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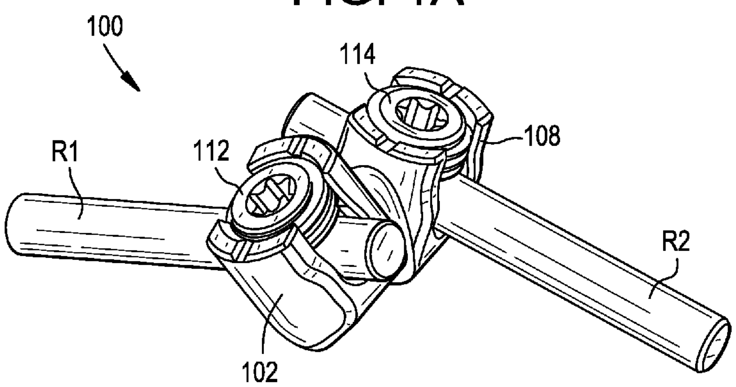
(54) **Title:** ARTICULATING IMPLANT CONNECTORS

FIG. 1A



(57) **Abstract:** Articulating implant connectors and related methods are disclosed herein. Exemplary connectors can include first and second bodies that are rotatable relative to one another about a rotation axis and selectively lockable to resist or prevent such rotation. Each of the bodies can be configured to couple to a rod or other fixation component, and the connector can be used to lock first and second rods together even when the rods are obliquely angled with respect to one another.

WO 2018/183423 A1

ARTICULATING IMPLANT CONNECTORS

RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. Patent Application No. 15/471,075, filed on March 28, 2017, the entire contents of which are incorporated herein by reference.

FIELD

[0002] Articulating implant connectors and related methods are disclosed herein.

BACKGROUND

[0003] Fixation systems can be used in orthopedic surgery to maintain a desired spatial relationship between multiple bones or bone fragments. For example, various conditions of the spine, such as fractures, deformities, and degenerative disorders, can be treated by attaching a spinal fixation system to one or more vertebrae. Such systems typically include a spinal fixation element, such as a rigid or flexible rod or plate, that is coupled to the vertebrae by attaching the element to various anchoring devices, such as screws, hooks, or wires. Once installed, the fixation system holds the vertebrae in a desired position until healing or spinal fusion can occur, or for some other period of time.

[0004] There are many instances in which it may be desirable to connect multiple implants to each other. For example, some revision surgeries involve extending a previously-installed construct to additional vertebral levels by coupling a newly-installed spinal rod to a previously-installed rod. By way of further example, aspects of the patient's anatomy, the surgical technique used, or the desired correction may require that multiple spinal rods be connected to one another. As yet another example, coupling multiple rods to one another can improve the overall strength and stability of an implanted construct.

[0005] There can be various difficulties associated with connecting multiple implants to each other. The available space for the implanted construct can often be very limited, particularly in the cervical area of the spine. Also, aligning and positioning implants and connectors in the surgical wound may be challenging or cumbersome for the surgeon. There is a continual need for improved implant connectors and related methods.

SUMMARY

[0006] Articulating implant connectors and related methods are disclosed herein. Exemplary connectors can include first and second bodies that are rotatable relative to one another about a rotation axis and selectively lockable to resist or prevent such rotation. Each of the bodies can be configured to couple to a rod or other fixation component, and the connector can be used to lock first and second rods together even when the rods are obliquely angled with respect to one another.

[0007] In some embodiments, a connector can include a first body that defines a first rod-receiving recess, the first body having proximal and distal ends that define a proximal-distal axis extending therebetween; a second body that defines a second rod-receiving recess, the second body having proximal and distal ends that define a proximal-distal axis extending therebetween; a hinge pin that couples the first body to the second body, a central longitudinal axis of the hinge pin defining a rotation axis about which the first and second bodies rotate relative to one another; and a fastener movable with respect to at least one of the first and second bodies to urge the first and second bodies towards one another along the rotation axis and thereby lock relative rotation of the first and second bodies about the rotation axis.

[0008] The fastener can secure a rod to one of the first and second rod-receiving recesses. The fastener can be a first fastener configured to secure a first rod within the first rod-receiving recess. The connector can include a second fastener configured to secure a second rod in the second rod-receiving recess. The hinge pin can be formed integrally with the first body. The hinge pin can be rotatable relative to both of the first and second bodies. The first and second bodies can include respective bearing surfaces configured to bear against one another to lock relative rotation of the first and second bodies about the rotation axis. The bearing surfaces can be defined by complementary male and female structures of the first and second bodies. The first body can include a conical male projection, an outer surface of which defines the bearing surface of the first body. The second body can include a conical female recess, an inner surface of which defines the bearing surface of the second body. The bearing surfaces can each include teeth or splines. The hinge pin can be received within a cavity formed in the first body or the second body. The hinge pin can translate longitudinally within the cavity as the fastener is

moved relative to said at least one of the first and second bodies. The proximal-distal axes of the first and second bodies can be obliquely angled with respect to one another. A force applied by the fastener can be transferred to the hinge pin through a saddle. The saddle can include a conical surface that engages and bears against a corresponding conical surface of the hinge pin to pull the first and second bodies towards one another. The saddle can include a keel extending distally therefrom. The keel can be received within a slot formed in the hinge pin. The keel can have a bearing surface that engages and bears against a corresponding bearing surface of the slot to pull the first and second bodies towards one another. The bearing surfaces of the keel and the slot can lie in planes that are obliquely angled with respect to the rotation axis. The saddle can include first and second keels defining a space therebetween in which a central rib of the hinge pin is received. The first and second keels can have bearing surfaces that engage and bear against corresponding bearing surface of the hinge pin. The hinge pin can include a rod seat formed therein. The rod seat can be configured such that urging a rod against the rod seat causes the hinge pin to translate relative to at least one of the first and second bodies along the rotation axis. The rod seat can be positioned relative to the first rod-receiving recess such that a lateral sidewall of the rod seat interferes with a rod as the rod is seated in the first rod-receiving recess. The rod seat can be curved in multiple planes.

[0009] In some embodiments, a connector can include a first body that defines a first rod-receiving recess; a hinge pin formed integrally with the first body and extending laterally therefrom to a free end; a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin is received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis; a first fastener configured to secure a first rod within the first rod-receiving recess; and a second fastener configured to secure a second rod within the second rod-receiving recess and to urge the first and second bodies towards one another along the rotation axis to lock relative rotation of the first and second bodies about the rotation axis.

[0010] The second fastener can be configured to bear against a saddle disposed within the second rod-receiving recess to urge a bearing surface of the saddle against a bearing surface of the hinge pin to move the first and second bodies towards one another. The second fastener can be configured to bear against a rod disposed within the second rod-receiving recess to urge the rod against a rod seat of the hinge pin to move the first and second bodies towards one another.

[0011] In some embodiments, a surgical method can include inserting a first rod into a first rod-receiving recess of a first body of a connector; inserting a second rod into a second rod-receiving recess of a second body of the connector, the second body being coupled to the first body by a hinge pin; rotating the first body relative to the second body about a rotation axis defined by the hinge pin; moving a fastener with respect to at least one of the first and second bodies to urge the first and second bodies towards one another along the rotation axis and thereby lock relative rotation of the first and second bodies about the rotation axis; and securing the first and second rods to an anatomy of a patient.

[0012] The first rod can be secured to a cervical spine of the patient by one or more bone anchors and the second rod can be secured to a thoracic spine of the patient by one or more bone anchors. Rotating the first body relative to the second body can cause the first and second rods to be obliquely angled with respect to one another. Moving the fastener can be effective both to secure one of the first and second rods to the connector and to lock rotation of the connector.

[0013] In some embodiments, a connector can include a first body that defines a first rod-receiving recess; a hinge pin extending laterally from the first body to a free end; a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin can be received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin; a first fastener configured to secure a first rod within the first rod-receiving recess; and a second fastener configured to secure a second rod within the second rod-receiving recess. The hinge pin can have planar surfaces that intersect to form one or more corners. The corners of the hinge pin can apply a force against the cavity of the second body that locks the hinge pin in place when the second fastener secures the second rod within the second rod-receiving recess.

[0014] A cross section of the hinge pin can have a polygonal profile. The connector can further include a saddle disposed within the second rod-receiving recess. The saddle can include a saddle protrusion extending distally therefrom. The saddle protrusion can be received within a slot formed in the hinge pin. The force applied by one or more corners of the hinge pin can be transferred from a force applied by the second fastener through the saddle. The saddle protrusion can limit a rotation of the hinge pin within the cavity of the second body when a terminal end of the slot of the hinge pin engages and bears against the saddle protrusion. The saddle can have a bearing surface adjacent to the saddle protrusion that engages and bears against a corresponding bearing surface of the hinge pin adjacent to the slot. The slot of the hinge pin can be formed radially about a central rib of the hinge pin. The saddle protrusion of the saddle can define a depression in which the central rib of the hinge pin is received.

[0015] In some embodiments, the connector can include a first body that defines a first rod-receiving recess; a hinge pin extending laterally from the first body to a free end; a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin can be received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin; a saddle defining a rod seat disposed within the second rod-receiving recess, the saddle including a saddle protrusion extending distally therefrom, the saddle protrusion being received within a slot formed in the hinge pin; a first fastener configured to secure a first rod within the first rod-receiving recess; and a second fastener configured to secure a second rod on the rod seat of the saddle. The slot of the hinge pin can have an angled cam surface that can engage and bear against a corresponding angled bearing surface of the saddle protrusion to lock the hinge pin in place when the second fastener secures the second rod within the second rod-receiving recess.

[0016] The angled cam surface of the slot can be oriented at an oblique angle with respect to the longitudinal axis of the hinge pin. The angled bearing surface of the saddle protrusion can be oriented at an oblique angle with respect to the longitudinal axis of the hinge pin. The angled bearing surface of the saddle protrusion can be oriented to match the oblique angle of the angled cam surface of the slot in the hinge pin. The saddle protrusion can have a wedge-shaped cross section that can apply a force against the angled cam surface of the slot of the hinge pin to lock the hinge pin in place when the second fastener secures the second rod within the second rod-receiving recess.

[0017] In some embodiments, the connector can include a first body that defines a first rod-receiving recess; a hinge pin extending laterally from the first body to a free end; a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin can be received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin; a first fastener configured to secure a first rod within the first rod-receiving recess; and a second fastener configured to secure a second rod within the second rod-receiving recess. The free end of the hinge pin can extend through the cavity and into an opening defined in the second body. The opening can have a cross sectional shape that limits rotation of the free end of the hinge pin relative to the second body about the rotation axis.

[0018] The free end of the hinge pin can have a cross sectional shape configured to rotate within the opening of the second body. The cross sectional shape of the free end of the hinge pin and the cross sectional shape of the opening can define a degree of rotation of the free end of the hinge pin. The cross sectional shape of the opening of the second body and the cross sectional shape of the free end of the hinge pin can be D-shaped. The D-shaped cross section of the opening of the second body can have an area greater than an area of the D-shaped cross section of the free end of the hinge pin.

[0019] The second fastener can be configured to bear against a saddle disposed within the second rod-receiving recess to urge a bearing surface of the saddle against a corresponding bearing surface of the hinge pin. The saddle can include a saddle protrusion extending distally from an edge of the saddle adjacent to the bearing surface of the saddle. The saddle protrusion can be received within a slot formed in the hinge pin adjacent to the bearing surface of the hinge pin. The slot of the hinge pin can be aligned with an edge of the second rod-receiving recess when the free end of the hinge pin is inserted into the through hole opening of the second body. The bearing surface of the hinge pin can bear against the bearing surface of the saddle for a continuous length that is greater than half the width of the second rod-receiving recess.

[0020] In some embodiments, the connector can include a first body that defines a first rod-receiving recess; a hinge pin extending laterally from the first body to a free end; a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin can be received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin; a saddle defining a rod seat disposed within the second rod-receiving recess, the saddle including a saddle protrusion extending distally therefrom, the saddle protrusion being received within a slot formed in the hinge pin; a first fastener configured to secure a first rod within the first rod-receiving recess; and a second fastener configured to secure a second rod on the rod seat of the saddle. The slot of the hinge pin can be aligned with an edge of the second rod-receiving recess when the free end of the hinge pin is inserted into the cavity of the second body.

[0021] The saddle protrusion can extend distally from an edge of the saddle adjacent to a bearing surface of the saddle. The saddle protrusion can be received within the slot of the hinge pin. The bearing surface of the saddle can bear against a bearing surface of the hinge pin for a continuous length that can be greater than half the width of the second rod-receiving recess.

[0022] In some embodiments, a surgical method can include inserting a first rod into a first rod-receiving recess of a first body of a connector, the first body including a hinge pin that extends laterally therefrom to a free end; inserting a second rod onto a rod seat formed in a saddle disposed in a second rod-receiving recess of a second body of the connector, the hinge pin of the first body being inserted into a cavity formed in the second body and thereby coupling the first body of the connector to the second body of the connector; rotating the first body relative to the second body about a rotation axis defined by the hinge pin, such that a slot formed in the hinge pin rotates about a saddle protrusion extending distally from the saddle; moving a fastener with respect to the second body to secure the second rod within the second rod-receiving recess and thereby lock relative rotation of the first and second bodies about the rotation axis; and securing the first and second rods to an anatomy of a patient.

[0023] Moving the fastener with respect to the second body can urge a bearing surface of the saddle against a corresponding bearing surface of the hinge pin and thereby cause one or more corners of the hinge pin to apply a force against the cavity of the second body. Rotating the first body relative to the second body about a rotation axis defined by the hinge pin can include rotating the first body with respect to the second body such that the saddle protrusion can limit a rotation of the hinge pin when a terminal end of the slot of the hinge pin engages and bear against the saddle protrusion. The slot of the hinge pin can have an angled cam surface and the saddle protrusion can have a corresponding angled bearing surface. Moving the fastener with respect to the second body can wedge the angled bearing surface of the saddle protrusion into the angled cam surface of the slot. Rotating the first body relative to the second body about a rotation axis defined by the hinge pin can include rotating the first body such that the free end of the hinge pin rotates within an opening defined in the second body of the connector. The opening can have a cross sectional shape that limits rotation of the free end of the hinge pin. Rotating the first body relative to the second body about a rotation axis defined by the hinge pin can include rotating the first body such that the slot of the hinge pin rotates about the saddle protrusion that extends distally from an edge of the saddle and can be aligned with an edge of the second rod-receiving recess. Moving the fastener with respect to the second body can urge a bearing surface of the saddle against a corresponding bearing surface of the hinge pin for a continuous length that is greater than half the width of the second rod-receiving recess.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] FIG. 1A is a perspective view of a connector, shown with first and second rods;

[0025] FIG. 1B is an exploded perspective view of the connector of FIG. 1A;

[0026] FIG. 1C is a sectional side view of the connector and rods of FIG. 1A;

[0027] FIG. 1D is a partial exploded view of the connector of FIG. 1A;

[0028] FIG. 1E is a perspective view of a first body of the connector of FIG. 1A;

[0029] FIG. 1F is another perspective view of the first body of FIG. 1E;

[0030] FIG. 1G is a perspective view of a first saddle of the connector of FIG. 1A;

[0031] FIG. 1H is another perspective view of the first saddle of FIG. 1G;

[0032] FIG. 1I is a perspective view of a hinge pin of the connector of FIG. 1A;

[0033] FIG. 1J is an end view of the hinge pin of FIG. 1I;

[0034] FIG. 1K is a side view of the hinge pin of FIG. 1I;

[0035] FIG. 1L is a top view of the hinge pin of FIG. 1I;

[0036] FIG. 2A is a perspective view of a connector, shown with first and second rods;

[0037] FIG. 2B is an exploded perspective view of the connector of FIG. 2A;

[0038] FIG. 2C is a sectional side view of the connector and rods of FIG. 2A;

[0039] FIG. 2D is a perspective view of a second body of the connector of FIG. 2A;

[0040] FIG. 2E is another perspective view of the second body of FIG. 2A;

[0041] FIG. 3A is a perspective view of a connector, shown with first and second rods;

[0042] FIG. 3B is an exploded perspective view of the connector of FIG. 3A;

[0043] FIG. 3C is a sectional side view of the connector and rods of FIG. 3A;

[0044] FIG. 3D is a perspective view of a saddle of the connector of FIG. 3A;

[0045] FIG. 3E is a side view of the saddle of FIG. 3D;

[0046] FIG. 3F is another perspective view of the saddle of FIG. 3D;

[0047] FIG. 3G is a perspective view of a first body of the connector of FIG. 3A;

[0048] FIG. 3H is a perspective view of a second body of the connector of FIG. 3A;

[0049] FIG. 3I is a top view of an alternate first body of the connector of FIG. 3A;

[0050] FIG. 3J is an end view of an alternate saddle of the connector of FIG. 3A

[0051] FIG. 3K is a side view of the alternate first body of FIG. 3I;

[0052] FIG. 3L is a side view of the alternate saddle of FIG. 3J;

[0053] FIG. 4A is a perspective view of a connector, shown with first and second rods and with first and second fasteners of the connector omitted;

[0054] FIG. 4B is an exploded perspective view of the connector of FIG. 4A;

[0055] FIG. 4C is a sectional side view of the connector of FIG. 4A;

[0056] FIG. 4D is a perspective view of a second body of the connector of FIG. 4A;

[0057] FIG. 4E is a side view of a first body of the connector of FIG. 4A;

[0058] FIG. 4F is a perspective sectional view of the first body of the connector of FIG. 4A;

[0059] FIG. 5A is a perspective view of a connector, shown with first and second spinal rods;

[0060] FIG. 5B is an exploded perspective view of the connector of FIG. 5A;

[0061] FIG. 5C is a perspective view of a first body of the connector of FIG. 5A;

[0062] FIG. 5D is another perspective view of the first body of FIG. 5C;

[0063] FIG. 5E is an end view of the first body of FIG. 5C;

[0064] FIG. 5F is a top view of the connector of FIG. 5A, shown with the saddle of the connector omitted;

[0065] FIG. 5G is a perspective view of a second body of the connector of FIG. 5A;

[0066] FIG. 5H is another perspective view of the second body of FIG. 5G;

[0067] FIG. 5I is a perspective view of the saddle of the connector of FIG. 5A;

[0068] FIG. 5J is a sectional side view of the connector of FIG. 5A, shown with the fasteners of the connector omitted;

[0069] FIG. 5K is another perspective view of the saddle of FIG. 5I;

[0070] FIG. 5L is an end view of the saddle of FIG. 5I;

[0071] FIG. 5M is another perspective view of a connector, shown with the second body as transparent;

[0072] FIG. 5N is a sectional end view of the connector of FIG. 5A, shown with the fasteners of the connector omitted;

[0073] FIG. 5O is another sectional end view of the connector of FIG. 5A, shown with the fasteners of the connector omitted;

[0074] FIG. 6A is a perspective view of a connector, shown with the fasteners of the connector omitted;

[0075] FIG. 6B is an exploded perspective view of the connector of FIG. 6A;

[0076] FIG. 6C is a perspective view of a first body of the connector of FIG. 6A;

[0077] FIG. 6D is top view of the connector of FIG. 6A, shown with the saddle of the connector omitted;

[0078] FIG. 6E is a perspective view of the saddle of the connector of FIG. 6A;

[0079] FIG. 6F is another perspective view of the saddle of FIG. 6E;

[0080] FIG. 6G is another perspective view of the saddle of FIG. 6E;

[0081] FIG. 6H is another perspective view of the connector of FIG. 6A, shown with the second body of the connector as transparent;

[0082] FIG. 6I is a sectional side view of the connector of FIG. 6A, shown with the fasteners omitted;

[0083] FIG. 6J is bottom view of the connector of FIG. 6A, shown with the second body of the connector as transparent;

[0084] FIG. 7A is a perspective view of a connector, shown without the fasteners of the connector;

[0085] FIG. 7B is an exploded perspective view of the connector of FIG. 7A;

[0086] FIG. 7C is a side view of a first body of the connector of FIG. 7A;

[0087] FIG. 7D is a top view of the first body of FIG. 7C;

[0088] FIG. 7E is an end view of the first body of FIG. 7C;

[0089] FIG. 7F is a side view of a second body of the connector of FIG. 7A;

[0090] FIG. 7G is a perspective view of the second body of FIG. 7F;

[0091] FIG. 7H is another perspective view of the second body of FIG. 7F;

[0092] FIG. 7I is a side view of the saddle of the connector of FIG. 7A;

[0093] FIG. 7J is a perspective view of the saddle of FIG. 7I;

[0094] FIG. 7K is another perspective view of the saddle of FIG. 7I;

[0095] FIG. 7L is another perspective view of the connector of FIG. 7A, shown with the saddle and the fasteners of the connector omitted;

[0096] FIG. 7M is a sectional side view of the connector of FIG. 7A;

[0097] FIG. 7N is an end view of the connector of FIG. 7A;

[0098] FIG. 7O is a sectional end view of the connector of FIG. 7A, shown with the fasteners of the connector omitted; and

[0099] FIG. 8 is a perspective view of a human spine with a fixation system attached thereto.

DETAILED DESCRIPTION

[00100] Articulating implant connectors and related methods are disclosed herein. Exemplary connectors can include first and second bodies that are rotatable relative to one another about a rotation axis and selectively lockable to resist or prevent such rotation. Each of the bodies can be configured to couple to a rod or other fixation component, and the connector can be used to lock first and second rods together even when the rods are obliquely angled with respect to one another.

[00101] Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those skilled in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments.

[00102] FIGS. 1A-1L illustrate an exemplary embodiment of a connector 100. As shown, the connector 100 can include a first body 102 that defines a first rod-receiving recess or channel 104 and a second body 106 that defines a second rod-receiving recess or channel 108. The first and second bodies 102, 106 can be connected to one another at least in part by a hinge pin 110. The hinge pin 110 can define a rotation axis A1 about which the first and second bodies 102, 106 can rotate relative to one another. The connector 100 can include first and second fasteners 112, 114 configured to secure respective first and second rods R1, R2 or other fixation elements to the connector 100.

[00103] At least one of the fasteners 112, 114 can further be configured to urge the first and second bodies 102, 106 towards one another and thereby lock relative rotation of the first and second bodies about the rotation axis A1. For example, the first fastener 112 can be tightened to secure a first rod R1 within the first body 102 and to apply a force to a first ramped, curved, or otherwise tapered surface 116 of the hinge pin 110 to draw the first and second bodies 102, 106 towards one another, locking rotation therebetween. In the illustrated embodiment, a force applied by the first fastener 112 is transferred to the hinge pin 110 through the first rod R1 and through a first saddle 118 disposed between the first rod and the hinge pin. In other arrangements, the saddle 118 can be omitted and the first rod R1 can bear directly against the hinge pin 110. In still further arrangements, the first fastener 112 can bear directly against the saddle 118. For example, the first fastener 112 can include an outer set screw that bears against the saddle 118 to lock relative rotation of the bodies 102, 106, and an inner set screw that bears against the first rod R1 to secure the first rod to the connector 100.

[00104] Similarly, the second fastener 114 can be tightened to secure a second rod R2 within the second body 106 and to apply a force to a second ramped, curved, or otherwise tapered surface 120 of the hinge pin 110 to draw the first and second bodies 102, 106 towards one another, locking rotation therebetween. In the illustrated embodiment, a force applied by the second fastener 114 is transferred to the hinge pin 110 through the second rod R2 and through a second saddle 122 disposed between the second rod and the hinge pin. In other arrangements, the saddle 122 can be omitted and the second rod R2 can bear directly against the hinge pin 110. In still further arrangements, the second fastener 114 can bear directly against the saddle 122. For example, the second fastener 114 can include an outer set screw that bears against the saddle 122 to lock relative rotation of the bodies 102, 106, and an inner set screw that bears against the second rod R2 to secure the second rod to the connector 100.

[00105] The geometries of the various components of the connector 100 can be configured such that tightening either of the fasteners 112, 114 individually is effective to lock relative rotation between the bodies 102, 106, or such that both fasteners 112, 114 must be tightened before relative rotation between the bodies 102, 106 is locked.

[00106] The ability to rotate the first and second bodies 102, 106 relative to one another about the rotation axis A1 can advantageously allow first and second rods R1, R2 to be locked together even when the rods are obliquely angled with respect to one another, e.g., in the sagittal plane or in the coronal plane. The connector 100 can be particularly useful in connecting tandem rods of a spinal fixation construct across the cervical-thoracic (CT) junction of a patient. For example, the connector 100 can secure the rods R1, R2 in a laterally-offset arrangement to accommodate the different screw trajectories that may occur at the CT junction. By way of further example, the ability of the connector 100 to articulate can allow a cervical rod and a thoracic rod to be locked to one another at an oblique angle in the sagittal plane, e.g., to restore natural lordosis or kyphosis. The connector 100 can also be particularly useful in spinal deformity correction and other procedures in which multiple angled rods are to be coupled to one another.

[00107] The first body 102 is shown in greater detail in FIGS. 1C, 1E, and 1F. The first body 102 can include proximal and distal ends 102p, 102d that define a proximal-distal axis A2. The proximal end 102p of the body 102 can include a pair of spaced apart arms 124, 126 that define

the first rod-receiving recess 104 therebetween. A rod R1 disposed in the first rod-receiving recess 104 can have a central longitudinal rod axis A3. The first rod-receiving recess 104 can be open in a proximal direction, such that a rod R1 can be inserted into the recess by moving the rod distally with respect to the connector 100. Alternatively, the first rod-receiving recess 104 can be open in distal direction, open in a lateral direction, or closed such that the rod R1 must be translated along the axis A3 to insert the rod into the recess 104.

[00108] Each of the arms 124, 126 can extend from the distal portion 102d of the body 102 to a free end. The outer surfaces of each of the arms 124, 126 can include a feature (not shown), such as a recess, dimple, notch, projection, or the like, to facilitate coupling of the connector 100 to various instruments. For example, the outer surface of each arm 124, 126 can include an arcuate groove at the respective free end of the arms for attaching the connector 100 to an extension tower or retractor. The arms 124, 126 can include or can be coupled to extension or reduction tabs (not shown) that extend proximally from the body 102 to functionally extend the length of the arms 124, 126. The extension tabs can facilitate insertion and reduction of a rod or other implant, as well as insertion and locking of the first fastener 112. The extension tabs can be configured to break away or otherwise be separated from the arms 124, 126.

[00109] The inner surfaces of each of the arms 124, 126 can be configured to mate with the first fastener 112. For example, the inner surfaces of the arms 124, 126 can include threads that correspond to external threads formed on the first fastener 112. Accordingly, rotation of the first fastener 112 with respect to the body 102 about the axis A2 can be effective to translate the first fastener with respect to the body axially along the axis A2.

[00110] The inner surfaces of each of the arms 124, 126 can include features for retaining the first saddle 118 within the first body 102 and/or for limiting or preventing certain movement of the saddle with respect to the body. For example, the arms 124, 126 can each include a recess 128 configured to receive a corresponding projection 144 formed on the saddle 118. Each recess 128 can define a distal-facing upper surface configured to limit proximal travel of the saddle 118 along the axis A2 and a proximal-facing lower surface configured to limit distal travel of the saddle 118 along the axis A2. The recess 128 can extend through less than an entire width of the arm in which the recess is formed, such that rotation of the saddle 118 relative to the body 102

about the axis A2 is limited or prevented when the projections 144 of the saddle are received within the recesses.

[00111] It will be appreciated that the illustrated retention features are exemplary, and that various other retention features can be used instead or in addition. For example, the structures can be reversed such that the body 102 includes projections received within corresponding recesses formed in the saddle 118. As another example, the saddle 118 and the body 102 can include opposed grooves in which a snap ring or C-clip is received to retain the saddle to the body. As yet another example, the saddle 118 and the hinge pin 110 can include opposed grooves in which a snap ring or C-clip is received to retain the saddle to the hinge pin.

[00112] The first body 102 can include an outer bearing surface 130 configured to contact and bear against a corresponding bearing surface 140 of the second body 106. The respective bearing surfaces 130, 140 of the bodies 102, 106 can bear against one another to lock relative rotation between the bodies as they are urged towards one another. In the illustrated embodiment, the bearing surfaces 130, 140 of the first and second bodies 102, 106 are opposed planar surfaces configured to frictionally-engage one another when the connector 100 is locked. It will be appreciated, however, that various other arrangements can be used instead or in addition. For example, the bearing surfaces 130, 140 can include or can be defined by complementary male and female structures of the first and second bodies 102, 106. In some embodiments, the first body 102 can include a conical male projection, an outer surface of which defines the bearing surface 130 of the first body, and the second body 106 can include a conical female recess, an inner surface of which defines the bearing surface 140 of the second body. As the projection of the first body 102 is urged into the recess of the second body 106, the conical surfaces wedge against one another to form a taper-lock connection. While conical surfaces are described in the example above, the male and female features can include concave or convex spherical surfaces, stepped surfaces, and so forth.

[00113] One or both of the bearing surfaces 130, 140 can include surface features for enhancing grip between the surfaces. For example, one or both surfaces can include teeth, grooves, roughening, surface textures or coatings, etc. In some embodiments, as shown in FIG. 1D, each bearing surface 130, 140 can include a plurality of teeth that extend radially outward from the

rotation axis A1. The teeth can selectively interlock to maintain the bodies 102, 106 in one of a plurality of discrete rotational positions relative to one another.

[00114] The distal end 102d of the body 102 can define an interior cavity 132 in which a first end of the hinge pin 110 can be received. The cavity 132 can be open to the bearing surface 130 of the first body 102 and open to the first rod-receiving recess 104 as shown. In some embodiments, the cavity 132 can be a blind bore formed in the bearing surface 130 of the body 102 and intersecting with the first rod-receiving recess 104. At least one dimension of the cavity 132 can be greater than a corresponding dimension of the hinge pin 110 to allow the hinge pin to translate within the cavity along the rotation axis A1. As described further below, the cavity 132 can be dimensioned to limit the degree to which the body 102 can rotate relative to the hinge pin 110 about the axis A1.

[00115] The second body 106 can be identical or substantially identical to the first body 102, or can have any of the features or variations described above with respect to the first body 102. Accordingly, only a brief description of the second body 106 is provided here for the sake of brevity. The second body 106 can include proximal and distal ends 106p, 106d that define a proximal-distal axis A4. The proximal end 106p of the body 106 can include a pair of spaced apart arms 134, 136 that define the second rod-receiving recess 108 therebetween. A rod R2 disposed in the second rod-receiving recess 108 can have a central longitudinal rod axis A5. The second rod-receiving recess 108 can be open in a proximal direction, such that a rod R2 can be inserted into the recess by moving the rod distally with respect to the connector 100. Alternatively, the second rod-receiving recess 108 can be open in distal direction, open in a lateral direction, or closed such that the rod R2 must be translated along the axis A5 to insert the rod into the recess 108.

[00116] Each of the arms 134, 136 can include features 138 for retaining the saddle 122 within the body 106. The second body 106 can include an outer bearing surface 140 configured to contact and bear against the outer bearing surface 130 of the first body 102. The distal end 106d of the second body 106 can define an interior cavity 142 in which a second end of the hinge pin 110 can be received. The cavity 142 can be open to the bearing surface 140 of the second body 106 and open to the second rod recess 108 as shown. In some embodiments, the cavity 142 can

be a blind bore formed in the bearing surface 140 of the body 106 and intersecting with the second rod recess 108. At least one dimension of the cavity 142 can be greater than a corresponding dimension of the hinge pin 110 to allow the hinge pin to translate within the cavity along the rotation axis A1. As described further below, the cavity 142 can be dimensioned to limit the degree to which the body 106 can rotate relative to the hinge pin 110 about the axis A1.

[00117] The bodies 102, 106 of the connector 100 can include various features for decreasing or increasing the center-to-center offset between the first and second rods R1, R2 when the rods are locked to the connector. In the illustrated embodiment, the bearing surfaces 130, 140 of the first and second bodies 102, 106 are obliquely angled with respect to the bodies' respective proximal-distal axes A2, A4. Accordingly, the rods R1, R2 move towards one another as they are advanced distally into the connector 100. This can advantageously reduce the center-to-center offset of the rods R1, R2, while preserving sufficient material thickness at the proximal ends of the bodies 102, 106 to withstand the relatively high forces subjected to the connector 100 during rod reduction, fastener tightening, and/or post-operative patient movement.

[00118] As another example, the bearing surfaces 130, 140 of the bodies 102, 106 can be parallel to the proximal-distal axes A2, A4, and instead the rod recesses 104, 108 can be obliquely angled or can follow a curved path with respect to the proximal-distal axes to bring the rods R1, R2 closer together.

[00119] As another example, the axis along which the first fastener 112 advances as it is tightened can be offset laterally from the first rod axis A3 when the first rod R1 is fully seated in the recess 104, or can be obliquely angled with respect to the proximal-distal axis A2 of the first body 102. Alternatively, or in addition, the axis along which the second fastener 114 advances as it is tightened can be offset laterally from the second rod axis A5 when the second rod R2 is fully seated in the recess 108, or can be obliquely angled with respect to the proximal-distal axis A4 of the second body 106.

[00120] The rotation axis A1 of the connector 100 can be perpendicular to the rod axis A3 and perpendicular to the rod axis A5. The rotation axis A1 can be perpendicular to the proximal-distal axis A2 of the first body, or can be obliquely angled with respect to the axis A2. The

rotation axis A1 can be perpendicular to the proximal-distal axis A4 of the second body, or can be obliquely angled with respect to the axis A4. The proximal-distal axes A2, A4 of the bodies 102, 106 can be parallel to one another or can extend at an oblique angle with respect to one another.

[00121] The first saddle 118 is shown in greater detail in FIGS. 1C, 1G, and 1H. The saddle 118 can be positioned within the body 102. The saddle 118 can be configured to translate within the body 102 along the axis A2, e.g., between proximal and distal limits defined by the interaction between the recesses 128 of the body 102 and projections 144 formed on the saddle.

[00122] The saddle 118 can be generally cylindrical with first and second arms 146, 148 extending in a proximal direction to respective free ends of the arms. The first and second arms 146, 148 can be aligned with the first and second arms 124, 126 of the body 102 such that a recess defined therebetween is aligned with the first rod-receiving recess 104. Accordingly, the first rod R1 can be simultaneously cradled between the arms 146, 148 of the saddle 118 and the arms 124, 126 of the body 102 when the rod is disposed in the first rod-receiving recess 104. The first and second arms 146, 148 of the saddle 118 can include projections 144 extending radially outward therefrom and configured to be received within the recesses 128 of the first body 102.

[00123] The distal-facing surface of the saddle 118 can define a recess 150 configured to receive at least a portion of the hinge pin 110. In the illustrated embodiment, the recess 150 is semi-cylindrical. The depth of the recess 150 can increase along the length of the recess as shown to account for a body geometry in which the proximal-distal axis A2 of the body is obliquely angled with respect to the rotation axis A1 of the hinge pin 110.

[00124] The saddle 118 can include one or more ramped, curved, or otherwise tapered surfaces configured to contact and bear against a counterpart surface of the hinge pin 110. For example, a depression formed in the outer surface of the first arm 146 of the saddle 118 can define a first bearing surface 152 that is a section of a cone. A depression formed in the outer surface of the second arm 148 of the saddle 118 can define a second bearing surface 154 that is a section of a cone.

[00125] The second saddle 122 can be identical or substantially identical to the first saddle 118, or can have any of the features or variations described above with respect to the first saddle 118. Accordingly, only a brief description of the second saddle 122 is provided here for the sake of brevity. The second saddle 122 can be positioned within the body 106. The saddle 122 can be configured to translate within the body 106 along the axis A4, e.g., between proximal and distal limits defined by the interaction between the recesses 138 of the body and projections 156 formed on the saddle.

[00126] The saddle 122 can be generally cylindrical with first and second arms 158, 160 extending in a proximal direction to respective free ends of the arms. The first and second arms 158, 160 can be aligned with the first and second arms 134, 136 of the body 106 such that a recess defined therebetween is aligned with the second rod-receiving recess 108. Accordingly, the second rod R2 can be simultaneously cradled between the arms 158, 160 of the saddle 122 and the arms 134, 136 of the body 106 when the rod is disposed in the second rod-receiving recess 108. The first and second arms 158, 160 of the saddle 122 can include projections 156 extending radially outward therefrom and configured to be received within the recesses 138 of the second body 106.

[00127] The distal-facing surface of the saddle 122 can define a recess 162 configured to receive at least a portion of the hinge pin 110. In the illustrated embodiment, the recess 162 is semi-cylindrical. The depth of the recess 162 can increase along the length of the recess as shown to account for a body geometry in which the proximal-distal axis A4 of the body 106 is obliquely angled with respect to the rotation axis A1 of the hinge pin 110.

[00128] The saddle 122 can include one or more ramped, curved, or otherwise tapered surfaces configured to contact and bear against a counterpart surface of the hinge pin 110. For example, a depression formed in the outer surface of the first arm 158 of the saddle 122 can define a first bearing surface 164 that is a section of a cone. A depression formed in the outer surface of the second arm 160 of the saddle 122 can define a bearing surface 166 that is a section of a cone.

