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(54) **BONE PLATE SYSTEM AND METHOD FOR SPINE STABILIZATION**

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Publication Classification

(51) **Int. Cl.**

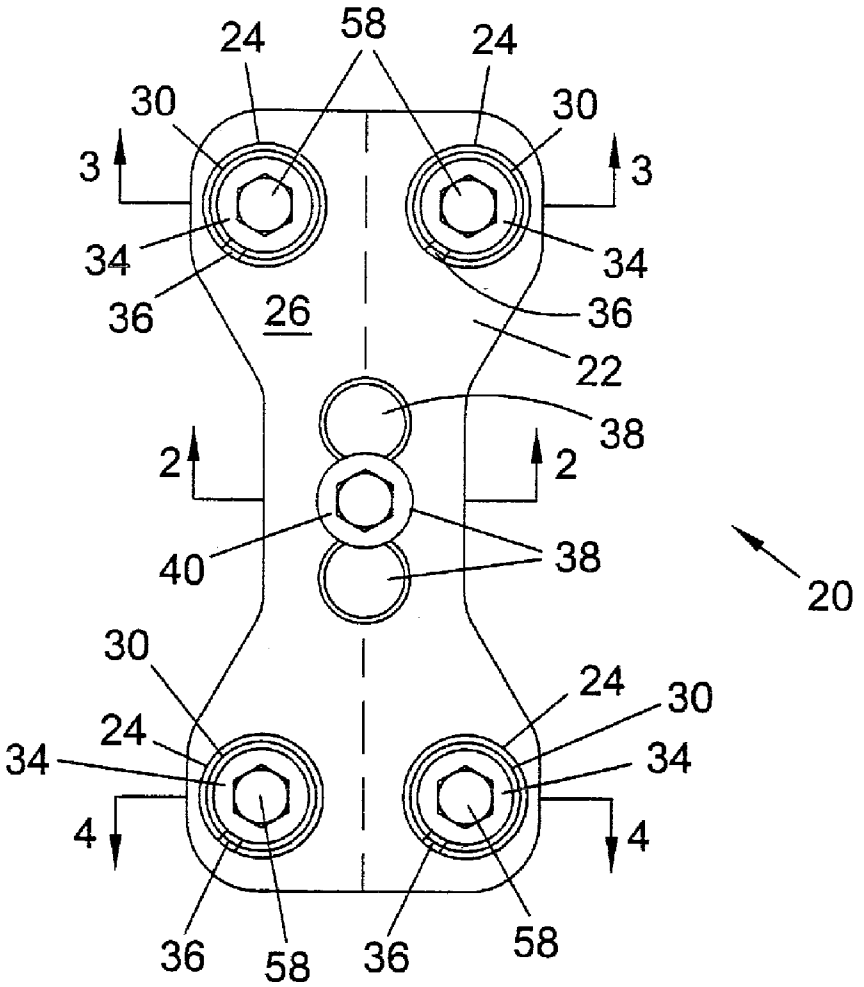
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A61B 17/88 (2006.01)

(52) **U.S. Cl.** **606/70**; 606/289; 606/281

(57) **ABSTRACT**

In an embodiment, a bone plating system may include a plate having end holes, each extending from an upper surface to a lower surface of the plate and comprising an inner surface having a curved contour. The bone plating system may include bone fasteners, each being sized to be placed in a ring for anchoring an end of the plate to a bone, the ring being sized to fit in a corresponding end hole and rotatable therein to define an angle of a corresponding bone fastener relative to the plate. The ring may have an outer surface that substantially corresponds to the curved contour of the inner surface of the hole to allow for rotation of the ring within the hole. The angles of the bone fasteners relative to the plate may define a converging or diverging configuration, which can prevent the bone fasteners from backing out.



