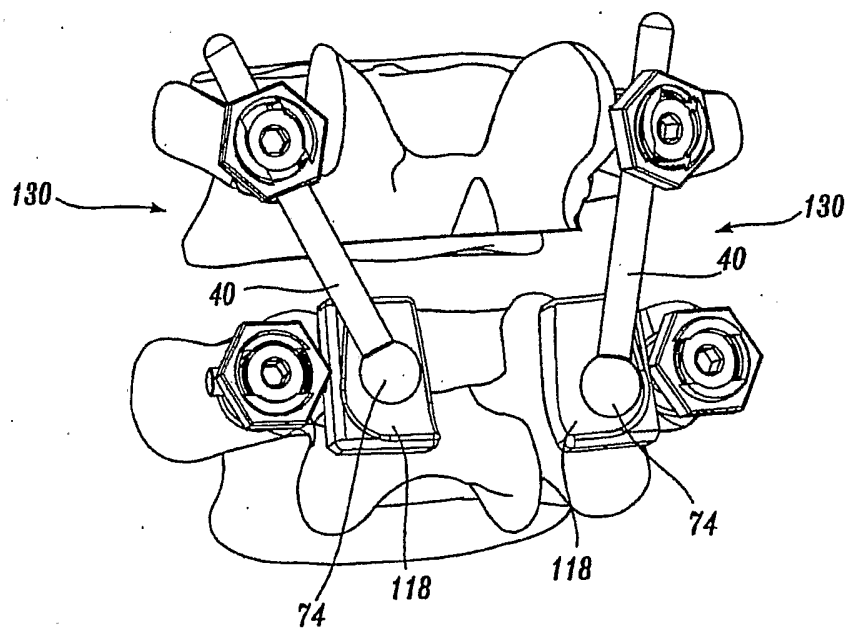


Fig. 21.

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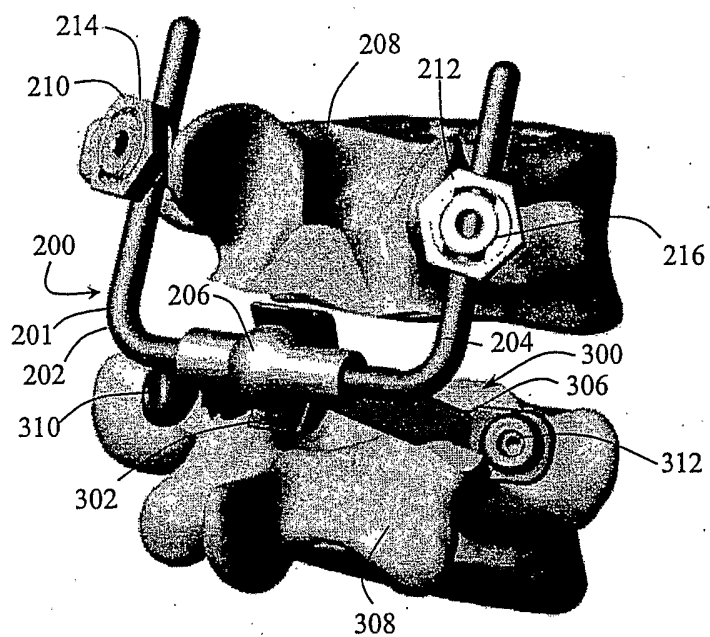


Fig. 22.