[00129] The first fastener 112 can include an exterior thread configured to mate with the interior threads formed on the arms 124, 126 of the body 102 to allow the first fastener to be advanced or retracted along the axis A2 with respect to the body by rotating the first fastener about the axis

A2. The first fastener 112 can include a driving interface 168 configured to receive a driver for applying a rotational force to the first fastener about the axis A2. The distal surface of the first fastener 112 can be configured to contact and bear against a rod R1 disposed in the first rod-receiving 104 recess to lock the rod to the connector 100. When tightened against the rod R1, the first fastener 112 can prevent the rod from translating relative to the connector 100 along the axis A3 and/or from rotating with respect to the connector about the axis A3. While a unitary set screw 112 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, a nut that threads onto an exterior of the body, or a dual-component set screw with independently-rotatable inner and outer members, the inner member acting on the rod R1 and the outer member acting on the saddle 118.

[00130] The second fastener 114 can include an exterior thread configured to mate with the interior threads formed on the arms 134, 136 of the second body 106 to allow the second fastener to be advanced or retracted along the axis A4 with respect to the body by rotating the second fastener about the axis A4. The second fastener 114 can include a driving interface 170 configured to receive a driver for applying a rotational force to the second fastener 114 about the axis A4. The distal surface of the second fastener 114 can be configured to contact and bear against a rod R2 disposed in the second rod-receiving 108 recess to lock the rod to the connector 100. When tightened against the rod R2, the second fastener 114 can prevent the rod from translating relative to the connector 100 along the axis A5 and/or from rotating with respect to the connector about the axis A5. While a unitary set screw 114 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, a nut that threads onto an exterior of the body, or a dual-component set screw with independently-rotatable inner and outer members, the inner member acting on the rod R2 and the outer member acting on the saddle 122.

[00131] The hinge pin 110 is shown in greater detail in FIGS. 1I-1L. As shown, the hinge pin 110 can include opposed first and second ends that define a central longitudinal axis A6 extending therebetween. The longitudinal axis A6 can be collinear with the rotation axis A1 of the connector 100. The hinge pin 110 can be formed as a substantially cylindrical shaft with one

or more protrusions 172 extending radially outward therefrom. One or both side surfaces of the protrusions 172 can be ramped, curved, or otherwise tapered and configured to contact and bear against counterpart surfaces of the saddles 118, 122 or, in embodiments in which the saddles are omitted, against counterpart surfaces of the rods R1, R2. The illustrated hinge pin 110 includes at least first and second protrusion surfaces 116, 120 that each form sections of respective cones. The middle protrusion 172 of the hinge pin 110 can help keep the hinge pin centered in the cavities 132, 142 and maintain the bodies 102, 106 in a position in which the bearing surfaces 130, 140 are parallel.

[00132] The protrusions 172 can extend around less than an entire circumference of the hinge pin 110, such that the protrusions have a non-cylindrical cross-section in a plane transverse to the axis A6. For example, as shown in FIG. 1J, each protrusion can define a lobe shape with first and second flat segments 172A, 172B joined by an arc 172C. The cavities 132, 142 formed in the bodies 102, 106 can have a corresponding shape, only with an arc that extends a greater degree about the circumference of the hinge pin 110. Accordingly, when the protrusions 172 are received within the cavities 132, 142, the degree to which the bodies 102, 106 are able to rotate relative to the hinge pin 110 about the axis A1 is limited to the difference between the arc length of the protrusions and the arc length of the cavity.

[00133] The connector 100 can be assembled by inserting one end of the hinge pin 110 into the cavity 132 of the first body 102 and the other end of the hinge pin into the cavity 142 of the second body 106. The saddles 118, 122 can be inserted into the proximal ends of the bodies 102, 106 and advanced distally until the projections 144, 156 of the saddles snap into the grooves 128, 138 of the bodies to retain the saddles therein. At this stage of assembly, even before locking rods within the connector 100, the saddles 118, 122 can interfere with the protrusions 172 of the hinge pin 110 to prevent the hinge pin from being removed from either of the first and second bodies 102, 106.

[00134] A first rod R1 can be seated in the first rod recess 104 and secured to the connector 100 by tightening the first fastener 112. As the first fastener 112 is tightened, the first rod R1 can be urged distally against the saddle 118, in turn urging the saddle distally against the hinge pin 110. As the saddle 118 is urged distally, the female conical surface 152 of the saddle bears against the

male conical surface 116 of the hinge pin protrusion 172, applying a force to the hinge pin 110 that urges the hinge pin deeper into the cavity 132.

[00135] A second rod R2 can be seated in the second rod recess 108 and secured to the connector 100 by tightening the second fastener 114. As the second fastener 114 is tightened, the second rod R2 can be urged distally against the saddle 122, in turn urging the saddle distally against the hinge pin 110. As the saddle 122 is urged distally, the female conical surface 166 of the saddle bears against the male conical surface 120 of the hinge pin protrusion 172, applying a force to the hinge pin 110 that urges the hinge pin deeper into the cavity 142.

[00136] Before fully tightening one or both fasteners 112, 114, the bodies 102, 106 can be rotated relative to one another about the axis A1 as desired by the user. The fasteners 112, 114 can then be tightened to lock such relative rotation. In particular, the opposing forces applied to the hinge pin 110 by the saddles 118, 122 as the fasteners 112, 114 are tightened can cause the bodies 102, 106 to translate relative to one another along the axis A1, urging the bearing surfaces 130, 140 of the bodies into engagement with each other. Friction, mechanical interlock, or other forces between the bearing surfaces 130, 140 can be effective to lock relative rotation of the bodies 102, 106 about the axis A1.

[00137] FIGS. 2A-2E illustrate an exemplary embodiment of a connector 200. As shown, the connector 200 can include a first body 202 that defines a first rod-receiving recess or channel 204 and a second body 206 that defines a second rod-receiving recess or channel 208. The first and second bodies 202, 206 can be connected to one another at least in part by a hinge pin 210. The hinge pin 210 can define a rotation axis A1 about which the first and second bodies 202, 206 can rotate relative to one another. The connector 200 can include first and second fasteners 212, 214 configured to secure respective first and second rods R1, R2 or other fixation elements to the connector 200.

[00138] At least one of the fasteners 212, 214 can further be configured to urge the first and second bodies 202, 206 towards one another and thereby lock relative rotation of the first and second bodies about the rotation axis A1. For example, the first fastener 212 can be tightened to secure a first rod R1 within the first body 202 and to apply a force to a first ramped, curved, or otherwise tapered surface 216 of the hinge pin 210 to draw the first and second bodies 202, 206

towards one another, locking rotation therebetween. In the illustrated embodiment, a force applied by the first fastener 212 is transferred to the hinge pin 210 through the first rod R1. In other arrangements, a saddle of the type described above can be disposed between the first rod R1 and the hinge pin 210. In still further arrangements, the first fastener 212 can bear directly against a saddle. For example, the first fastener 212 can include an outer set screw that bears against a saddle to lock relative rotation of the bodies 202, 206, and an inner set screw that bears against the first rod R1 to secure the first rod to the connector 200.

[00139] The second fastener 214 can be tightened to secure a second rod R2 within the second body 206. The second fastener 214 can bear directly against the second rod R2, or against an intermediate rod pusher 222 as shown.

[00140] The ability to rotate the first and second bodies 202, 206 relative to one another about the rotation axis A1 can advantageously allow first and second rods R1, R2 to be locked together even when the rods are obliquely angled with respect to one another, e.g., in the sagittal plane or in the coronal plane. The connector 200 can be particularly useful in connecting tandem rods of a spinal fixation construct across the cervical-thoracic (CT) junction of a patient. For example, the connector 200 can secure the rods R1, R2 in a laterally-offset arrangement to accommodate the different screw trajectories that may occur at the CT junction. By way of further example, the ability of the connector 200 to articulate can allow a cervical rod and a thoracic rod to be locked to one another at an oblique angle in the sagittal plane, e.g., to restore natural lordosis or kyphosis. The connector 200 can also be particularly useful in spinal deformity correction and other procedures in which multiple angled rods are to be coupled to one another.

[00141] The first body 202 can include proximal and distal ends 202p, 202d that define a proximal-distal axis A2. The proximal end 202p of the body 202 can include a pair of spaced apart arms 224, 226 that define the first rod-receiving recess 204 therebetween. A rod R1 disposed in the first rod-receiving recess 204 can have a central longitudinal rod axis A3. The first rod-receiving recess 204 can be open in a proximal direction, such that a rod R1 can be inserted into the recess by moving the rod distally with respect to the connector 200. Alternatively, the first rod-receiving recess 204 can be open in distal direction, open in a lateral

direction, or closed such that the rod R1 must be translated along the axis A3 to insert the rod into the recess 204.

[00142] Each of the arms 224, 226 can extend from the distal portion 202d of the body 202 to a free end. The outer surfaces of each of the arms 224, 226 can include a feature (not shown), such as a recess, dimple, notch, projection, or the like, to facilitate coupling of the connector 200 to various instruments. For example, the outer surface of each arm 224, 226 can include an arcuate groove at the respective free end of the arms for attaching the connector 200 to an extension tower or retractor. The arms 224, 226 can include or can be coupled to extension or reduction tabs (not shown) that extend proximally from the body 202 to functionally extend the length of the arms 224, 226. The extension tabs can facilitate insertion and reduction of a rod or other implant, as well as insertion and locking of the first fastener 212. The extension tabs can be configured to break away or otherwise be separated from the arms 224, 226.

[00143] The inner surfaces of each of the arms 224, 226 can be configured to mate with the first fastener 212. For example, the inner surfaces of the arms 224, 226 can include threads that correspond to external threads formed on the first fastener 212. Accordingly, rotation of the first fastener 212 with respect to the body 202 about the axis A2 can be effective to translate the first fastener with respect to the body axially along the axis A2.

[00144] The first body 202 can include an outer bearing surface 230 configured to contact and bear against a corresponding bearing surface 240 of the second body 206. The respective bearing surfaces 230, 240 of the bodies 202, 206 can bear against one another to lock relative rotation between the bodies as they are urged towards one another. In the illustrated embodiment, the bearing surfaces 230, 240 of the first and second bodies 202, 206 are defined by complementary male and female structures of the first and second bodies 202, 206. As shown, the first body 202 can include a conical male projection, an outer surface of which defines the bearing surface 230 of the first body, and the second body 206 can include a conical female recess, an inner surface of which defines the bearing surface 240 of the second body. As the projection of the first body 202 is urged into the recess of the second body 206, the conical surfaces 230, 240 wedge against one another to form a taper-lock connection. While conical surfaces are described in the example above, the male and female features can include concave

or convex spherical surfaces, stepped surfaces, and so forth. It will be appreciated that various other arrangements can be used instead or in addition, such as opposed planar surfaces configured to frictionally-engage one another as in the connector 100 described above.

[00145] One or both of the bearing surfaces 230, 240 can include surface features for enhancing grip between the surfaces. For example, one or both surfaces can include teeth, grooves, roughening, surface textures or coatings, etc. In some embodiments, each bearing surface 230, 240 can include a plurality of teeth that extend radially outward from the rotation axis A1. The teeth can selectively interlock to maintain the bodies 202, 206 in one of a plurality of discrete rotational positions relative to one another.

[00146] The distal end 202d of the body 202 can define an interior cavity 232 in which a first end of the hinge pin 210 can be received. The cavity 232 can be open to the bearing surface 230 of the first body 202 and open to the first rod-receiving recess 204 as shown. In some embodiments, the cavity 232 can be a blind bore formed in the bearing surface 230 of the body 202 and intersecting with the first rod-receiving recess 204. At least one dimension of the cavity 232 can be greater than a corresponding dimension of the hinge pin 210 to allow the hinge pin to translate within the cavity along the rotation axis A1.

[00147] The second body 202 is shown in greater detail in FIGS. 2C, 2D, and 2E. The second body 206 can include proximal and distal ends 206p, 206d that define a proximal-distal axis A4. The body 206 can include a pair of spaced apart arms 234, 236 that define the second rod-receiving recess 208 therebetween. A rod R2 disposed in the second rod-receiving recess 208 can have a central longitudinal rod axis A5. The second rod-receiving recess 208 can be open in a lateral direction, as shown, such that a rod R2 can be inserted into the recess by moving the rod laterally with respect to the connector 200. Alternatively, the second rod-receiving recess 208 can be open in a proximal direction, open in a distal direction, or closed such that the rod R2 must be translated along the axis A5 to insert the rod into the recess 208.

[00148] The second body 206 can include an outer bearing surface 240 configured to contact and bear against the outer bearing surface 230 of the first body 202. The second body 206 can define an interior cavity 242 in which a second end of the hinge pin 210 can be received. The cavity 242 can be open to the bearing surface 240 of the second body 206 and open to the second

rod recess 208 as shown. The cavity 242 can include a shoulder 274 configured to limit translation of the hinge pin 210 relative to the body 206 along the axis A1.

[00149] A rod pusher 222 can be disposed within the cavity 242 and can be configured to bear against the second rod R2. The rod pusher 222 can be coupled to the second body 206 by a bias element configured to bias the rod pusher towards the rod R2, e.g., to provide a "snap and drag" effect when seating the rod in the second recess 208. Further details on such features can be found in U.S. Application No. 15/158,127 filed on May 18, 2016 and entitled "IMPLANT CONNECTORS AND RELATED METHODS," which is hereby incorporated by reference in its entirety.

[00150] At least one of the arms 234, 236 of the second body 206 can include an opening 276 configured to receive the second fastener 214 therein. For example, as shown, the first arm 234 can include a threaded opening 276 in which the second fastener 214 can be advanced to urge the rod pusher 222 against a second rod R2 seated in the second rod-receiving recess 208.

[00151] The bodies 202, 206 of the connector 200 can include various features for decreasing or increasing the center-to-center offset between the first and second rods R1, R2 when the rods are locked to the connector. In the illustrated embodiment, the outer surface of the first body 202 that opposes the second body 206 is obliquely angled with respect to the proximal-distal axis A2. Accordingly, the rods R1, R2 move towards one another as they are advanced into the connector 200. This can advantageously reduce the center-to-center offset of the rods R1, R2, while preserving sufficient material thickness at the proximal end of the first body 202 to withstand the relatively high forces subjected to the connector 200 during rod reduction, fastener tightening, and/or post-operative patient movement.

[00152] As another example, the opposing outer surfaces of the bodies 202, 206 can be parallel to the proximal-distal axes A2, A4, and instead the rod recesses 204, 208 can be obliquely angled or can follow a curved path with respect to the proximal-distal axes to bring the rods R1, R2 closer together.

[00153] As another example, the axis along which the first fastener 212 advances as it is tightened can be offset laterally from the first rod axis A3 when the first rod R1 is fully seated in

the recess 204, or can be obliquely angled with respect to the proximal-distal axis A2 of the first body 202. Alternatively, or in addition, the axis along which the second fastener 214 advances as it is tightened can be offset laterally from the second rod axis A5 when the second rod R2 is fully seated in the recess 208, or can be obliquely angled with respect to the proximal-distal axis A4 of the second body 206.

[00154] The rotation axis A1 of the connector 200 can be perpendicular to the rod axis A3 and perpendicular to the rod axis A5. The rotation axis A1 can be perpendicular to the proximal-distal axis A2 of the first body, or can be obliquely angled with respect to the axis A2. The rotation axis A1 can be perpendicular to the proximal-distal axis A4 of the second body, or can be obliquely angled with respect to the axis A4. The proximal-distal axes A2, A4 of the bodies 202, 206 can be parallel to one another or can extend at an oblique angle with respect to one another.

[00155] The first fastener 212 can include an exterior thread configured to mate with the interior threads formed on the arms 224, 226 of the body 202 to allow the first fastener to be advanced or retracted along the axis A2 with respect to the body by rotating the first fastener about the axis A2. The first fastener 212 can include a driving interface 268 configured to receive a driver for applying a rotational force to the first fastener about the axis A2. The distal surface of the first fastener 212 can be configured to contact and bear against a rod R1 disposed in the first rod-receiving 204 recess to lock the rod to the connector 200. When tightened against the rod R1, the first fastener 212 can prevent the rod from translating relative to the connector 200 along the axis A3 and/or from rotating with respect to the connector about the axis A3. While a unitary set screw 212 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, a nut that threads onto an exterior of the body, or a dual-component set screw with independently-rotatable inner and outer members, the inner member acting on the rod R1 and the outer member acting on a saddle of the type described above.

[00156] The second fastener 214 can include an exterior thread configured to mate with the interior threads formed in the first arm 234 of the second body 206 to allow the second fastener to be advanced or retracted along the axis A4 with respect to the body by rotating the second

fastener about the axis A4. The second fastener 214 can include a driving interface 270 configured to receive a driver for applying a rotational force to the second fastener 214 about the axis A4. The distal surface of the second fastener 214 can be configured to contact and bear against the rod pusher 222 or, in embodiments in which the rod pusher is omitted, against a rod R2 disposed in the second rod-receiving 208 recess to lock the rod to the connector 200. When tightened, the second fastener 214 can prevent the rod R2 from translating relative to the connector 200 along the axis A5 and/or from rotating with respect to the connector about the axis A5. While a unitary set screw 214 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, or a nut that threads onto an exterior of the body.

[00157] The hinge pin 210 can include opposed first and second ends that define a central longitudinal axis A6 extending therebetween. The longitudinal axis A6 can be collinear with the rotation axis A1 of the connector 200. The hinge pin 210 can be formed as a substantially cylindrical shaft. The portion of the hinge pin 210 received within the first body 202 can include a rod seat 278. The portion of the hinge pin 210 received within the second body 206 can include a protrusion 272 extending radially outward therefrom.

[00158] The protrusion 272 can be seated in and can bear against the shoulder 274 formed in the second body 206. Accordingly, lateral translation of the hinge pin 210 along the axis A1, e.g., as the first rod R1 is urged against the hinge pin, can cause the second body 206 to be urged towards the first body to lock relative rotation therebetween. The rod seat 278 can be ramped, curved, or otherwise tapered and configured to contact and bear against the first rod R1. The rod seat 278 can have a width parallel to the axis A1 that is greater than the diameter of the first rod R1 and/or greater than the width of the first rod-receiving recess 204. The rod seat 278 can be located along the length of the hinge pin 210 at a position in which a lateral sidewall 216 of the rod seat interferes with a rod R1 as the rod is seated in the first rod-receiving recess 204. As the rod R1 is advanced into the first rod-receiving recess 204, it can bear against the lateral sidewall 216 of the rod seat 278 to cause the hinge pin 210 to translate laterally along the axis A1, pulling the second body 206 towards the first body 202 to lock relative rotation therebetween. The hinge pin 210 can be rotatable relative to the first and second bodies 202, 206 about the axis A1, such

that the floor of the rod seat 278 remains aligned with a floor of the first rod-receiving recess 204 or is moved into such alignment automatically as a rod R1 is seated therein. Prior to seating the first rod R1, the hinge pin 210 can be retained within the cavity 232 of the first body 202 using various techniques, such as swaging or a retention pin that limits axial translation of the hinge pin 210 relative to the body without limiting rotation of the hinge pin relative to the body about the axis A1.

[00159] The connector 200 can be assembled by inserting the hinge pin 210 through the cavity 242 of the second body 206 to seat the protrusion 272 of the hinge pin against the shoulder 274 and then installing the rod pusher 222 within the second body to retain the hinge pin therein. The free end of the hinge pin 210 can then be inserted into the cavity 232 of the first body 202 and retained therein with a retention feature of the type described above. At this stage of assembly, even before locking rods within the connector 200, the hinge pin 210 can be prevented from being removed from either of the first and second bodies 202, 206.

[00160] A second rod R2 can be seated in the second rod recess 208 and secured to the connector 200 by tightening the second fastener 214. As the second fastener 214 is tightened, the rod pusher 222 can be urged distally against the second rod R2 to lock the rod to the connector 200. The second body 206 can remain free to rotate relative to the first body 202 about the axis A1 even after the second rod R2 is locked to the connector 200.

[00161] A first rod R1 can be seated in the first rod recess 204 and secured to the connector 200 by tightening the first fastener 212. As the first fastener 212 is tightened, the first rod R1 can be urged distally against the rod seat 278 of the hinge pin 210, applying a force to the hinge pin that urges the hinge pin deeper into the cavity 232.

[00162] Before fully tightening one or both fasteners 212, 214, the bodies 202, 206 can be rotated relative to one another about the axis A1 as desired by the user. The fastener 212 can then be tightened to lock such relative rotation. In particular, the force applied to the hinge pin 210 by the first rod R1 when the fastener 212 is tightened can cause the bodies 202, 206 to translate relative to one another along the axis A1, urging the bearing surfaces 230, 240 of the bodies into engagement with each other. Friction, mechanical interlock, or other forces between the bearing surfaces 230, 240 can be effective to lock relative rotation of the bodies 202, 206

about the axis A1. It will be appreciated that the connector 200 can allow locking of the second rod R2 to the connector and locking of the rotational degree-of-freedom of the connector to be performed independently of one another.

[00163] FIGS. 3A-3L illustrate an exemplary embodiment of a connector 300. As shown, the connector 300 can include a first body 302 that defines a first rod-receiving recess or channel 304 and a second body 306 that defines a second rod-receiving recess or channel 308. The first and second bodies 302, 306 can be connected to one another at least in part by a hinge pin 310. The hinge pin 310 can define a rotation axis A1 about which the first and second bodies 302, 306 can rotate relative to one another. The connector 300 can include first and second fasteners 312, 314 configured to secure respective first and second rods R1, R2 or other fixation elements to the connector 300.

[00164] At least one of the fasteners 312, 314 can further be configured to urge the first and second bodies 302, 306 towards one another and thereby lock relative rotation of the first and second bodies about the rotation axis A1. For example, the second fastener 314 can be tightened to secure a second rod R2 within the second body 306 and to apply a force to a ramped, curved, or otherwise tapered surface 320 of the hinge pin 310 to draw the first and second bodies 302, 306 towards one another, locking rotation therebetween. In the illustrated embodiment, a force applied by the second fastener 314 is transferred to the hinge pin 310 through the second rod R2 and through a saddle 322 disposed between the second rod and the hinge pin. In other arrangements, the saddle 322 can be omitted and the second rod R2 can bear directly against the hinge pin 310. In still further arrangements, the second fastener 314 can bear directly against the saddle 322. For example, the second fastener 314 can include an outer set screw that bears against the saddle 322 to lock relative rotation of the bodies 302, 306, and an inner set screw that bears against the second rod R2 to secure the second rod to the connector 300.

[00165] The first fastener 312 can be tightened to secure a first rod R1 within the first body 302. The first fastener 312 can bear directly against the first rod R1 as shown, or against an intermediate rod pusher of the type described above with respect to the connector 200.

[00166] The ability to rotate the first and second bodies 302, 306 relative to one another about the rotation axis A1 can advantageously allow first and second rods R1, R2 to be locked together

even when the rods are obliquely angled with respect to one another, e.g., in the sagittal plane or in the coronal plane. The connector 300 can be particularly useful in connecting tandem rods of a spinal fixation construct across the cervical-thoracic (CT) junction of a patient. For example, the connector 300 can secure the rods R1, R2 in a laterally-offset arrangement to accommodate the different screw trajectories that may occur at the CT junction. By way of further example, the ability of the connector 300 to articulate can allow a cervical rod and a thoracic rod to be locked to one another at an oblique angle in the sagittal plane, e.g., to restore natural lordosis or kyphosis. The connector 300 can also be particularly useful in spinal deformity correction and other procedures in which multiple angled rods are to be coupled to one another.

[00167] The first body 302 is shown in greater detail in FIGS. 3C and 3G. The first body 302 can include proximal and distal ends 302p, 302d that define a proximal-distal axis A2. The proximal end 302p of the body 302 can include a pair of spaced apart arms 324, 326 that define the first rod-receiving recess 304 therebetween. A rod R1 disposed in the first rod-receiving recess 304 can have a central longitudinal rod axis A3. The first rod-receiving recess 304 can be open in a proximal direction, such that a rod R1 can be inserted into the recess by moving the rod distally with respect to the connector 300. Alternatively, the first rod-receiving recess 304 can be open in distal direction, open in a lateral direction, or closed such that the rod R1 must be translated along the axis A3 to insert the rod into the recess 304.

[00168] Each of the arms 324, 326 can extend from the distal portion 302d of the body 302 to a free end. The outer surfaces of each of the arms 324, 326 can include a feature (not shown), such as a recess, dimple, notch, projection, or the like, to facilitate coupling of the connector 300 to various instruments. For example, the outer surface of each arm 324, 326 can include an arcuate groove at the respective free end of the arms for attaching the connector 300 to an extension tower or retractor. The arms 324, 326 can include or can be coupled to extension or reduction tabs (not shown) that extend proximally from the body 302 to functionally extend the length of the arms 324, 326. The extension tabs can facilitate insertion and reduction of a rod or other implant, as well as insertion and locking of the first fastener 312. The extension tabs can be configured to break away or otherwise be separated from the arms 324, 326.

[00169] The inner surfaces of each of the arms 324, 326 can be configured to mate with the first fastener 312. For example, the inner surfaces of the arms 324, 326 can include threads that correspond to external threads formed on the first fastener 312. Accordingly, rotation of the first fastener 312 with respect to the body 302 about the axis A2 can be effective to translate the first fastener with respect to the body axially along the axis A2.

[00170] The first body 302 can include an outer bearing surface 330 configured to contact and bear against a corresponding bearing surface 340 of the second body 306. The respective bearing surfaces 330, 340 of the bodies 302, 306 can bear against one another to lock relative rotation between the bodies as they are urged towards one another. In the illustrated embodiment, the bearing surfaces 330, 340 of the first and second bodies 302, 306 are defined by complementary male and female structures of the first and second bodies 302, 306. As shown, the first body 302 can include a conical male projection, an outer surface of which defines the bearing surface 330 of the first body, and the second body 306 can include a conical female recess, an inner surface of which defines the bearing surface 340 of the second body. As the projection of the first body 302 is urged into the recess of the second body 306, the conical surfaces 330, 340 wedge against one another to form a taper-lock connection. While conical surfaces are described in the example above, the male and female features can include concave or convex spherical surfaces, stepped surfaces, and so forth. It will be appreciated that various other arrangements can be used instead or in addition, such as opposed planar surfaces configured to frictionally-engage one another as in the connector 100 described above.

[00171] One or both of the bearing surfaces 330, 340 can include surface features for enhancing grip between the surfaces. For example, one or both surfaces can include teeth, grooves, roughening, surface textures or coatings, etc. In some embodiments, each bearing surface 330, 340 can include a plurality of teeth that extend radially outward from the rotation axis A1. The teeth can selectively interlock to maintain the bodies 302, 306 in one of a plurality of discrete rotational positions relative to one another.

[00172] As described further below, the hinge pin 310 can be formed integrally with the first body 302. The hinge pin 310 can project laterally from the distal end 302d of the first body 302

along the axis A1. The bearing surface 330 of the first body 302 can be an exterior surface of the integrally-formed hinge pin 310.

[00173] The second body 302 is shown in greater detail in FIGS. 3C and 3H. Except as described below, the second body 306 can be identical or substantially identical to the first body 302, or can have any of the features or variations described above with respect to the first body 302. Accordingly, only a brief description of the second body 306 is provided here for the sake of brevity. The second body 306 can include proximal and distal ends 306p, 306d that define a proximal-distal axis A4. The proximal end 306p of the body 306 can include a pair of spaced apart arms 334, 336 that define the second rod-receiving recess 308 therebetween. A rod R2 disposed in the second rod-receiving recess 308 can have a central longitudinal rod axis A5. The second rod-receiving recess 308 can be open in a proximal direction, such that a rod R2 can be inserted into the recess by moving the rod distally with respect to the connector 300. Alternatively, the second rod-receiving recess 308 can be open in distal direction, open in a lateral direction, or closed such that the rod R2 must be translated along the axis A5 to insert the rod into the recess 308.

[00174] Each of the arms 334, 336 can include features 338 for retaining the saddle 322 within the body 306, e.g., of the type described above with respect to the connector 100. The second body 306 can include an outer bearing surface 340 configured to contact and bear against the outer bearing surface 330 of the first body 302. The distal end 306d of the second body 306 can define an interior cavity 342 in which a free end of the hinge pin 310 can be received. The cavity 342 can be open to the bearing surface 340 of the second body 306 and open to the second rod recess 308 as shown. In some embodiments, the cavity 342 can be a blind bore formed in the bearing surface 340 of the body 306 and intersecting with the second rod recess 308. At least one dimension of the cavity 342 can be greater than a corresponding dimension of the hinge pin 310 to allow the hinge pin to translate within the cavity along the rotation axis A1.

[00175] The bodies 302, 306 of the connector 300 can include various features for decreasing or increasing the center-to-center offset between the first and second rods R1, R2 when the rods are locked to the connector. For example, one or both of the outer surfaces of the bodies 302, 306 that oppose one another can be obliquely angled with respect to the respective proximal-distal

axes A2, A4. Accordingly, the rods R1, R2 can move towards one another as they are advanced into the connector 300. This can advantageously reduce the center-to-center offset of the rods R1, R2, while preserving sufficient material thickness at the proximal ends of the bodies 302, 306 to withstand the relatively high forces subjected to the connector 300 during rod reduction, fastener tightening, and/or post-operative patient movement.

[00176] As another example, the opposing outer surfaces of the bodies 302, 306 can be parallel to the proximal-distal axes A2, A4, and instead the rod recesses 304, 308 can be obliquely angled or can follow a curved path with respect to the proximal-distal axes to bring the rods R1, R2 closer together.

[00177] As another example, the axis along which the first fastener 312 advances as it is tightened can be offset laterally from the first rod axis A3 when the first rod R1 is fully seated in the recess 304, or can be obliquely angled with respect to the proximal-distal axis A2 of the first body 302. Alternatively, or in addition, the axis along which the second fastener 314 advances as it is tightened can be offset laterally from the second rod axis A5 when the second rod R2 is fully seated in the recess 308, or can be obliquely angled with respect to the proximal-distal axis A4 of the second body 306.

[00178] The rotation axis A1 of the connector 300 can be perpendicular to the rod axis A3 and perpendicular to the rod axis A5. The rotation axis A1 can be perpendicular to the proximal-distal axis A2 of the first body, or can be obliquely angled with respect to the axis A2. The rotation axis A1 can be perpendicular to the proximal-distal axis A4 of the second body, or can be obliquely angled with respect to the axis A4. The proximal-distal axes A2, A4 of the bodies 302, 306 can be parallel to one another or can extend at an oblique angle with respect to one another.

[00179] The saddle 322 is shown in greater detail in FIGS. 3C, 3D, 3E, and 3F. The saddle 322 can be positioned within the body 306. The saddle 322 can be configured to translate within the body 306 along the axis A4, e.g., between proximal and distal limits defined by the interaction between the recesses 338 of the body 306 and projections 356 formed on the saddle.

[00180] The saddle 322 can be generally cylindrical with first and second arms 358, 360 extending in a proximal direction to respective free ends of the arms. The first and second arms 358, 360 can be aligned with the first and second arms 334, 336 of the body 306 such that a recess defined therebetween is aligned with the second rod-receiving recess 308. Accordingly, the second rod R2 can be simultaneously cradled between the arms 358, 360 of the saddle 322 and the arms 334, 336 of the body 306 when the rod is disposed in the second rod-receiving recess 308. The first and second arms 358, 360 of the saddle 322 can include projections 356 extending radially outward therefrom and configured to be received within the recesses 338 of the second body 306.

[00181] The distal-facing surface of the saddle 322 can define a recess 362 configured to receive at least a portion of the hinge pin 310. In the illustrated embodiment, the recess 362 is semi-cylindrical. The depth of the recess 362 can increase along the length of the recess to account for a body geometry in which the proximal-distal axis A4 of the body 306 is obliquely angled with respect to the rotation axis A1 of the hinge pin 310.

[00182] The saddle 322 can include one or more ramped, curved, or otherwise tapered surfaces configured to contact and bear against a counterpart surface of the hinge pin 310. For example, a keel projection 380 extending distally from the recess 362 of the saddle 322 can define a first bearing surface 366. The first bearing surface 366 can be planar. The first bearing surface 366 can lie in a plane that is obliquely angled with respect to the rotation axis A1. As shown in FIG. 3F, the first bearing surface 366 can include first and second planar portions that are obliquely angled relative to one another and relative to the axis A1, and that meet at a central ridge. This can facilitate smoother ramping when the connector bodies 302, 306 are rotated relative to one another from a neutral position.

[00183] The first fastener 312 can include an exterior thread configured to mate with the interior threads formed on the arms 324, 326 of the body 302 to allow the first fastener to be advanced or retracted along the axis A2 with respect to the body by rotating the first fastener about the axis A2. The first fastener 312 can include a driving interface 368 configured to receive a driver for applying a rotational force to the first fastener about the axis A2. The distal surface of the first fastener 312 can be configured to contact and bear against a rod R1 disposed in the first rod-

receiving 304 recess to lock the rod to the connector 300. When tightened against the rod R1, the first fastener 312 can prevent the rod from translating relative to the connector 300 along the axis A3 and/or from rotating with respect to the connector about the axis A3. While a unitary set screw 312 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, or a nut that threads onto an exterior of the body.

[00184] The second fastener 314 can include an exterior thread configured to mate with the interior threads formed on the arms 334, 336 of the second body 306 to allow the second fastener to be advanced or retracted along the axis A4 with respect to the body by rotating the second fastener about the axis A4. The second fastener 314 can include a driving interface 370 configured to receive a driver for applying a rotational force to the second fastener 314 about the axis A4. The distal surface of the second fastener 314 can be configured to contact and bear against a rod R2 disposed in the second rod-receiving 308 recess to lock the rod to the connector 300. When tightened against the rod R2, the second fastener 314 can prevent the rod from translating relative to the connector 300 along the axis A5 and/or from rotating with respect to the connector about the axis A5. While a unitary set screw 314 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, a nut that threads onto an exterior of the body, or a dual-component set screw with independently-rotatable inner and outer members, the inner member acting on the rod R2 and the outer member acting on the saddle 322.

[00185] The hinge pin 310 can include opposed first and second ends that define a central longitudinal axis A6 extending therebetween. The longitudinal axis A6 can be collinear with the rotation axis A1 of the connector 300. The hinge pin 310 can be formed integrally or monolithically with the first body 302 as shown, or can be fixedly attached thereto, e.g., by welding or other processes. A free end of the hinge pin 310 can be received within the second body 306. The portion of the hinge pin 310 received within the second body 306 can include a slot 382 formed therein in which the keel 380 of the saddle 322 can be received. One or more sidewalls of the slot 382 can be ramped, curved, or otherwise tapered and configured to contact and bear against a counterpart surface of the saddle 322 or, in embodiments in which the saddle

322 is omitted, against a counterpart surface of the second rod R2. The illustrated hinge pin 310 includes a ramped bearing surface 320 configured to contact and bear against the bearing surface 366 of the saddle 322 as the second fastener 314 is tightened. The bearing surface 320 can be planar. The bearing surface 320 can lie in a plane that is obliquely angled with respect to the rotation axis A1.

[00186] As the second fastener 314 is tightened, the saddle 322 can be urged distally to translate the keel 380 distally within the slot 382. As the keel 380 moves within the slot 382, the bearing surface 366 of the keel can be urged along the counterpart bearing surface 320 of the hinge pin 310, causing the hinge pin to translate laterally within the cavity 342 of the second body 306 along the axis A1, thereby pulling the first body 302 towards the second body to lock relative rotation therebetween.

[00187] The distal end of the keel 380 can be tapered or bulleted to facilitate insertion of the keel into the slot 382. Insertion of the keel 380 into the slot 382 of the hinge pin 310 can prevent the hinge pin from being removed from the second body 306, thereby retaining the first and second bodies 302, 306 to one another, even before one or both rods R1, R2 are locked to the connector 300. Interaction between the keel 380 and the slot 382 can also be effective to limit the range of articulation between the first and second bodies 302, 306. For example, the slot 382 can have a width in a direction perpendicular to the axis A1 and perpendicular to the axis A4 that is greater than a corresponding width of the keel 380. The degree to which the bodies 302, 306 can rotate relative to one another about the axis A1 can be limited by the difference between the width of the slot 382 and the width of the keel 380.

[00188] The connector 300 can be assembled by inserting the free end of the hinge pin 310 into the cavity 342 of the second body 306. The saddle 322 can be inserted into the proximal end of the second body 306 and advanced distally until the projections 356 of the saddle snap into the grooves 338 of the second body 306 to retain the saddle therein. At this stage of assembly, even before locking rods within the connector 300, the saddle 322 can interfere with the slot 382 of the hinge pin 310 to prevent the hinge pin from being removed from the second body 306.

[00189] A first rod R1 can be seated in the first rod recess 304 and secured to the connector 300 by tightening the first fastener 312. The second body 306 can remain free to rotate relative to the first body 302 about the axis A1 even after the first rod R1 is locked to the connector 300.

[00190] A second rod R2 can be seated in the second rod recess 308 and secured to the connector 300 by tightening the second fastener 314. As the second fastener 314 is tightened, the second rod R2 can be urged distally against the saddle 322, in turn urging the saddle distally against the hinge pin 310. As the saddle 322 is urged distally, the ramped surface 366 of the saddle bears against the ramped surface 320 of the slot 382 in the hinge pin 310, applying a force to the hinge pin that urges the hinge pin deeper into the cavity 342.