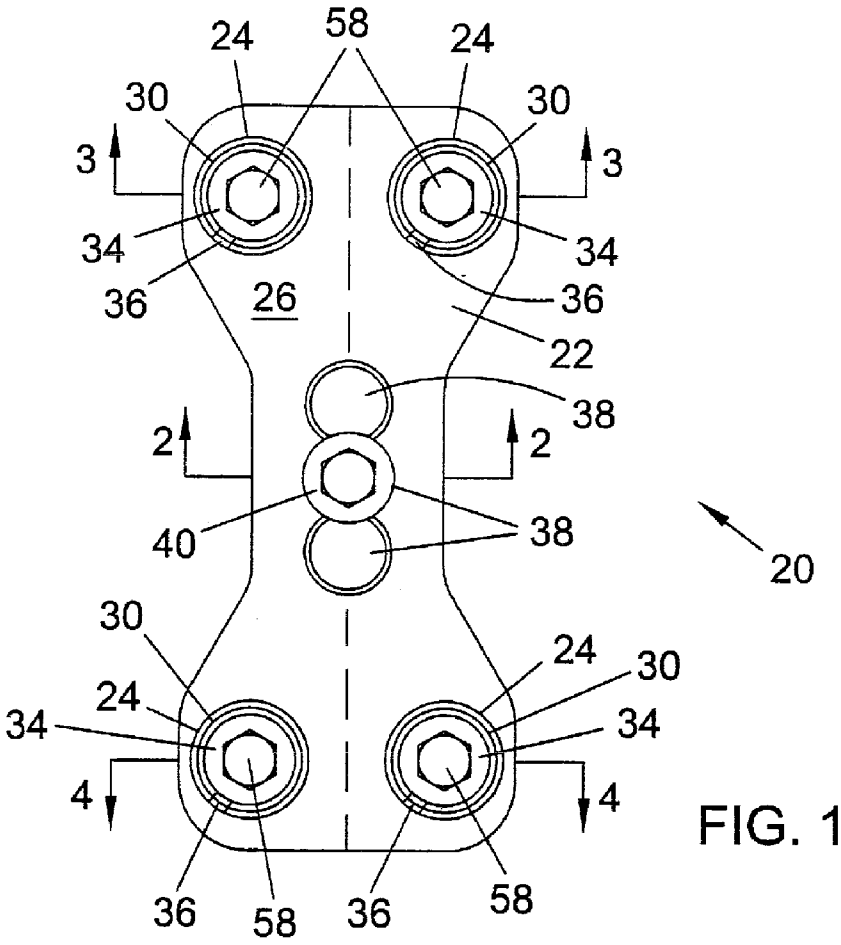

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FIG. 1

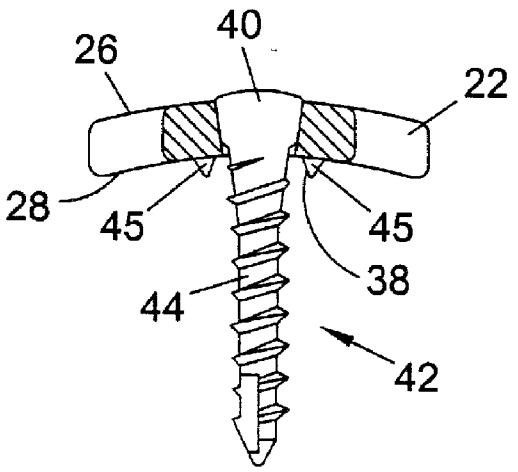

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FIG. 2

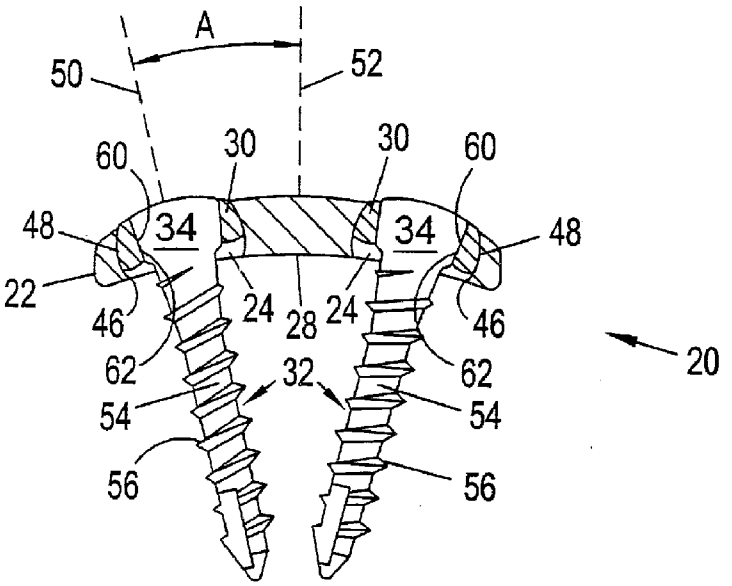

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FIG. 3

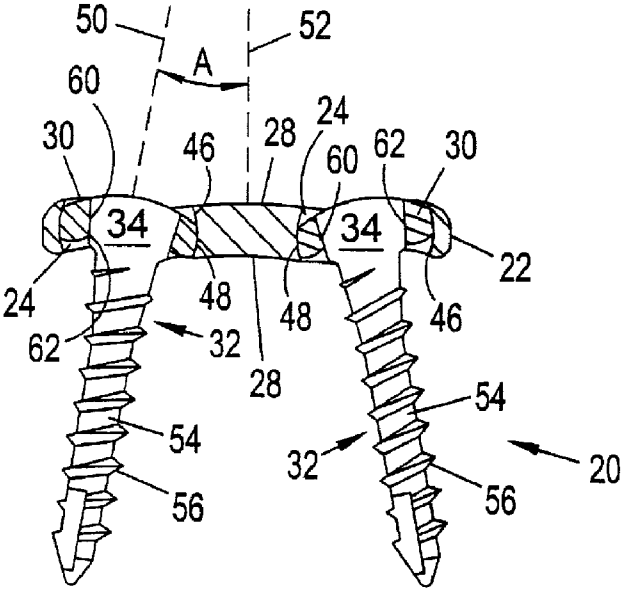

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FIG. 4

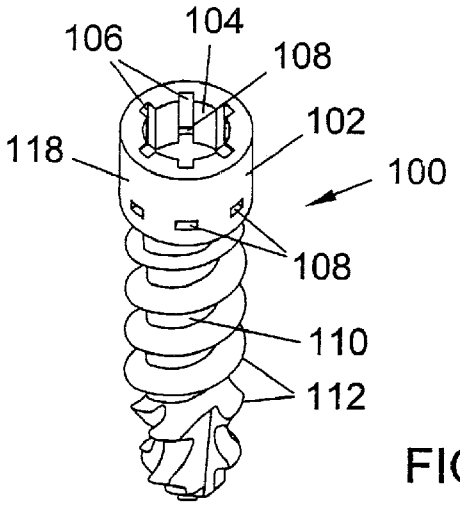


FIG. 5

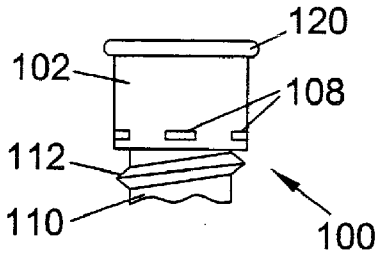


FIG. 6

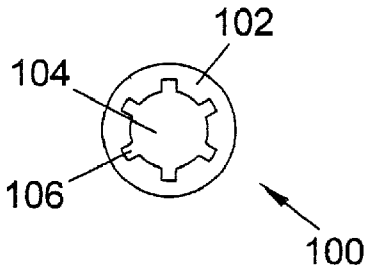


FIG. 7

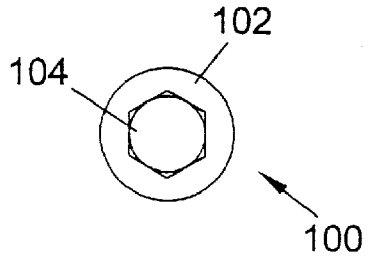


FIG. 8

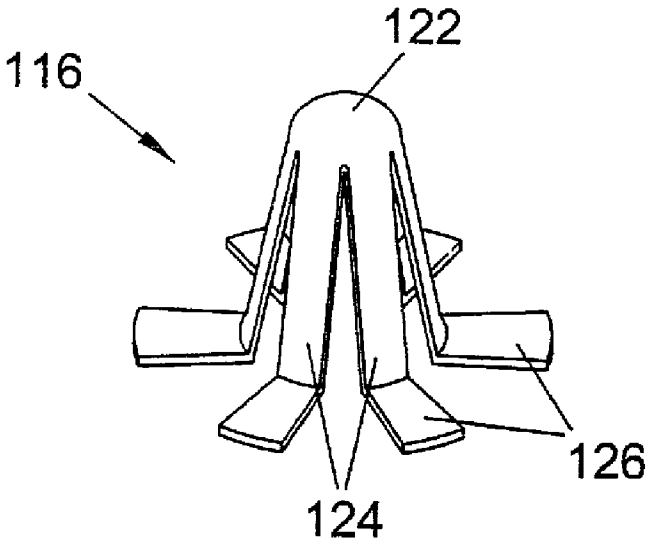


FIG. 9

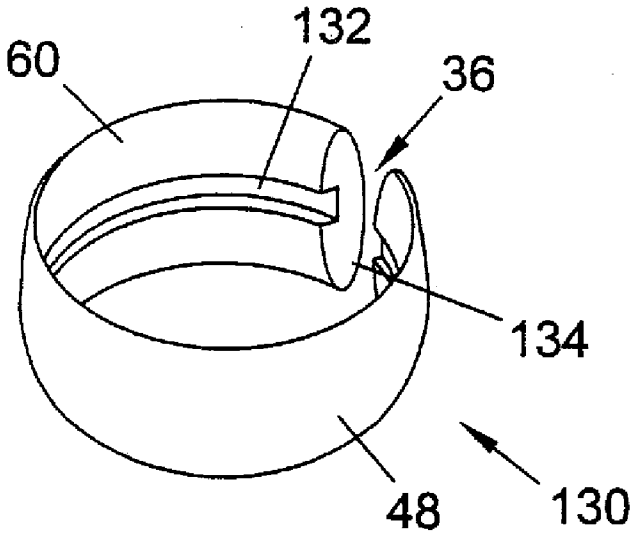


FIG. 10

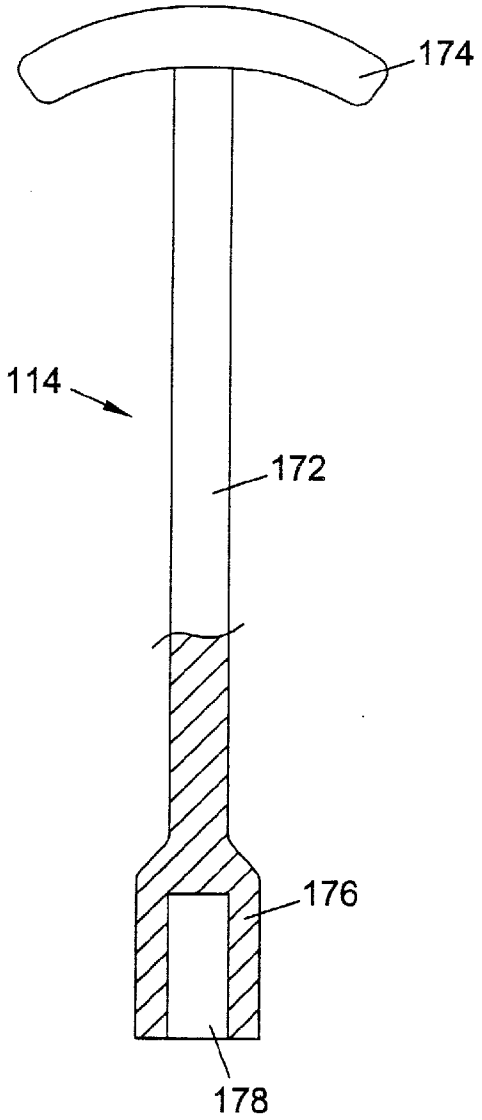


FIG. 11

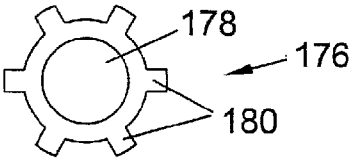


FIG. 12a

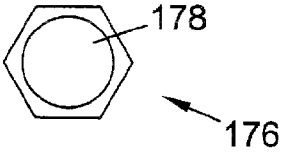


FIG. 12b

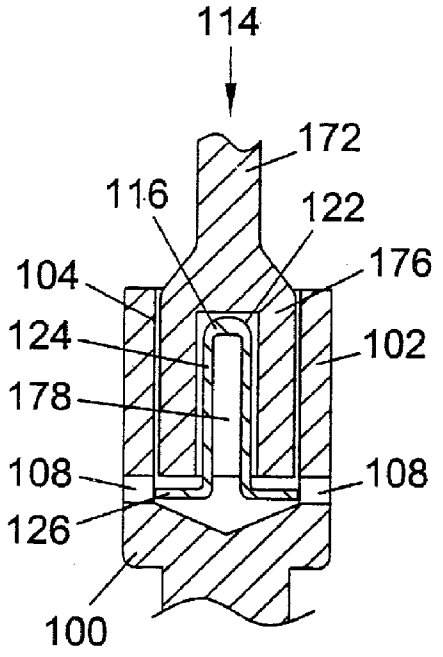

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FIG. 13

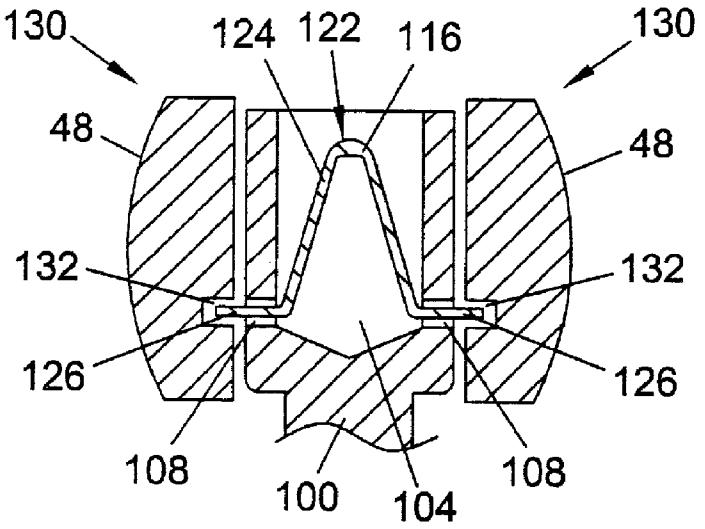

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FIG. 14

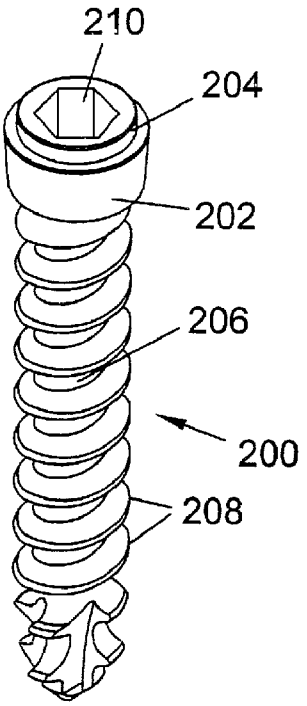


FIG. 15

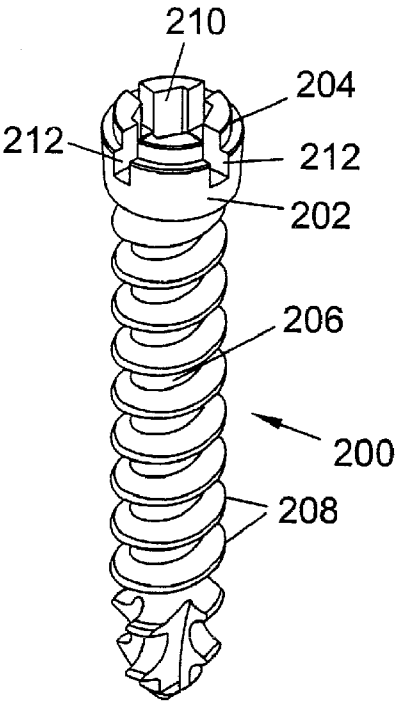


FIG. 17

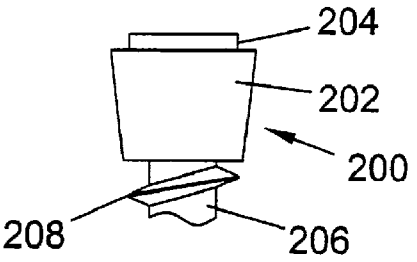


FIG. 16

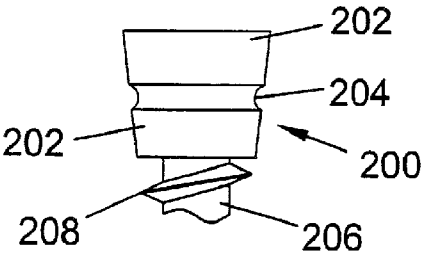


FIG. 18

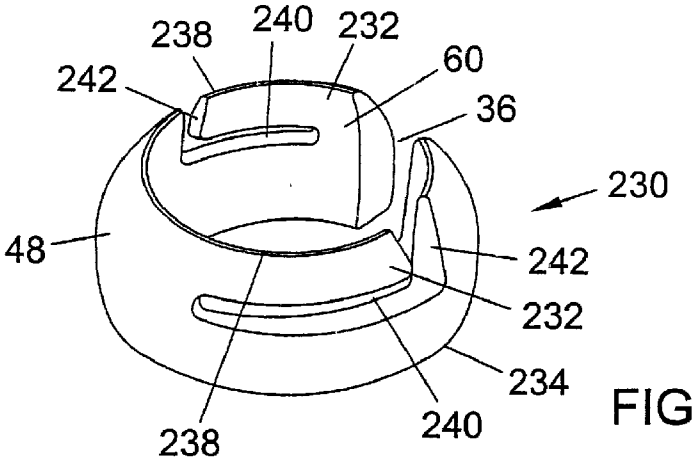


FIG. 19

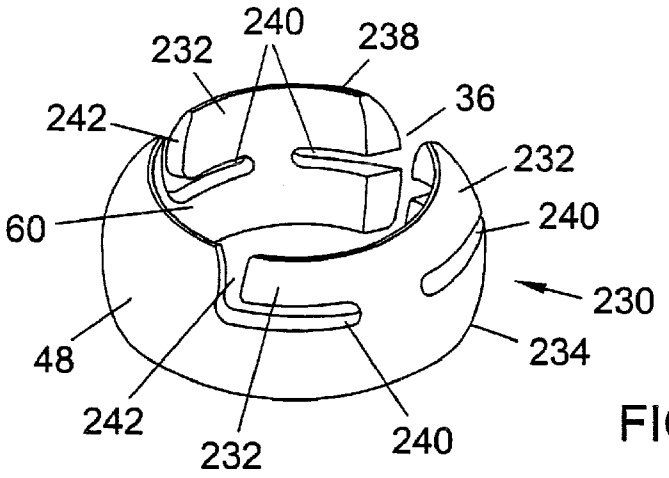


FIG. 20

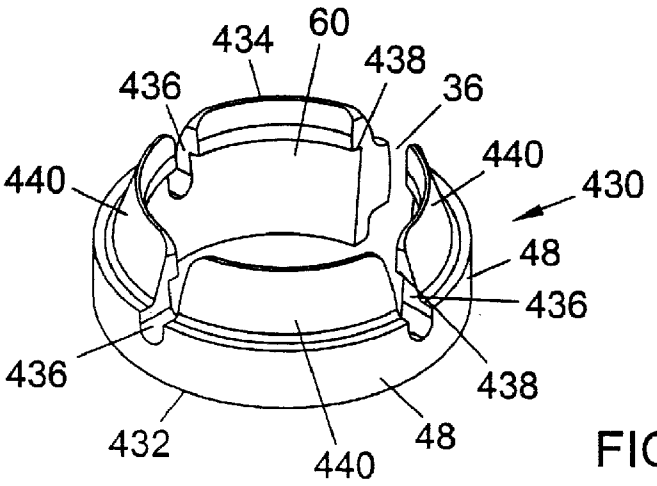


FIG. 21

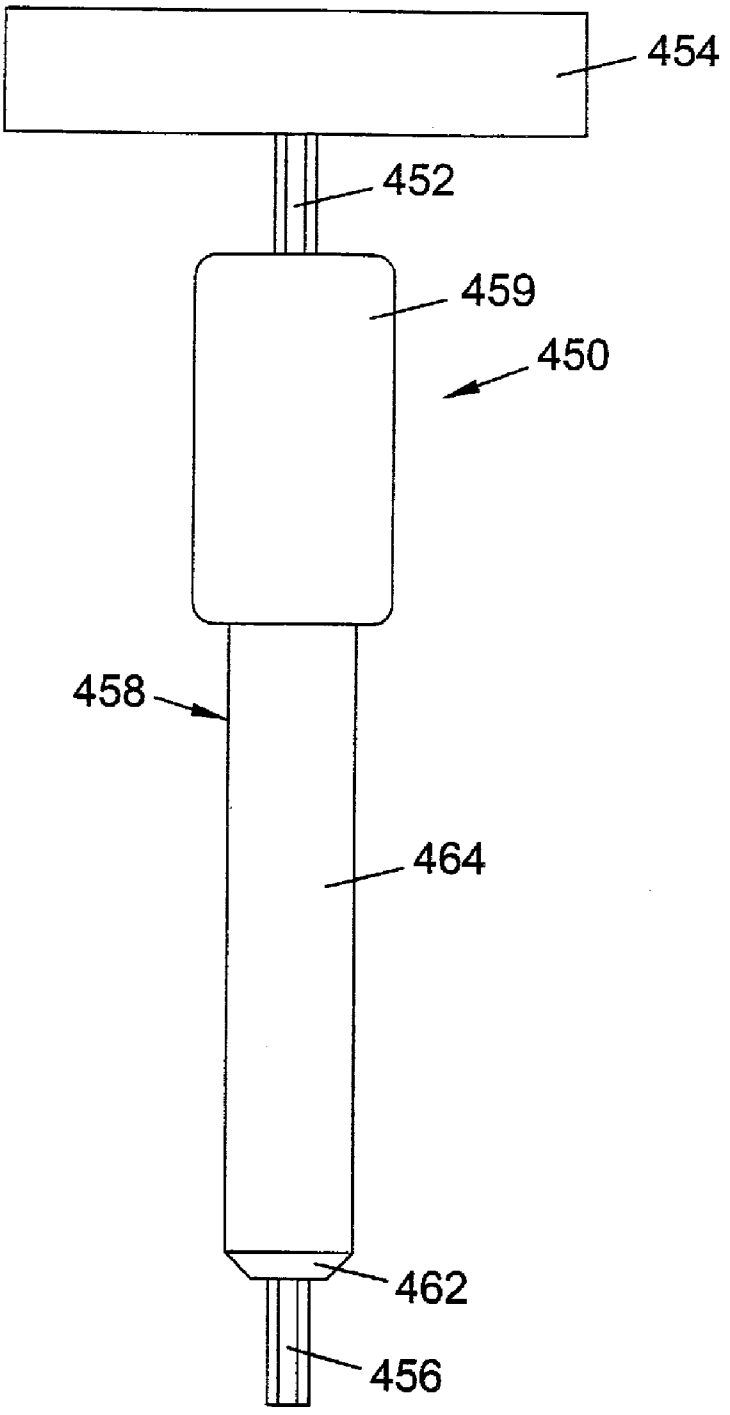


FIG. 22

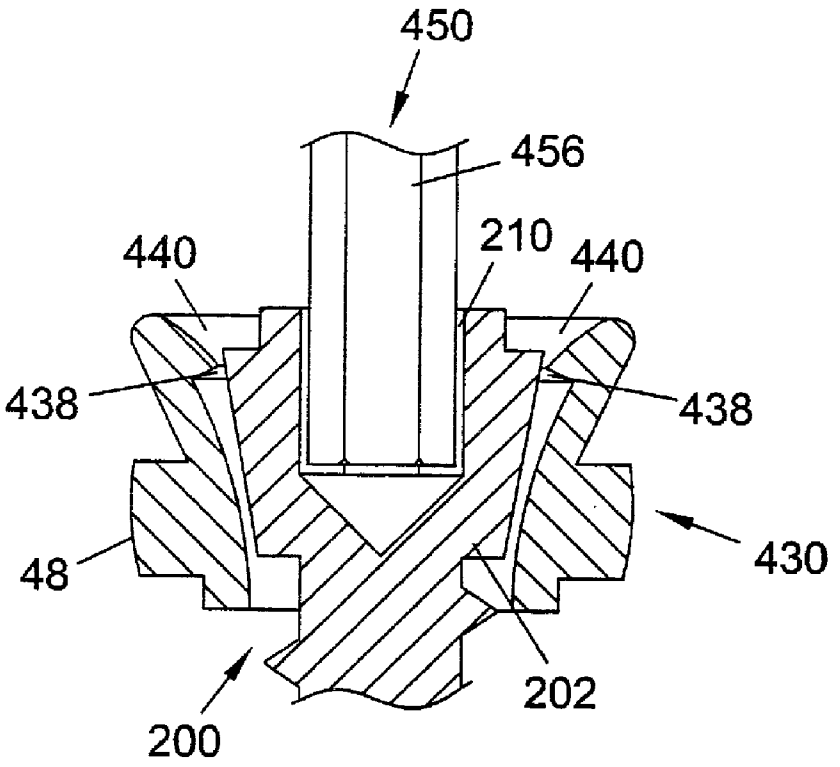


FIG. 23a

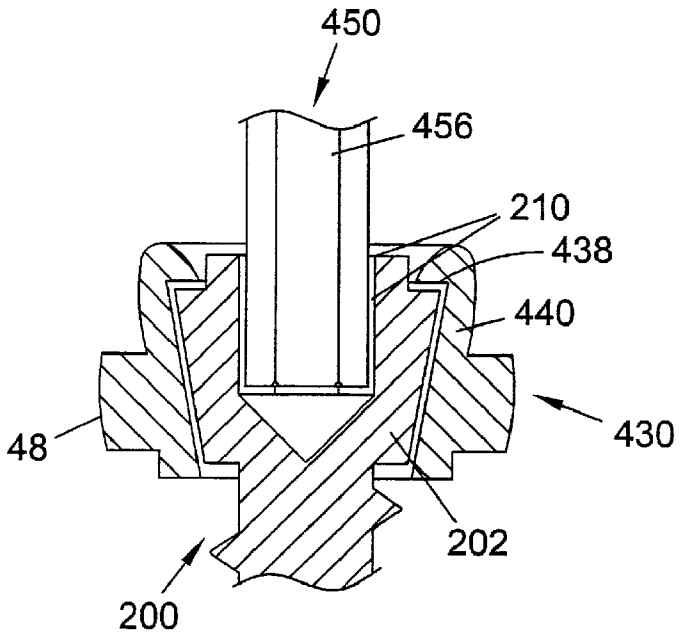


FIG. 23b

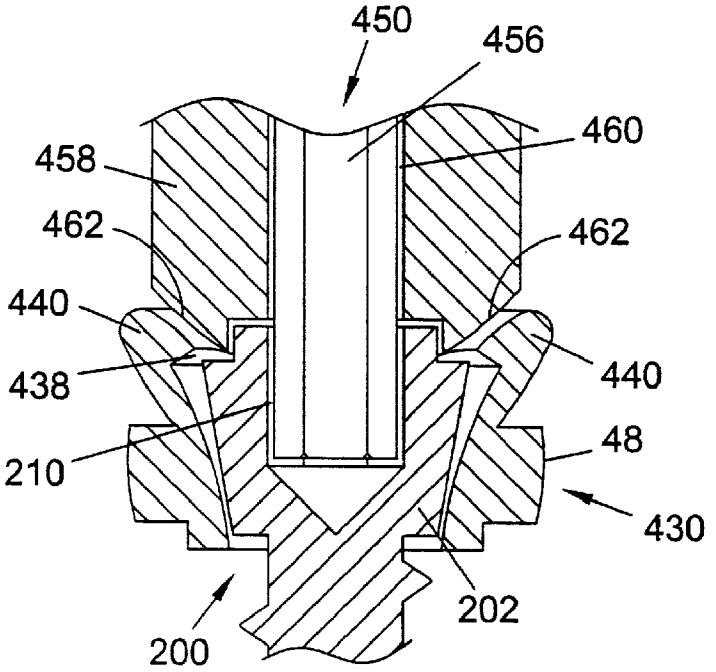


FIG. 23c

BONE PLATE SYSTEM AND METHOD FOR SPINE STABILIZATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of, and claims a benefit of priority under 35 U.S.C.§120 of the filing date of U.S. patent application Ser. No. 12/575,639, entitled "SYSTEM AND METHOD FOR STABILIZING THE HUMAN SPINE WITH A BONE PLATE," filed Oct. 8, 2009, now allowed, which is a continuation of U.S. patent application Ser. No. 10/735,976, entitled "SYSTEM AND METHOD FOR STABILIZING THE HUMAN SPINE WITH A BONE PLATE," filed Dec. 15, 2003, now U.S. Pat. No. 7,611,527, which is a continuation of U.S. patent application Ser. No. 10/015,206, entitled "SYSTEM AND METHOD FOR STABILIZING THE HUMAN SPINE WITH A BONE PLATE," filed Nov. 19, 2001, now U.S. Pat. No. 6,964,664, which is a continuation of U.S. patent application Ser. No. 09/479,458, entitled "SYSTEM AND METHOD FOR STABILIZING THE HUMAN SPINE WITH A BONE PLATE," filed Jan. 6, 2000, now U.S. Pat. No. 6,331,179; the contents of applications referenced herein are hereby expressly incorporated by reference for all purposes.

TECHNICAL FIELD

[0002] This disclosure generally relates to spinal fixation systems and the like. This disclosure also generally relates to a spinal plate system that includes a mechanism for fixably attaching heads of fasteners to a spinal plate.

DESCRIPTION OF THE RELATED ART

[0003] The use of spinal fixation plates for correction of spinal deformities and for fusion of vertebrae is well known. Typically, a rigid plate is positioned to span bones or bone segments that need to be immobilized with respect to one another. Bone screws may be used to fasten the plate to the bones. Spinal plating systems are commonly used to correct problems in the lumbar and cervical portions of the spine, and are often installed posterior or anterior to the spine.