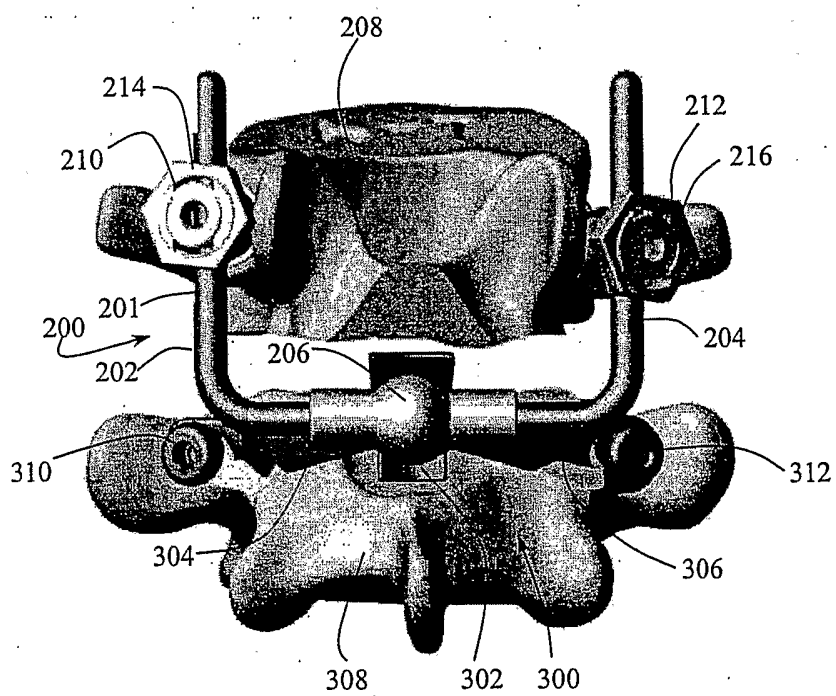


Fig. 23.

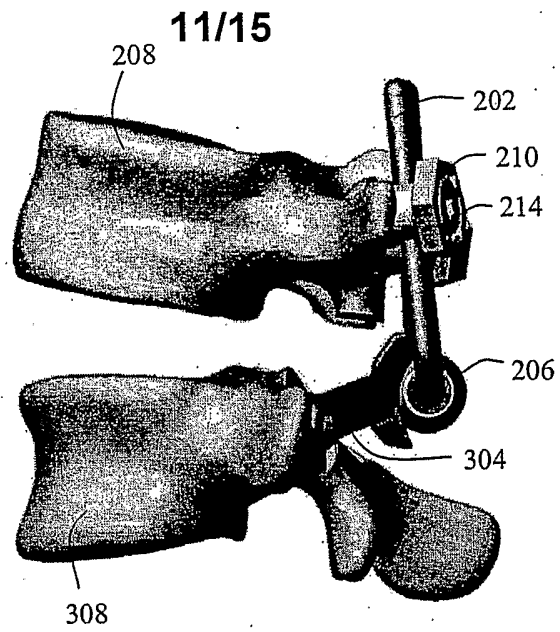


Fig. 24.

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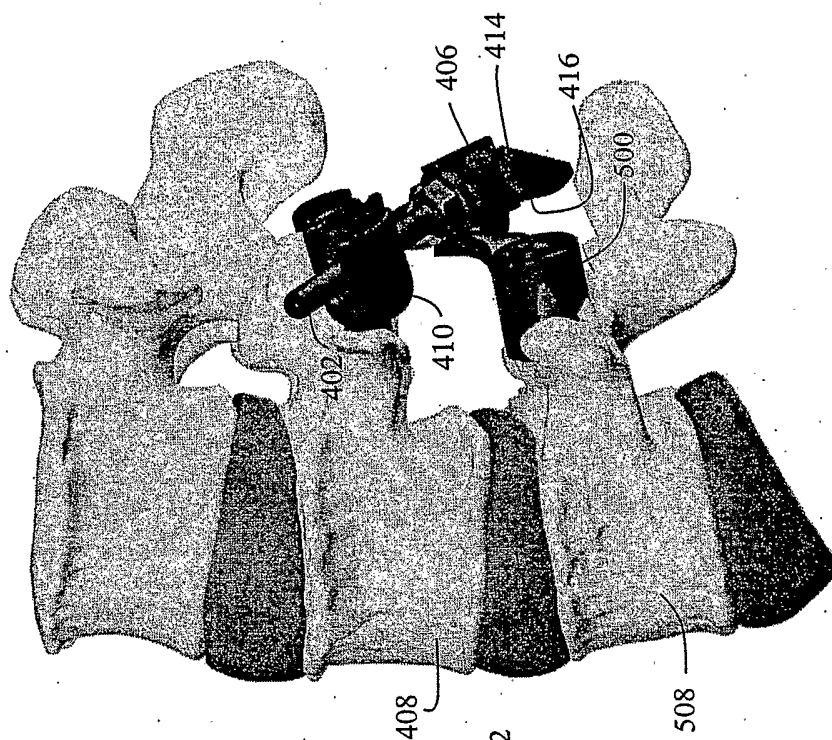