[00191] Before fully tightening one or both fasteners 312, 314, the bodies 302, 306 can be rotated relative to one another about the axis A1 as desired by the user. The fastener 314 can then be tightened to lock such relative rotation. In particular, the force applied to the hinge pin 310 by the saddle 322 when the fastener 314 is tightened can cause the bodies 302, 306 to translate relative to one another along the axis A1, urging the bearing surfaces 330, 340 of the bodies into engagement with each other. Friction, mechanical interlock, or other forces between the bearing surfaces 330, 340 can be effective to lock relative rotation of the bodies 302, 306 about the axis A1. It will be appreciated that the connector 300 can allow locking of the first rod R1 to the connector and locking of the rotational degree-of-freedom of the connector to be performed independently of one another.

[00192] While a single, centrally-mounted keel 380 is described above, it will be appreciated that other configurations are possible. For example, as shown in FIGS. 3I-3L, the saddle 322 can include first and second keels 380A, 380B spaced apart from one another in the width dimension of the saddle. As also shown, the slot of the hinge pin 310 can be replaced with first and second slots 382A, 382B that form a reduced-width portion or central rib 384 of the hinge pin configured to be received between the keels 380A, 380B of the saddle 322 when the connector 300 is assembled. Each keel 380A, 380B can include a ramped, curved, or otherwise tapered bearing surface that contacts and bears against a corresponding surface of the hinge pin 310 adjacent the central rib 384. The relative widths of the rib 384 and the space between the keels

380A, 380B can be selected to limit the degree to which the first body 302 can rotate relative to the second body 306 about the axis A1.

[00193] FIGS. 4A-4F illustrate an exemplary embodiment of a connector 400. As shown, the connector 400 can include a first body 402 that defines a first rod-receiving recess or channel 404 and a second body 406 that defines a second rod-receiving recess or channel 408. The first and second bodies 402, 406 can be connected to one another at least in part by a hinge pin 410. The hinge pin 410 can define a rotation axis A1 about which the first and second bodies 402, 406 can rotate relative to one another. The connector 400 can include first and second fasteners 412, 414 configured to secure respective first and second rods R1, R2 or other fixation elements to the connector 400.

[00194] At least one of the fasteners 412, 414 can further be configured to urge the first and second bodies 402, 406 towards one another and thereby lock relative rotation of the first and second bodies about the rotation axis A1. For example, the second fastener 414 can be tightened to secure a second rod R2 within the second body 406 and to apply a force to a ramped, curved, or otherwise tapered surface 420 of the hinge pin 410 to draw the first and second bodies 402, 406 towards one another, locking rotation therebetween. In the illustrated embodiment, a force applied by the second fastener 414 is transferred to the hinge pin 410 through the second rod R2. The first fastener 412 can be tightened to secure a first rod R1 within the first body 402. The first fastener 412 can bear directly against the first rod R1 as shown, or against an intermediate rod pusher of the type described above with respect to the connector 200.

[00195] Except as indicated below and as will be readily appreciated by one having ordinary skill in the art in view of the present disclosure, the structure and operation of the connector 400 is the same as the connector 300 described above, and therefore a detailed description is omitted here for the sake of brevity.

[00196] As shown, the connector 400 can omit a saddle component, such that the second rod R2 bears directly against a rod seat 420 formed in the hinge pin 410. The rod seat 420 can be ramped, curved, or otherwise tapered. The rod seat 420 can have a width parallel to the axis A1 that is greater than the diameter of the second rod R2 and/or greater than the width of the second rod-receiving recess 408. The rod seat 420 can be located along the length of the hinge pin 410

at a position in which a lateral sidewall of the rod seat interferes with a rod R2 as the rod is seated in the second rod-receiving recess 408. As the rod R2 is advanced into the second rod-receiving recess 408, it can bear against the lateral sidewall of the rod seat 420 to cause the hinge pin 410 to translate along the axis A1, pulling the second body 406 towards the first body 402 to lock relative rotation therebetween.

[00197] The rod seat 420 can be curved in multiple planes to allow the above-described bearing action to occur at any of a plurality of relative rotational positions about the axis A1 of the hinge pin 410 and the second body 406. For example, the rod seat 420 can be curved in a first plane defined by the axes A1, A2 and in a second plane defined by the axes A2, A3. As shown in FIG. 4E, the rod seat can have a circular cross section in a first plane P1. As shown in FIG. 4F, the rod seat 420 can have a cross section in a plane P2 perpendicular to the first plane P1 that is defined by first and second straight segments angled relative to one another and joined by an arcuate segment.

[00198] The rod seat 420 can be configured such that approximately the same ramp geometry is presented to the rod R2, regardless of the articulation angle of the first and second bodies 402, 406. The degree of curvature of the rod seat 420 in the second plane P2 can be configured to limit articulation of the first and second bodies 402, 406.

[00199] The hinge pin 410 can be retained within the second body 406 using various techniques, such as swaging or a retention pin that limits axial translation of the hinge pin relative to the body while still permitting rotation of the hinge pin relative to the second body. In the illustrated embodiment, the free end of the hinge pin 410 includes a post or rivet tail 486 that projects axially therefrom. The post 486 can be received within a through-hole 488 formed in the second body 406 and thereafter swaged, deformed, flattened, or otherwise modified such that the post cannot be freely removed from the through-hole. The terminal end of the post 486 can be cupped or hollowed to facilitate deformation of the post during the swaging process.

[00200] FIGS. 5A-5O illustrate an exemplary embodiment of a connector 500. As shown, the connector 500 can include a first body 510 that defines a first rod-receiving recess or channel 512 and a second body 580 that defines a second rod-receiving recess or channel 582. The first and second bodies 510, 580 can be connected to one another at least in part by a hinge pin 514

that defines a rotation axis A1 about which the bodies can rotate relative to one another. The hinge pin 514 can project laterally from the first body 510 to a free end. The free end of the hinge pin 514 can be received within an interior cavity 584 formed in the second body 580, thereby coupling the first and second bodies 510, 580. The connector 500 can include first and second fasteners 520, 522 configured to secure first and second rods R1, R2 or other fixation elements to the connector 500 within the respective rod-receiving recesses 512, 582. The second fastener 522 can also be configured to apply a force on the hinge pin and thereby lock the relative rotation of the first and second bodies 510, 580. As shown in the illustrated embodiment, the force applied by the second fastener 522 can be transferred to the hinge pin 514 through a saddle 550.

[00201] As discussed further below, to increase the locking strength of the connector 500, the exterior surface of the hinge pin 514 can include sharp corners 516 or other surface features that bear against the inner wall of the cavity 584 of the second body 580. As force is applied by the second fastener 522 to the hinge pin 514, the corners 516 of the pin may cut into or otherwise deform the inner wall of the cavity 584, and thereby increase the resistance of the connector bodies 510, 580 to rotation. The hinge pin 514 of the first body 510 can include a slot 518 configured to receive a distal projection of a saddle 550 disposed in the second rod-receiving recess 582, thereby preventing disassembly of the first and second bodies 510, 580 and limiting the relative rotation between the first and second bodies 510, 580.

[00202] The first body 510 of the connector 500, including the hinge pin 514, is shown in greater detail in FIGS. 5C through 5F. The first body 510 can include proximal and distal ends 510p, 510d that define a proximal-distal axis A2. The proximal end 510p of the body 510 can include a pair of spaced apart arms 524, 526 that extend from the distal portion 510d of the body 510 to a free end. The spaced apart arms 524, 526 can define the first rod-receiving recess 512 therebetween. The first rod-receiving recess 512 can be open in a proximal direction, such that a rod R1 can be inserted into the recess by moving the rod distally with respect to the connector 500. Alternatively, the first rod-receiving recess 512 can be open in distal direction, open in a lateral direction, or closed such that the rod R1 must be translated along the axis A3 to insert the rod into the recess 512.

[00203] The hinge pin 514 can project along the rotation axis A1 from an outer surface 528 of the arm 526. As shown in the illustrated embodiment, the outer surface 528 of the arm 526 can extend vertically from the distal end 510d of the first body 510. The hinge pin 514 can extend perpendicular from a distal end portion of the outer surface 528 of the arm 526. The hinge pin 514 can include opposed first and second ends that define a central longitudinal axis A6 extending therebetween. The longitudinal axis A6 can be collinear with the rotation axis A1 of the connector 500. The hinge pin 514 can be formed integrally or monolithically with the first body 510 as shown, or can be fixedly attached thereto, e.g., by welding or other processes.

[00204] The hinge pin 514 can have an exterior surface that includes sharp corners 516 radially disposed at least partially about a perimeter of the pin. As discussed further below, when the hinge pin is locked down, the sharp corners 516 of the pin can cut into and/or deform an inner wall of the cavity 584 of the second body 580, thereby increasing the locking strength of the connector 500 through edge loading. For example, through such edge loading, the sharp corners 516 of the hinge pin 514 can create additional friction, mechanical interlock, or increase the radial force applied by the pin against the second body 580 to effectively lock relative rotation of the bodies 510, 580 about the axis A1. The corners 516 of the hinge pin 514 can be formed by planar surface segments 530 that extend longitudinally at least partially around the pin. Each of the planar surface segments 530 can be obliquely angled with respect to one or more adjacent planar surface segments, such that the planar surface segments 530 intersect with each other to form the sharp corners 516 of the hinge pin 514.

[00205] As shown in FIG. 5E, the hinge pin 514 can have five (5) planar surface segments 530 that form the lateral and distal surfaces of the pin. The planar segments 530 can intersect obliquely at their respective edges such that the corners 516 of hinge pin 514 form a cross sectional profile of a partial octagon. The proximal surface 532 of the hinge pin 514 can have a rounded, curved, ramped or other contoured shape. It will be appreciated that, in some embodiments, the planar surface segments 530 can form the exterior surface of the hinge pin 514, such that the sharp corners 516 are radially disposed about the entire circumference of the pin. In some embodiments, more than five (5) planar surface segments 530 can be used to form the corners 516 of the hinge pin 514 with a cross sectional profile of a polygon or portion

thereof. In some embodiments, less than five planar surface segments can be used to form the corners 516 of the hinge pin 514 with a cross sectional profile of a polygon or portion thereof.

[00206] As shown in FIGS. 5C and 5F, a slot 518 can be formed in the proximal surface 532 of the hinge pin 514. The slot 518 can be an arcuate or rectangular shaped slot. The length of the slot 518 can be defined between a first pair of opposing sidewalls 540, 542. Each of the opposing sidewalls 540, 542 can lie in a plane perpendicular to the rotation axis A1. The width of the slot 518 can be defined between a second pair of sidewalls 544, 546 disposed between the first pair of opposing sidewalls. Each of the sidewalls 544, 546 can lie in a plane perpendicular or oblique to the opposing sidewalls 540, 542 of the slot. A rib 548 can be formed in the slot 518 between the sidewalls 544, 546. As discussed further below, the slot 518 can be configured to receive a distal projection of a saddle 550 disposed in the second rod-receiving recess 582, thereby preventing disassembly of the first and second bodies 510, 580 and limiting the relative rotation between the first and second bodies 510, 580.

[00207] The second body 580 is shown in greater detail in FIGS. 5G and 5H. The second body 580 can include proximal and distal ends 580p, 580d that define a proximal-distal axis A4. The proximal end 580p of the body 580 can include a pair of spaced apart arms 586, 588 that define the second rod-receiving recess 582 therebetween. A rod R2 disposed in the second rod-receiving recess 582 can have a central longitudinal rod axis A5. The second rod-receiving recess 582 can be open in a proximal direction, such that a rod R2 can be inserted into the recess by moving the rod distally with respect to the connector 500. Alternatively, the second rod-receiving recess 582 can be open in distal direction, open in a lateral direction, or closed such that the rod R2 must be translated along the axis A5 to insert the rod into the recess 582. Each of the arms 586, 588 can include recesses or grooves 590 for retaining the saddle 550 within the body 580. The second body 580 can include an outer surface 592 that opposes the outer surface 528 of the first body 510.

[00208] The distal end 580d of the second body 580 can define an interior cavity 584 in which a free end of the hinge pin 514 can be received. The cavity 584 can be open from the outer surface 592 of the second body 580 and open to the second rod recess 582. As shown in the illustrated embodiment, the cavity 584 can be a blind bore formed in the outer surface 592 of the body 580

and intersecting with the second rod recess 582. In some embodiments, the cavity 584 can be a through bore. At least one dimension of the cavity 584 can be greater than a corresponding dimension of the hinge pin 514 to allow the hinge pin to translate within the cavity along the rotation axis A1.

[00209] The saddle 550 is shown in greater detail in FIGS. 5I through 5L. The saddle 550 can be positioned within the second body 580. The saddle 550 can be generally cylindrical with first and second arms 554, 556 extending in a proximal direction to respective free ends of the arms. The first and second arms 554, 556 can define a rod-receiving recess or rod seat 558 therebetween. The first and second arms 554, 556 of the saddle 550 can be aligned with the first and second arms 586, 588 of the second body 580 such that rod seat 558 is aligned with the second rod-receiving recess 582. Accordingly, the second rod R2 can be simultaneously cradled between the arms 554, 556 of the saddle 550 and the arms 586, 588 of the second body 580 when the rod R2 is disposed in the second rod-receiving recess 582. The first and second arms 554, 556 of the saddle 550 can include projections 560 (e.g., spring tabs) extending radially outward therefrom and configured to be received within the grooves or other recesses 590 of the second body 580. The saddle 550 can be configured to translate within the body 580 along the axis A4, e.g., between proximal and distal limits defined by the interaction between the grooves or recesses 590 of the second body 580 and the radial projections 560 of the arms 554, 556.

[00210] As shown in FIGS. 5J through 5L, the saddle 550 can have a recessed distal-facing bearing surface 562 and a saddle projection 552 extending distally therefrom. The recessed bearing surface 562 can have a curved or other suitable shape configured to contact and bear against a semi-cylindrical, exterior surface of the hinge pin 514. The distal saddle projection 552 can be configured to be received within the slot 518 of the hinge pin 514, and thereby maintain coupling of the first body 510 and the second body 580. The distal saddle projection 552 can also be configured to interfere with the slot 518 as the hinge pin 514 rotates, thereby limiting the rotation range of the first body 510 relative to the second body 580.

[00211] As shown in the illustrated embodiment, the distal saddle projection 552 can be centrally disposed within the recessed bearing surface 562. The distal saddle projection 552 can have lateral-facing bearing surfaces 564, 566 extending distally from the recess. The lateral-

facing bearing surfaces 564, 566 of the saddle projection can lie in a plane that is perpendicular with respect to the recessed bearing surface 562 and the rotation axis A1. The lateral-facing bearing surfaces 564, 566 of the saddle projection can be planar or curved. The lateral-facing bearing surfaces 564, 566 of the saddle projection can be configured to respectively contact and bear against the opposing sidewalls 540, 542 of the slot 518 of the hinge pin 514 perpendicular to the rotation axis A1, and thereby prevent disassembly of the first and second bodies 510, 580.

[00212] The lateral-facing bearing surfaces 564, 566 of the saddle projection can meet at a ridge 570 having a distal-facing bearing surface. The ridge 570 of the saddle projection 552 can extend perpendicular with respect to the proximal-distal axis A4 of the second body 580. In the illustrated embodiment, the ridge 570 can include a recess 572 formed in the distal-facing bearing surface. The recess 572 can be sized to accommodate the rib 548 formed in the slot 518. As discussed further below, the distal-facing bearing surface of the ridge 570 adjacent to the recess 572 can be configured to interfere with the side walls 544, 546 of the slot 518 as the hinge pin 514 rotates, thereby limiting the rotation range of the first body 510 relative to the second body 580.

[00213] As shown in FIG. 5M through 5O, the connector 500 can be assembled by inserting the free end of the hinge pin 514 through the opening in the outer bearing surface 592 and into the cavity 584 of the second body 580. The hinge pin 514 can be oriented within the cavity 584, such that the slot 518 of the pin is aligned with the second rod-receiving recess 582. The saddle 550 can be inserted into the proximal end 580p of the second body 580 and distally advanced until the distal saddle projection 552 is received in the slot 518 of the hinge pin 514. The radial projections 560 of the saddle arms 554, 556 can snap into the grooves or recesses 590 of the second body 580 to retain the saddle 550.

[00214] At this stage of assembly, even before locking rods within the connector 500, the saddle 550 can interfere with the slot 518 of the hinge pin 514 to prevent the pin from being removed from the second body 580. For example, when the saddle projection 552 is received in the slot 518, the lateral-facing surfaces 564, 566 of the saddle projection can bear against the opposing sidewalls 540, 542 of the slot to prevent removal of the pin, and thereby maintain coupling of the first and second bodies 510, 580. The distal saddle projection 552 can also interfere with the slot

518 of the hinge pin 514 to limit the relative rotation of the connector bodies 510, 580. For example, as shown in FIG. 5N, when the hinge pin 514 rotates clockwise or counter clockwise about the rotation axis A1, the extent of such rotation can be restricted by one of the sidewalls 544, 546 of the slot 518 contacting the ridge 570 of the saddle projection 552.

[00215] In the illustrated embodiment, the ridge 570 of the saddle projection 552 can have a distal-facing contact surface that lies in a plane perpendicular with respect to the proximal-distal axis A4 of the second body. As shown, the sidewalls 544, 546 of the slot 518 can lie in a common plane. When the saddle projection 552 is disposed within the slot 518, a gap can be formed between the planar contact surfaces of the ridge 570 and the slot 518, thereby enabling the hinge pin 514 to rotate within the limits defined therebetween.

[00216] In some embodiments, a recess 572 can be formed in the ridge 570 that is sized to at least partially receive a rib 548 disposed between the sidewalls 544, 546 of the slot. Such embodiments can facilitate an increase in the range of rotation of the hinge pin 514 without a corresponding increase in the width of the gap. Alternatively or additionally, such embodiments can facilitate a decrease the width of the gap without a corresponding decrease in the range of rotation of the hinge pin. In some embodiments, the sidewalls 544, 546 of the slot can lie in respective planes that intersect obliquely to increase or decrease the range of rotation of the pin.

[00217] In some embodiments, the interaction between the slot 518 of the hinge pin 514 and the saddle projection 552 can limit the range of rotation of the pin symmetrically with respect to the rotation axis A1. For example, in some embodiments, the range of rotation of the hinge pin 514 can be limited to ±30 degrees, ±60 degrees, ±180 degrees, or other symmetrical range suitable depending on the surgical procedure. In some embodiments, the interaction between the slot 518 of the hinge pin 514 and the saddle projection 552 can limit the range of rotation of the pin asymmetrically with respect to the rotation axis A1. Limiting the range of rotation of the pin 514 by forming a smaller slot 518 can allow more material to be retained on the pin, thereby increasing the strength of the pin.

[00218] A first rod R1 can be seated in the first rod receiving recess 512 of the first body 510 and secured to the connector 500 by tightening the first fastener 520. The first fastener 520 can include an exterior thread configured to mate with the interior threads formed on the arms 524,

526 of the first body 510 to allow the first fastener to be advanced or retracted along the axis A2 with respect to the body by rotating the first fastener about the axis A2. The first fastener 520 can include a driving interface configured to receive a driver for applying a rotational force to the first fastener about the axis A2. While a unitary set screw 520 is shown, it will be appreciated that other fasteners can be used instead or addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, or a nut that threads onto an exterior of the body.

[00219] The distal surface of the first fastener 520 can be configured to contact and bear against a rod R1 disposed in the first rod-receiving recess 512 to lock the rod to the connector 500. When tightened against the rod R1, the first fastener 520 can prevent the rod from translating relative to the connector 500 along the axis A3 and/or from rotating with respect to the connector about the axis A3. The first rod R1 can be seated in the first rod-receiving recess 512, while the second body 580 can remain free to rotate relative to the first body 510 about the rotation axis A1 even after the first rod R1 is locked to the connector 500.

[00220] A second rod R2 can be seated in the rod seat 558 of the saddle 550 disposed in the second rod receiving recess 582 of the second body 580. The second rod R2 can be secured to the connector 500 by tightening the second fastener 522. The second fastener 522 can include an exterior thread configured to mate with the interior threads formed on the arms 586, 588 of the second body 580 to allow the second fastener to be advanced or retracted along the axis A4 with respect to the body by rotating the second fastener about the axis A4. The second fastener 522 can include a driving interface configured to receive a driver for applying a rotational force to the second fastener 522 about the axis A4.

[00221] The distal surface of the second fastener 522 can be configured to contact and bear against the rod R2 disposed in the saddle 550 to lock the rod to the connector 500. When tightened against the rod R2, the second fastener 522 can prevent the rod from translating relative to the connector 500 along the axis A5 and/or from rotating with respect to the connector about the axis A5. While a unitary set screw 522 is shown, it will be appreciated that other fasteners can be used, instead or in addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, a nut that threads onto

an exterior of the body, or a dual-component set screw with independently-rotatable inner and outer members, the inner member acting on the rod R2 and the outer member acting on proximal free ends of the saddle arms 554, 556.

[00222] As the second fastener 522 is tightened, the second rod R2 can be urged distally against the saddle 550, thereby causing the saddle to urge distally against the hinge pin 514. As shown in FIG. 5O, the recessed distal-facing bearing surface 562 of the saddle 550, adjacent to the distal saddle projection 552, can bear against a counter bearing surface of the hinge pin 514. The downward force applied by the saddle 550 can urge the pin 514 against the inner wall of the cavity 582 of the second body 580.

[00223] Before fully tightening one or both fasteners 520, 522, the bodies 510, 580 can be rotated relative to one another about the axis A1 as desired by the user. The second fastener 522 can then be tightened to lock such relative rotation. In particular, when the fastener 522 is tightened, the force applied to the hinge pin 514 by the saddle 550 can urge the sharp corners 516 of the pin to cut and/or deform the inner wall of the cavity 584 of the second body 580. Through such edge loading, the sharp corners 516 of the hinge pin 514 can create additional friction, mechanical interlock, or increase the radial force applied by the pin against the second body 580 to effectively lock relative rotation of the bodies 510, 580 about the axis A1. It will be appreciated that the connector 500 can allow locking of the first rod R1 to the connector and locking of the rotational degree-of-freedom of the connector to be performed independently of one another.

[00224] In other arrangements, the second fastener 522 can bear directly against the saddle 550. For example, the second fastener 522 can include an outer set screw that bears against the saddle arms 554, 556 to lock relative rotation of the bodies 510, 580, and an inner set screw that bears against the second rod R2 to secure the second rod to the connector 500. In still further arrangements, the saddle 522 can be omitted and the second rod R2 can bear directly against the hinge pin 514.

[00225] The ability to rotate the first and second bodies 510, 580 relative to one another about the rotation axis A1 can advantageously allow first and second rods R1, R2 to be locked together even when the rods are obliquely angled with respect to one another, e.g., in the sagittal plane or

in the coronal plane. The connector 500 can be particularly useful in connecting tandem rods of a spinal fixation construct across the cervical-thoracic (CT) junction of a patient. For example, the connector 500 can secure the rods R1, R2 in a laterally-offset arrangement to accommodate the different screw trajectories that may occur at the CT junction. By way of further example, the ability of the connector 500 to articulate can allow a cervical rod and a thoracic rod to be locked to one another at an oblique angle in the sagittal plane, e.g., to restore natural lordosis or kyphosis. The connector 500 can also be particularly useful in spinal deformity correction and other procedures in which multiple angled rods are to be coupled to one another.

[00226] In some embodiments, the bodies 510, 580 of the connector 500 can include various features for decreasing or increasing the center-to-center offset between the first and second rods R1, R2 when the rods are locked to the connector. For example, one or both of the outer surfaces of the bodies 510, 580 that oppose one another can be obliquely angled with respect to the respective proximal-distal axes A2, A4. Accordingly, the rods R1, R2 can move towards one another as they are advanced into the connector 500. This can advantageously reduce the center-to-center offset of the rods R1, R2, while preserving sufficient material thickness at the proximal ends of the bodies 510, 580 to withstand the relatively high forces subjected to the connector 500 during rod reduction, fastener tightening, and/or post-operative patient movement.

[00227] As another example, the opposing outer surfaces of the bodies 510, 580 can be parallel to the proximal-distal axes A2, A4, and instead the rod recesses 512, 582 can be obliquely angled or can follow a curved path with respect to the proximal-distal axes to bring the rods R1, R2 closer together.

[00228] As another example, the axis along which the first fastener 520 advances as it is tightened can be offset laterally from the first rod axis A3 when the first rod R1 is fully seated in the recess 512, or can be obliquely angled with respect to the proximal-distal axis A2 of the first body 510. Alternatively, or in addition, the axis along which the second fastener 522 advances as it is tightened can be offset laterally from the second rod axis A5 when the second rod R2 is fully seated in the recess 582, or can be obliquely angled with respect to the proximal-distal axis A4 of the second body 580.

[00229] The arms 524, 526 can include or can be coupled to extension or reduction tabs (not shown) that extend proximally from the body 510 to functionally extend the length of the arms 524, 526. The extension tabs can facilitate insertion and reduction of a rod or other implant, as well as insertion and locking of the first fastener 520. The extension tabs can be configured to break away or otherwise be separated from the arms 524, 526. The inner surfaces of each of the arms 524, 526 can be configured to mate with the first fastener 520. For example, the inner surfaces of the arms 524, 526 can include threads that correspond to external threads formed on the first fastener 520. Accordingly, rotation of the first fastener 520 with respect to the body 510 about the axis A2 can be effective to translate the first fastener with respect to the body axially along the axis A2. The arms 586, 588 can similarly include or be coupled to extension or reduction tabs.

[00230] In some embodiments, the connector 500 can include various features of a unilateral locking interface, including but not limited to one or more grooves 594 and surface projections 596. The unilateral locking interface enables a surgical instrument that includes a unilateral locking mechanism (not shown) to rigidly hold onto one side of the connector 500. Exemplary unilateral locking interfaces that can be included in the connector 500 are disclosed in U.S. Patent Application No. 15/843,618, filed on December 15, 2017 and entitled “Unilateral Implant Holders and Related Methods,” the entire contents of which are hereby incorporated by reference.

[00231] FIGS. 6A-6J illustrate an exemplary embodiment of a connector 600. As shown, the connector 600 can include a first body 610 that defines a first rod-receiving recess or channel 612 and a second body 680 that defines a second rod-receiving recess or channel 682. The first and second bodies 610, 680 can be connected to one another at least in part by a hinge pin 614 that defines a rotation axis A1 about which the bodies can rotate relative to one another. In the illustrated embodiment, the hinge pin 614 can project laterally from the first body 610 to a free end. The free end of the hinge pin 614 can be received within an interior cavity 684 formed in the second body 680. The connector 600 can include first and second fasteners 620, 622 configured to secure first and second rods R1, R2 or other fixation elements to the connector 600 within the respective rod-receiving recesses 612, 682. The hinge pin 614 of the first body 610 can include a slot 618 configured to receive a distal projection 652 of a saddle 650 disposed in

the second rod-receiving recess 682, thereby preventing disassembly of the first and second bodies 610, 680 and limiting the relative rotation between the first and second bodies 610, 680.

[00232] As discussed further below, to increase the locking strength of the connector 600, the slot 618 of the pin can be obliquely angled with respect to the rotation axis A1 of the pin. The angled slot 618 can be configured to receive the distal projection 652 of a saddle 650 disposed in the second rod-receiving recess 682. The distal saddle projection 652 can be oriented at an oblique angle to match or coincide with the angled slot 618 of the hinge pin 614. The distal saddle projection 652 can have a wedge-shaped cross section with tapered bearing surfaces that facilitate wedging of the saddle projection in the slot 618 in response to a force applied by the second fastener 622 against the rod R2 and/or saddle 650 itself. Wedging the distal saddle projection 652 into the angled slot 618 of the hinge pin 614 can create additional friction, mechanical interlock, or increased force applied by the pin against the second body 680 to effectively lock relative rotation of the bodies 610, 680 about the axis A1.

[00233] Except as described below or as will be readily appreciated by one having ordinary skill in the art, the first body 610, the second body 680, the first fastener 620, and the second fastener 622 of the connector 600 are substantially similar to the first body 510, the second body 580, the first fastener 520, and the second fastener 522 of the connector 500 described above with respect to FIGS. 5A-5O. A detailed description of the structure and function thereof is thus omitted here for the sake of brevity. The connector 600 can include any combination of the features of the connector 500 described above.

[00234] The first body 610 of the connector 600, including the hinge pin 614, is shown in greater detail in FIGS. 6C and 6D. The first body 610 can include proximal and distal ends 610p, 610d that define a proximal-distal axis A2. The proximal end 610p of the body 610 can include a pair of spaced apart arms 624, 626 that extend from the distal portion 610d of the body 610 to a free end. The spaced apart arms 624, 626 can define the first rod-receiving recess 612 therebetween.

[00235] The hinge pin 614 can project along the rotation axis A1 from an outer surface 628 of the arm 626. The hinge pin 614 can extend perpendicular from a distal end portion of the outer surface 628 of the arm 626. The hinge pin 614 can include opposed first and second ends that

define a central longitudinal axis A6 extending therebetween. The longitudinal axis A6 can be collinear with the rotation axis A1 of the connector 600. As discussed above with respect to FIGS. 5A-5O, the exterior surface of the hinge pin 614 can include sharp corners 616 or other surface features that can bear against the inner wall of the cavity 684 of the second body 680 to increase the locking strength of the connector 600.

[00236] The slot 618 can be formed in the proximal surface of the hinge pin 614. The slot 618 of the pin can be oriented at an oblique angle with respect to the rotation axis A1 of the pin and a central longitudinal rod axis A5 of the second rod-receiving recess 682. In some embodiments, the slot 618 can be oriented at an oblique angle of approximately 7 degrees with respect to the rod axis A5. When the bodies are rotated, the oblique angle causes the bodies to move further or closer apart in relation to each other in the lateral direction. This additional motion creates drag and thereby increases rotational resistance in axis A1 when the first body is locked down. In some embodiments, the slot 618 can be oriented at an oblique angle within an approximate range between 5 and 10 degrees with respect to the rod axis A5, inclusively.

[00237] The length of the slot 618 can be defined between a first pair of opposing sidewalls 640, 642 that form angled cam surfaces. Each of the opposing sidewalls 640, 642 can lie in a plane that is oblique to the rotation axis A1 and the rod axis A5 of the second rod-receiving recess 682. The opposing sidewalls 640, 642 can lie in substantially parallel planes or can be obliquely angled with respect to one another. The width of the slot 618 can be defined by a proximal-facing surface 644 disposed between the first pair of opposing sidewalls 640, 642 of the slot. As discussed further below, the slot 618 can be configured to receive the distal projection 652 of the saddle 650 disposed in the second rod-receiving recess 682, and thereby prevent disassembly of the first and second bodies 610, 680 and increase the locking strength of the connector 600 to resist relative rotation between the first and second bodies 610, 680.

[00238] The saddle 650 is shown in greater detail in FIGS. 6E through 6J. The saddle 650 can be generally cylindrical with first and second arms 654, 656 extending in a proximal direction to respective free ends of the arms. The first and second arms 654, 656 of the saddle 650 can define a rod seat 658 therebetween. The first and second arms 654, 656 of the saddle 650 can include projections 660 (e.g., spring tabs) extending radially outward therefrom. The radial

projections 660 can be configured to snap into or otherwise be received within grooves or other recesses 690 of the second body 680 to retain the saddle 650 therein.

[00239] The saddle 650 can have a distal-facing bearing surface 662. The distal-facing bearing surface 662 can have a planar, ramped, curved or other suitable contour configured to contact and bear against a counterpart bearing surface of the hinge pin 614. The saddle 650 can include a saddle projection 652 that extends distally from the distal-facing bearing surface 662 to maintain coupling of the first and second bodies 610, 680 and to increase the locking strength of the connector 600 to resist relative rotation of the bodies. In some embodiments, only the saddle projection 652 is configured to contact and bear against the hinge pin 614.

[00240] As shown in the illustrated embodiment, the distal saddle projection 652 can be obliquely angled with respect to a central longitudinal rod axis A5 defined by the rod seat 658. The distal saddle projection 652 can be oriented at an oblique angle to match or coincide with the angle of the slot 618 of the hinge pin 614. Thus, when disposed in the second body 680, the distal saddle projection 652 can be oriented at an oblique angle with respect to the rotation axis A1 of the pin and a central longitudinal rod axis A5 of the second rod-receiving recess 682. The obliquely angled geometry of the saddle projection 652 and the slot 618 can provide increased resistance to relative rotation between the bodies 610, 680 about the axis A1 when the connector 600 is locked.

[00241] The distal saddle projection 652 can have tapered bearing surfaces 665, 667 configured to facilitate wedging of the saddle projection in the slot 618 in response to a downward force applied against the saddle 650. To facilitate wedging, the tapered bearing surfaces 665, 667 of the distal saddle projection 652 can be angled or ramped to intersect with the sidewalls 640, 642 of the slot 618 of the hinge pin 614 at a mismatched angle. Put another way, the tapered bearing surfaces 665, 667 of the distal saddle projection can lie in respective planes that are skewed relative to the opposing sidewalls 640, 642 of the slot 618. Wedging the distal saddle projection 652 into the angled slot 618 of the hinge pin 614 can create additional friction, mechanical interlock, or increased force to effectively lock relative rotation of the bodies 610, 680 about the axis A1.

[00242] As shown in FIGS. 6H through 6J, the connector 600 can be assembled by inserting the free end of the hinge pin 614 through the opening in the outer surface 692 and into the cavity 684 of the second body 680. The hinge pin 614 can be oriented within the cavity 684, such that the slot 618 of the pin is aligned with the second rod-receiving recess 682. The saddle 650 can be inserted into the proximal end 680p of the second body 680. The saddle 650 can be configured to translate within the body 680 along the axis A4 and can thus be distally advanced until the distal saddle projection 652 is received in the slot 618 of the hinge pin 614.

[00243] In some embodiments, the saddle 650 can be configured to translate between proximal and distal limits defined by the interaction between the grooves or recesses 690 of the second body 680 and the radial projections 660 of the arms 654, 656. When disposed in the second body 680, the first and second arms 654, 656 of the saddle 650 can be aligned with the first and second arms 686, 688 of the second body such that rod seat 658 is aligned with the second rod-receiving recess 682. Accordingly, the second rod R2 can be simultaneously cradled between the arms 654, 656 of the saddle 650 and the arms 686, 688 of the second body 680 when the rod R2 is disposed in the second rod-receiving recess 682.

[00244] At this stage of assembly, even before locking rods within the connector 600, the saddle 650 can interfere with the slot 618 of the hinge pin 614 to prevent the pin from being removed from the second body 680. For example, when the saddle projection 652 is received in the slot 618, the tapered bearing surfaces 665, 667 of the saddle projection can bear against the opposing sidewalls 640, 642 of the slot to prevent removal of the pin, and thereby maintain coupling of the first and second bodies 610, 680.

[00245] The distal saddle projection 652 can also interfere with the slot 618 of the hinge pin 614 to limit the relative rotation of the connector bodies 610, 680. For example, when the hinge pin 614 rotates clockwise or counter clockwise about the rotation axis A1, the extent of such rotation can be restricted by an outer edge 668 of the proximal-facing surface 644 of the slot 618 contacting a ridge 670 of the saddle projection 652. In the illustrated embodiment, the ridge 670 of the saddle projection 652 can have a distal-facing contact surface that lies in a plane perpendicular with respect to the proximal-distal axis A4 of the second body. When the saddle projection 622 is disposed within the slot 618, a gap can be formed between the ridge 670 and

the proximal-facing surface 644 of the slot 618, thereby enabling the hinge pin 614 to rotate within the limits defined therebetween.

[00246] In some embodiments, the interaction between the slot 618 of the hinge pin 614 and the saddle projection 652 can limit the range of rotation of the pin symmetrically with respect to the rotation axis A1. For example, in some embodiments, the range of rotation of the hinge pin 614 can be limited to ±30 degrees, ±60 degrees, ±180 degrees, or other symmetrical range suitable depending on the surgical procedure. In some embodiments, the interaction between the slot 618 of the hinge pin 614 and the saddle projection 652 can limit the range of rotation of the pin asymmetrically with respect to the rotation axis A1.

[00247] A first rod R1 can be seated in the first rod receiving recess 612 of the first body 610 and secured to the connector 600 by tightening the first fastener 620. The first fastener 620 can include an exterior thread configured to mate with the interior threads formed on the arms 624, 626 of the first body 610 to allow the first fastener to be advanced or retracted along the axis A2 with respect to the body by rotating the first fastener about the axis A2. The distal surface of the first fastener 620 can be configured to contact and bear against a rod R1 disposed in the first rod-receiving recess 612 to lock the rod to the connector 600. When tightened against the rod R1, the first fastener 620 can prevent the rod from translating relative to the connector 600 along the axis A3 and/or from rotating with respect to the connector about the axis A3. The first rod R1 can be seated in the first rod-receiving recess 612, while the second body 680 can remain free to rotate relative to the first body 610 about the rotation axis A1 even after the first rod R1 is locked to the connector 600.