[0004] Spinal plate fixation to the cervical portion of the spine may be risky because complications during surgery may cause injury to vital organs, such as the brain stem or the spinal cord. When attaching a fixation plate to a bone, bone screws are placed either bi-cortically (i.e., entirely through the vertebrae such that a portion of the fastener extends into the spinal cord region) or uni-cortically (i.e., the fastener extends into but not through the vertebrae). Uni-cortical positioning of bone screws has grown in popularity because it is generally safer to use. Bi-cortical fasteners are intended to breach the distal cortex for maximum anchorage into the bone; however, this placement of the fasteners may place distal soft tissue structures at risk. Fastener placement is particularly important in anterior cervical plate procedures because of the presence of the spinal cord opposite the distal cortex. Unfortunately, uni-cortical fasteners may move from their desired positions because of the soft texture of the bone marrow. In fact, the portion of the bone surrounding such fasteners may fail to maintain the fasteners in their proper positions. The result is backout of the fastener.

[0005] Backout of the fastener is particularly problematic when two fasteners are implanted perpendicular to the plate. When the fasteners are placed in such a manner, backout may occur as a result of bone failure over a region that is the size of the outer diameter of the fastener threads. To overcome this problem, two fasteners may be angled in converging or diverging directions with respect to each other within the bone. The amount of bone that is required to fail before backout may occur is increased by this configuration as compared to fasteners that are implanted in parallel. Although positioning convergent or divergent fasteners in a bone reduces the risk of backout, backout may still occur.

[0006] Backout may damage internal tissue structures and cause complications if the dislocated fastener penetrates the tissue structures. For example, if backout occurs, the fastener might breach the esophageal wall of the patient. Such a breach may permit bacterial contamination of surrounding tissues, including the critical nerves in and around the spinal cord. Such a breach could be fatal.

[0007] In an attempt to reduce the risk of damage to internal tissue structures, some cervical fastener plate systems have uni-cortical fasteners that attach both to the bone and to the plate. If a fastener does backout, the fastener remains connected to the plate so that it does not contact internal tissue structures. U.S. Pat. No. 5,364,399 to Lowery et al. describes one such system and is incorporated by reference as if fully set forth herein. The Lowery et al. plating system includes a locking fastener at each end of the plate. The locking fastener engages the head of the bone screw to trap the fastener within a recess of the plate. Since the locking fastener is positioned over portions of the bone screws, the locking fastener may extend above the upper surface of the plate. Thus, the locking fastener may come into contact with internal tissue structures, such as the esophagus.