Fig. 26.

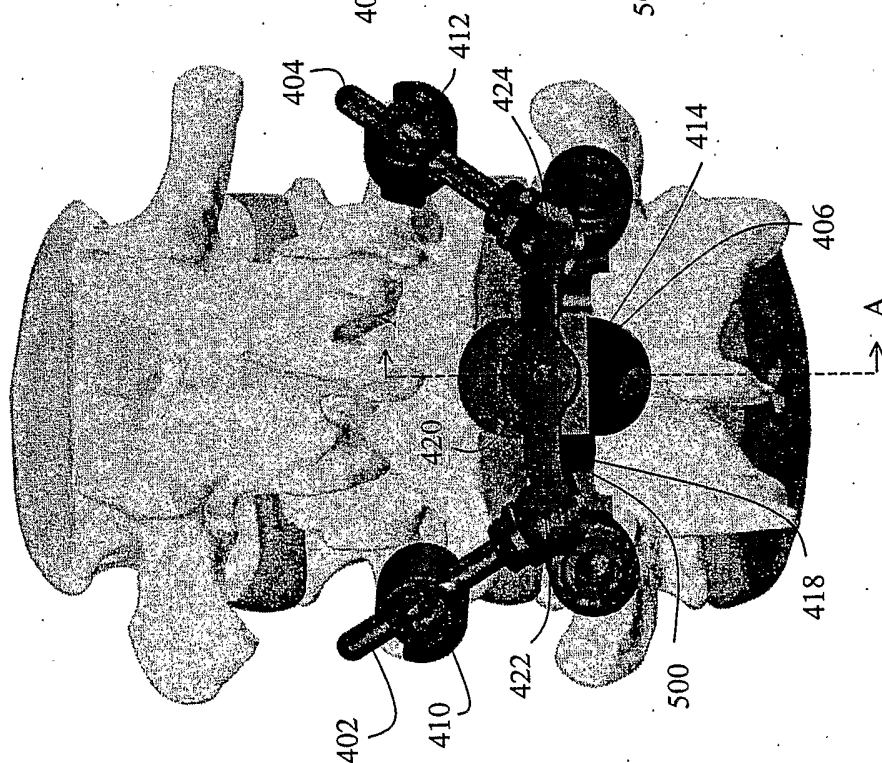


Fig. 25.