[00248] A second rod R2 can be seated in the rod seat 658 of the saddle 650 disposed in the second rod receiving recess 682 of the second body 680. The second rod R2 can be secured to the connector 600 by tightening the second fastener 622. The second fastener 622 can include an exterior thread configured to mate with the interior threads formed on the arms 686, 688 of the second body 680 to allow the second fastener to be advanced or retracted along the axis A4 with respect to the body by rotating the second fastener about the axis A4. The distal surface of the second fastener 622 can be configured to contact and bear against the rod R2 disposed in the saddle 650 to lock the rod to the connector 600. When tightened against the rod R2, the second

fastener 622 can prevent the rod from translating relative to the connector 600 along the axis A5 and/or from rotating with respect to the connector about the axis A5.

[00249] As the second fastener 622 is tightened, the second rod R2 can be urged distally against the saddle 650, thereby causing the saddle projection 652 to be urged distally into the slot 618 of the hinge pin 614 and lock relative rotation of the bodies 610, 680. In other arrangements, the second fastener 622 can bear directly against the saddle 650. For example, the second fastener 622 can include an outer set screw that bears against the saddle arms 654, 656 to lock relative rotation of the bodies 610, 680, and an inner set screw that bears against the second rod R2 to secure the second rod to the connector 600.

[00250] Before fully tightening one or both fasteners 620, 622, the bodies 610, 680 can be rotated relative to one another about the axis A1 as desired by the user. The second fastener 622 can then be tightened to lock such relative rotation. In particular, the force applied by the second fastener 622 to the saddle 650 can wedge the saddle projection 652 into the slot 618 of the hinge pin 614. For example, as shown in FIG. 6I, the distal saddle projection 652 can be wedged into the slot 618 of the hinge pin 614 such that the tapered bearing surfaces 665, 667 intersect with the sidewalls 640, 642 of the slot 618 at a mismatched angle. The downward force applied by wedging the distal saddle projection 652 into the angled slot 618 of the hinge pin 614 can urge the pin 614 against the inner wall of the cavity 684 of the second body 680, and thereby effectively lock relative rotation of the bodies 610, 680 about the axis A1.

[00251] In some embodiments, the force applied to the hinge pin 614 by wedging the saddle 650 into the slot 618 of the pin can urge the sharp edges or corners 616 of the pin to cut and/or deform the inner wall of the cavity 684 of the second body 680. Through such edge loading, the sharp corners 616 of the hinge pin 614 can create additional friction, mechanical interlock, or increase the radial force applied by the pin against the second body 680 to effectively lock relative rotation of the bodies 610, 680 about the axis A1. It will be appreciated that the connector 600 can allow locking of the first rod R1 to the connector and locking of the rotational degree-of-freedom of the connector to be performed independently of one another.

[00252] The ability to rotate the first and second bodies 610, 680 relative to one another about the rotation axis A1 can advantageously allow first and second rods R1, R2 to be locked together

even when the rods are obliquely angled with respect to one another, e.g., in the sagittal plane or in the coronal plane. The connector 600 can be particularly useful in connecting tandem rods of a spinal fixation construct across the cervical-thoracic (CT) junction of a patient. For example, the connector 600 can secure the rods R1, R2 in a laterally-offset arrangement to accommodate the different screw trajectories that may occur at the CT junction. By way of further example, the ability of the connector 600 to articulate can allow a cervical rod and a thoracic rod to be locked to one another at an oblique angle in the sagittal plane, e.g., to restore natural lordosis or kyphosis. The connector 600 can also be particularly useful in spinal deformity correction and other procedures in which multiple angled rods are to be coupled to one another.

[00253] FIGS. 7A-7O illustrate an exemplary embodiment of a connector 700. As shown, the connector 700 can include a first body 710 that defines a first rod-receiving recess or channel 712 and a second body 780 that defines a second rod-receiving recess or channel 782. The first and second bodies 710, 780 can be connected to one another at least in part by a hinge pin 714 that defines a rotation axis A1 about which the bodies can rotate relative to one another. In the illustrated embodiment, the hinge pin 714 can project laterally from the first body 710 to a free end. The free end of the hinge pin 714 can be received within an interior cavity 784 formed in the second body 780. The connector 700 can include first and second fasteners 720, 722 configured to secure first and second rods R1, R2 or other fixation elements to the connector 700 within the respective rod-receiving recesses 712, 782. The hinge pin 714 of the first body 710 can include a retention slot 718 configured to receive a distal projection 752 of a saddle 750 disposed in the second rod-receiving recess 782, thereby preventing disassembly of the first and second bodies 710, 780.

[00254] As discussed further below, the structural integrity of the connector 700 can be improved to reduce the risk of the hinge pin 714 breaking under an applied shear force between the first and second bodies 710, 780. For example, as shown in the illustrated embodiment, the structural integrity of the hinge pin 714 can be improved by forming the retention slot 718 in close proximity to the free end of the hinge pin 714, such that the slot can be exposed through the second rod-receiving recess 782 while providing the hinge pin with a maximum cross sectional area for a significant portion of its length. Alternatively or in addition, in some embodiments, the locking strength of the connector 700 can be increased by maximizing the contact surface

area between the saddle 750 and the hinge pin 714. Alternatively or in addition, in some embodiments, the free end of the hinge pin 714 can be configured to interact with a through hole opening 798 defined in the second body 780 to limit the degree of rotation by the pin, and thereby limit the relative rotation permitted between the bodies 710, 780.

[00255] The first body 710 of the connector 700, including the hinge pin 714, is shown in greater detail in FIGS. 7C through 7E. The first body 710 can include proximal and distal ends 710p, 710d that define a proximal-distal axis A2. The proximal end 710p of the body 710 can include a pair of spaced apart arms 724, 726 that extend from the distal portion 710d of the body 710 to a free end. The spaced apart arms 724, 726 can define the first rod-receiving recess 712 therebetween. The first rod-receiving recess 712 can be open in a proximal direction, such that a rod R1 can be inserted into the recess by moving the rod distally with respect to the connector 700. Alternatively, the first rod-receiving recess 712 can be open in distal direction, open in a lateral direction, or closed such that the rod R1 must be translated along the axis A3 to insert the rod into the recess 712.

[00256] The hinge pin 714 can project along the rotation axis A1 from an outer surface 728 of the arm 726. As shown in the illustrated embodiment, the outer surface 728 of the arm 726 can extend vertically from the distal end 710d of the first body 710. The hinge pin 714 can extend perpendicular from a distal end portion of the outer surface 728 of the arm 726. The hinge pin 714 can include opposed first and second ends that define a central longitudinal axis A6 extending therebetween. The longitudinal axis A6 can be collinear with the rotation axis A1 of the connector 700. The hinge pin 714 can be formed integrally or monolithically with the first body 710 as shown, or can be fixedly attached thereto, e.g., by welding or other processes.

[00257] The hinge pin 714 can have a first portion 730, a second portion 732 and an intermediate portion or rib 734 that connects the first and second portions. The first portion 730 of the hinge pin 714 can have a cylindrical or other suitable shape that allows the pin to freely rotate within the cavity 784 of the second body 780. The second portion 732 of the hinge pin 714 can have a semi-cylindrical or other suitable shape having a cross section that can interact with the second body 780 to limit rotation of the pin within the cavity 784. In some embodiments, the second portion 732 of the pin 714 can have a semi-circular or D-shaped cross

section. The rib 734 of the hinge pin 714 can have a cylindrical or other suitable shape to form the retention slot 718 between the first portion 730 and the second portion 732 of the pin. The length of the slot 718 can be defined by the length of the rib 734 disposed between a sidewall 740 of the first portion 730 and an opposing sidewall 742 of the second portion 732. Each of the opposing sidewalls 740, 742 can lie in a plane perpendicular to the rotation axis A1. As discussed further below, the slot 718 can be configured to receive a distal projection of a saddle 750 disposed in the second rod-receiving recess 782, thereby preventing disassembly of the first and second bodies 710, 780.

[00258] The second body 780 is shown in greater detail in FIGS. 7F through 7H. The second body 780 can include proximal and distal ends 780p, 780d that define a proximal-distal axis A4. The proximal end 780p of the body 780 can include a pair of spaced apart arms 786, 788 that define the second rod-receiving recess 782 therebetween. A rod R2 disposed in the second rod-receiving recess 782 can have a central longitudinal rod axis A5. The second rod-receiving recess 782 can be open in a proximal direction, such that a rod R2 can be inserted into the recess by moving the rod distally with respect to the connector 700. Alternatively, the second rod-receiving recess 782 can be open in distal direction, open in a lateral direction, or closed such that the rod R2 must be translated along the axis A5 to insert the rod into the recess 782. Each of the arms 786, 788 can include recesses or grooves 790 for retaining the saddle 750 within the body 780. The second body 780 can include an outer surface 792 that opposes the outer surface 728 of the first body 710.

[00259] The distal end 780d of the second body 780 can define an interior cavity 784 in which a free end of the hinge pin 714 can be received. As shown in the illustrated embodiment, the cavity 784 be a through hole that extends from a first opening 794 formed in the outer surface 792 to a second opening 798 formed in the opposite outer surface 796 of the second body 780. As discussed further below, the second opening 798 formed in the outer surface 796 of the second body 780 can be configured to at least partially receive and interact with the free end portion 732 of the hinge pin 714 and thereby limit rotation of the pin within the cavity 784. As shown in FIG. 7H, the second opening in the outer surface 796 of the second body can have a semi-circular or D-shaped cross section. At least one dimension of the cavity 784 can be greater

than a corresponding dimension of the hinge pin 714 to allow the hinge pin to translate within the cavity along the rotation axis A1.

[00260] The saddle 750 is shown in greater detail in FIGS. 7I through 7K. The saddle 750 can be generally cylindrical with first and second arms 754, 756 extending in a proximal direction to respective free ends of the arms. The first and second arms 754, 756 of the saddle 750 can define a rod seat 758 therebetween. The first and second arms 754, 756 of the saddle 750 can include projections 760 (e.g., spring tabs) extending radially outward therefrom. The radial projections 760 can be configured to snap into or otherwise be received within grooves or other recesses 790 of the second body 780 to retain the saddle 750 therein.

[00261] The saddle 750 can have a recessed distal-facing bearing surface 762 and a saddle projection 752 extending therefrom. The recessed distal-facing bearing surface 762 can have a planar, ramped, curved or other suitable contour configured to contact and bear against an exterior surface of the hinge pin 714. As shown in the illustrated embodiment, the recessed bearing surface 762 of the saddle 750 can be curved to contact and bear against the cylindrical-shaped surface of the first portion 730 of the hinge pin 714. The saddle projection 752 can extend distally from the distal-facing bearing surface 762 to maintain coupling of the first and second bodies 710, 780.

[00262] As shown in the FIGS. 7J and 7K, the distal saddle projection 752 can be aligned with an arm 756 of the saddle 750. For example, as shown in the illustrated embodiment, the distal saddle projection 752 can extend distally along an edge of the saddle 750 coplanar with the saddle arm 756. In some embodiments, the distal saddle projection 752 can extend distally from the recessed bearing surface 762 of the saddle, such that the projection is disposed adjacent to the edge of the saddle 750 in a plane parallel to the saddle arm 756.

[00263] As discussed further below, by disposing the distal saddle projection 752 at the edge or adjacent to the edge of the saddle 750, the contact surface area can be maximized between the first portion 730 of the hinge pin 714 and the distal-facing bearing surface 762 of the saddle 750. Maximizing the contact surface area between the hinge pin 714 and the saddle 750 can increase the locking strength of the connector 700 to resist rotation between the first and second bodies 710, 780. In some embodiments, the saddle projection 752 can define a recess 754 sized to

partially receive the intermediate portion (or rib) 734 of the hinge pin 714 and thereby allow the rib to rotate within the recess.

[00264] As shown in FIG. 7L through 7O, the connector 700 can be assembled by inserting the hinge pin 714 through the first opening 794 of the outer surface 792 of the second body 780 and into the cavity 784 until the free end portion 732 of the pin is received in the second opening 798 of the outer surface 796. When the free end portion 732 of the hinge pin 714 is received in the second opening 798 of the second body 780, the retention slot 718 of the pin can be exposed proximally through the second rod-receiving recess 782, such that the slot is aligned with the edge of the recess 782 closest to the arm 788 of the second body 780. In some embodiments, the slot 718 can be offset from the edge of the second rod-receiving recess 782 between the central longitudinal rod axis A5 and the arm 788 of the second body 780.

[00265] By forming the retention slot 718 in close proximity to the free end of the hinge pin 714, *e.g.*, such that the slot is exposed at or adjacent to the edge of the second rod-receiving recess 782, the hinge pin can have a maximum cross sectional area for a significant portion of its length, and thereby improve the structural integrity of the connector 700. For example, in some embodiments, the first portion 730 of the hinge pin 714 can have a maximum cross sectional area that extends longitudinally from the outer bearing surface 728 of the first body 710 to more than halfway across the width of the second rod-receiving recess 782. In such embodiments, the risk of the hinge pin 714 breaking under an applied shear force between the first and second bodies 710, 780 can be reduced.

[00266] As shown in FIG. 7M, the saddle 750 can be inserted into the proximal end 780p of the second body 780 and distally advanced until the distal saddle projection 752 is received in the slot 718 of the hinge pin 714. The radial projections 760 of the saddle arms 754, 756 can snap into the grooves or recesses 790 of the second body 780 to retain the saddle 750. When disposed in the second body 780, the first and second arms 754, 756 of the saddle 750 can be aligned with the first and second arms 786, 788 of the second body such that rod seat 758 is aligned with the second rod-receiving recess 782. Accordingly, the second rod R2 can be simultaneously cradled between the arms 754, 756 of the saddle 750 and the arms 786, 788 of the second body 780 when the rod R2 is disposed in the second rod-receiving recess 782.

[00267] At this stage of assembly, even before locking rods within the connector 700, the saddle 750 can interfere with the slot 718 of the hinge pin 714 to prevent the pin from being removed from the second body 780. For example, when the saddle projection 752 is received in the slot 718, the lateral-facing surfaces of the projection can bear against the opposing sidewalls 740, 742 of the slot to prevent removal of the pin, and thereby maintain coupling of the first and second bodies 710, 780. The depth of the slot 718 can be configured to be greater than the height of the distal saddle projection 752 to ensure that the distal-facing surface 762 of the saddle bears against the first portion 730 of the pin during locking.

[00268] A first rod R1 can be seated in the first rod receiving recess 712 of the first body 710 and secured to the connector 700 by tightening the first fastener 720. The first fastener 720 can include an exterior thread configured to mate with the interior threads formed on the arms 724, 726 of the first body 710 to allow the first fastener to be advanced or retracted along the axis A2 with respect to the body by rotating the first fastener about the axis A2. The distal surface of the first fastener 720 can be configured to contact and bear against a rod R1 disposed in the first rod-receiving recess 712 to lock the rod to the connector 700. When tightened against the rod R1, the first fastener 720 can prevent the rod from translating relative to the connector 700 along the axis A3 and/or from rotating with respect to the connector about the axis A3. The first rod R1 can be seated in the first rod-receiving recess 712, while the second body 780 can remain free to rotate relative to the first body 710 about the rotation axis A1 even after the first rod R1 is locked to the connector 700.

[00269] A second rod R2 can be seated in the rod seat 758 of the saddle 750 disposed in the second rod receiving recess 782 of the second body 780. The second rod R2 can be secured to the connector 700 by tightening the second fastener 722. The second fastener 722 can include an exterior thread configured to mate with the interior threads formed on the arms 786, 788 of the second body 780 to allow the second fastener to be advanced or retracted along the axis A4 with respect to the body by rotating the second fastener about the axis A4. The second fastener 722 can include a driving interface configured to receive a driver for applying a rotational force to the second fastener 722 about the axis A4.

[00270] The distal surface of the second fastener 722 can be configured to contact and bear against the rod R2 disposed in the saddle 750 to lock the rod to the connector 700. When tightened against the rod R2, the second fastener 722 can prevent the rod from translating relative to the connector 700 along the axis A5 and/or from rotating with respect to the connector about the axis A5. While a unitary set screw 722 is shown, it will be appreciated that other fasteners can be used, instead or in addition, such as a closure cap that advances and locks by quarter-turn rotation, a closure cap that slides in laterally without rotating, a nut that threads onto an exterior of the body, or a dual-component set screw with independently-rotatable inner and outer members, the inner member acting on the rod R2 and the outer member acting on proximal free ends of the saddle arms 754, 756.

[00271] Before fully tightening one or both fasteners 720, 722, the bodies 710, 780 can be rotated relative to one another about the axis A1 as desired by the user. The degree of rotation of the hinge pin 714, and thereby the relative rotation permitted between the bodies 710, 780, can be limited by the interaction between the free end portion 732 of the hinge pin 714 and the opening 798 in the outer surface 796 of the second body 780.

[00272] As shown in FIG. 7N, the through hole opening 798 in the outer surface 796 of the second body 780 and the free end portion 732 of the hinge pin 714 can be configured to have respective cross sectional profiles, perpendicular to the rotation axis A1, that allow the pin to rotate clockwise and counter-clockwise between a predetermined range of angles about the rotation axis A1. For example, in the illustrated embodiment, the free end portion 732 of the pin and the through hole opening 798 of the second body 780 can both have semi-circular or D-shaped cross sectional profiles. As shown, the semi-circular profile of the through hole opening 798 is larger than the semi-circular profile of the free end portion 732 of the pin to allow the free end portion of the pin to rotate about the rotation axis A1 within the through hole opening of the second body. When the hinge pin 714 rotates clockwise or counter clockwise about the rotation axis A1, the extent of such rotation can be restricted by bearing surfaces 735, 737 of the free end portion 732 contacting an inner wall of through hole opening 798. In some embodiments, the interaction between the through hole opening 798 and the free end portion 732 of the hinge pin 714 can limit the range of rotation of the pin symmetrically with respect to the rotation axis A1. For example, in some embodiments, the range of rotation of the hinge pin 714 can be limited to

±30 degrees, ±60 degrees, ±180 degrees, or other symmetrical range suitable depending on the surgical procedure. In some embodiments, the interaction between the through hole opening 798 and the free end portion 732 of the hinge pin 714 can limit the range of rotation of the pin asymmetrically with respect to the rotation axis A1.

[00273] Once the first and second bodies 710, 780 are rotated to the desired orientation, the second fastener 722 can then be tightened to lock the relative rotation of the first and second bodies 710, 780. As the second fastener 722 is tightened, the second rod R2 can be urged distally against the saddle 750, thereby causing the saddle to urge distally against the hinge pin 714. For example, as shown in the illustrated embodiment of FIG. 7O, the distal-facing bearing surface 762 of the saddle 750 can urged to contact and bear against the counter bearing surface of the first portion 730 of the hinge pin 714. By forming the slot 718 as close as possible to the free end portion 732 of the pin, the contact surface area between the distal-facing bearing surface 762 of the saddle 750 and the counter bearing surface of the hinge pin 714 can be maximized. For example, in some embodiments, the contact surface area between the saddle 750 and the hinge pin 714 can extend in the direction of the longitudinal axis A6 for a continuous length that is greater than half the width of the second rod-receiving recess 782. In some embodiments, the contact surface area between the saddle 750 and the pin 714 can extend for a continuous length between 70% and 90% of the width of the second rod-receiving recess 782. By maximizing the contact surface area between the saddle 750 and the pin 714, the locking force and thus the locking strength of the connector 700 can be increased to resist relative rotation of the first and second bodies 710, 780.

[00274] In other arrangements, the second fastener 722 can bear directly against the saddle 750. For example, the second fastener 722 can include an outer set screw that bears against the saddle arms 754, 756 to lock relative rotation of the bodies 710, 780, and an inner set screw that bears against the second rod R2 to secure the second rod to the connector 700.

[00275] It will be appreciated that the connector 700 can allow locking of the first rod R1 to the connector and locking of the rotational degree-of-freedom of the connector to be performed independently of one another.

[00276] In some embodiments, the connector 700 can include various features of a unilateral locking interface, including but not limited to one or more grooves 702 and surface projections 704. The unilateral locking interface enables a surgical instrument that includes a unilateral locking mechanism (not shown) to rigidly hold onto one side of the connector 700. Exemplary unilateral locking interfaces that can be included in the connector 700 are disclosed in U.S. Patent Application No. 15/843,618, filed on December 15, 2017 and entitled "Unilateral Implant Holders and Related Methods," the entire contents of which are hereby incorporated by reference.

[00277] The connector 700 can include any combination of the features of the connector 500 described above. For example, as discussed above with respect to FIGS. 5A-5O, the exterior surface of the hinge pin 714 can include sharp corners or other surface features (now shown) that can bear against the inner wall of the cavity 784 of the second body 780 to increase the locking strength of the connector 700.

[00278] The ability to rotate the first and second bodies 710, 780 relative to one another about the rotation axis A1 can advantageously allow first and second rods R1, R2 to be locked together even when the rods are obliquely angled with respect to one another, e.g., in the sagittal plane or in the coronal plane. The connector 500 can be particularly useful in connecting tandem rods of a spinal fixation construct across the cervical-thoracic (CT) junction of a patient. For example, the connector 500 can secure the rods R1, R2 in a laterally-offset arrangement to accommodate the different screw trajectories that may occur at the CT junction. By way of further example, the ability of the connector 500 to articulate can allow a cervical rod and a thoracic rod to be locked to one another at an oblique angle in the sagittal plane, e.g., to restore natural lordosis or kyphosis. The connector 500 can also be particularly useful in spinal deformity correction and other procedures in which multiple angled rods are to be coupled to one another.

[00279] Any of the connectors 100, 200, 300, 400, 500, 600, and 700 described above can include a taper-lock mating between the first and second bodies. The taper lock can be formed by a conical male feature wedged into a conical female feature. The cone angle of the male feature can be in the range of about 5 degrees to about 35 degrees. The cone angle of the male feature can be about 20 degrees. The cone angle of the female feature can be in the range of

about 5 degrees to about 35 degrees. The cone angle of the female feature can be about 20 degrees. The male and female cone features can have the same cone angle or different cone angles. The connector geometry can be selected such that there is a space between the first and second bodies along the axis A1 when the connector is fully tightened, which can ensure that the taper lock bears most or all of the locking force. The male and female features can be flat cones, or can include surface features such as axial splines.

[00280] The degree to which the first and second bodies can rotate relative to one another can vary in any of the connectors 100, 200, 300, 400, 500, 600, and 700 described above. The first body can be rotatable up to 360 degrees with respect to the second body. The first body can be rotatable up to about 180 degrees with respect to the second body. The first body can be rotatable up to about 60 degrees with respect to the second body.

[00281] The geometries of the rod-receiving recesses of any of the connectors 100, 200, 300, 400, 500, 600, and 700 described above can vary. One or both recesses can include a V-shaped seat configured to accommodate rods of different diameters.

[00282] An exemplary method of using the connectors disclosed herein is described below.

[00283] The procedure can begin by forming an open or percutaneous incision in the patient to access a target site. The target site can be one or more vertebrae, a long bone or multiple portions of a long bone, or any other bone or non-bone structure of the patient. As shown in FIG. 8, the target site can be multiple vertebrae in the patient's cervical and thoracic spine.

[00284] Bone anchors can be driven into one or more of the vertebrae and spinal rods can be attached thereto using known techniques. In the illustrated example, bilateral spinal rods R1, R2 are coupled to four adjacent vertebrae V1-V4 using eight bone anchors S1-S8. In addition, bilateral rods R3, R4 are coupled to two additional vertebrae V5-V6 using four bone anchors S9-S12. The rods R1, R2 can be connected to the rods R3, R4, respectively, using two connectors C1-C2 of the type described herein (e.g., any of the connectors 100, 200, 300, 400, 500, 600, 700 or combinations or variations thereof).

[00285] The connectors C1-C2 can be articulated and locked in an articulated position as shown. This can allow the principal longitudinal axes of the rods R1, R3 to be obliquely angled with

respect to each other, and/or for the principal longitudinal axes of the rods R2, R4 to be obliquely angled with respect to each other.

[00286] All of the rods R1-R4, the connectors C1-C2, and the bone anchors S1-S12 can be installed in a single procedure.

[00287] Alternatively, the rods R1, R2 and the bone anchors S1-S8 may have been installed in a previous procedure, and the current procedure can be a revision procedure in which the rods R3, R4, the connectors C1-C2, and the bone anchors S9-S12 are installed to extend the previously-installed construct to additional levels.

[00288] The connectors C1-C2 can be attached to position the rods R1-R4 such that they overlap in a lateral view. One or both connectors C1-C2 can also be rotated 90 degrees from the orientation shown to position one or both rod pairs R1, R3 and R2, R4 such that they overlap in a posterior or anterior view.

[00289] The above steps can be repeated to install additional rods and/or connectors at the same or at different vertebral levels. Final tightening or other adjustment of the construct can be performed and the procedure can be completed using known techniques and the incision closed.

[00290] It should be noted that any ordering of method steps expressed or implied in the description above or in the accompanying drawings is not to be construed as limiting the disclosed methods to performing the steps in that order. Rather, the various steps of each of the methods disclosed herein can be performed in any of a variety of sequences. In addition, as the described methods are merely exemplary embodiments, various other methods that include additional steps or include fewer steps are also within the scope of the present disclosure.

[00291] While the methods illustrated and described herein generally involve attaching spinal rods to multiple vertebrae, it will be appreciated that the connectors and methods herein can be used with various other types of fixation or stabilization hardware, in any bone, in non-bone tissue, or in non-living or non-tissue objects. The connectors disclosed herein can be fully implanted, or can be used as part of an external fixation or stabilization system. The devices and methods disclosed herein can be used in minimally-invasive surgery and/or open surgery.

[00292] The devices disclosed herein and the various component parts thereof can be constructed from any of a variety of known materials. Exemplary materials include those which are suitable for use in surgical applications, including metals such as stainless steel, titanium, or alloys thereof, polymers such as PEEK, ceramics, carbon fiber, and so forth. The various components of the devices disclosed herein can be rigid or flexible. One or more components or portions of the device can be formed from a radiopaque material to facilitate visualization under fluoroscopy and other imaging techniques, or from a radiolucent material so as not to interfere with visualization of other structures. Exemplary radiolucent materials include carbon fiber and high-strength polymers.

[00293] Although specific embodiments are described above, it should be understood that numerous changes may be made within the spirit and scope of the concepts described.

CLAIMS:

1. A connector, comprising:

a first body that defines a first rod-receiving recess, the first body having proximal and distal ends that define a proximal-distal axis extending therebetween;

a second body that defines a second rod-receiving recess, the second body having proximal and distal ends that define a proximal-distal axis extending therebetween;

a hinge pin that couples the first body to the second body, a central longitudinal axis of the hinge pin defining a rotation axis about which the first and second bodies rotate relative to one another; and

a fastener movable with respect to at least one of the first and second bodies to urge the first and second bodies towards one another along the rotation axis and thereby lock relative rotation of the first and second bodies about the rotation axis.

2. The connector of claim 1, wherein the fastener secures a rod to one of the first and second rod-receiving recesses.

3. The connector of claim 1, wherein the fastener is a first fastener configured to secure a first rod within the first rod-receiving recess and wherein the connector further comprises a second fastener configured to secure a second rod in the second rod-receiving recess.

4. The connector of claim 1, wherein the hinge pin is formed integrally with the first body.

5. The connector of claim 1, wherein the hinge pin is rotatable relative to both of the first and second bodies.

6. The connector of claim 1, wherein the first and second bodies include respective bearing surfaces configured to bear against one another to lock relative rotation of the first and second bodies about the rotation axis.

7. The connector of claim 6, wherein the bearing surfaces are defined by complementary male and female structures of the first and second bodies.

8. The connector of claim 6, wherein the first body includes a conical male projection, an outer surface of which defines the bearing surface of the first body, and the second body includes a conical female recess, an inner surface of which defines the bearing surface of the second body.

9. The connector of claim 6, wherein the bearing surfaces each include teeth or splines.

10. The connector of claim 1, wherein the hinge pin is received within a cavity formed in the first body or the second body.

11. The connector of claim 10, wherein the hinge pin translates longitudinally within the cavity as the fastener is moved relative to said at least one of the first and second bodies.

12. The connector of claim 1, wherein the proximal-distal axes of the first and second bodies are obliquely angled with respect to one another.

13. The connector of claim 1, wherein a force applied by the fastener is transferred to the hinge pin through a saddle.

14. The connector of claim 13, wherein the saddle includes a conical surface that engages and bears against a corresponding conical surface of the hinge pin to pull the first and second bodies towards one another.

15. The connector of claim 13, wherein the saddle includes a keel extending distally therefrom, the keel being received within a slot formed in the hinge pin and having a bearing surface that engages and bears against a corresponding bearing surface of the slot to pull the first and second bodies towards one another.

16. The connector of claim 15, wherein the bearing surfaces of the keel and the slot lie in planes that are obliquely angled with respect to the rotation axis.

17. The connector of claim 13, wherein the saddle includes first and second keels defining a space therebetween in which a central rib of the hinge pin is received, the first and second keels having bearing surfaces that engage and bear against corresponding bearing surface of the hinge pin.

18. The connector of claim 1, wherein the hinge pin includes a rod seat formed therein, the rod seat being configured such that urging a rod against the rod seat causes the hinge pin to translate relative to at least one of the first and second bodies along the rotation axis.

19. The connector of claim 18, wherein the rod seat is positioned relative to the first rod-receiving recess such that a lateral sidewall of the rod seat interferes with a rod as the rod is seated in the first rod-receiving recess.

20. The connector of claim 18, wherein the rod seat is curved in multiple planes.

21. A connector, comprising:

a first body that defines a first rod-receiving recess;

a hinge pin formed integrally with the first body and extending laterally therefrom to a free end;

a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin is received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis;

a first fastener configured to secure a first rod within the first rod-receiving recess; and

a second fastener configured to secure a second rod within the second rod-receiving recess and to urge the first and second bodies towards one another along the rotation axis to lock relative rotation of the first and second bodies about the rotation axis.

22. The connector of claim 21, wherein the second fastener is configured to bear against a saddle disposed within the second rod-receiving recess to urge a bearing surface of the saddle against a bearing surface of the hinge pin to move the first and second bodies towards one another.

23. The connector of claim 21, wherein the second fastener is configured to bear against a rod disposed within the second rod-receiving recess to urge the rod against a rod seat of the hinge pin to move the first and second bodies towards one another.

24. A surgical method, comprising:

inserting a first rod into a first rod-receiving recess of a first body of a connector;

inserting a second rod into a second rod-receiving recess of a second body of the connector, the second body being coupled to the first body by a hinge pin;

rotating the first body relative to the second body about a rotation axis defined by the hinge pin;

moving a fastener with respect to at least one of the first and second bodies to urge the first and second bodies towards one another along the rotation axis and thereby lock relative rotation of the first and second bodies about the rotation axis; and

securing the first and second rods to an anatomy of a patient.

25. The method of claim 24, wherein the first rod is secured to a cervical spine of the patient by one or more bone anchors and the second rod is secured to a thoracic spine of the patient by one or more bone anchors.

26. The method of claim 24, wherein rotating the first body relative to the second body causes the first and second rods to be obliquely angled with respect to one another.

27. The method of claim 24, wherein moving the fastener is effective both to secure one of the first and second rods to the connector and to lock rotation of the connector.

28. A connector, comprising:

a first body that defines a first rod-receiving recess;

a hinge pin extending laterally from the first body to a free end;

a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin is received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin;

a first fastener configured to secure a first rod within the first rod-receiving recess; and

a second fastener configured to secure a second rod within the second rod-receiving recess, and

wherein the hinge pin has a plurality of planar surfaces that intersect to form one or more corners, the one or more corners of the hinge pin applying a force against the cavity of the second body that locks the hinge pin in place when the second fastener secures the second rod within the second rod-receiving recess.

29. The connector of claim 28 wherein a cross section of the hinge pin has a polygonal profile.

30. The connector of claim 28 further comprising a saddle disposed within the second rod-receiving recess, the saddle including a saddle protrusion extending distally therefrom, the saddle protrusion being received within a slot formed in the hinge pin.

31. The connector of claim 30, wherein the force applied by the one or more corners of the hinge pin is transferred from a force applied by the second fastener through the saddle.

32 The connector of claim 30, wherein the saddle protrusion limits a rotation of the hinge pin within the cavity of the second body when a terminal end of the slot of the hinge pin engages and bears against the saddle protrusion.

33. The connector of claim 30, wherein the saddle has a bearing surface adjacent to the saddle protrusion that engages and bears against a corresponding bearing surface of the hinge pin adjacent to the slot.

34. The connector of claim 30, wherein the slot of the hinge pin is formed radially about a central rib of the hinge pin, the saddle protrusion of the saddle defining a depression in which the central rib of the hinge pin is received.

35. A connector, comprising:

a first body that defines a first rod-receiving recess;

a hinge pin extending laterally from the first body to a free end;

a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin is received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin;

a saddle defining a rod seat disposed within the second rod-receiving recess, the saddle including a saddle protrusion extending distally therefrom, the saddle protrusion being received within a slot formed in the hinge pin;

a first fastener configured to secure a first rod within the first rod-receiving recess;

a second fastener configured to secure a second rod on the rod seat of the saddle, and

wherein the slot of the hinge pin has an angled cam surface that engages and bears against a corresponding angled bearing surface of the saddle protrusion to lock the hinge pin in place when the second fastener secures the second rod within the second rod-receiving recess.

36. The connector of claim 35, wherein the angled cam surface of the slot is oriented at an oblique angle with respect to the longitudinal axis of the hinge pin.

37. The connector of claim 36 wherein the angled bearing surface of the saddle protrusion is oriented at an oblique angle with respect to the longitudinal axis of the hinge pin.

38. The connector of claim 37, wherein the angled bearing surface of the saddle protrusion is oriented to match the oblique angle of the angled cam surface of the slot in the hinge pin.

39. The connector of claim 35 wherein the saddle protrusion has a wedge-shaped cross section that applies a force against the angled cam surface of the slot of the hinge pin to lock the

hinge pin in place when the second fastener secures the second rod within the second rod-receiving recess.

40. A connector, comprising:

a first body that defines a first rod-receiving recess;

a hinge pin extending laterally from the first body to a free end;

a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin is received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin;

a first fastener configured to secure a first rod within the first rod-receiving recess; and

a second fastener configured to secure a second rod within the second rod-receiving recess, and

wherein the free end of the hinge pin extends through the cavity and into an opening defined in the second body, the opening having a cross sectional shape that limits rotation of the free end of the hinge pin relative to the second body about the rotation axis.

41. The connector of claim 40, wherein the free end of the hinge pin has a cross sectional shape configured to rotate within the opening of the second body, wherein the cross sectional shape of the free end of the hinge pin and the cross sectional shape of the opening define a degree of rotation of the free end of the hinge pin.

42. The connector of claim 41, wherein the cross sectional shape of the opening of the second body and the cross sectional shape of the free end of the hinge pin are D-shaped, wherein the D-shaped cross section of the opening of the second body has an area greater than an area of the D-shaped cross section of the free end of the hinge pin.

43. The connector of claim 40, wherein the second fastener is configured to bear against a saddle disposed within the second rod-receiving recess to urge a bearing surface of the saddle against a corresponding bearing surface of the hinge pin.

44. The connector of claim 43, wherein the saddle includes a saddle protrusion extending distally from an edge of the saddle adjacent to the bearing surface of the saddle, the saddle protrusion being received within a slot formed in the hinge pin adjacent to the bearing surface of the hinge pin.

45. The connector of claim 43, wherein the slot of the hinge pin is aligned with an edge of the second rod-receiving recess when the free end of the hinge pin is inserted into the through hole opening of the second body.

46. The connector of claim 45, wherein the bearing surface of the hinge pin bears against the bearing surface of the saddle for a continuous length that is greater than half the width of the second rod-receiving recess.

47. A connector, comprising:

a first body that defines a first rod-receiving recess;

a hinge pin extending laterally from the first body to a free end;

a second body that defines a second rod-receiving recess, the second body having a cavity in which the free end of the hinge pin is received to couple the second body to the first body such that the first and second bodies rotate relative to one another about a rotation axis of the hinge pin;

a saddle defining a rod seat disposed within the second rod-receiving recess, the saddle including a saddle protrusion extending distally therefrom, the saddle protrusion being received within a slot formed in the hinge pin;

a first fastener configured to secure a first rod within the first rod-receiving recess; and

a second fastener configured to secure a second rod on the rod seat of the saddle, and

wherein the slot of the hinge pin is aligned with an edge of the second rod-receiving recess when the free end of the hinge pin is inserted into the cavity of the second body.

48. The connector of claim 47, wherein the saddle protrusion extends distally from an edge of the saddle adjacent to a bearing surface of the saddle, the saddle protrusion being received within the slot of the hinge pin.

49. The connector of claim 48, wherein the bearing surface of the saddle bears against a bearing surface of the hinge pin for a continuous length that is greater than half the width of the second rod-receiving recess.