[0008] Another plating system that includes a fastener-to-plate locking mechanism is the Aline.™. Anterior Cervical Plating System sold by Smith & Nephew Richards Inc. in Memphis, Tenn. A description of this system can be found in the Aline.™. Anterior Cervical Plating System Surgical Technique Manual by Foley, K. T. et al., available from Smith & Nephew Richards Inc., September 1996, pp. 1-16 and is incorporated by reference as if fully set forth herein. The bone screws of this system have openings within each bone screw head for receiving a lock fastener coaxially therein. Each bone screw may be inserted into a bone such that the head of the fastener is positioned within a hole of a plate placed adjacent to the bone. The head of each bone screw is slotted so that portions of the head are deflected toward the plate during insertion of the lock fastener within the opening of the bone screw. Positioning and inserting a lock fastener within the opening can be difficult due to the small size of the lock fastener. The surgeon may be unable to hold onto the lock fastener without dropping it. If a lock fastener falls into the surgical wound, it may be difficult to retrieve. In some instances, the lock fastener may be unretrievable.

SUMMARY OF THE INVENTION

[0009] An implant system may be used to immobilize a portion of a human spine. The implant system may include a plate comprising end holes, midline holes, fasteners, and expandable/contractible rings. The fasteners and rings may include mechanisms for anchoring or locking the fastener heads within the rings to inhibit backout of the fastener.

[0010] The end holes extend from an upper surface to a lower surface of the plate. The end holes may be disposed in pairs at opposite ends of the plate. Each end hole receives at least a portion of a head of a fastener. Herein, "fastener"

means any elongated member, threaded or non-threaded, which is securable within a bone. Fasteners include, but are not limited to screws, nails, rivets, trocars, pins, and barbs. The fastener may be a bone screw. A fastener may have a fastener head. The fastener head typically includes an opening adapted to mate with a tool. The tool allows the insertion of the fastener into a bone. Each end hole may also be spherically contoured to permit the fastener to be "obliquely angulated" relative to the plate. Herein, "obliquely angulated" means that the fastener may be positioned throughout a wide range of angles relative to an axis that is perpendicular to the plate. Obliquely angulating a fastener into a bone may reduce the risk of backout of the fastener.

[0011] The expandable/contractible rings may be sized so that a ring seats within an end hole between the plate and the fastener. The inner surface of each ring may be shaped to mate with a fastener head while the outer surface may be shaped to mate with the inside surface of an end hole. The outer surface of each fastener head may be tapered so that an upper portion of the head is larger than a lower portion of the head. The inner surface of the ring may have a taper that generally corresponds to the taper of the fastener head.

[0012] Each ring may also have a gap that extends vertically through the ring to make the ring more readily expandable and contractible. During insertion of the fastener head into the ring, the fastener head exerts force against the ring to expand the ring against the inner surface of the hole. Expanding the ring against the inner surface of the hole may securely fix the fastener to the plate.