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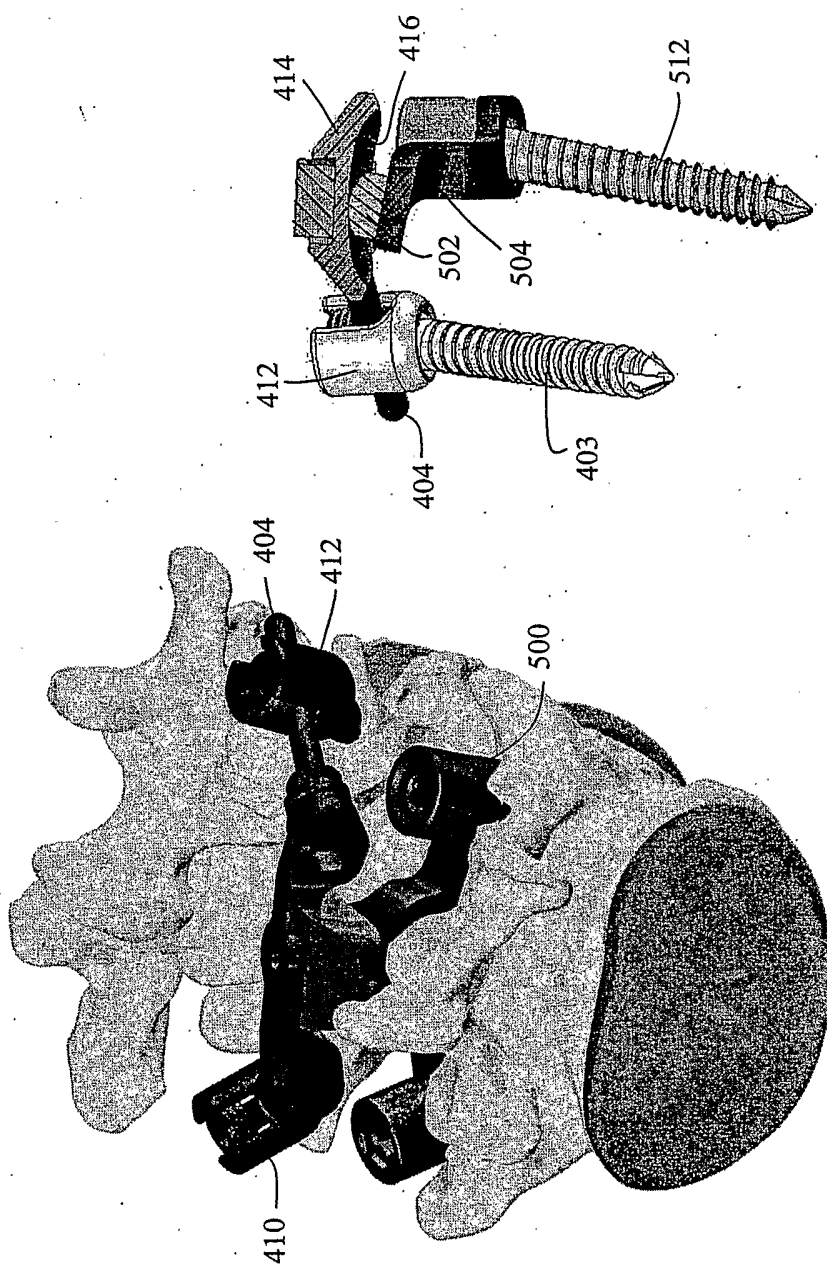


Fig. 28.

Fig. 27.

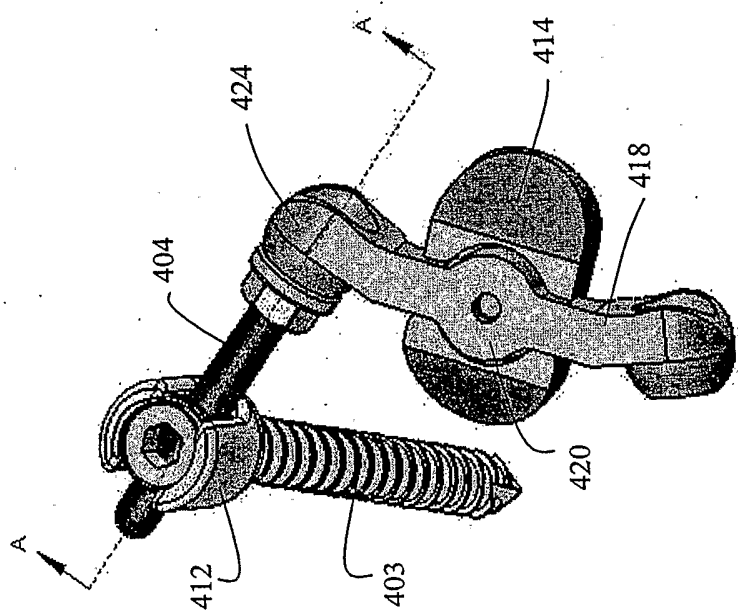


Fig. 29.