50. A surgical method, comprising:

inserting a first rod into a first rod-receiving recess of a first body of a connector, wherein the first body includes a hinge pin that extends laterally therefrom to a free end;

inserting a second rod onto a rod seat formed in a saddle disposed in a second rod-receiving recess of a second body of the connector, wherein the hinge pin of the first body is inserted into a cavity formed in the second body and thereby coupling the first body of the connector to the second body of the connector;

rotating the first body relative to the second body about a rotation axis defined by the hinge pin, such that a slot formed in the hinge pin rotates about a saddle protrusion extending distally from the saddle;

moving a fastener with respect to the second body to secure the second rod within the second rod-receiving recess and thereby lock relative rotation of the first and second bodies about the rotation axis; and

securing the first and second rods to an anatomy of a patient.

51. The surgical method of claim 50, wherein moving the fastener with respect to the second body urges a bearing surface of the saddle against a corresponding bearing surface of the hinge pin and thereby causes one or more corners of the hinge pin to apply a force against the cavity of the second body.

52. The surgical method of claim 50, wherein rotating the first body relative to the second body about a rotation axis defined by the hinge pin comprises rotating the first body with respect to the second body such that the saddle protrusion limits a rotation of the hinge pin when a terminal end of the slot of the hinge pin engages and bears against the saddle protrusion.

53. The surgical method of claim 50, wherein the slot of the hinge pin has an angled cam surface and the saddle protrusion has a corresponding angled bearing surface, and wherein moving the fastener with respect to the second body wedges the angled bearing surface of the saddle protrusion into the angled cam surface of the slot.

54. The surgical method of claim 50, wherein rotating the first body relative to the second body about a rotation axis defined by the hinge pin comprises rotating the first body such that the free end of the hinge pin rotates within an opening defined in the second body of the connector, the opening having a cross sectional shape that limits rotation of the free end of the hinge pin.

55. The surgical method of claim 50, wherein rotating the first body relative to the second body about a rotation axis defined by the hinge pin comprises rotating the first body such that the slot of the hinge pin rotates about the saddle protrusion that extends distally from an edge of the saddle and is aligned with an edge of the second rod-receiving recess.

56. The surgical method of claim 55, wherein moving the fastener with respect to the second body urges a bearing surface of the saddle against a corresponding bearing surface of the hinge pin for a continuous length that is greater than half the width of the second rod-receiving recess.

FIG. 1A

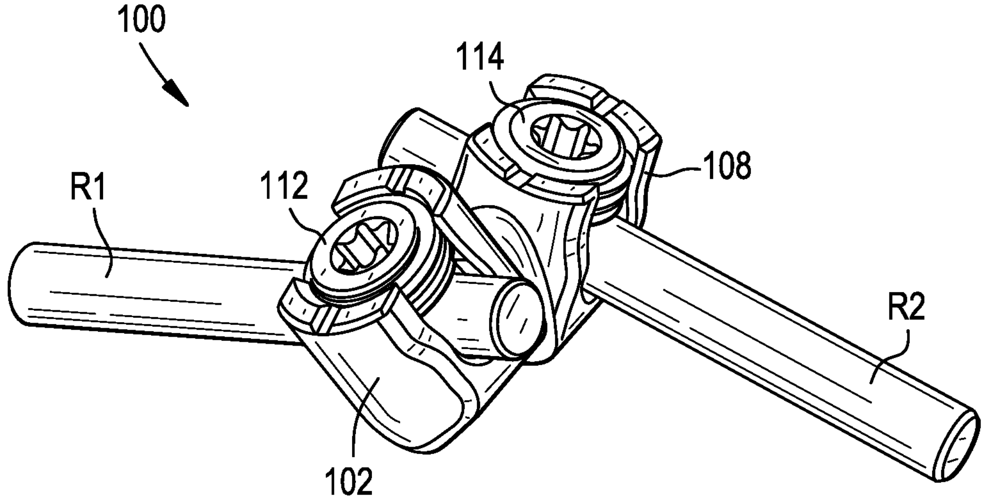
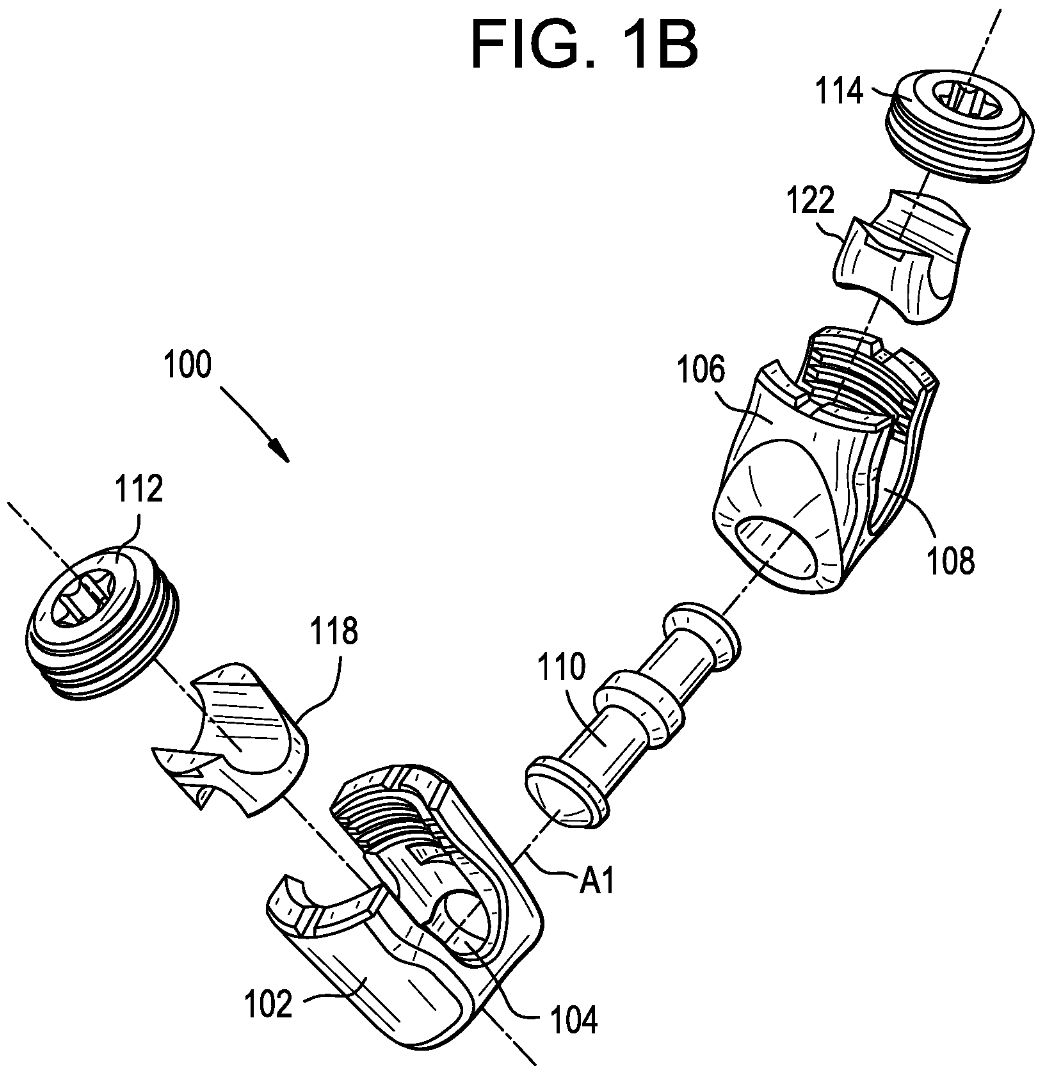

100
114
108
R1
112
R2
102

FIG. 1B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122
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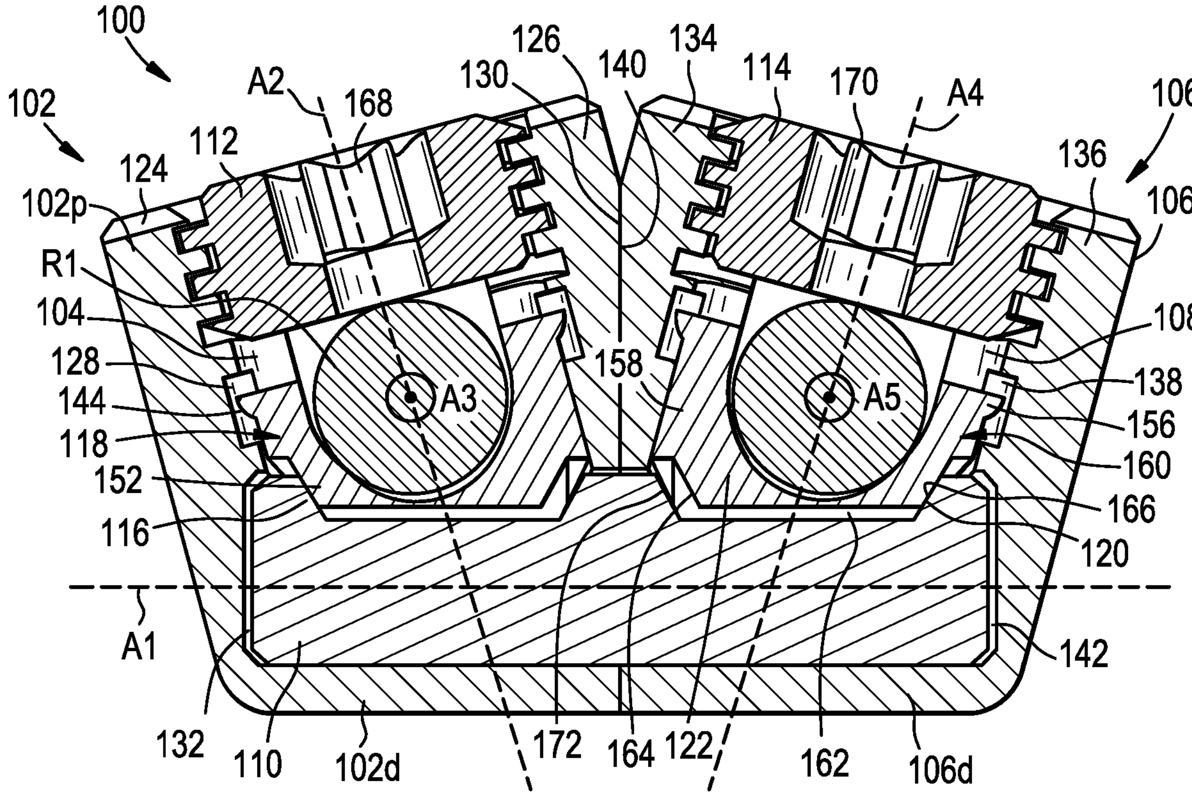
110
A1
102
104

FIG. 1C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102
A2
168
130
126
140
134
114
170
A4
106
112
124
136
102p
106p
R1
104
108
128
158
138
144
A3
A5
156
118
160
152
166
116
120
A1
142
132
110
102d
172
164
122
162
106d

FIG. 1D

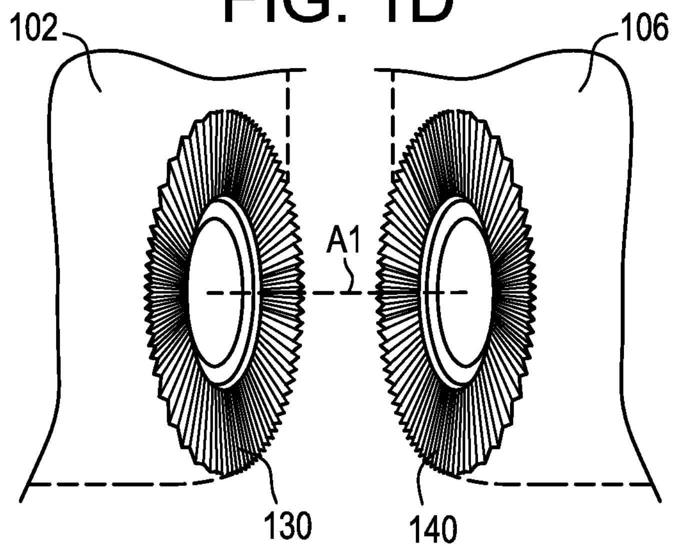

102
106
A1
130
140

FIG.1E

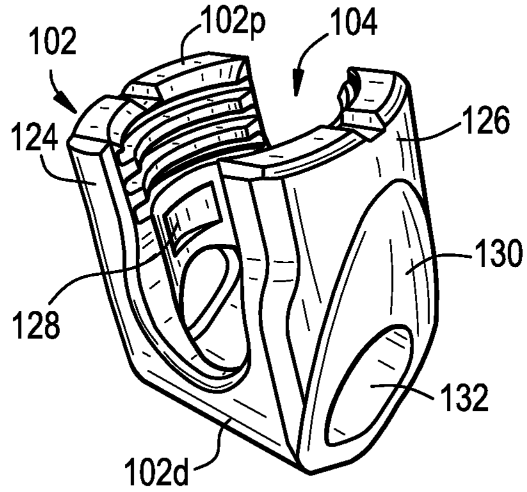


FIG.1F

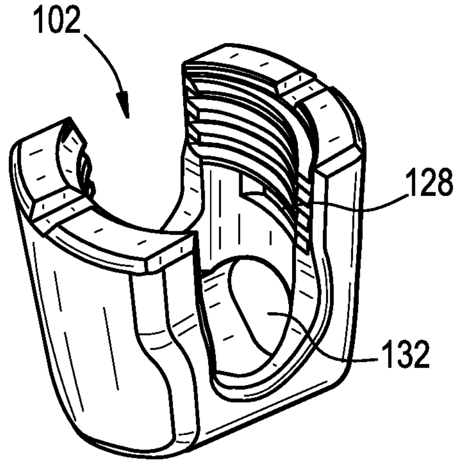


FIG.1G

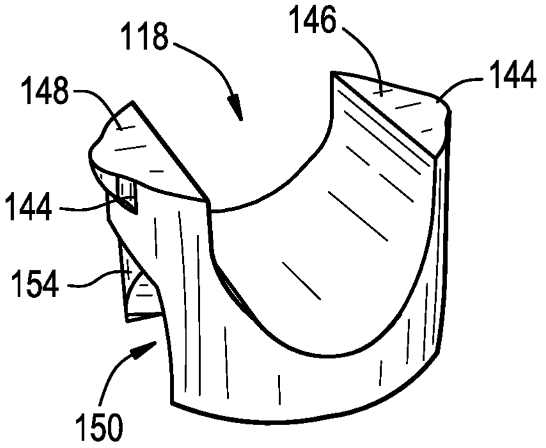


FIG.1H

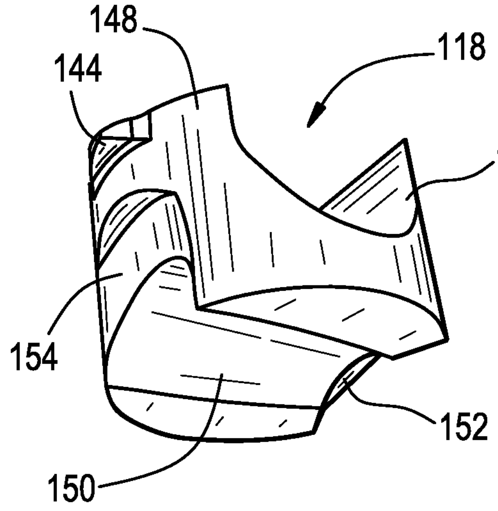


FIG. 1I

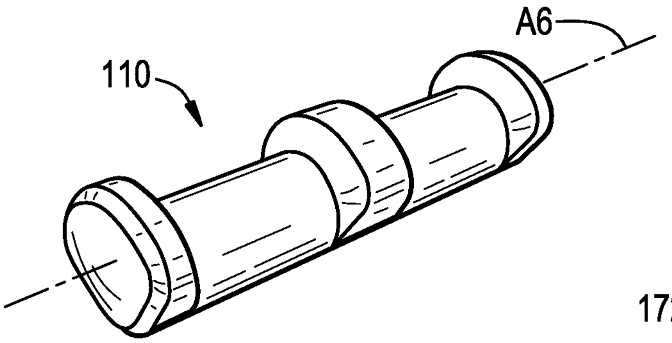


FIG. 1J

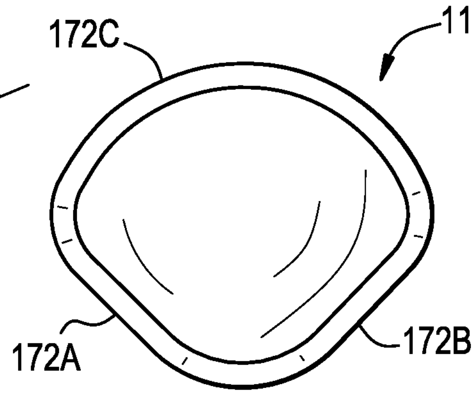


FIG. 1K

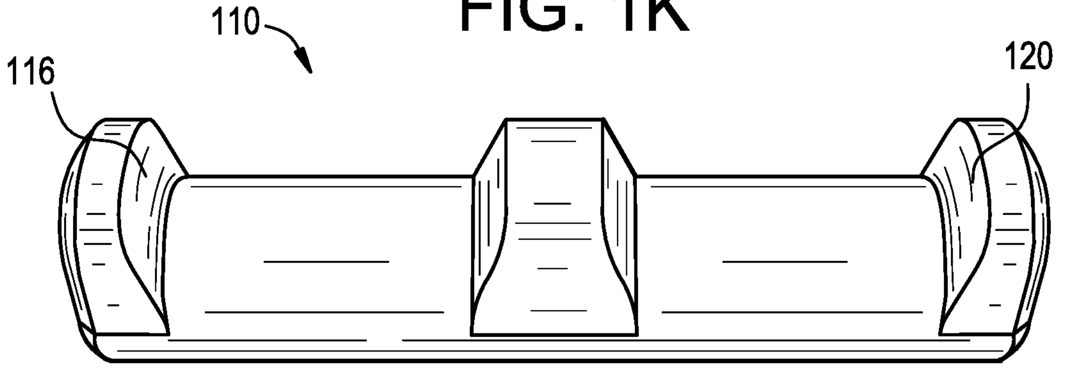


FIG. 1L

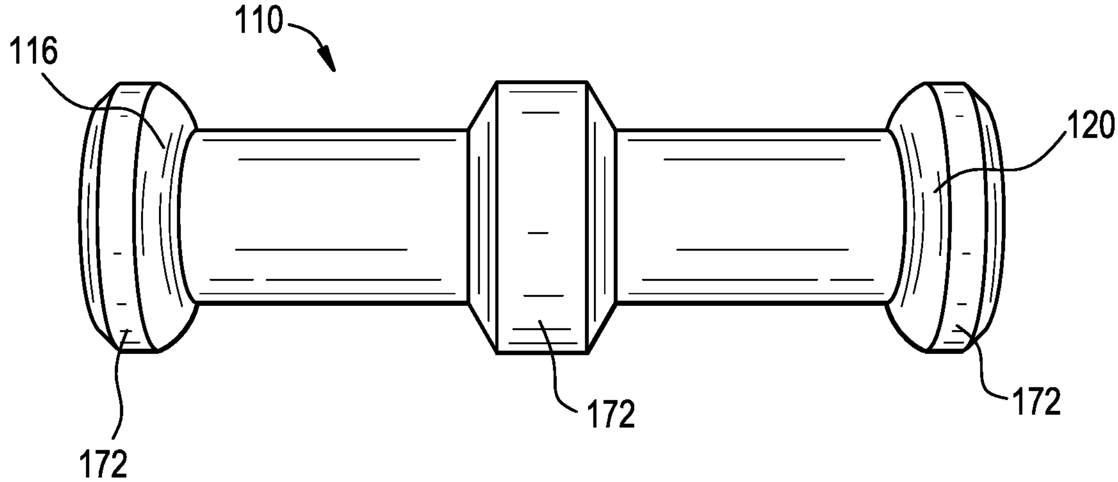
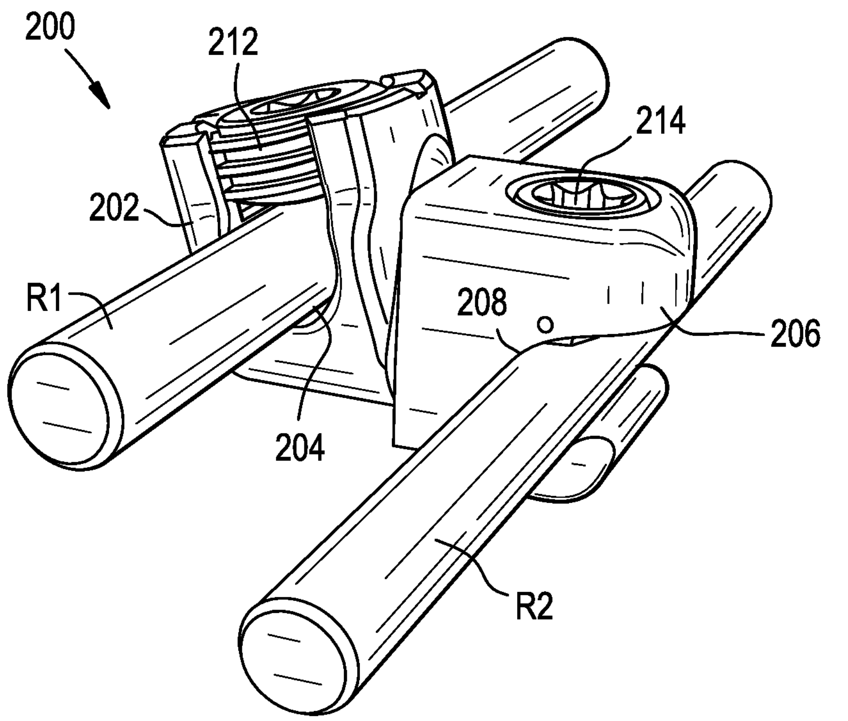
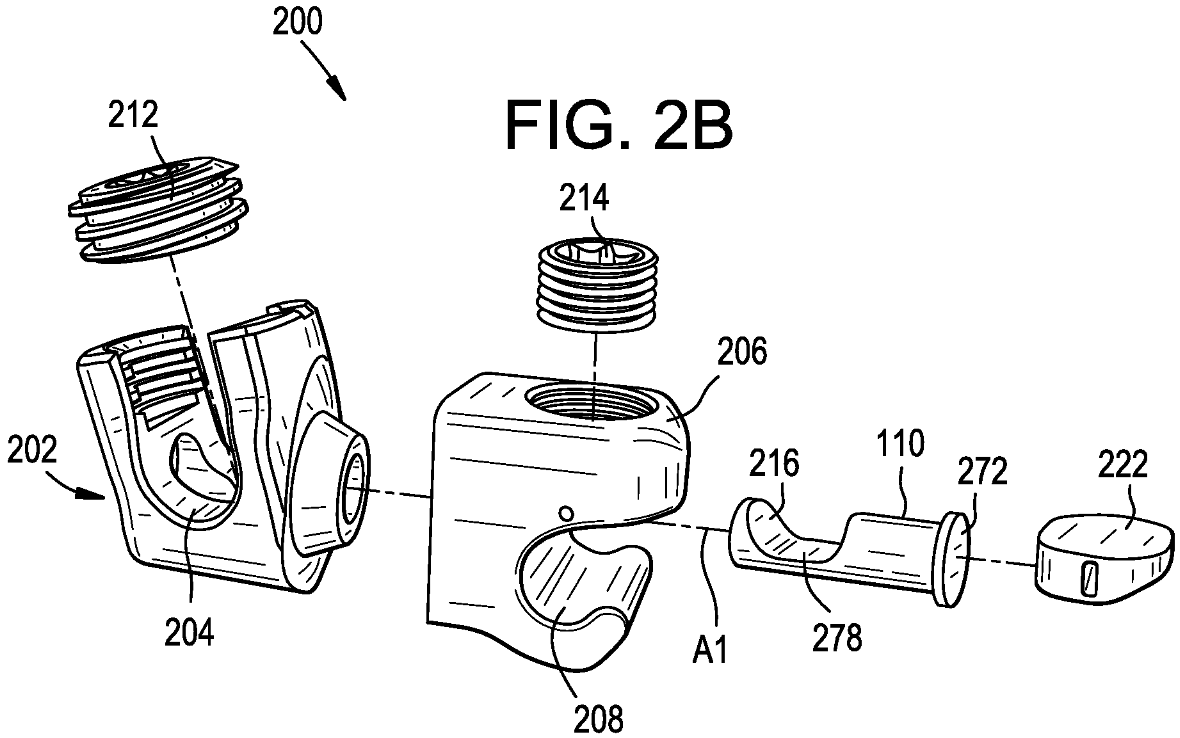


FIG. 2A


200
212
214
202
R1
208
206
204
R2


200
212
214
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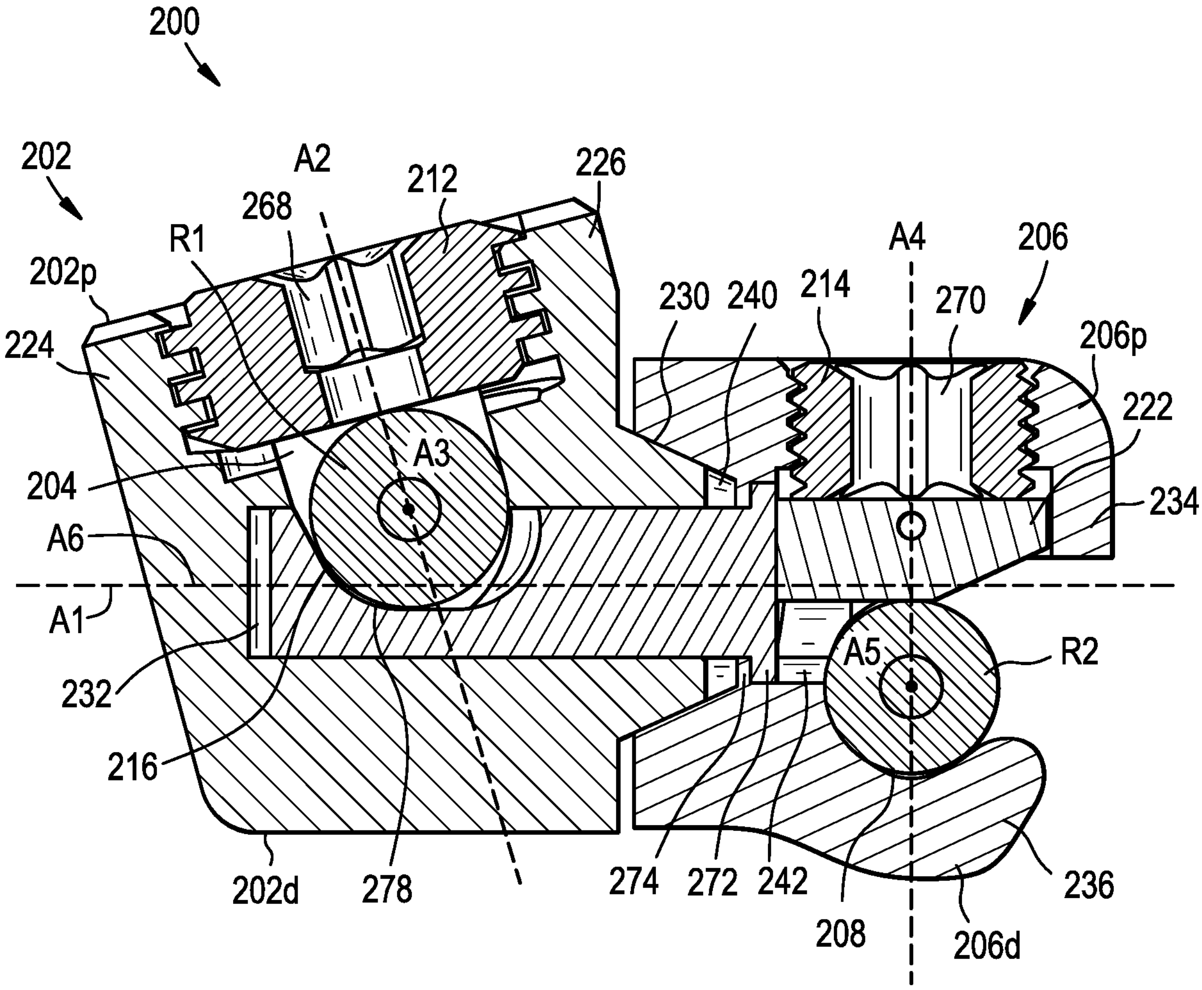
216
110
272
222
204
A1
278
208

FIG. 2B

FIG. 2C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202
A2
212
226
268
R1
202p
224
A4
206
230
240
214
270
206p
222
A3
204
234
A6
A1
A5
R2
232
216
202d
278
274
272
242
208
236
206d

FIG. 2D

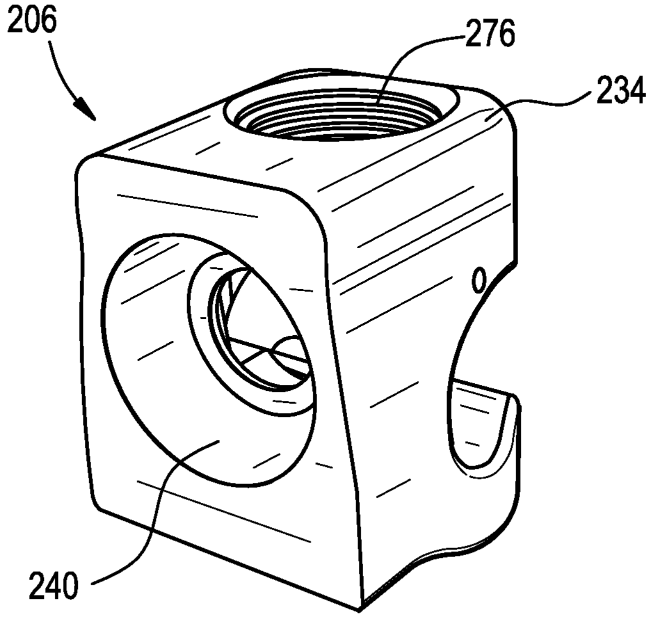


FIG. 2E

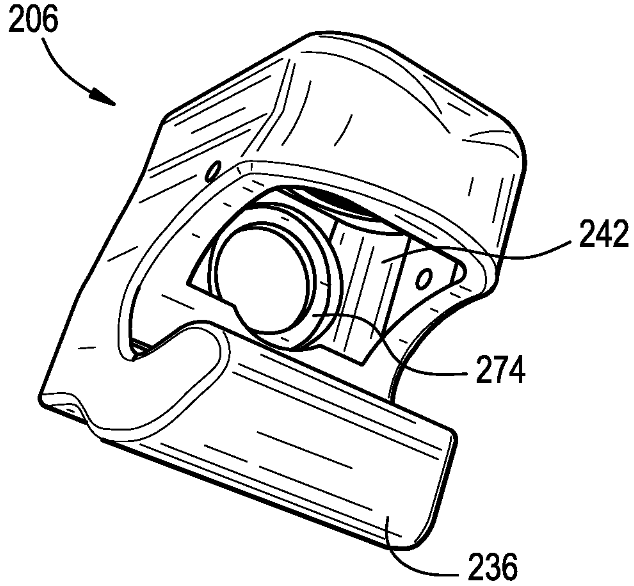


FIG. 3A

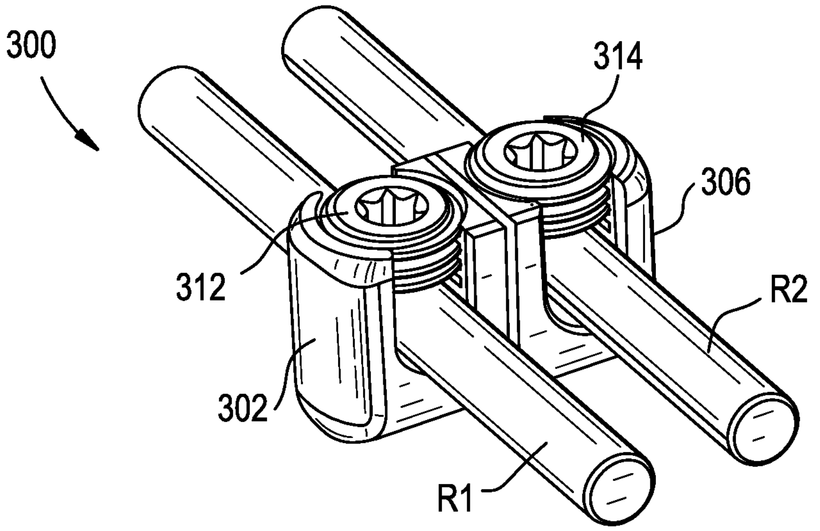
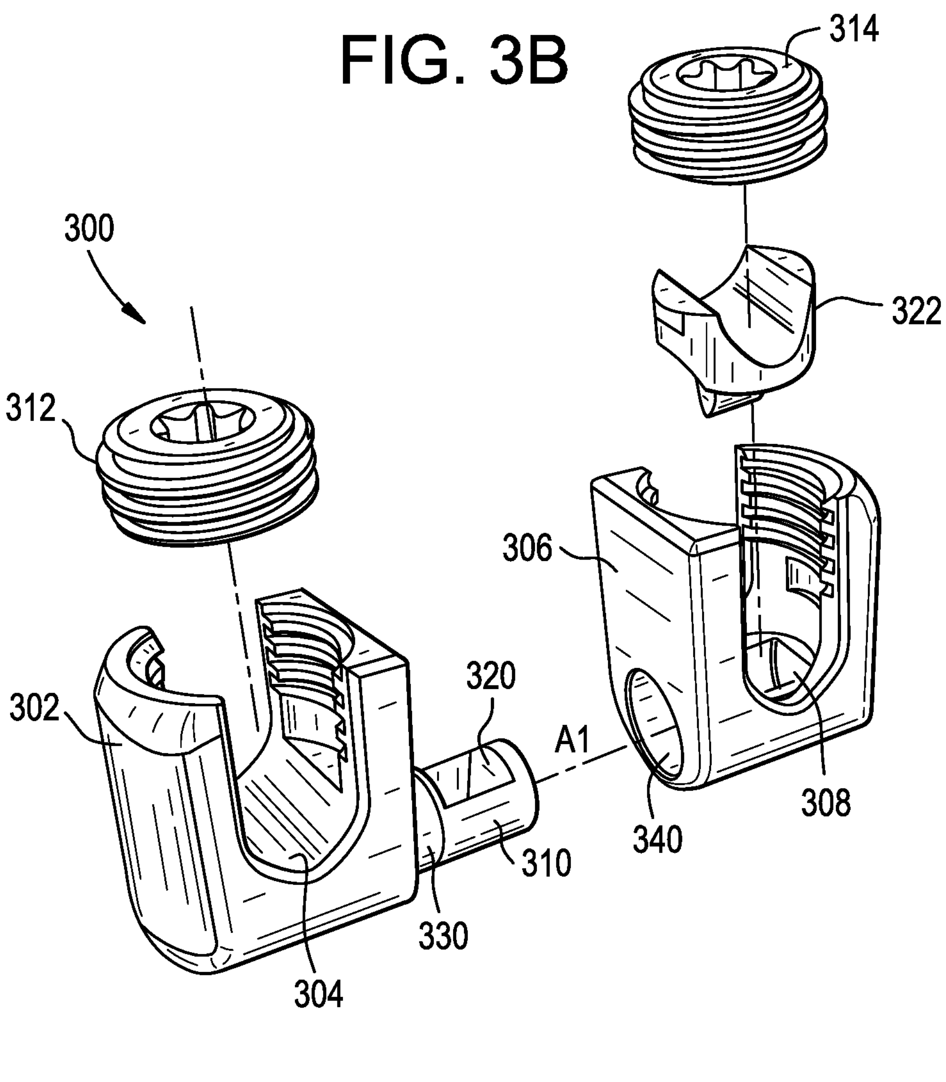