[0013] The fastener head and the ring may include a locking mechanism to attach the fastener head to the plate. The locking mechanism may inhibit backout of the fastener head from the ring if the fastener loosens in the bone. The locking mechanism may also inhibit the fastener head from contacting adjacent tissue structures since the locking mechanism attaches the fastener head to the plate. In some embodiments, there is tolerance for some freedom of movement in an axial direction between a locking mechanism and a fastener head. The availability of some axial movement may allow the fastener to back out or loosen slightly from the bone during a normal period of adjustment after implantation of a spinal fixation system.

[0014] Midline holes may be formed through the plate at various locations along a midline axis extending across the plate. The surface of the plate that surrounds each midline hole may be tapered. Further, the heads of fasteners that may be positioned within the plates may have tapered outer surfaces that generally correspond to the tapered surface of the plate. Thus, when such a fastener head is inserted into a midline hole, the shape of the plate causes the fastener to become fixably attached to the plate in a position that is substantially perpendicular to the plate. Midline holes may be used to attach a bone graft to the bore plate. Oblique angulation of fasteners positioned within the midline holes may not be required.

[0015] The bone plate may have one or more spikes located on the surface of the plate that faces the spinal column. Spikes may be disposed in pairs at opposite ends of the plate proximate the end holes. The spikes may be tapped into the bone to help inhibit the bone plate from slipping during surgical implantation.

[0016] Prior to surgical implantation of the spinal plate system, the expandable/contractible rings may be placed within the end holes of the plate. The plate may then be positioned adjacent to a portion of the spine that requires spinal fixation. Holes may be drilled and/or tapped at desired angles into portions of the bone underlying the end holes of a plate. Fasteners may be inserted through the end holes into the holes in the bone. The heads of the fasteners may be positioned within the end holes such that the rings surround at least a portion of the heads. The rings may lock the fasteners in place without occupying regions outside of the end holes. Further, since the rings are pre-positioned within the end holes, surgeons do not have to worry that they may drop the rings during insertion of the rings into the end holes of the plate.

[0017] In one embodiment, a locking mechanism secures a fastener head to a ring. A locking mechanism may have a top and one or more flexible arms that angle downwards and outwards from the top. The ends of the arms have prongs that are substantially parallel to the top of the locking mechanism. A locking mechanism in a compressed configuration, fits into an opening formed in the head of a fastener. The prongs of the locking mechanism fit within holes located near the bottom of the opening. The holes extend from the outer surface of the head to the opening. When the prongs are positioned in the holes, the prongs extend through the holes so that the locking mechanism is in an extended configuration. The prongs that extend out of the head of the fastener fit within a groove on the inner surface of the ring to enhance the connection between the fastener and the ring.

[0018] The locking mechanism may be inserted in the fastener head prior to the surgical procedure to avoid the risk of dropping the locking mechanism during the surgical procedure. An insertion and extraction tool retracts the prongs on the locking mechanism into the head during insertion or extraction of a fastener. The tool may include a handle, a shaft, and a hollow driver head shaped to match a drive section of the opening on the fastener head. Inserting the driver head into the opening slides the head over the locking mechanism and compresses the shafts of the locking mechanism. Compressing the shafts of the locking mechanism retracts the prongs into the fastener head. To insert a fastener into a bone, the user inserts the fastener into the bone until the head is fully inserted in the ring. Removing the driver head from the opening causes the shafts of the locking mechanism to expand outwards so that the prongs extend out of the holes into the fastener head.

[0019] To remove a fastener that has a locking mechanism, the user inserts the driver head of the insertion and extraction tool into the opening of the fastener head. The driver head compresses the shafts of the locking mechanism and causes the prongs to retract within the fastener head. The user may then remove the fastener from the bone.

[0020] In another embodiment, a tapered fastener head locks into a ring by one or more fingers on the ring that snap into grooves on the fastener head. L-shaped slots cut into the top of the ring may define the fingers. The fingers have spring-like action so that the fingers snap into the grooves on the fastener head when a fastener head is inserted into the ring. As the fastener head passes into the ring, the tapered outer surface of the head expands the ring against the inner surface of the plate. When the groove on the fastener head reaches the fingers, the fingers snap into the groove, fixing the fastener in the ring and helping to inhibit backout.

[0021] In another embodiment, a fastener head locks to a ring by one or more ridges on the ring that snap into grooves on the fastener head. Notches cut into the top of the ring may

form paddles. A ridge may extend along an inside surface of each paddle proximate the top of the ring. The paddles have a spring-like action so that the ridges snap into the grooves on the fastener head during insertion of the fastener head into the ring. The ridges of the ring residing within a groove of the fastener head may fix the fastener in the ring and help inhibit backout of the fastener.

[0022] An extraction tool module fits over an insertion tool and allows the retraction of the ring ridges from the fastener head. The insertion tool includes a handle, a shaft, and a driver head shaped to match the opening on the fastener head. The extraction module slides over the shaft of the insertion tool. The extraction module may include a handle and an extraction head. The extraction head may include a tip that slides over the fastener head and contacts the ends of the paddles. The outer surface of the tip tapers. As the extraction module is pushed down, the tapered surface of the tip forces the paddles outwards and disengages the ridges on the paddles from the grooves on the fastener head. Disengaging the ridges on the paddles from the grooves on the fastener head allows the fastener to be backed out of the bone.

[0023] Using a locking mechanism between the fastener head and the ring may result in a strong connection between the fastener and the plate. Even if the shank of a fastener loosens within the bone, the fastener head will tend to remain within the hole of the plate so as not to protrude from the plate into surrounding body tissue. Allowing some axial freedom of movement for the fastener head in the ring may allow the fastener to back out slightly during an adjustment period after installation of the spinal fixation system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Further advantages of the invention will become apparent to those skilled in the art with the benefit of the following detailed description of embodiments and upon reference to the accompanying drawings in which:

[0025] FIG. **1** is a top view of an embodiment of a spinal plating system that may be used for fixation of the human spine.

[0026] FIG. **2** is a partial cross-sectional view of the spinal plating system taken substantially along line **2-2** of FIG. **1**. The fastener is not shown in section.

[0027] FIG. **3** is a partial cross-sectional view of the spinal plating system taken substantially along line **3-3** of FIG. **1**, wherein the fasteners are in a converging orientation within end holes of a plate. The fasteners are not shown in section.

[0028] FIG. **4** is a partial cross-sectional view of the spinal plating system taken substantially along line **4-4** of FIG. **1**, wherein the fasteners are in a diverging orientation within end holes of a plate **5**, the fasteners are not shown in section.

[0029] FIG. **5** depicts an embodiment of a fastener with grooves and holes to engage a locking mechanism.

[0030] FIG. **6** is a partial front view of a fastener with holes in the fastener head.

[0031] FIG. **7** is a top view of a fastener head having grooves for engaging a locking mechanism.

[0032] FIG. **8** is a top view of an embodiment of a fastener head with a hexagonal opening and holes to engage a locking mechanism.

[0033] FIG. **9** is a perspective view of a locking mechanism.

[0034] FIG. **10** is a perspective view of a ring that may be used with a fastener and a locking mechanism.

[0035] FIG. **11** is a partial sectional view of an insertion/extraction tool for fasteners with locking mechanisms.

[0036] FIG. **12***a* is a bottom view of a driver head of the insertion/extraction tool shown in FIG. **11**. The tool may be used with the fastener head shown in FIG. **7**.

[0037] FIG. **12***b* is a bottom view of the driver head of the insertion and removal tool shown in FIG. **11** which may be used with the fastener head shown in FIG. **8**.

[0038] FIG. **13** is a sectional view of a fastener head with an insertion/extraction tool and compressed locking mechanism during an insertion process.

[0039] FIG. **14** is a sectional view of a fastener head and locking mechanism inserted into a ring.

[0040] FIG. **15** is a perspective view of an embodiment of a fastener.

[0041] FIG. **16** is a front view of an embodiment of a fastener head.

[0042] FIG. **17** is a perspective view of an embodiment of a fastener.

[0043] FIG. **18** is a front view of an embodiment of a fastener head with a groove.

[0044] FIG. **19** is a perspective view of an embodiment of a ring.

[0045] FIG. **20** is a perspective view of an embodiment of a ring.

[0046] FIG. **21** is a perspective view of an embodiment of a ring.

[0047] FIG. **22** is front view of an insertion/extraction tool which may be used with the ring of

[0048] FIG. **21**.

[0049] FIG. **23***a* is a partial cross sectional view of a fastener during insertion in the ring of FIG. **21**. The shaft of the insertion/extraction tool is not shown in cross section.

[0050] FIG. **23***b* is a partial cross sectional view of a fastener after insertion in the ring of FIG. **21**. The shaft of the insertion/extraction tool is not shown in cross section; and

[0051] FIG. **23***c* is a partial cross sectional view of a fastener during removal from the ring of FIG. **21**. The shaft of the insertion/extraction tool is not shown in cross section.

[0052] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but to the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0053] Referring to the drawings, and particularly to FIG. **1**, a spinal plating system is designated generally as **20**. The spinal plating system **20** may be used to correct problems in the lumbar and cervical portions of the spine. For example, the plating system **20** may be implanted into the occiput bone that is located at the base of the skull. The plating system **20** may also be installed anterior to the spine. The spinal plating system **20** includes plate **22** that is placed adjacent to a portion of the spine and spans at least two vertebrae. Plate **22** may include four end holes **24**, located at corners of the plate. End holes **24** pass vertically through plate **22** such that the holes extend from an upper surface **26** to a lower surface **28** of the plate as depicted in FIG. **2**. End holes **24** are configured to receive rings **30**. Fasteners **32** fit within the rings **30**. Herein, "fastener" means any elongated member, threaded or non-

threaded, which is securable within a bone. Fasteners include, but are not limited to screws, nails, rivets, trocars, pins, and barbs. The fastener may be a bone screw. Rings **30** fixedly attach fastener heads **34** of fasteners **32** to plate **22**. Gap **36** may exist in each of the rings **30**. A gap **36** allows for expansion and contraction of a ring **30**. Ring contraction allows a ring **30** to be easily inserted into an end hole **24** of the plate **22**.