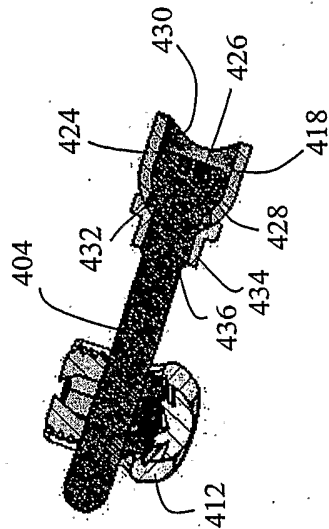


Fig. 30.

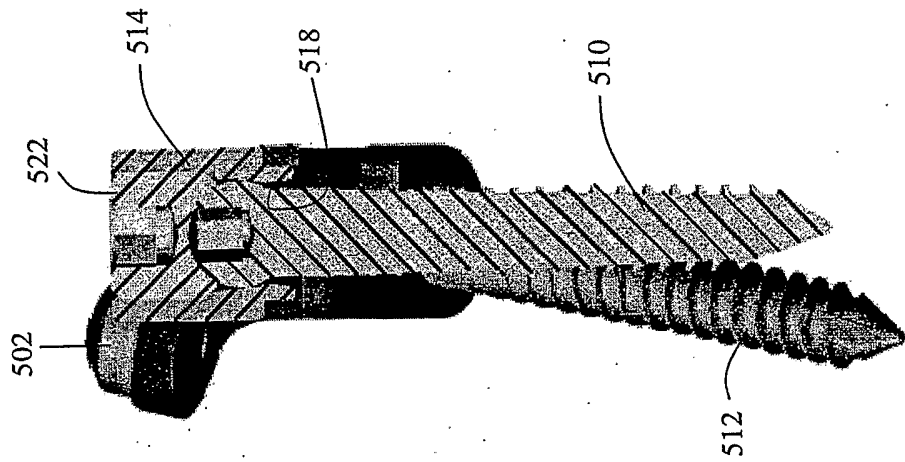


Fig. 32.

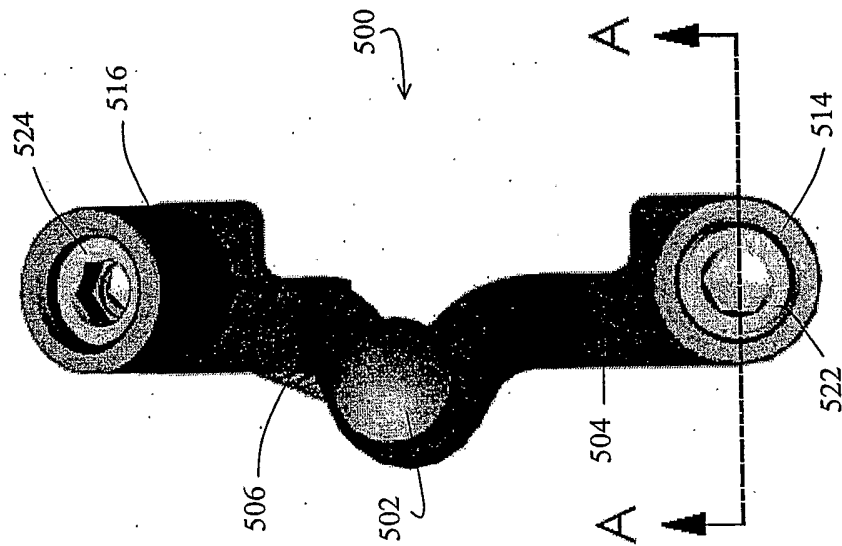


Fig. 31.