300
314
306
312
R2
302
R1

FIG. 3B


314
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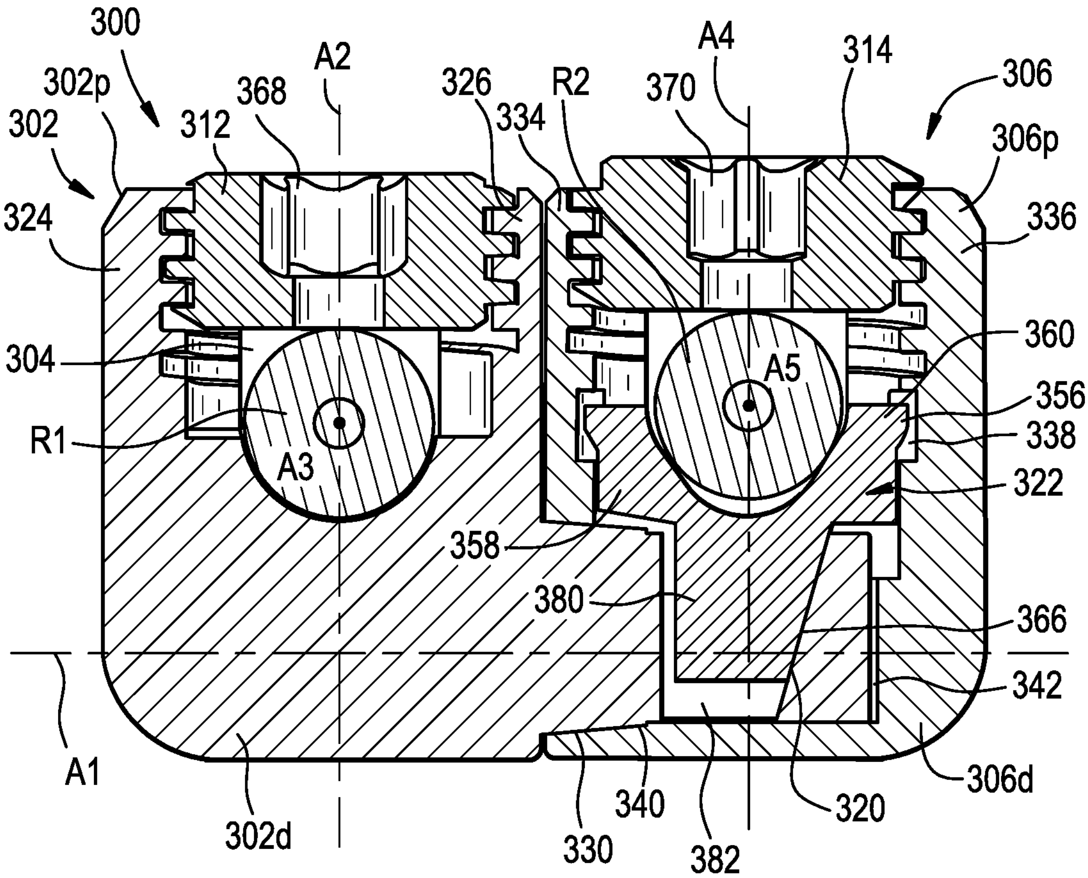
306
320
302
A1
308
340
310
330
304

FIG. 3C


300
302p
302
324
312
368
A2
326
334
R2
370
A4
314
306
306p
336
304
R1
A3
A5
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338
322
358
380
366
342
A1
302d
330
340
382
320
306d

FIG. 3D

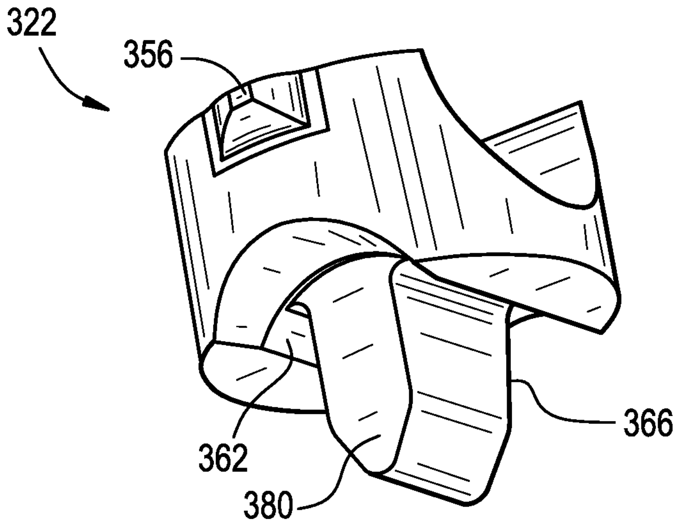


FIG. 3E

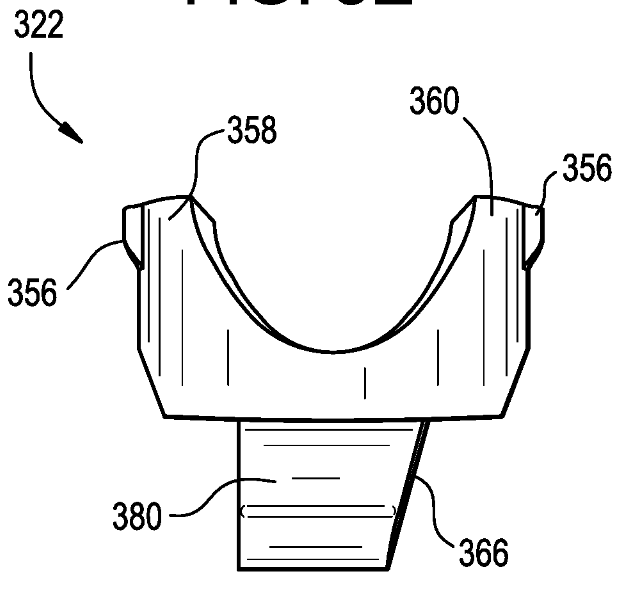


FIG. 3F

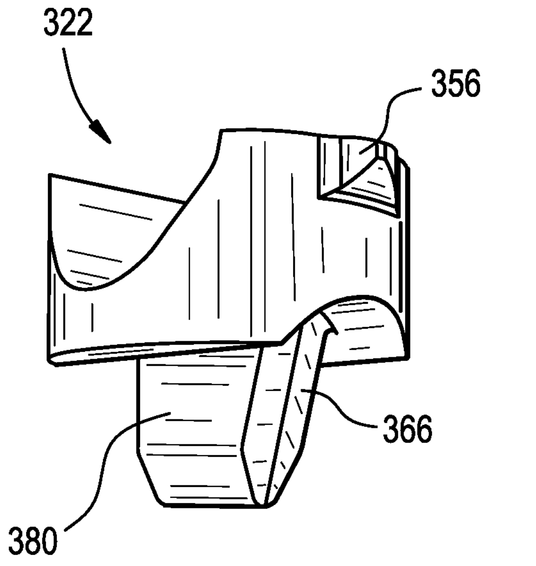


FIG. 3G

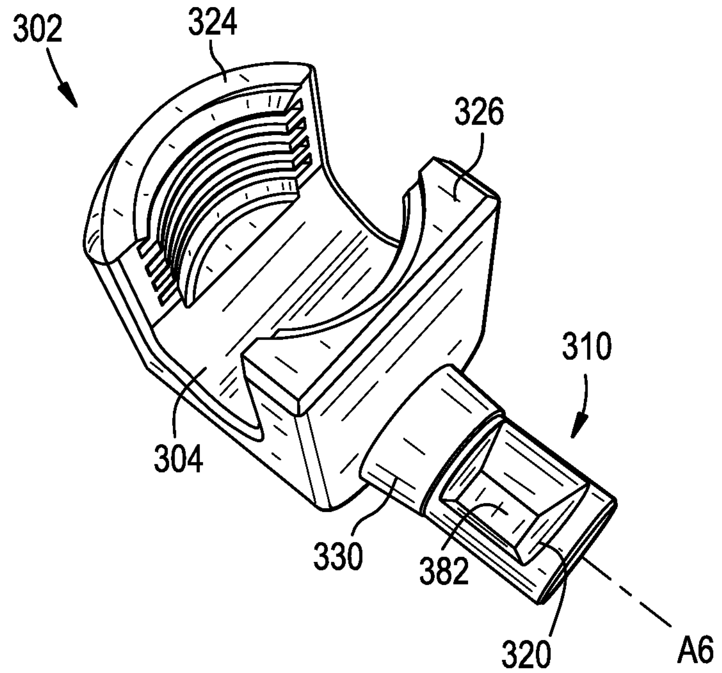


FIG. 3H

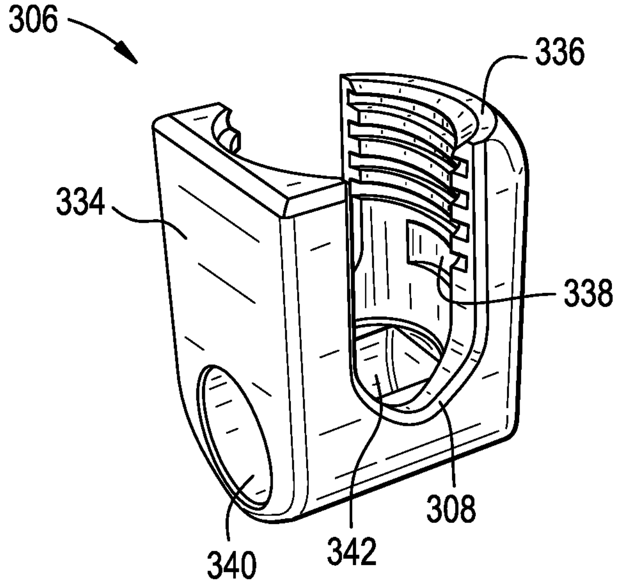


FIG. 3I

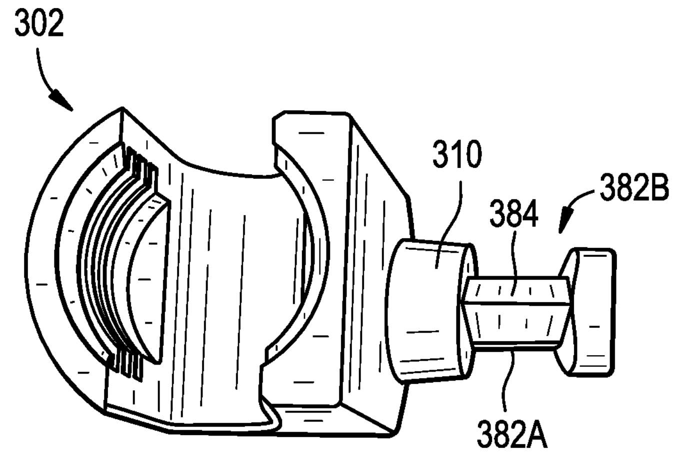


FIG. 3J

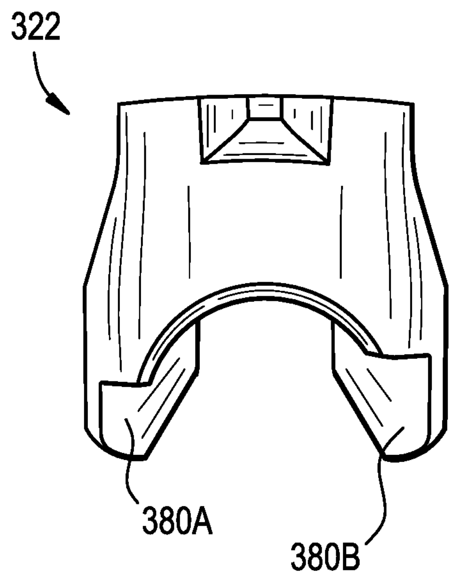


FIG. 3K

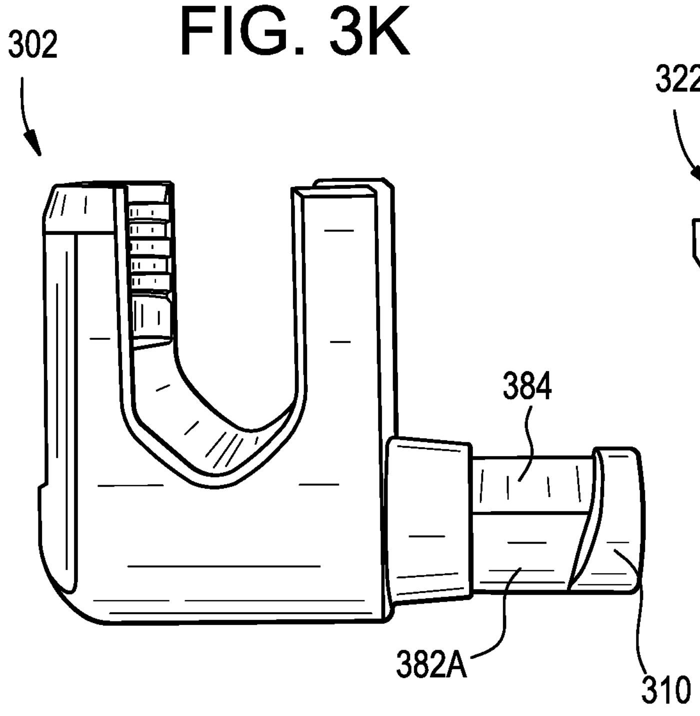


FIG. 3L

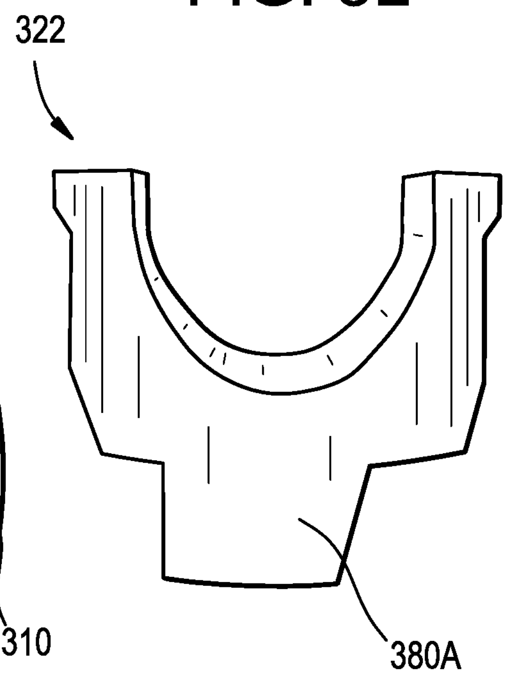


FIG. 4A

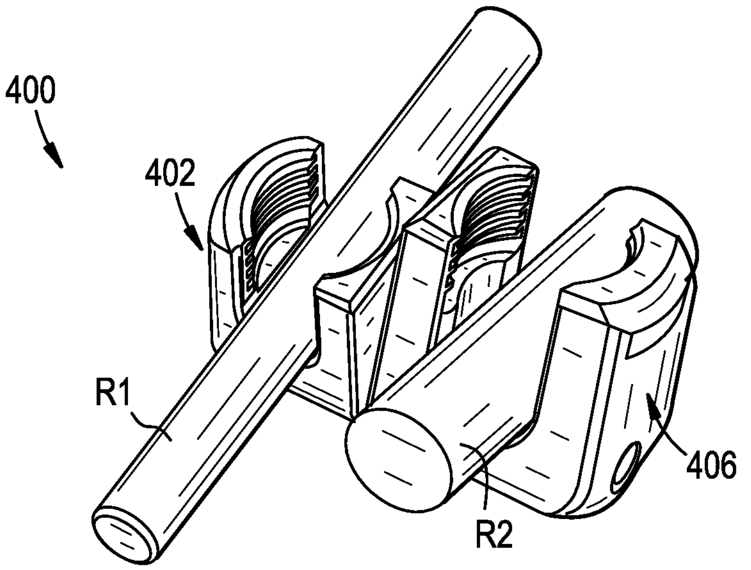

400
402
R1
R2
406

FIG. 4B

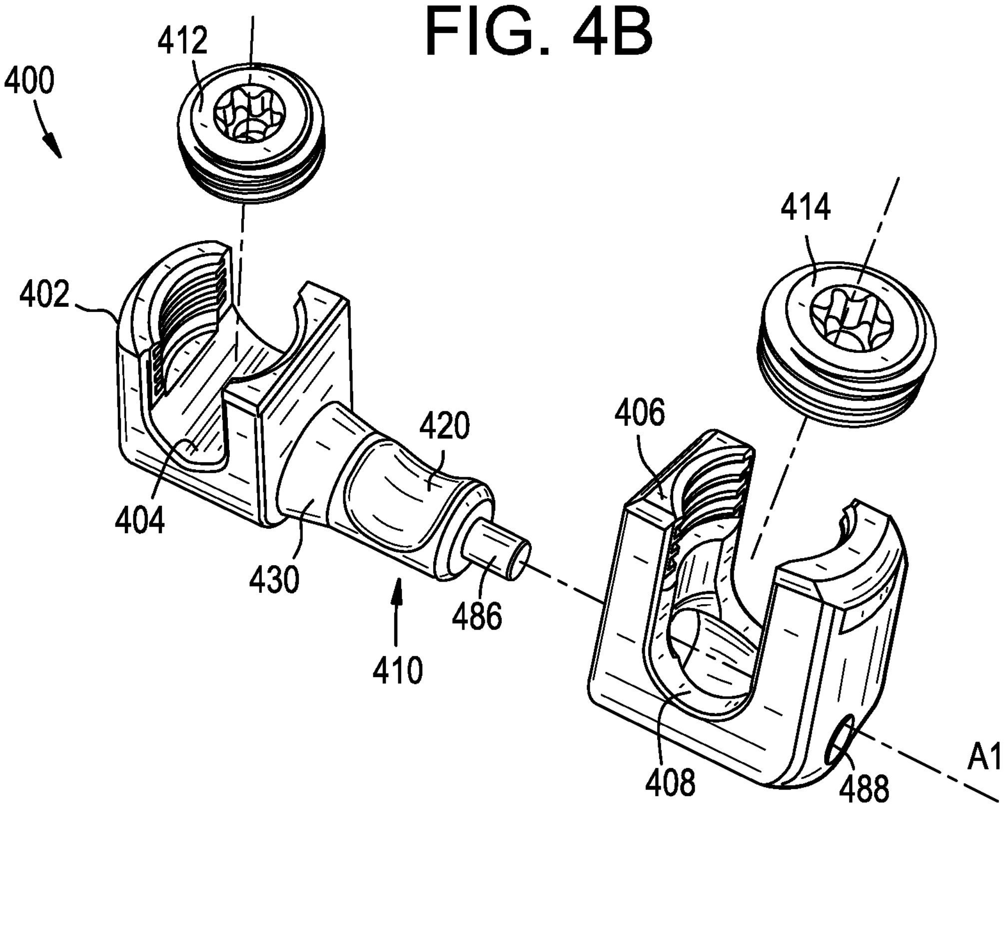
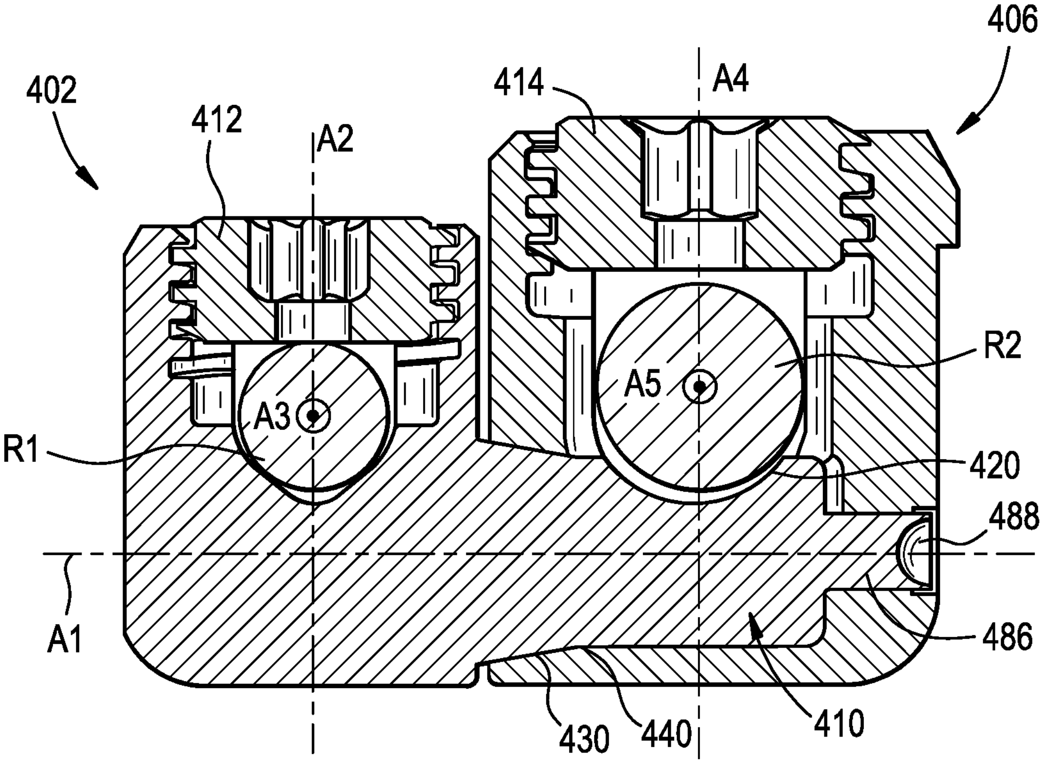

412
400
402
404
430
420
410
486
414
406
408
488
A1

FIG. 4C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A4
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R2
A5
A3
R1
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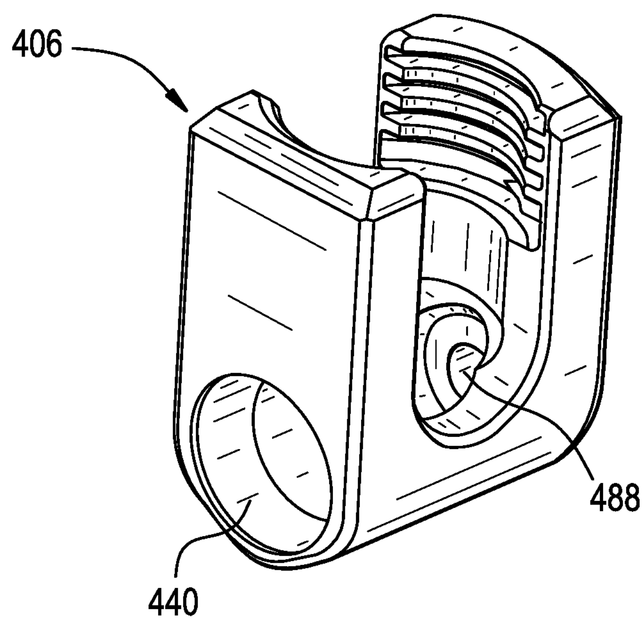
488
A1
486
430
440
410