[0054] The spinal plating system **20** may also include one or more central holes **38** that extend vertically through plate **22**. One of the central holes **38** may be located at about the mid-point of the plate **22**. Head **40** of fastener **42** is positioned within one of the central holes **38**. Multiple central holes **38** provide a surgeon with options as to the most desirable location for placement of a fastener **42**. Fastener **42** may be used to connect plate **22** to a bone graft (not shown).

[0055] FIG. **2** shows a fastener **42** within one of the central holes **38** of plate **22**. Fastener **42** may include head **40** and shank **44**. The shank **44** extends from the base of head **40**. In one embodiment, the inner surface of a central hole **38** tapers so that the hole is larger at upper plate surface **26** than at the lower plate surface **28**. The outer surface of the fastener head **40** has a taper that generally corresponds to the taper of the central hole **38**. During implantation of a fastener **42** into a bone graft, the shank **44** of the fastener **42** is inserted into a hole that has been formed in the bone graft under hole **38**. Because the lower portion of hole **38** is smaller than the upper portion of the fastener head **40**, fastener **42** may become locked into place within the central hole **38** once the fastener has been inserted to a desired depth within the bone graft. The bone plate **22** may have spikes **45** extending from the lower plate surface **28**.

[0056] As shown in FIG. **2**, the plate **22** may have a curvature. The curvature may enhance fixation of the plate **22** to a bone. The bone plate **22** may have one or more spikes **45** located on the surface of the plate that faces the bone. The spikes **45** may be disposed in pairs at opposite ends of the plate proximate the end holes **24**. The spikes **45** may be tapped into the bone to help inhibit the bone plate **22** from slipping during surgical implantation.

[0057] FIG. **3** depicts a cross-sectional view of an embodiment of a final plating system **20** wherein a pair of fasteners **32** are in a converging configuration. FIG. **4** depicts a cross-sectional view of an embodiment of a spinal plating system wherein a pair of fasteners **32** is in a diverging configuration. Ring **30** fits into a hole **24** between plate **22** and fastener head **34**. Inner surfaces **46** of holes **24** may have arcuate or spherical contours. Outside surfaces **48** of rings **30** may have arcuate or spherical contours that substantially correspond to the contours of the inner surfaces **46** of the holes **24**. Having a contoured ring outer surface **48** that substantially corresponds to the contour of the inner hole surface **46** allows a ring **30** positioned in a hole **24** to be capable of polyaxial rotation within the end hole **24**.

[0058] The combination of ring **30** within end hole **24** functions like a ball and socket since the ring may be swiveled or polyaxially rotated within the end hole. The ability of the ring **30** to rotate polyaxially within the end hole **24** allows a fastener **32** to be positioned through the plate **22** at various angles with respect to an axis that is perpendicular to the plate. FIGS. **3** and **4** show angle A for particular fastener configurations. The angle A is defined between the longitudinal axis **50** of the fastener **32** and imaginary axis **52** that is perpendicular to the plate **22**. The angle A may range from 0 to about 45 degrees, preferably from about 0 to about 30 degrees, and more preferably from 0 to about 0 and 15 degrees.

[0059] Fasteners **32** may also be set in positions such that the fasteners are non-planar with respect to a latitudinal plane extending through plate **22**. For example, one fastener **32** may be positioned out of the page and another fastener **32** may be positioned into the page, as depicted in FIGS. **3** and **4**. Fasteners **32** set in diverging or converging directions in the end holes **24** may reduce the possibility of backout. Further, the use of rings **30** to fixedly attach fasteners **32** to plate **22** may inhibit damage to tissue structures by any fasteners that do loosen within a bone, since such fasteners would remain attached to the plate **22**. Fasteners **32** may be placed in unicortical positions within a bone since the problem of fastener backout is reduced by having obliquely angulated fasteners in converging or diverging configurations.

[0060] Ring **30** may at least partially surrounds head **34** of fastener **32** positioned within end hole **24**. A shank **54** of fastener **32** may include threading **56** to allow the fastener to be inserted into a bone when fastener **32** is rotated. As depicted in FIG. **1**, fastener head **34** may include a cavity **58** that extends from the top of the head to an inner portion of the head. Cavity **58** may be shaped to receive an end of a tool that inserts or removes the fastener **32** from a bone. The tool end may be in the form of a hex wrench, a star wrench or a screwdriver blade.

[0061] Inner surface **60** of ring **30** and outer surface **62** of head **34** may have mating tapered surfaces, as depicted in FIG. **3** and FIG. **4**. In one embodiment, the bottom portion of head **34** may be smaller than the upper portion of an unstressed ring **30**, while the upper portion of the head may be larger than the upper portion of the ring. As fastener **32** is inserted into a bone, head **34** applies a radial force to ring **30** which causes the ring to expand within the end hole **24**. Expanding the ring **30** increases the size of gap **36** and may cause the outside surface **46** of the ring to abut against inner surface **46** of the end hole **24**. An interference fit forms between fastener head **34**, ring **30**, and plate **22** in which these elements fit together such that each element obstructs the movement of the other elements. Hoop stress of ring **30** on head **34** fixedly attaches fastener **32** to plate **22**.

[0062] Ring **30** may be capable of swiveling within a hole **24** so that one portion of ring **30** is adjacent to the upper surface **26** of bone plate **22** while another portion of the ring lies adjacent to the lower surface **28** of the bone plate. In one embodiment, ring **30** may sufficiently thin to reside within end hole **24** without extending beyond the upper or lower surface **26**, **28** of bone plate **22**. The ring **30** and fastener head **34** remain within end hole **24** so that the spinal plating system **20** may have a minimal profile width. Having rings **30** and the fastener heads **34** which do not extend above the upper surface **26** or below the lower surface **28** of plate **22** may prevent the rings and heads from contacting adjacent tissue structures. In other embodiments, however, fasteners **32** may be capable of being angulated relative to bone plate **22** such that the rings **30** extend from the end holes **24** beyond upper and/or lower surfaces of the bone plate.

[0063] In one embodiment, the spinal plating system **20** is prepared for surgical implantation by positioning rings **30** within end holes **24**. During the surgical procedure, holes may be drilled and tapped into the bones to which plate **22** is to be attached. Plate **22** may then positioned adjacent to the bones and over the holes in the bones. Fasteners **32** may be placed through a ring **30** and into the bone holes. Each fastener **32**

may be obliquely angulated into the plate **22**. The fasteners **32** may be inserted into the bone until the fastener heads **34** expand the rings **30** against the inner surfaces **46** of the holes **24**; thus fixing the fasteners to the rings, and the rings to the plate **22**. If necessary, a fastener **42** may be positioned in one of the central holes **38**.

[0064] In one embodiment, ring **30** has an outer width that is less than or about equal to the width of an end hole **24** in bone plate **22** at a location between an upper surface **26** and lower surface **28** of the bone plate. The width of each end hole **24** proximate the upper and lower surfaces **26**, **28** of bone plate **22** is less than or about equal to an outer width of ring **30**. The width of the ring may inhibit a ring positioned in a hole from falling out of the hole. Prior to surgery, a ring **30** may be positioned within each end hole **24** of bone plate **22**. When seated within hole **24**, ring **30** may be capable of swiveling within the hole, but the ring is inhibited from falling out of the hole because of reduced width of the hole proximate the upper and lower surfaces **26**, **28** of the plate **22**. A surgeon may use a bone plate **22** having rings **30** positioned within holes **24** prior to surgery. Alternatively, rings **30** may be manually positioned within holes **24** during surgery.

[0065] Texturing the outer surface **48** of a ring **30** or an inner surface **46** of a hole **24** may further inhibit movement of a fastener **32** with respect to a bone plate **22**. Both surfaces may be textured to more effectively inhibit movement of a fastener **32** with respect to a bone plate **22**. During manufacturing procedures, the outer surface **48** of ring **30** and the inner surface of end hole **24** are formed as relatively smooth surfaces. While the friction between these smooth surfaces tends to be sufficient to maintain fastener **32** in a fixed position with respect to plate **22**; under stressful conditions ring **30** may rotate within hole **24**. By providing at least one textured surface, the coefficient of friction between hole **24** and ring **30** is increased. The increase in friction between hole **24** and ring **30** may help to inhibit fastener movement relative to plate **22**.

[0066] Several types of textured surfaces may be used to increase the coefficient of friction between ring **30** and hole **24**. In general, any process that transforms a relatively smooth surface into a textured surface having an increased coefficient of friction may be used. Methods for forming a textured surface include, but are not limited to: sanding, forming grooves within a surface, shot peening processes, electric discharge processes, and embedding of hard particles within a surface.

[0067] A shot peening process for forming a textured surface is described in U.S. Pat. No. 5,526,664 to Vetter which is incorporated by reference as if set forth herein. In general, a shot peening process involves propelling a stream of hardened balls, typically made of steel, at a relatively high velocity at a surface. To create a pattern upon an area of the surface the stream is typically moved about the surface. The speed by which the stream is moved about the surface determines the type of textured surface formed.

[0068] An electrical discharge process is based on the principle of removal of portions of a metal surface by spark discharges. Typically a spark is generated between the surface to be treated and an electrode by creating potential differential between the tool and the electrode. The spark produced tends to remove a portion of the surface disposed between the electrode and the surface. Typically, the electrode is relatively small such that only small portions of the surface are removed. By moving the electrode about the surface numerous cavities may be formed within the surface. Typically these cavities are somewhat pyramidal in shape. Various patterns may be formed within the surface depending on how the electrode is positioned during the discharge. Electric discharge machines are well known in the art. A method for forming a frictional surface within a metal surface using an electric discharge process is described in U.S. Pat. No. 4,964,641 to Miesch et al., which is incorporated by reference as if set forth herein.

[0069] Embedding hardened particles in a surface produces a textured surface. A method for embedding hardened particles in a metal surface is described in U.S. Pat. No. 4,768,787 to Shira, which is incorporated by reference as if set forth herein. The method of Shira involves using a laser or other high-energy source to heat the surface such that the surface melts in selected areas. Just before the molten area re-solidifies, a stream of abrasive particles is directed to the area. In this manner some of the particles tend to become embedded within the molten surface. The particles typically have a number of sharp edges that protrude from the surface after the particles have been embedded within the surface.

[0070] Any of the above methods of texturing may be used in combination with another method. For example, the inner surface **46** of hole **24** may be textured using a pattern of grooves. The outer surface **48** of ring **30**, however, may be textured using an electrical discharge method. When coupled together the textured surfaces of hole **24** and ring **30** may interact with each other to provide additional resistance to movement of the ring within the hole.

[0071] FIG. **5** illustrates an embodiment of fastener **100**. The fastener **100** may include fastener head **102**, opening **104**, optional grooves **106**, holes **108**, shank **110** and threads **112**. Opening **104** accepts a drive tool, such as drive tool **114**, which is described below. The opening **104**, grooves **106** and holes **108** accept locking mechanism **116**, as described below. Holes **108** extend from the outer surface **118** of head **102** to the opening **104**. In one embodiment, the outer surface **118** is substantially cylindrical. In another embodiment, the head **102** tapers from a widest portion near the upper surface of the head to a narrowest portion near the shank **110**.

[0072] FIG. **6** is a side view of the head **102** of an embodiment of fastener **100** showing holes **108** and optional rim **120**. Rim **120** may serve to limit the insertion of fastener **100** into a ring **30** during use.

[0073] FIG. **7** is a top view of the head **102** of a fastener **100** with optional grooves **106**. FIG. **8** shows an alternate embodiment of fastener **100** having a hexagonal shape opening **104** and no grooves.

[0074] FIG. **9** illustrates a locking mechanism **116** used with fastener **100**. Locking mechanism **116** includes top **122** with shafts **124** extending downwards and outwards from the top. Prongs **126** are located at ends of shafts **124**. Prongs **126** may be substantially parallel to each other and also may be substantially parallel to the locking mechanism top **122**. The shafts **124** have a spring-like action which allows the shafts **124** to be compressed. The spring-like action also allows the shafts to return to an original configuration when not compressed.

[0075] FIG. **10** illustrates an embodiment of a ring **130** that may be used in combination with fastener **100** and locking mechanism **116**. Ring **130** includes groove **132**. Groove **132** engages prongs **126** on locking mechanism **116** to secure fastener **100** in ring **130** after insertion. Gap **36** in ring **130** allows the ring to contract during insertion of the ring **130** into an end hole **24** of the bone plate **22**. Gap **36** also allows ring

130 to be expanded by the head 102 of fastener 100 in the ring 130 to abut the ring against the inner surface 46 of the end hole 24. Abutting the ring 130 against the inner surface 46 of the end hole 24 may fix the position of fastener 32 relative to the bone plate 22.

[0076] FIG. 11 illustrates tool 114. The tool 114 may be used during the insertion and extraction of a fastener 100 and locking mechanism 116. The insertion/extraction tool 114 includes a shaft 172. One end of shaft 172 may include a handle 174 for turning the tool during insertion and removal of a fastener 100. FIG. 11 shows a modified T-handle 174 coupled to the shaft 172, but any type of handle that allows torque to be applied to the fastener during insertion and removal may be used. At an opposite end of shaft 172 from handle 174 is driver head 176. The outer surface of driver head 176 may be shaped to complement the shape of opening 104 in the head of the fastener 100. Driver head 176 may be inserted into the opening 104 of the fastener 100. The fastener may be inserted in an end hole 24 of a bone plate 22 and into a bone by rotating insertion/extraction tool 114. Driver head 176 includes cavity 178. The inner surface of the cavity may slide over and compress the shafts 124 and prongs 126 of a locking mechanism 116.

[0077] FIG. 12*a* shows a bottom view of an embodiment of a driver head 176 of an insertion/extraction tool 114. The driver head of FIG. 12*a* may be used with the type of fastener head 102 shown in FIG. 7. The driver head 176 has cavity 178 which allows the driver head to slide over and compress a locking mechanism 116. The driver head 176 includes ridges 180 for engaging complementary grooves 106 in the opening 104 of a fastener head 102. FIG. 12*b* shows an alternate embodiment of a driver head 176 of an insertion/extraction tool 114. The driver head of FIG. 12*b* may be used with the type of fastener head 102 shown in FIG. 8. The driver head 176 has cavity 178 which allows the driver head to slide over and compresses a locking mechanism 116. The driver head 176 may be hexagonal shaped to mate with opening 104 of a fastener head 102.

[0078] FIG. 13 shows a cross sectional view of an embodiment of a fastener 100, locking mechanism 116, and insertion/extraction tool 114 during the insertion process. Driver head 176 inserts into opening 104 of fastener head 102. Shafts 124 of locking mechanism 116 are compressed within cavity 178 of driver head 176. The compression of shafts 124 causes prongs 126 to retract in holes 108, which allow fastener head 102 to be inserted into a ring 130 without interference by extended prongs 126. When insertion/extraction tool 114 is removed, the shafts 124 uncompress, which causes the prongs 126 to extend out of holes 108.

[0079] FIG. 14 shows a cross sectional view of an embodiment of a fastener 100, locking mechanism 116, and ring 130 after the fastener has been fully inserted in the ring and the insertion/extraction tool 114 has been removed. Shafts 124 of locking mechanism 116 are uncompressed, allowing prongs 126 to extend out of holes 108 in fastener head 102. Prongs 126 extend into groove 132 on the ring 130.

[0080] To remove a threaded fastener 100 from ring 130, insertion/extraction tool 114 is inserted in the opening 104 in fastener head 102 to compress the shafts 124 of the locking mechanism 116. Compressing the shafts 124 causes the prongs 126 to retract through holes 108 and removes the connection between the prongs and the ring 130. The tool 114 may then be rotated to remove the fastener 100 from the bone.

[0081] After insertion of a fastener 100 and locking mechanism 116 into a bone, if the fastener 100 becomes loose within the bone, fastener backout from the bone plate may be resisted by the locking mechanism-groove connection between locking mechanism 116 and the ring 130. Thus, even if fastener shank 110 loosens within the bone, the fastener head 102 will tend to remain within ring 130 in the hole 24 of the plate 22. There may be some freedom of movement in the connection between the prongs 126 and the groove 130 to allow a fastener 100 to back out slightly from a bone after insertion.

[0082] During the surgical procedure for attaching a bone plate to bones using the devices depicted in FIGS. 5-14, holes may be drilled and tapped into the bones to which the bone plate 22 is to be attached. The bone plate 22 may be positioned adjacent to the bones. Rings 130 may be positioned within each end hole 24 before or during the surgical procedure. A fastener 100, with a pre-inserted locking mechanism, may be positioned through a ring 130. An insertion/extraction tool 114 may be inserted in the opening 104 of threaded fastener 100 to compress the locking mechanism 116 within the cavity of the driver head of the tool. Compressing the locking mechanism 116 retracts the prongs 126 of the locking mechanism within the fastener opening 104. The fastener 100 may then be rotated to insert the fastener 100 into a bone. As the fastener 100 is rotated, fastener head 102 moves into the ring 130. Movement of head 102 into ring 130 causes the ring to expand against the end hole 24 to fix the fastener 100 relative to the plate 22. Once the fastener 100 is fully inserted, insertion/extraction tool 114 is removed. Removing the tool 114 causes the locking mechanism 116 to uncompress so that the prongs 126 extend through the holes 108 in the fastener head 102 and engage ring the groove 132 in the ring 130. Fasteners 100 may be inserted through the remaining end holes 24 and into bone to securely attach the plate 22 to the bones.

[0083] FIG. 15 illustrates an embodiment of a fastener 200 with fastener head 202 having groove 204. When a fastener 200 is inserted through a ring 230 positioned in a plate 22, the groove 204 may engage fingers 232 on ring 230 (the ring shown in FIGS. 19 and 20) to secure the fastener 200 within the ring 230. Fastener 200 may include the head 202 and shank 206 with threading 208. Head 202 may include opening 210 configured to accept a driving tool.

[0084] The engagement of a finger 232 of a ring 230 on groove 204 may inhibit fastener 200 from backing out of the ring after insertion of the fastener into the plate 22. In an embodiment, the outer surface of head 202 is substantially cylindrical. In another embodiment, as shown in FIG. 16, the head 202 may taper. The widest portion of the head 202 may be near the top surface of the head, and the narrowest portion may be near the shank 206.

[0085] FIG. 17 illustrates an embodiment of a fastener 200 which has radial slots 212 extending from the outer surface of the head into the opening 210. The radial slots 212 may allow a portion of head 202 to contract during insertion. The radial slots 212 may also be used to engage a portion of a drive head of an insertion/extraction tool (not shown).

[0086] FIGS. 15, 16, and 17 illustrate fastener heads 202 wherein the grooves 204 are rims along top edges of the heads. FIG. 18 illustrates an embodiment of a fastener 200 wherein the groove 204 is located at a position along the side of the fastener head 202. The groove 204 may be located at any position along the side of the fastener head 202. When the fastener head 202 is driven through a ring 230, the interaction of the fastener head, the ring, and the end hole 24 allows

fingers **232** of the ring to snap into the groove **214**. The fingers **232** may secure the fastener head **202** to the ring **230**.

[0087] FIGS. **19** and **20** show perspective views of embodiments of ring **230** that may be used with fasteners having a groove. Ring **230** may include bottom **234**, top **238**, an outer surface **48**, an inner surface **60**, gap **36**, and slots **240** and notches **242**. The slots **240** and notches **240** may form the fingers **232**. Gap **36** may allow ring **230** to contract. Contraction of the ring **230** may facilitate the insertion of the ring into an end hole **24** in a bone plate **22**. Gap **36** may also allow the ring **230** to expand against the end hole **24** when a fastener head **202** passes into the ring. Expansion of the ring against the hole **24** fixes the fastener **200** relative to the bone plate **22**.