FIG. 4D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440

FIG. 4E

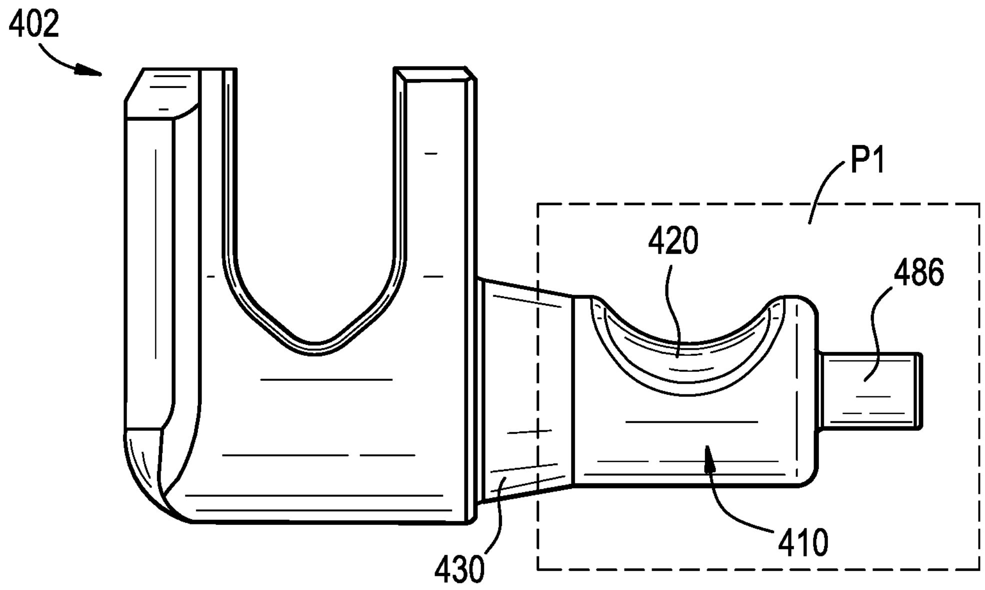


FIG. 4F

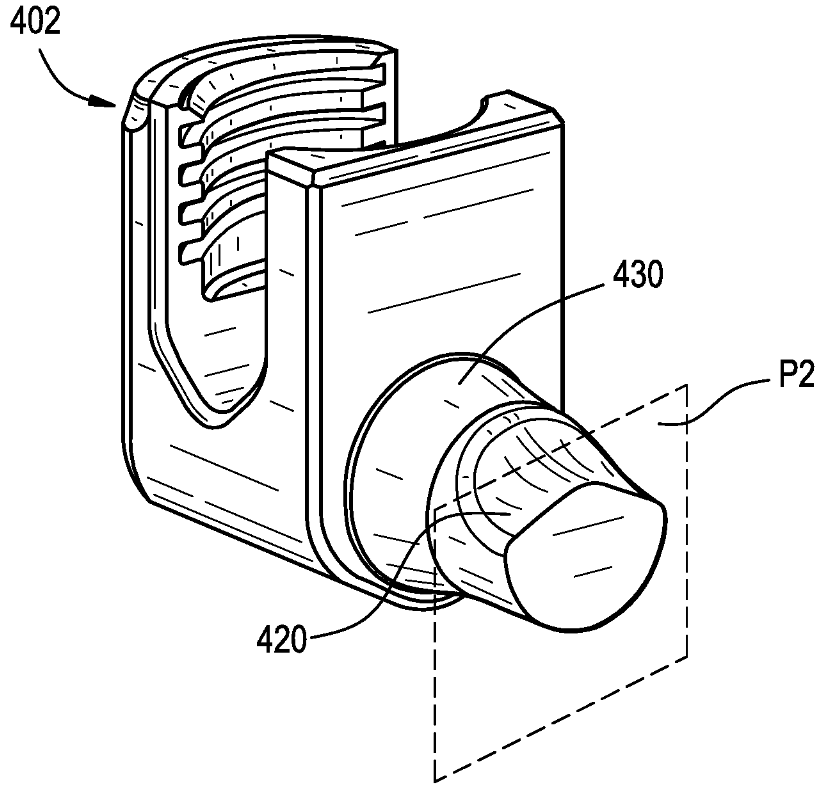


FIG. 5A

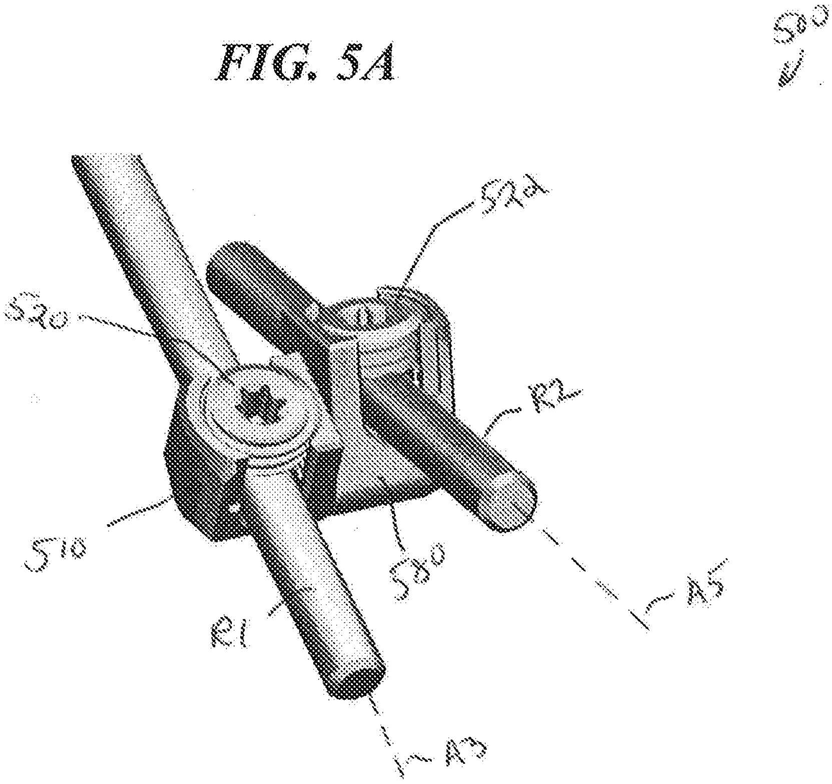

500
522
520
R2
510
580
A5
R1
A3

FIG. 5B

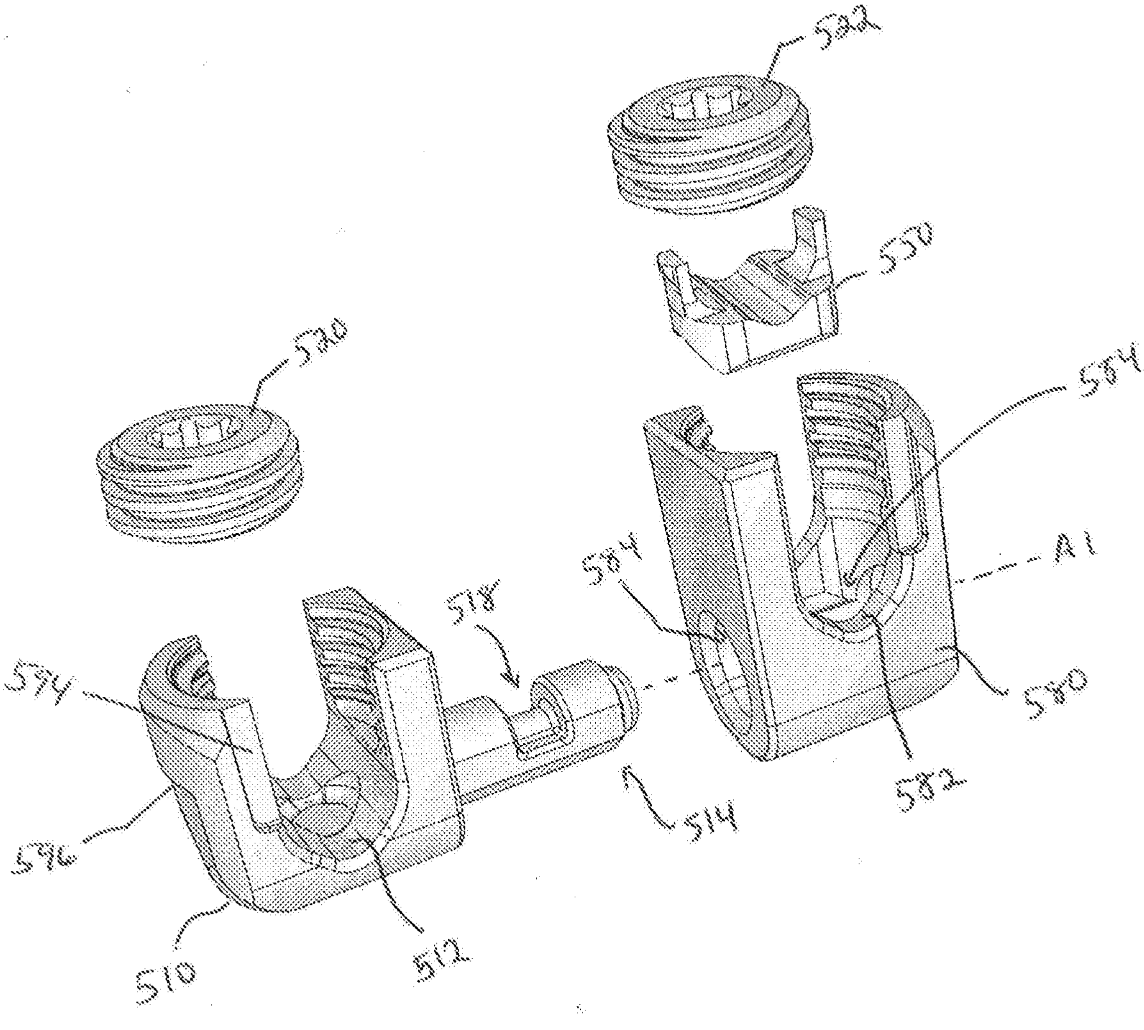

522
550
520
584
518
584
A1
594
580
582
514
596
510
512

FIG. 5C

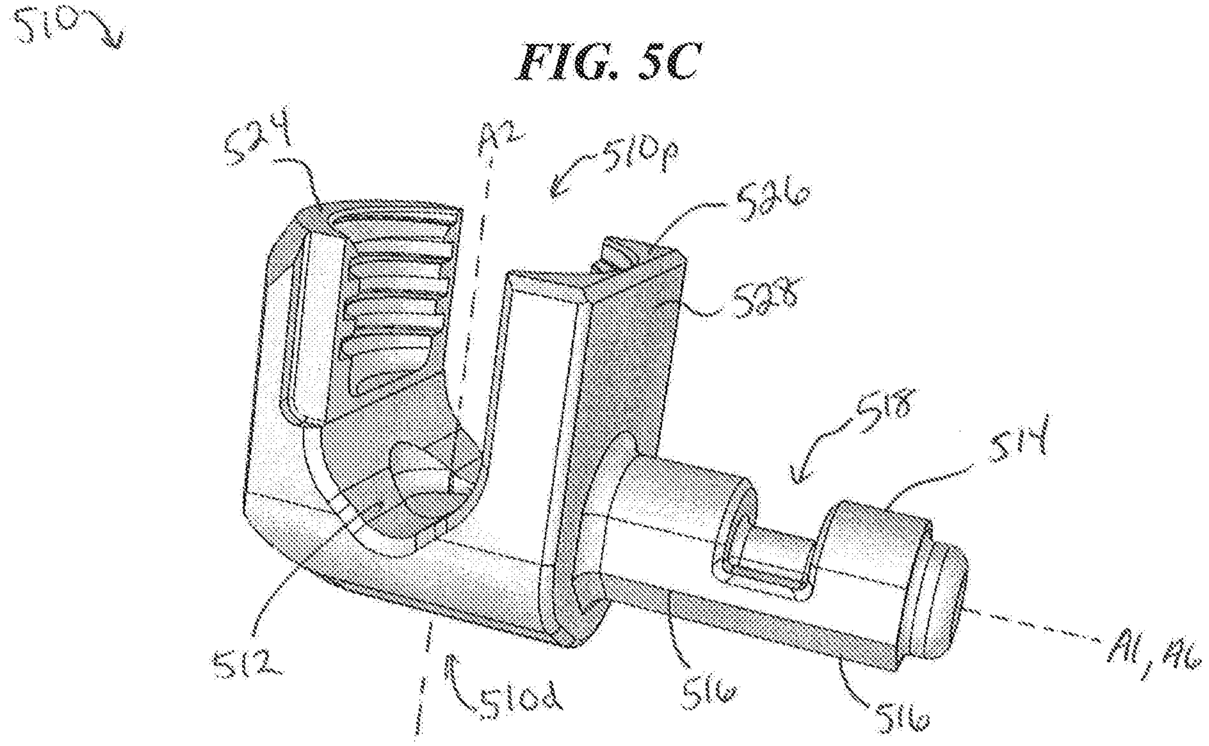


FIG. 5D

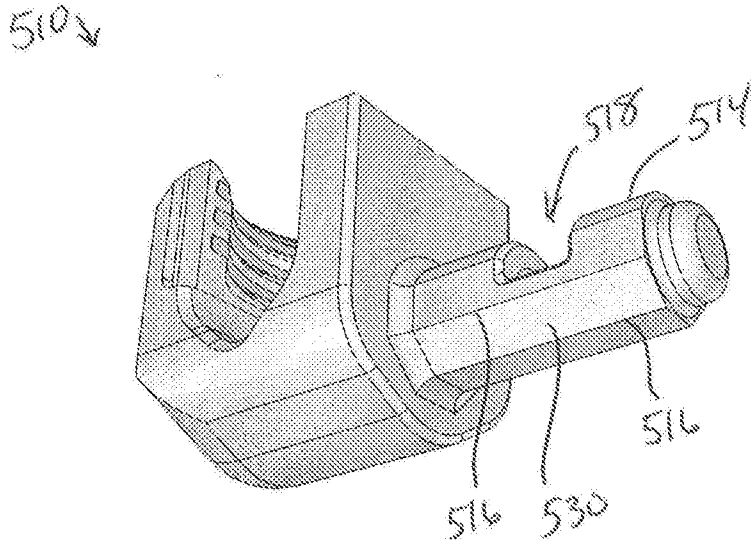


FIG. 5E

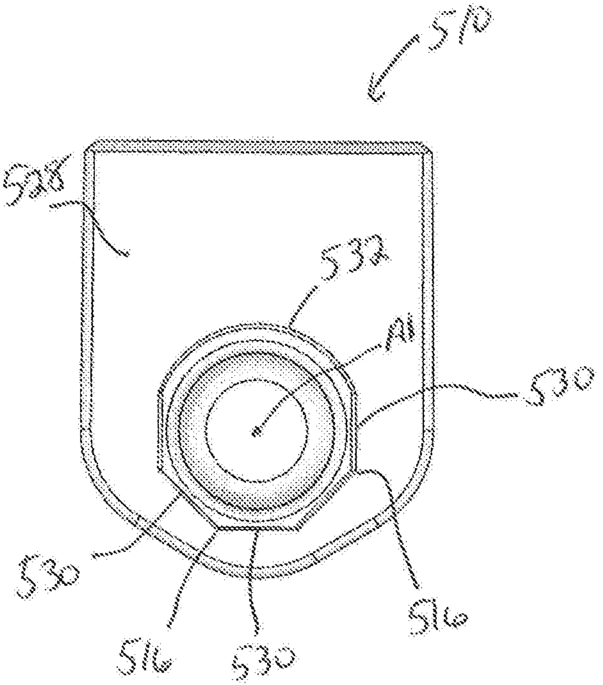


FIG. 5F

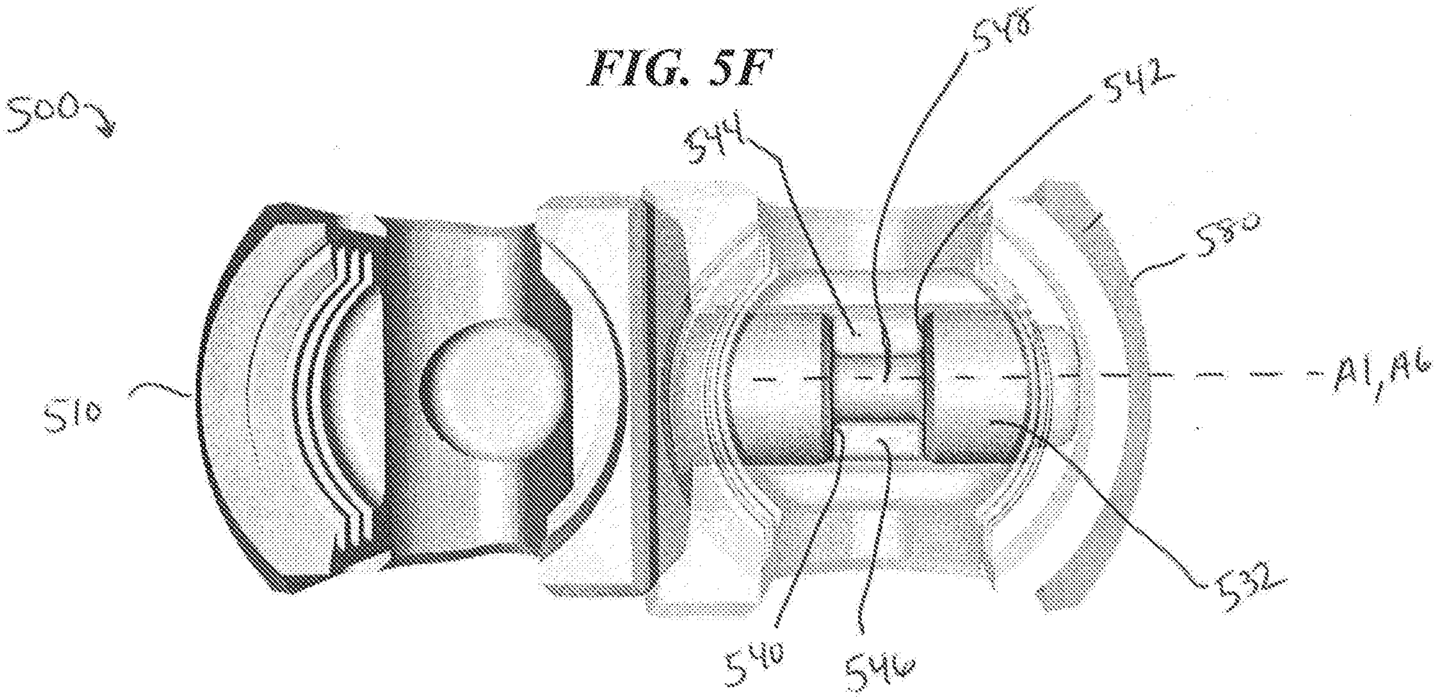


FIG. 5G

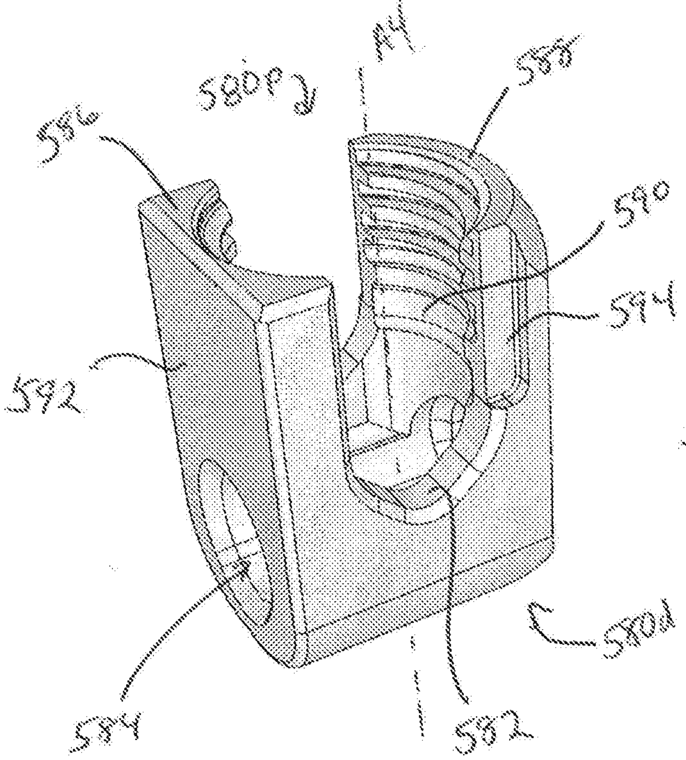


FIG. 5H

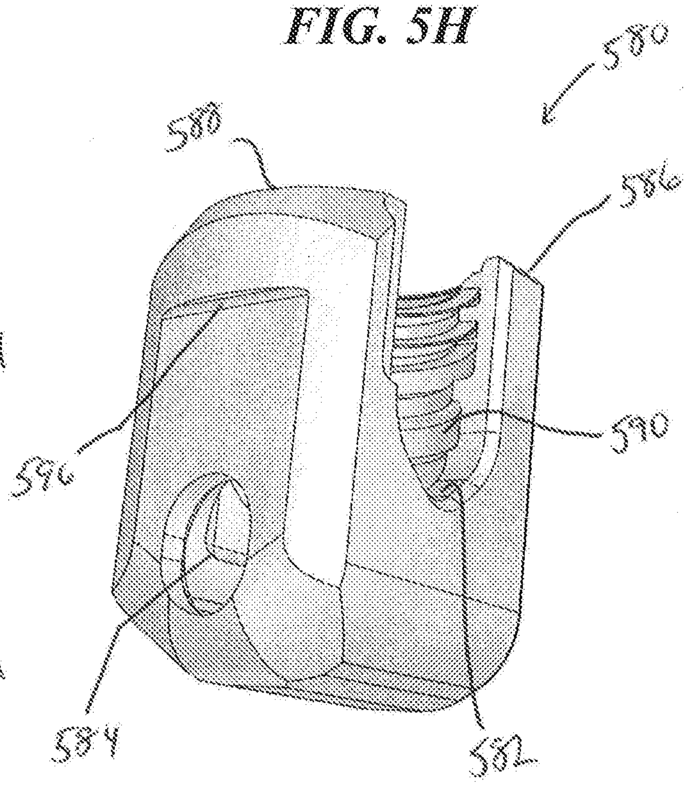


FIG. 5I

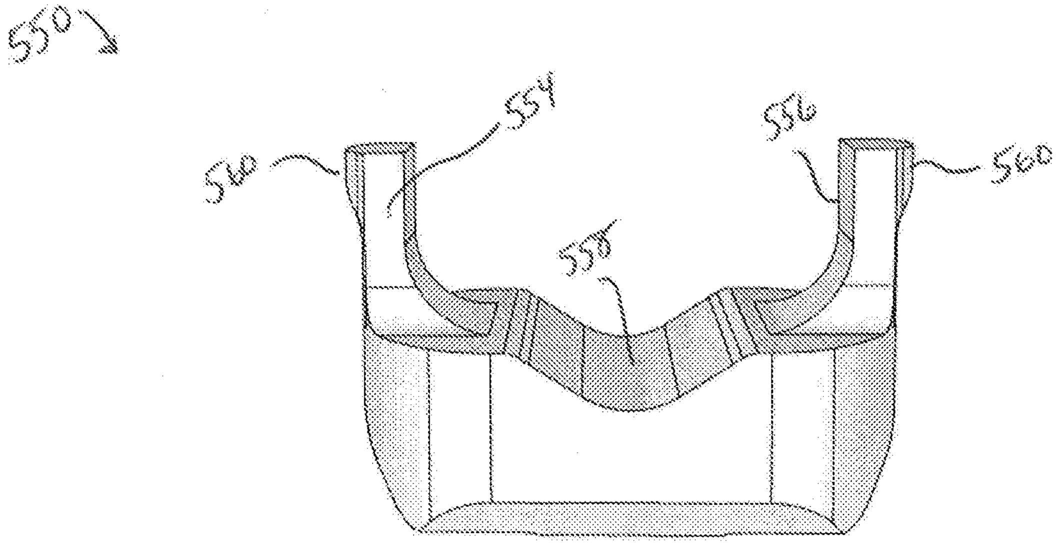
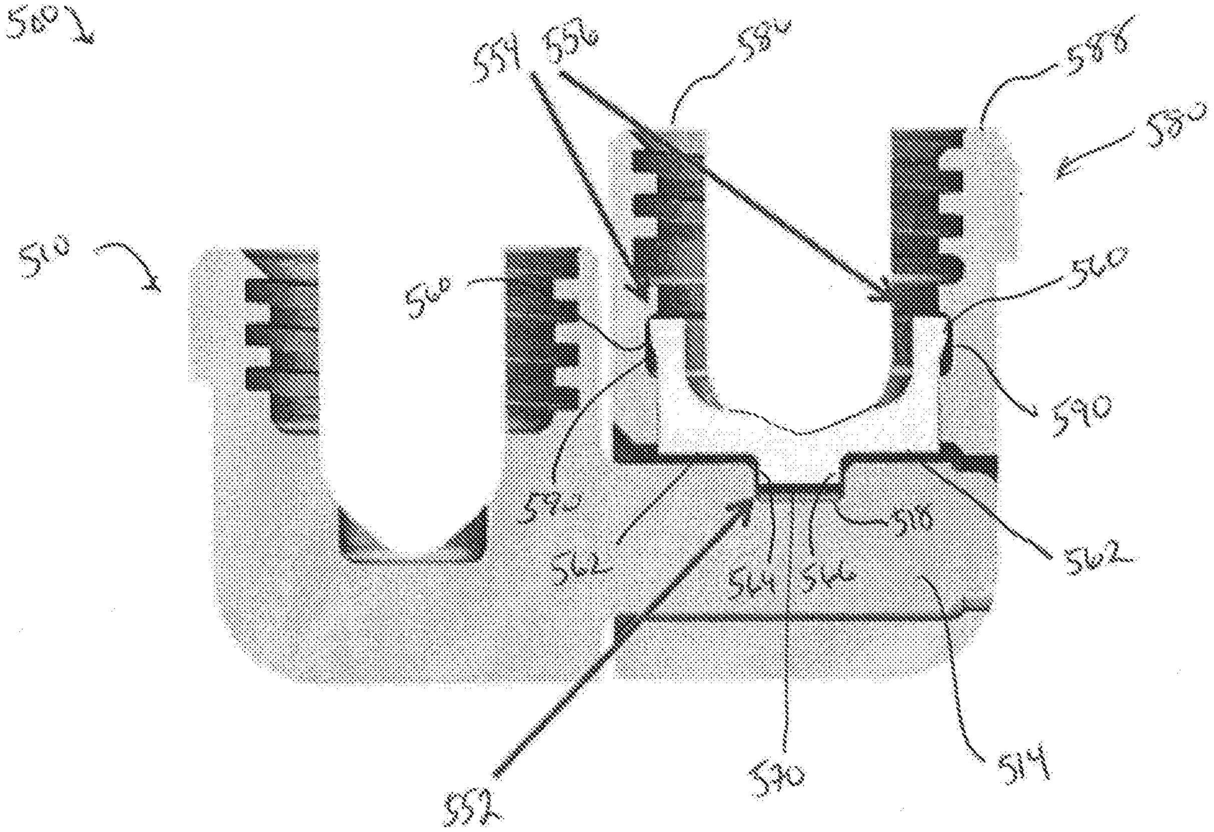

550
554
556
560
560
558

FIG. 5J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554 556
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510
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560
590
592
518
562
562
564 566
552
570
514

FIG. 5K

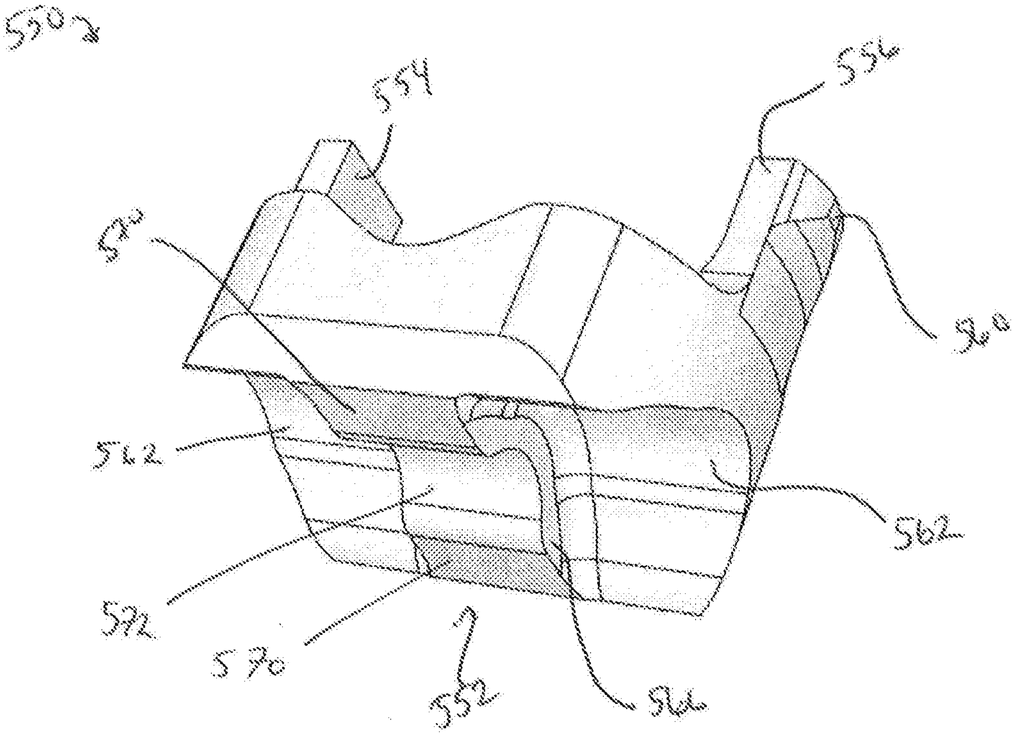
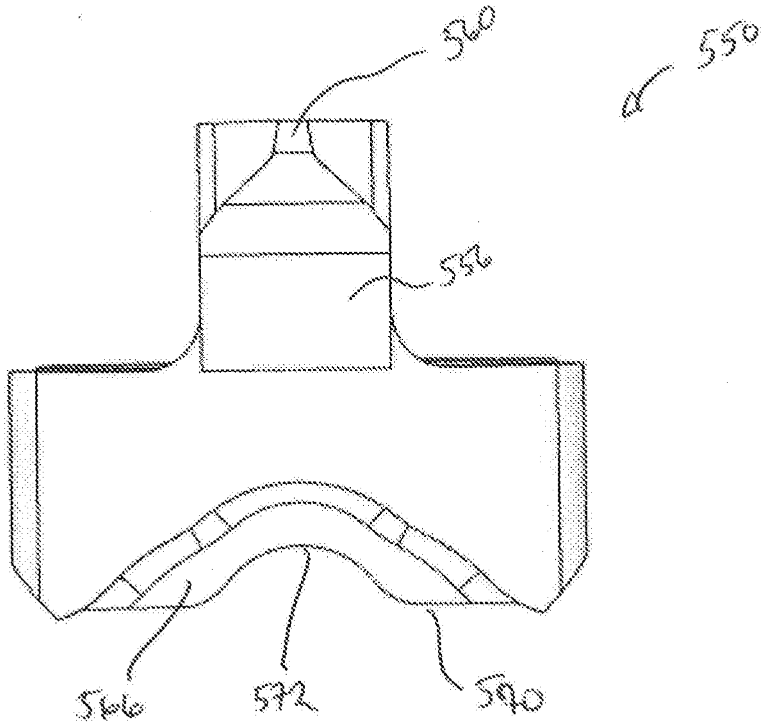