[0088] In some embodiments, outer surface **48** of the ring **230** may be textured to increase the coefficient of friction between ring **230** and the hole **24**. In some embodiments, inner surface **60** of the ring **230** may be tapered to match a tapered head of a fastener **200**. Having tapered surfaces may facilitate the expansion of ring in an end hole **24** during insertion of the fastener into the bone plate system **20**.

[0089] The shape of the end hole **24** may push the fingers **232** inwards past the edge of the groove **204** of a fastener **200** when the groove is inserted into a ring **230** so that the groove passes an upper edge of the ring slots **240**. The inward positioned fingers **232** may inhibit fastener **200** from backing out of the ring **230** and the hole **24**. When the fastener **200** is inserted into the ring **230**, the fastener head **202** may expand the outside surface **48** of the ring against the inner surface **46** of the end hole **24** to fix the fastener **200** to the ring **230**, and the ring to the plate **22**.

[0090] FIG. **21** is a perspective view of an embodiment of a ring that may be used with fasteners **200** that have rims **204**, such as the fasteners shown in FIGS. **15-17**. Ring **430** may include bottom **432**, top **434**, outer surface **48**, inner surface **60**, gap **36**, notches **436**, and ridges **438**. Notches **436** divide the ring **430** into segments or paddles **440**. Notches **436** and gap **36** may allow ring **430** to contract, facilitating the insertion of the ring into a hole **24** of a bone plate **22**. Notches **436** and gap **36** may also allow ring **430** to expand when a fastener head **202** passes into the ring to fix the position of the fastener relative to the bone plate **22**. Notches **436** may also allow paddles **436** to bend outwards during insertion of a fastener **200**. The outer surface **48** and/or the inner surface **60** may be textured. The inner surface of the ring **430** may be tapered to correspond to the taper of a fastener head **202**.

[0091] FIG. **22** illustrates an embodiment of an insertion tool/extraction tool **450** for use with a fastener **200** and ring **430**. Insertion/extraction tool **450** may include shaft **452**, handle **454**, driver head **456**, and extraction member **458**. At one end of shaft **452** is handle **454** for turning the tool during insertion and removal of a fastener **200**. The illustration shows a T-handle, but any other type of handle that allows sufficient torque to be applied to the fastener **200** to allow for insertion or removal of the fastener may be used. At the opposite end of shaft **452** from handle **454** is driver head **456**. The outer surface of driver head **456** may be shaped complementary to the shape of the opening **210** in the head **202** of the fastener **200**.

[0092] The extraction member **458** shown in FIG. **22** may include grip **459**, passage **460**, (shown in FIG. **23***c*), tip **462**, and extraction head **464**. The passage **460** extends through the grip **459** and the extraction head **464**. During the insertion process, extraction member **458** may be removed from shaft **452**. To extract a fastener from a ring **430**, extraction member **458** may be slid back on to shaft **452**. Driver head **456** is inserted into the opening **210** of the fastener **200**. Extraction member **458** slides down shaft **452** until tip **462** of extraction head **464** contacts the top of the ring **430**. Downwards pressure on the extraction member **458** forces paddles **440** of the ring **430** outwards, and disengages the ridge **438** on the paddles **440** from the rim **204** on the fastener head **202**. The fastener **200** may then be backed out of the plate **22** by rotating the shaft **452** with the handle **454**. Preferably, rotating shaft **452** does not rotate the extraction member **458**.

[0093] FIGS. **23***a*, **23***b*, and **23***c* show partial cross sectional views of a threaded fastener **200**, ring **430**, and insertion/extraction tool **450** during the insertion and extraction processes. Referring to FIG. **23***a*, driver head **456** of insertion/extraction tool **450** is inserted in opening **210** of fastener head **202**. Ring **430** is positioned inside a hole **24** in a bone plate and the bone plate is positioned on a bone (bone and bone plate not shown). Fastener **200** is screwed into the bone until the outer surface of fastener head **202** contacts the surfaces of the paddles **440**. The tapering of the outer surface of fastener head **202** provides a ramping force on the surfaces of the paddles **440**, to bend the paddles outwards as fastener **200** is screwed farther into the bone.

[0094] In FIG. **23***b*, fastener **200** has been screwed in to the desired depth. Fastener head **202** penetrates ring **430** far enough to allow ridges **438** to snap onto rim **204** on fastener head **202**. Driver head **456** of insertion/extraction tool **450** is shown still inserted in opening **210** prior to removal from the opening. After insertion, if the fastener **200** becomes loose within the bone, fastener backout from the bone plate may be resisted by the ridge-rim connection between fastener head **202** and ring **430**. Thus, even if the fastener shank loosens within the bone, the fastener head **202** will tend to remain within ring **430** in the hole **24** of the plate **22** so as not to protrude from the plate into surrounding body tissue. In some embodiments, there may be some freedom of movement in the connection between the ridges **438** on the paddles **440** and the rim **204** to allow a fastener **200** to back out slightly from a bone after insertion. Typically, the freedom of movement is limited so that the fastener head **202** may not protrude from the plate **22**.

[0095] FIG. **23***c* shows insertion/extraction tool **250** being used to remove a fastener **200**. Driver head **256** is inserted in opening **210** of fastener **200**. Extraction head **464** is slid down shaft **452** of insertion/extraction tool **450** until the sloped surface of tip **462** applies a wedging force against the sloped upper surfaces of paddles **440**. The wedging force bends the paddles **440** outwards to disengage the ridges **438** from the rim **204**. Fastener **200** may then be backed out of the bone, the ring **430** and the plate **22**.

[0096] The plate, fasteners, and locking mechanisms may be made of steel (e.g, stainless steel), titanium, steel alloys or titanium alloys. These materials are generally nontoxic, biocompatible, strong, and non-corrosive. Other materials that have these properties may also be used. The plate and the rings may be made of a number of bio-compatible materials including metals, plastics, and composites.

[0097] Any of the embodiments described above may be used individually or in combination with other embodiments described above. Further modifications and alternative embodiments of various aspects of the invention will be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art

the general manner of carrying out the invention. It is to be understood that the forms of the invention shown and described herein are to be taken as examples of embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims.

What is claimed is:

1. A system, comprising:

a plate comprising:

a first end having a first hole;

a second end opposite the first end and having a second hole, wherein each hole of the first and second holes extends from an upper surface to a lower surface of the plate and comprises an inner surface having a curved contour;

a first bone fastener sized to be placed in a first ring for anchoring the first end of the plate to a first bone, the first ring being sized to fit in the first hole and rotatable in the first hole to define a first angle of the first bone fastener relative to the plate; and

a second bone fastener sized to be placed in a second ring for anchoring the second end of the plate to a second bone, the second ring being sized to fit in the second hole and rotatable in the second hole to define a second angle of the second bone fastener relative to the plate, wherein each ring of the first and second rings comprises an outer surface that substantially corresponds to the curved contour of the inner surface of the hole to allow for rotation of the ring within the hole.

2. The system of claim **1**, wherein the first angle is defined by a longitudinal axis of the first bone fastener and a first axis perpendicular to the plate and wherein the second angle is defined by a longitudinal axis of the second bone fastener and a second axis perpendicular to the plate.

3. The system of claim **1**, wherein the plate further comprises a portion between the first end and the second end, the portion having a width that is different than widths of the first end and the second end.

4. The system of claim **1**, wherein each ring of the first and second rings further comprises a plurality of deflectable portions.

5. The system of claim **4**, wherein each ring of the first and second rings further comprises a gap to allow for expansion and contraction of the ring.

6. The system of claim **1**, wherein each ring of the first and second rings is sized to have a height not exceeding a thickness of the plate.

7. The system of claim **1**, wherein the plate has a thickness that is constant or substantially constant across the plate.

8. The system of claim **1**, wherein the first angle and the second angle define a converging or diverging configuration of the first and second bone fasteners.

9. The system of claim **1**, wherein each bone fastener of the first and second bone fasteners comprises a head and wherein each ring of the first and second rings is sized to surround at least partially the head of the bone fastener positioned within the hole.

10. The system of claim **1**, wherein the plate further comprises a third hole extending from the upper surface to the lower surface of the plate.

11. The system of claim **10**, wherein the third hole is sized to be larger at the upper surface and smaller at the lower surface of the plate.

12. The system of claim **10**, wherein the third hole is located at about a mid-point of the plate.

13. The system of claim **12**, wherein the mid-point of the plate has a width that is different than widths of the first end and the second end of the plate.

14. The system of claim **1**, wherein the plate further comprises one or more spikes extending from the lower surface of the plate.

15. The system of claim **1**, wherein the plate has a curved contour.

16. A method for implanting a spinal plate, wherein the plate comprises a plurality of holes, wherein each of the holes extends from an upper surface to a lower surface of the plate, the method comprising:

drilling and tapping holes into bones to which the plate is to be attached;

positioning the plate adjacent to the bones and over the holes in the bones; and

for each bone fastener of a plurality of bone fasteners:

placing the bone fastener in a ring, the ring being positioned in a hole of the plurality of holes in the plate;

rotating the bone fastener to define an oblique angle relative to the plate, the bone fastener being rotated via the ring positioned in the hole, wherein the ring has an outer surface that substantially corresponds to a curved contour of an inner surface of the hole to allow for rotation of the ring within the hole; and

advancing the bone fastener into a bone at the oblique angle to thereby anchor the plate to the bone.

17. The method according to claim **16**, wherein the plurality of holes comprises a first hole at a first end of the plate, a second hole at a second end of the plate, and a third hole at about a mid-point of the plate, further comprising:

positioning a fastener in the third hole.

18. The method according to claim **17**, wherein the mid-point of the plate has a width that is different than widths of the first end and the second end of the plate.

19. The method according to claim **16**, wherein the ring further comprises a plurality of deflectable portions.

20. The method according to claim **16**, wherein the ring is positioned in the hole before or after the bone fastener is placed in the ring.

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