FIG. 5L



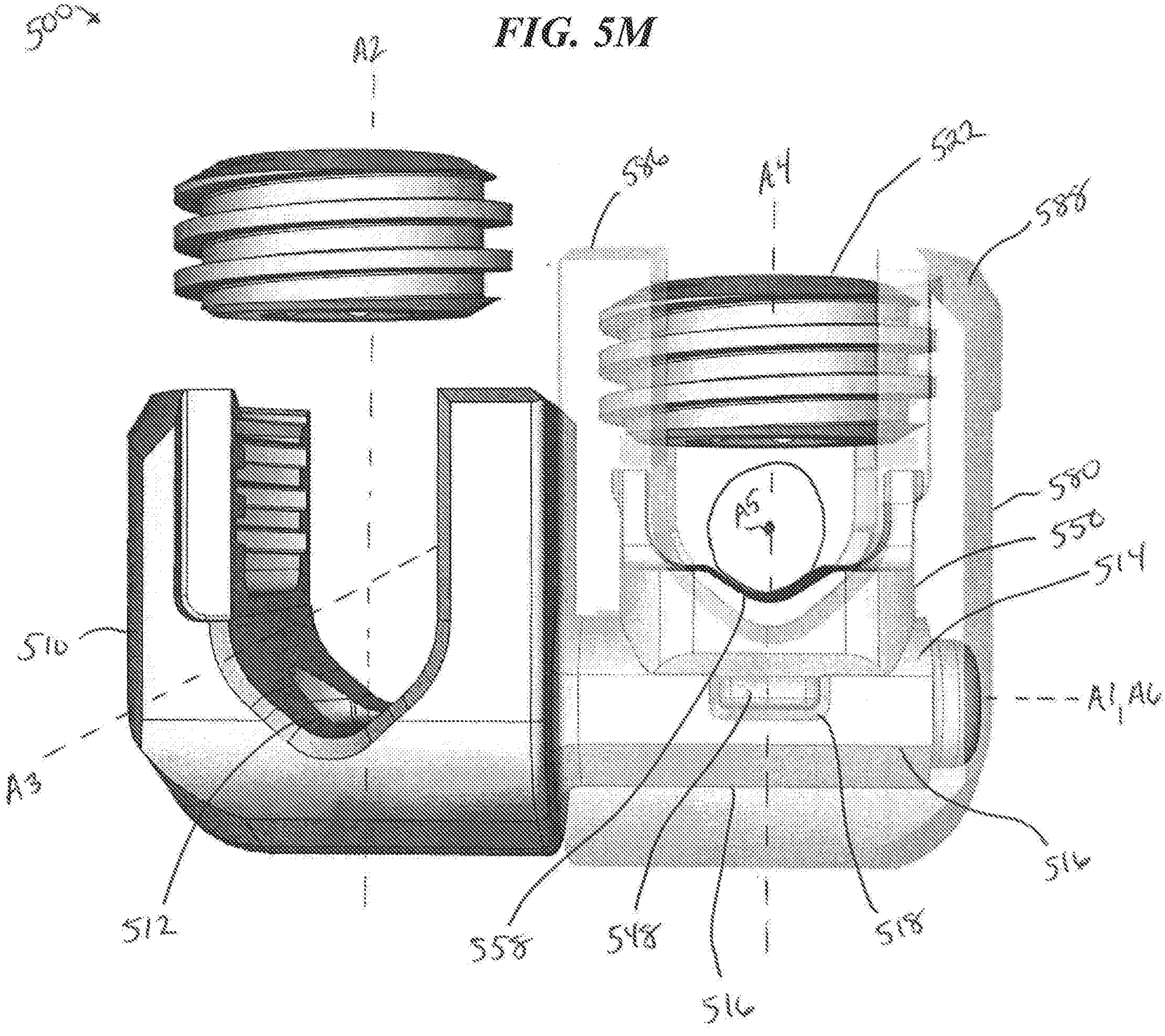

500
A2
586
A4
522
588
580
550
514
A5
510
A1, A6
A3
512
558
548
516
518
516

FIG. 5M

FIG. 5N

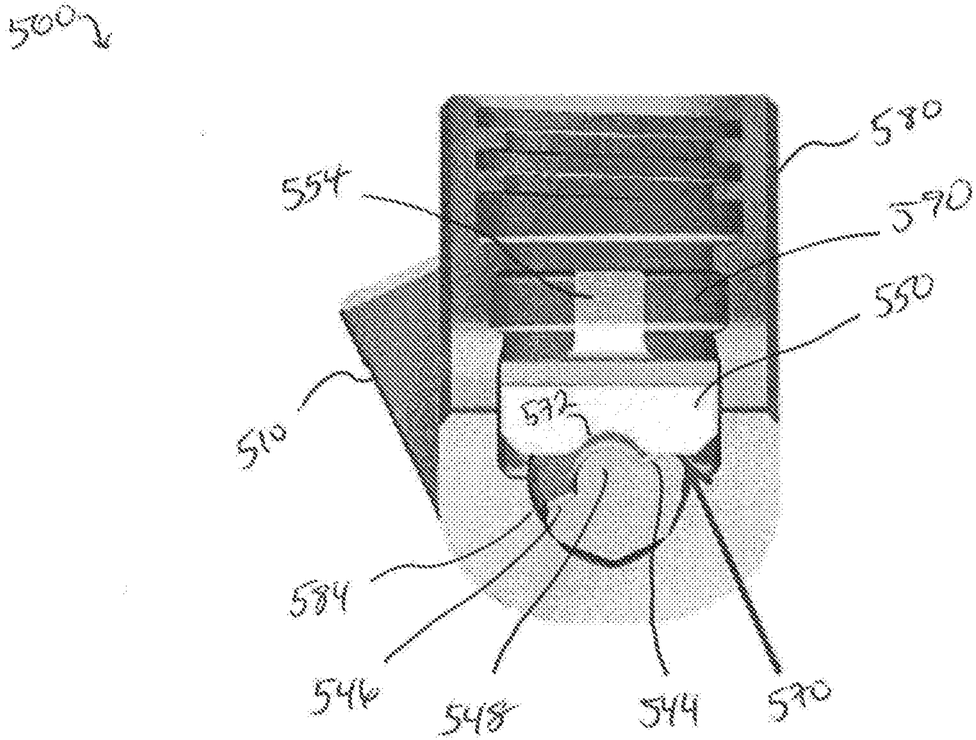

500
580
554
590
550
510
592
584
546
548
544
570

FIG. 5O

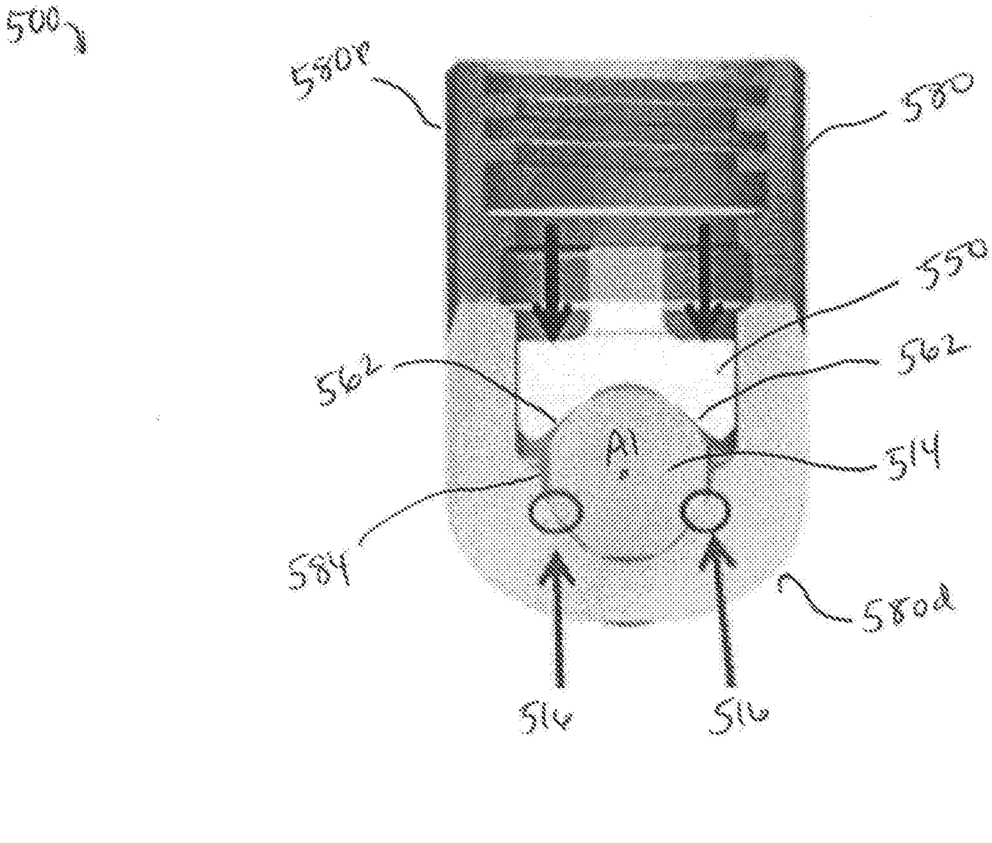

500
580p
580
550
562
562
514
A1
584
580d
516
516

FIG. 6A

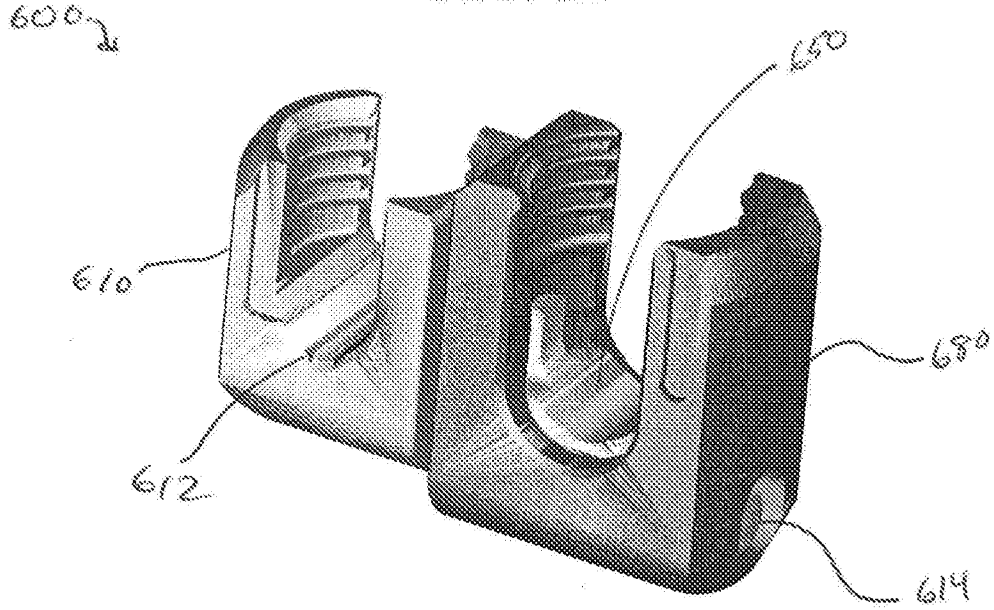

600
650
610
680
612
614

FIG. 6B

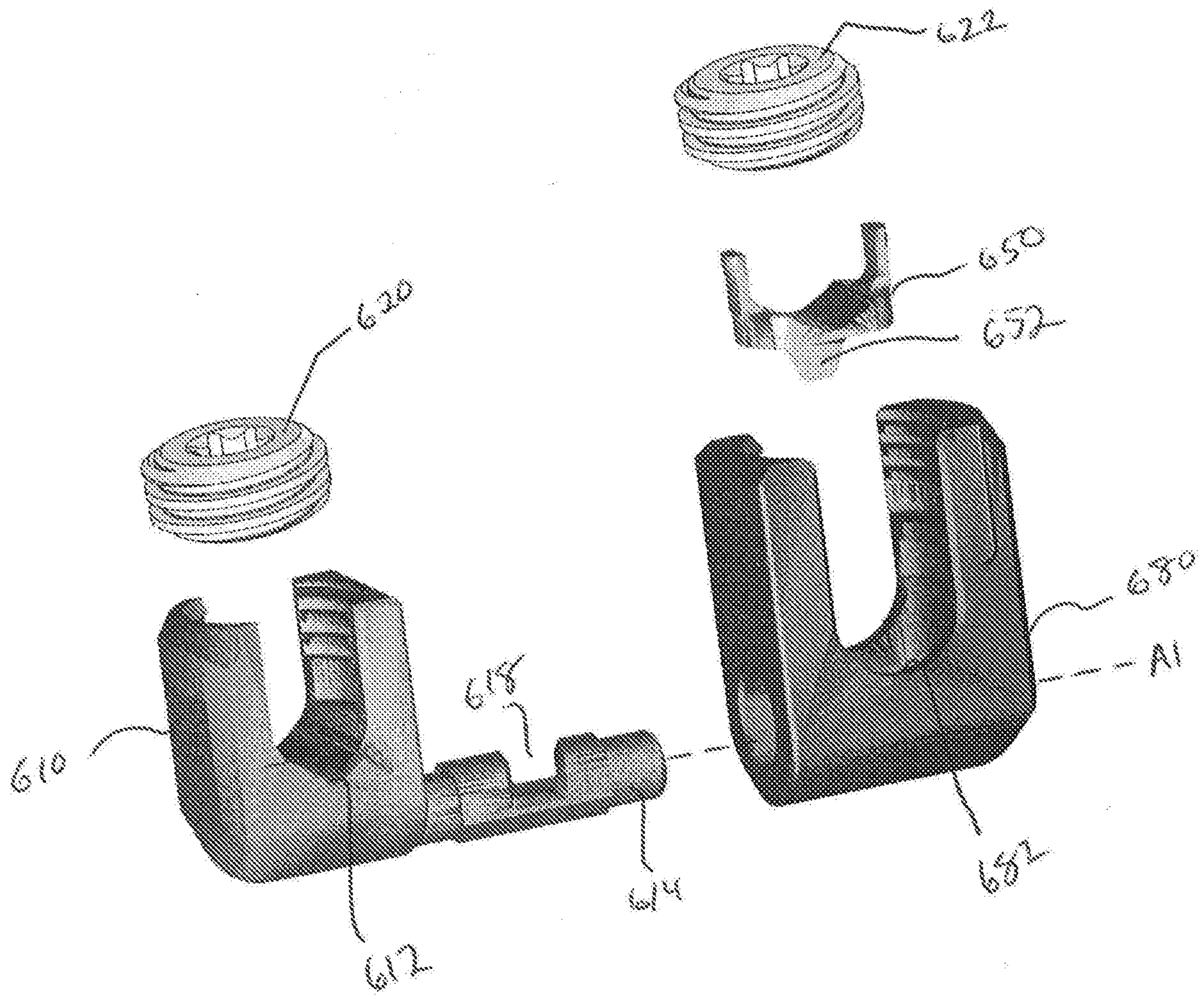

622
650
652
620
680
A1
618
610
614
682
612

FIG. 6C

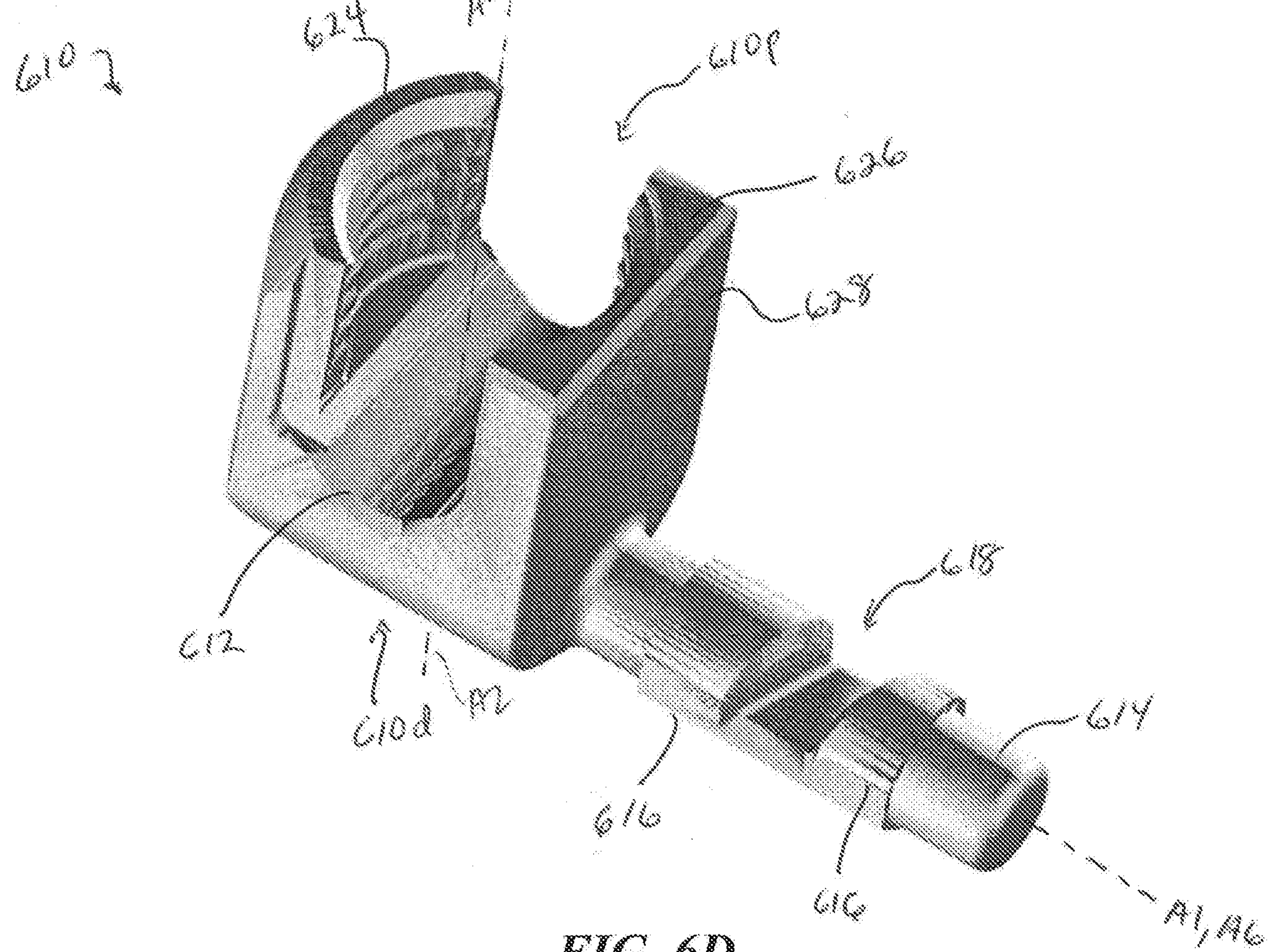

610
624
A2
610p
626
628
612
610d
A2
618
614
616
616
A1, A6

FIG. 6D

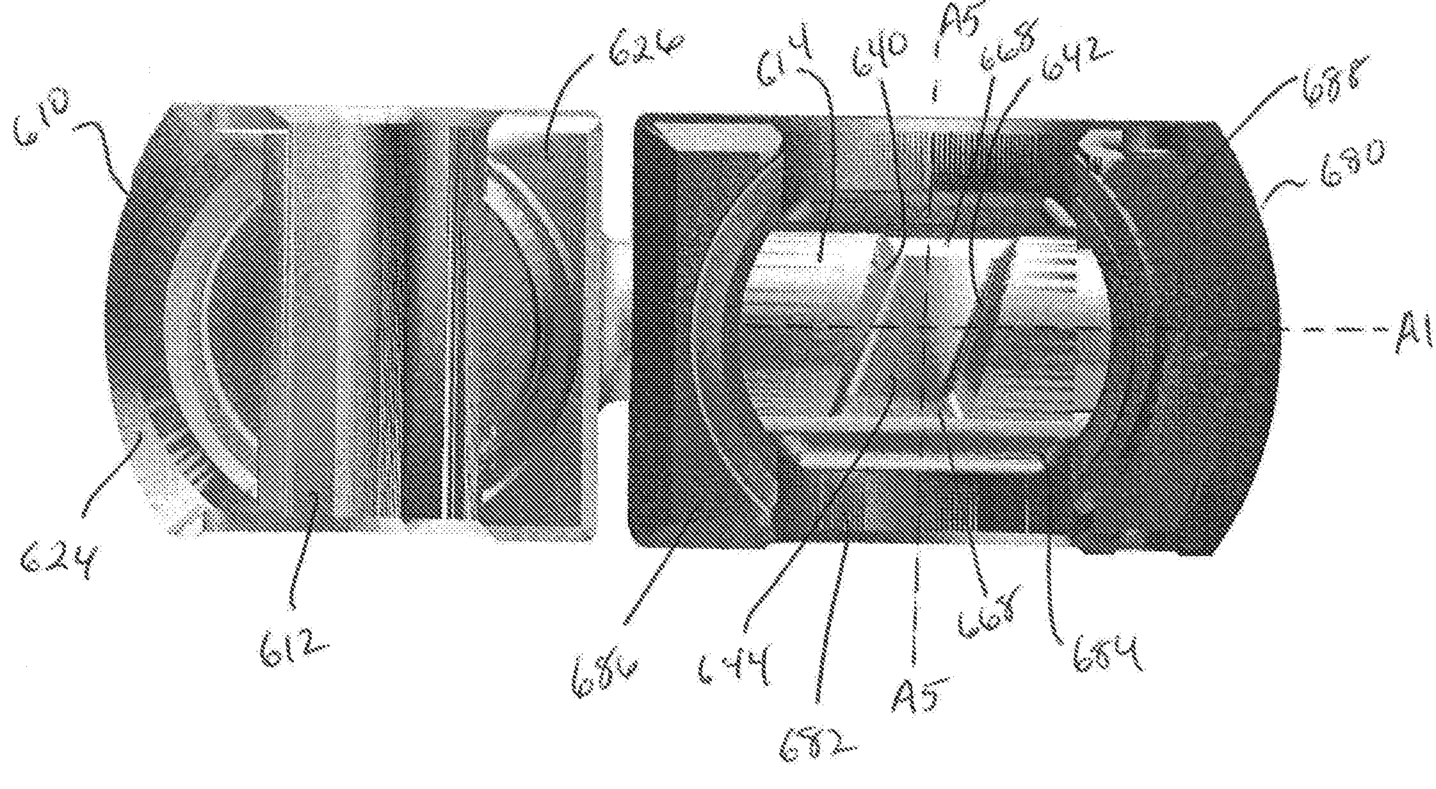

610
626
614
640
A5
668
642
688
680
A1
624
612
686
644
682
A5
668
684

FIG. 6E

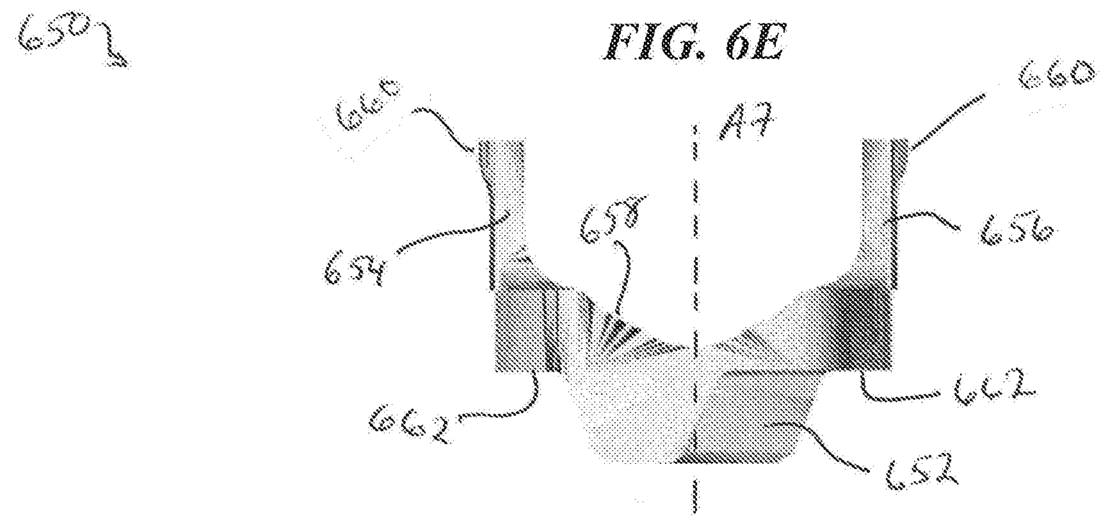


FIG. 6F

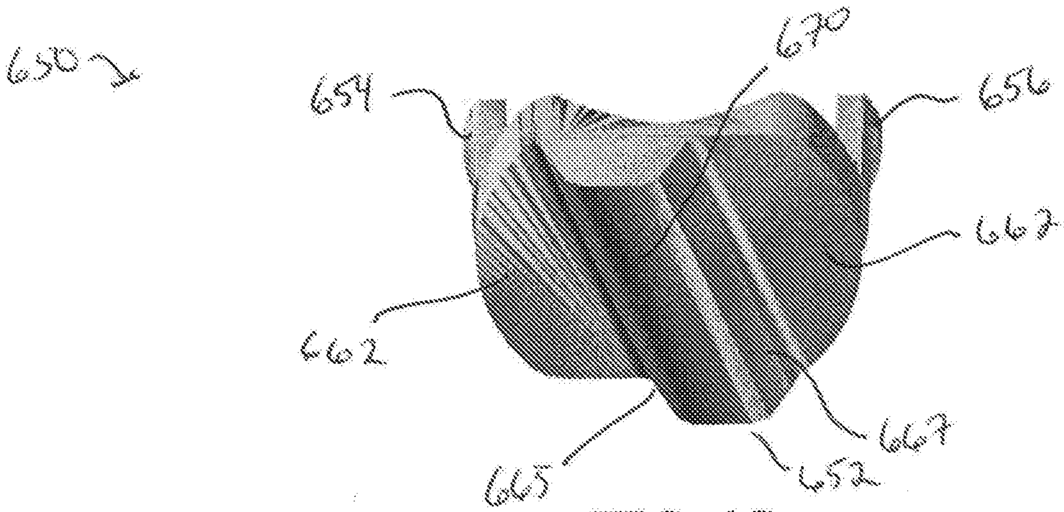


FIG. 6G

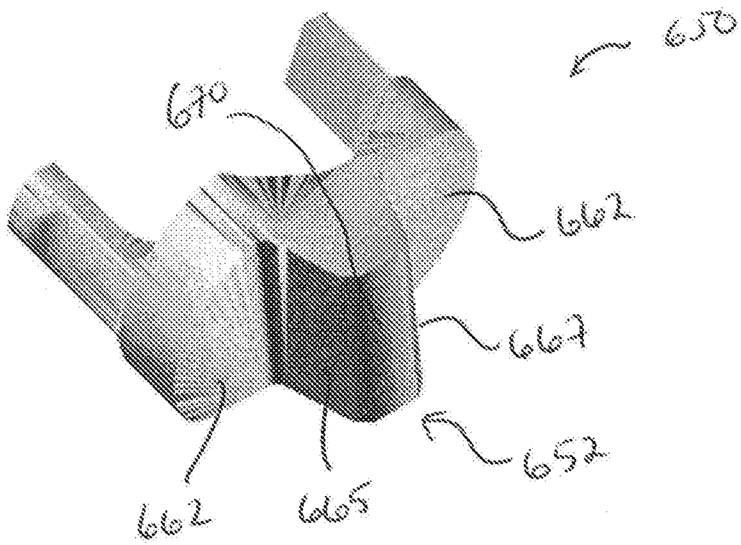


FIG. 6H

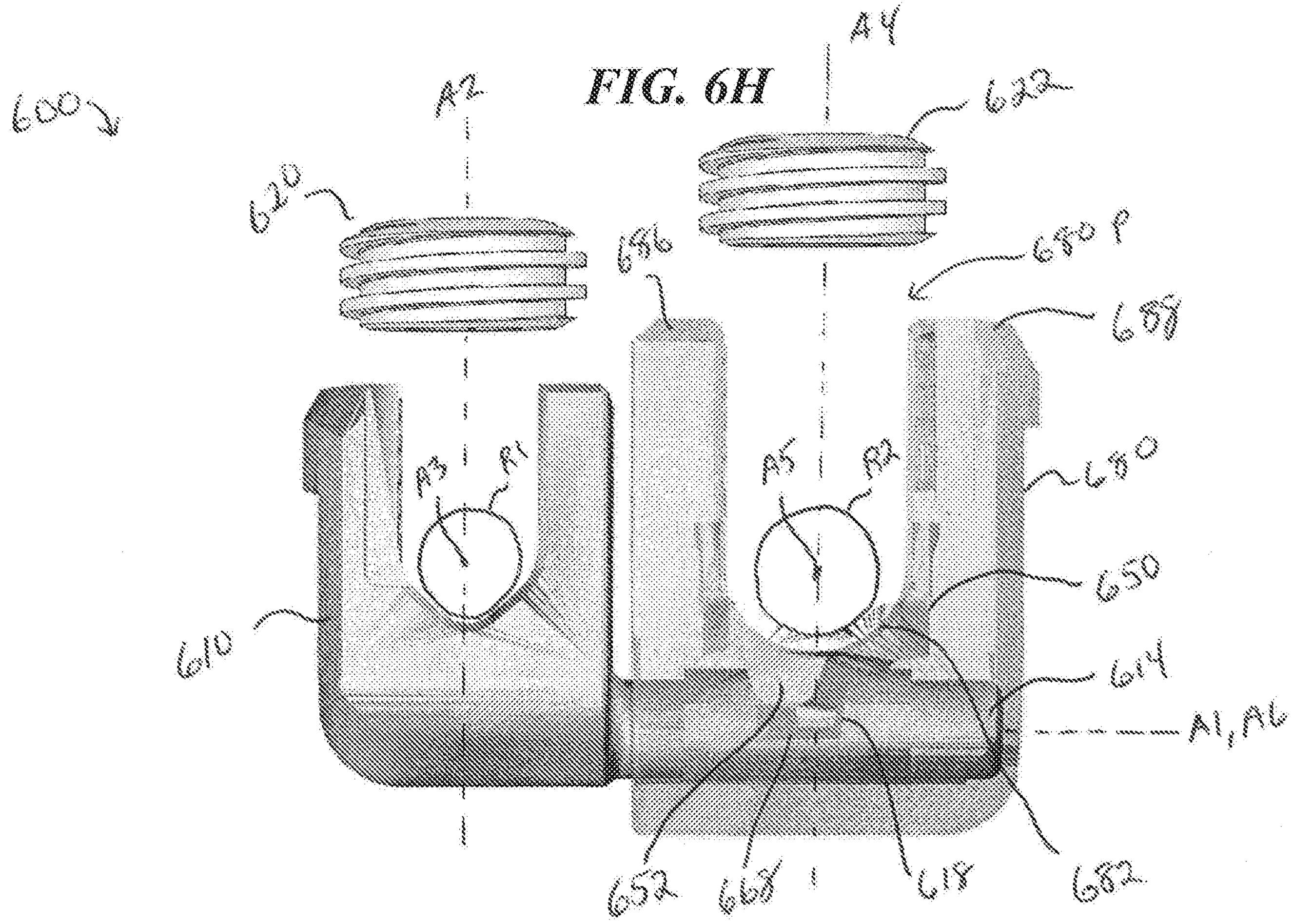

600
A2
A4
622
620
686
680 P
688
A3
R1
A5
R2
680
650
610
614
A1, A6
652
668
618
682

FIG. 6I

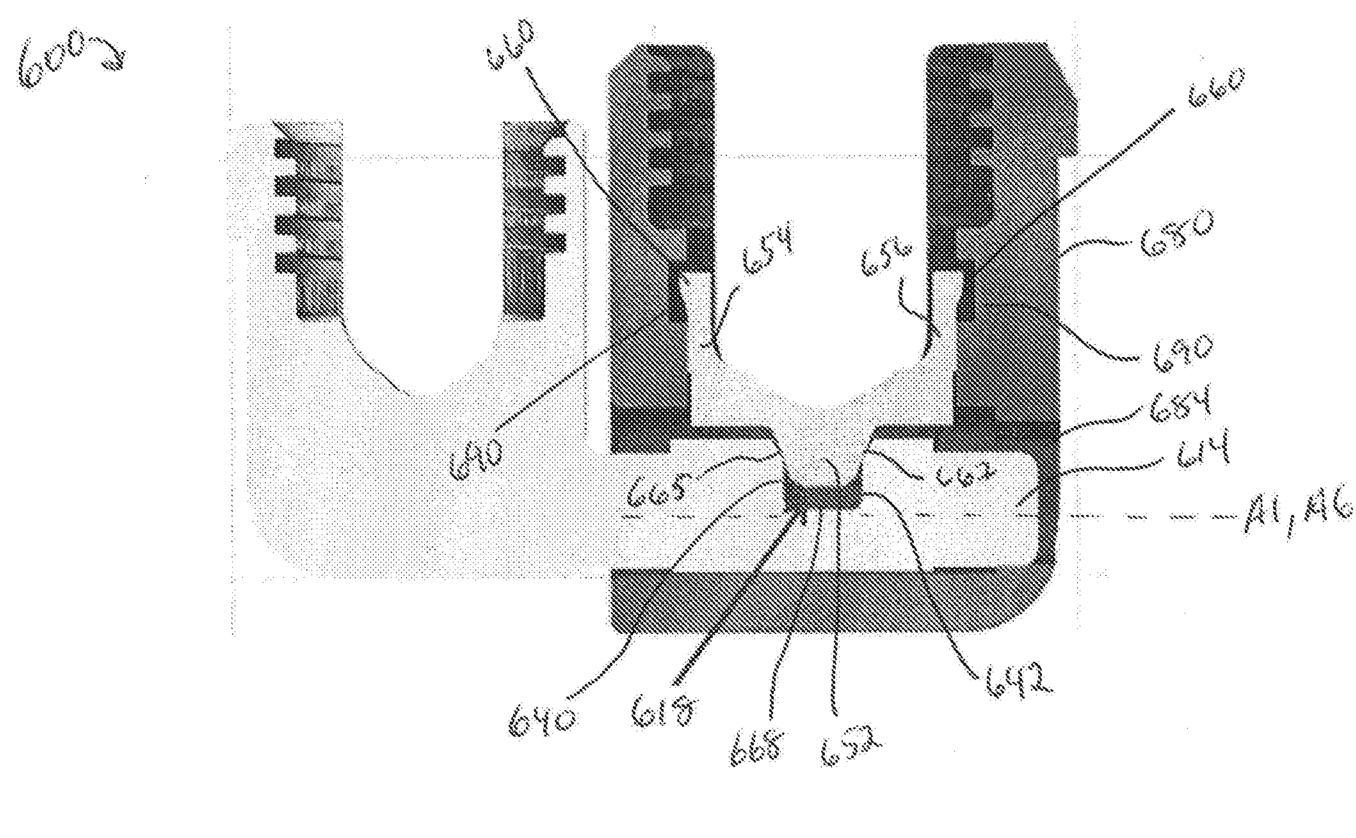
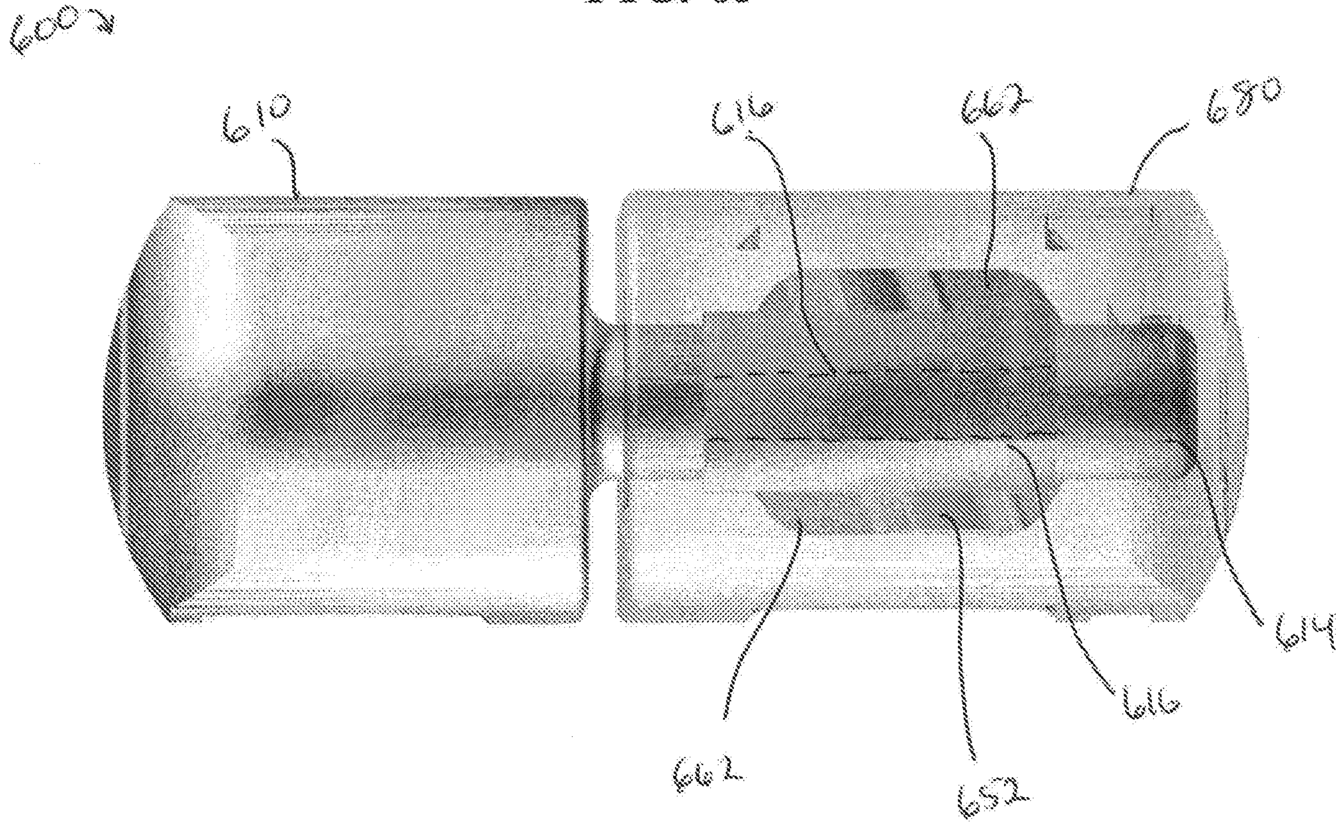

600
660
660
654
656
680
690
690
684
614
665
662
A1, A6
640
618
668
652
642

FIG. 6J



700

FIG. 7A

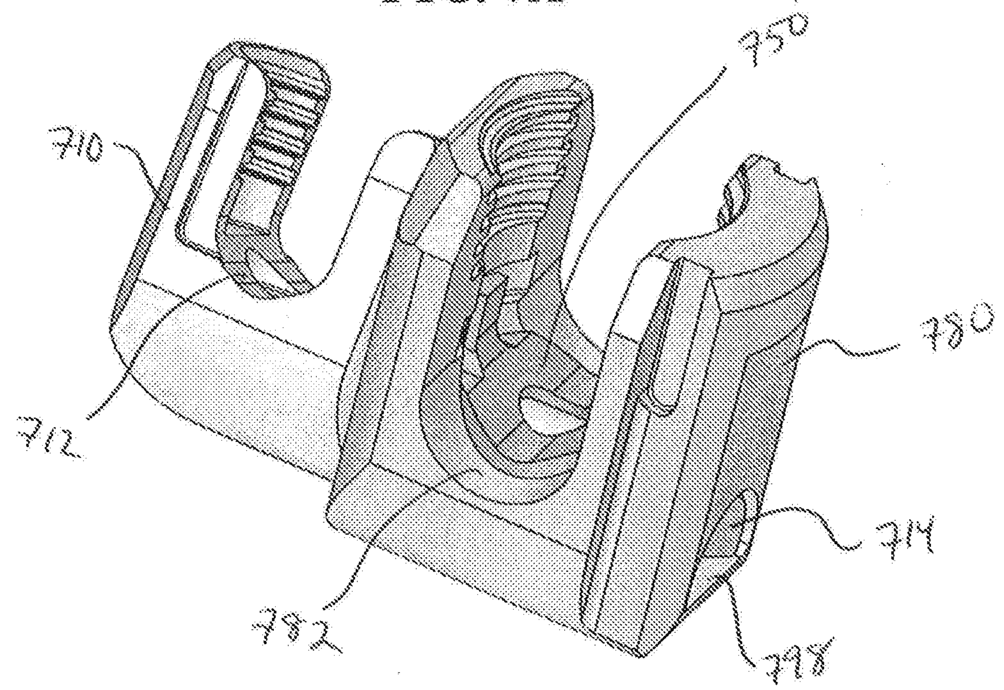


FIG. 7B

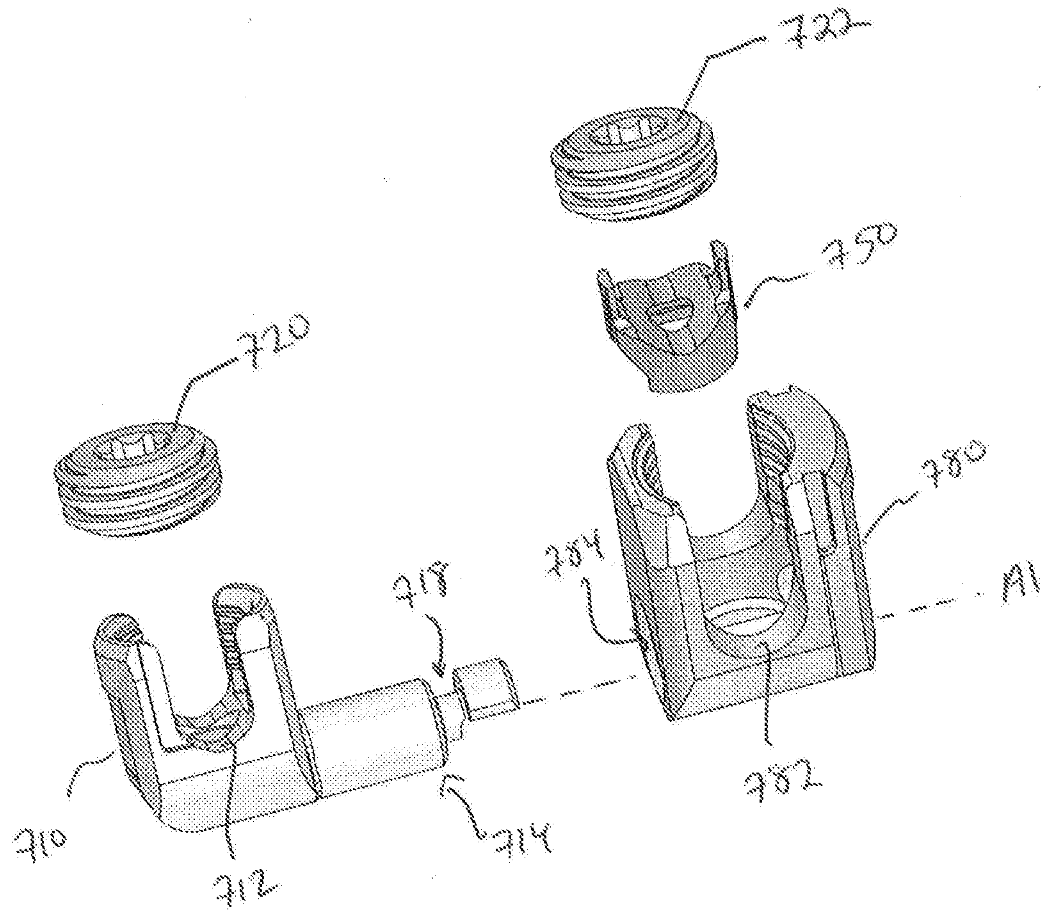


FIG. 7C

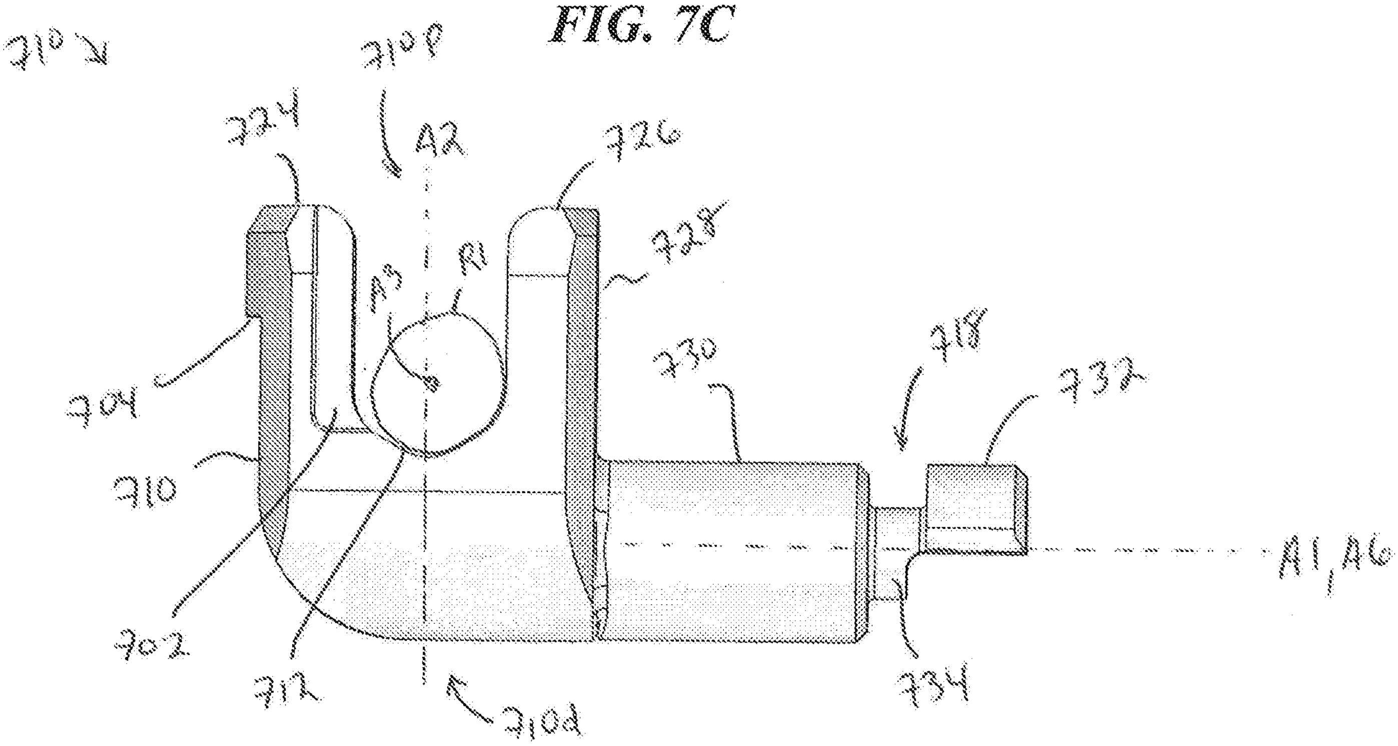


FIG. 7D

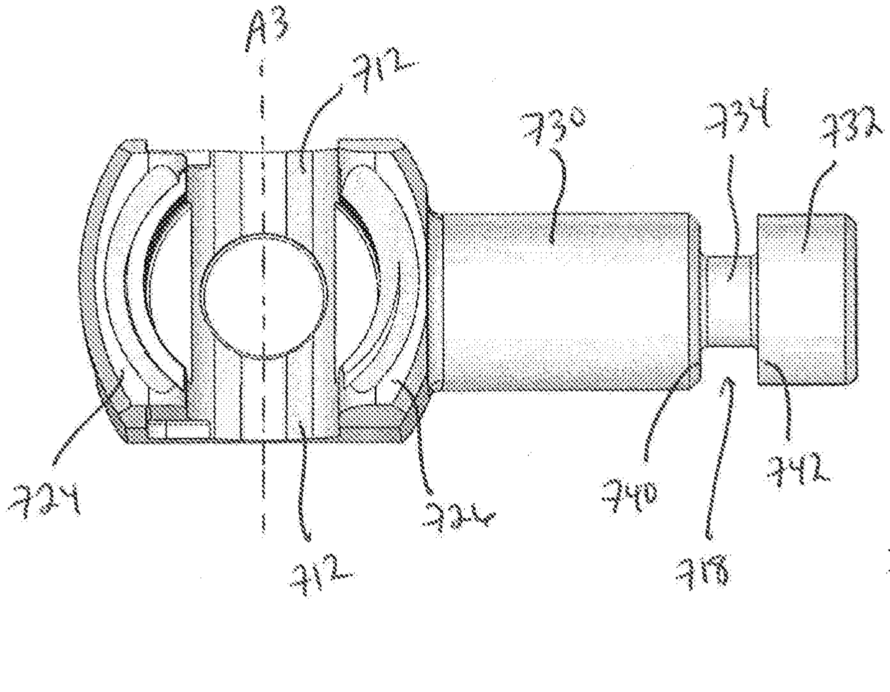


FIG. 7E

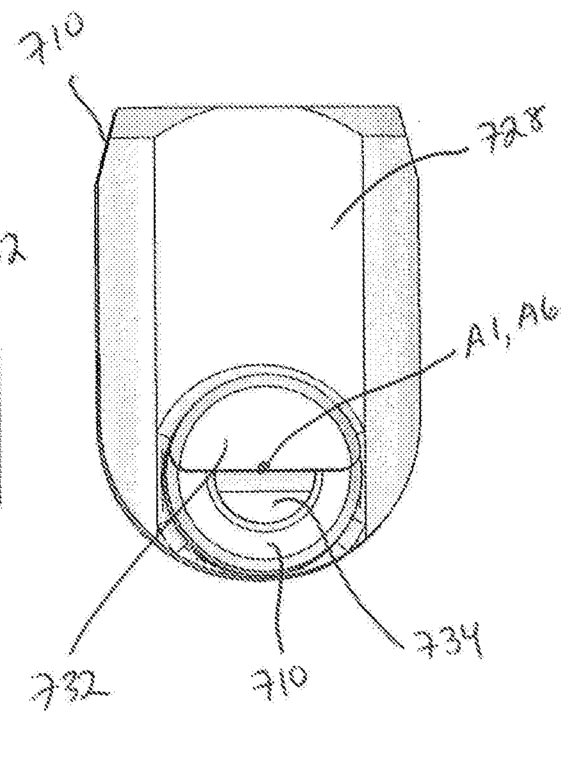


FIG. 7F

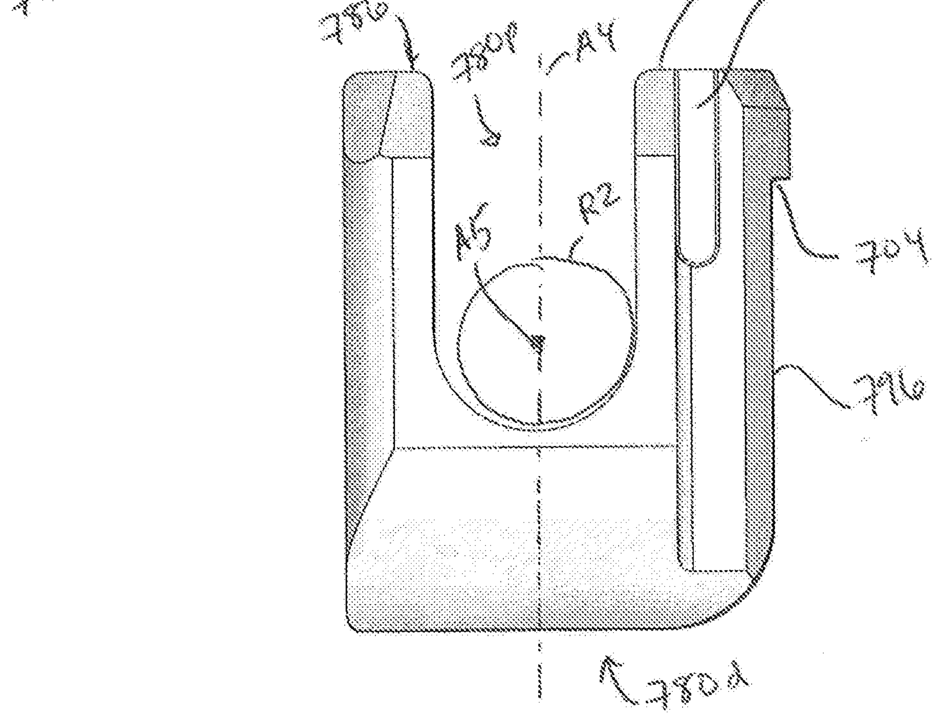


FIG. 7G

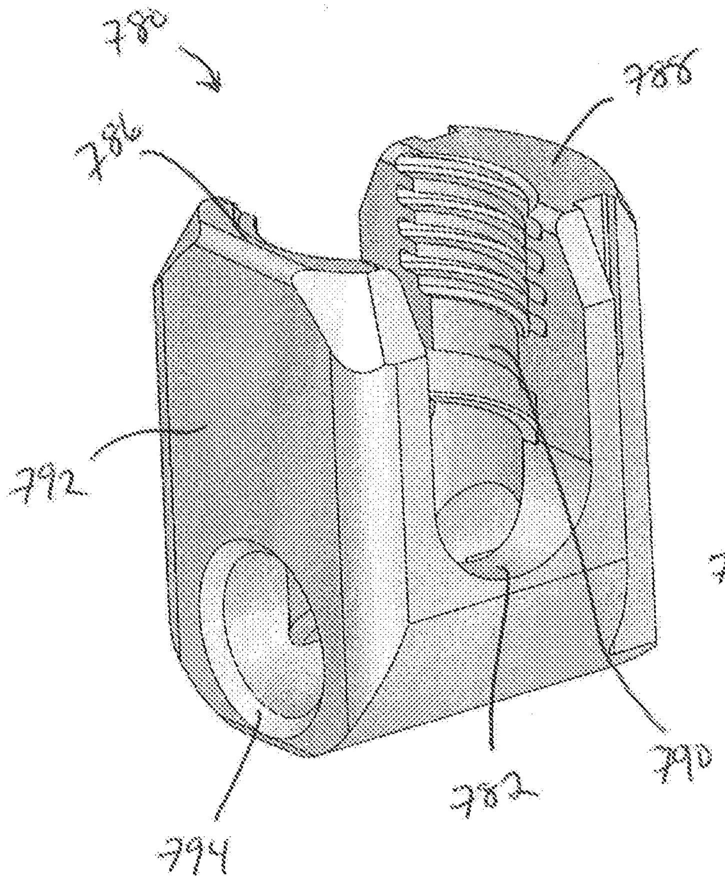
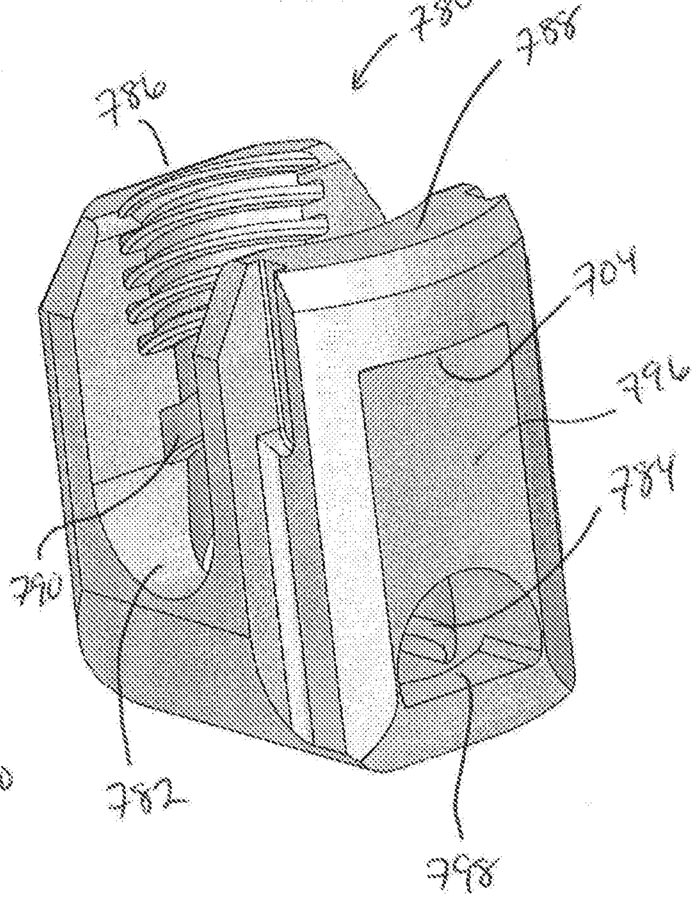


FIG. 7H



750

FIG. 7I

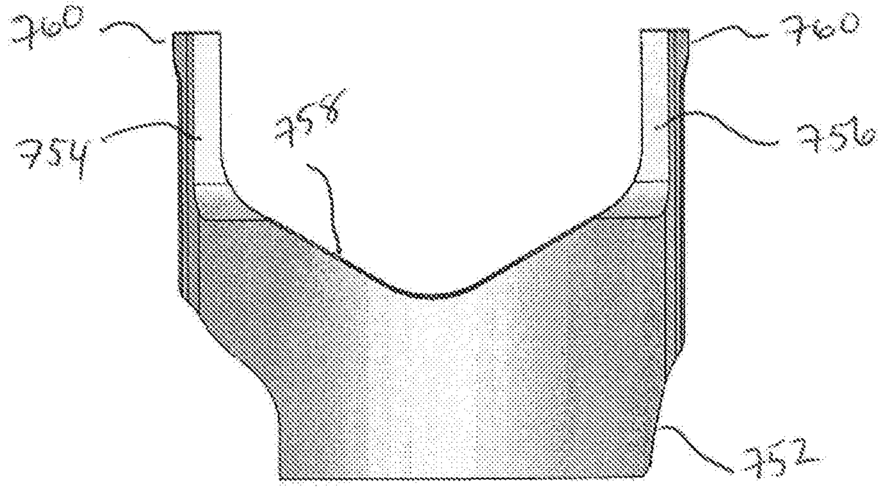


FIG. 7J

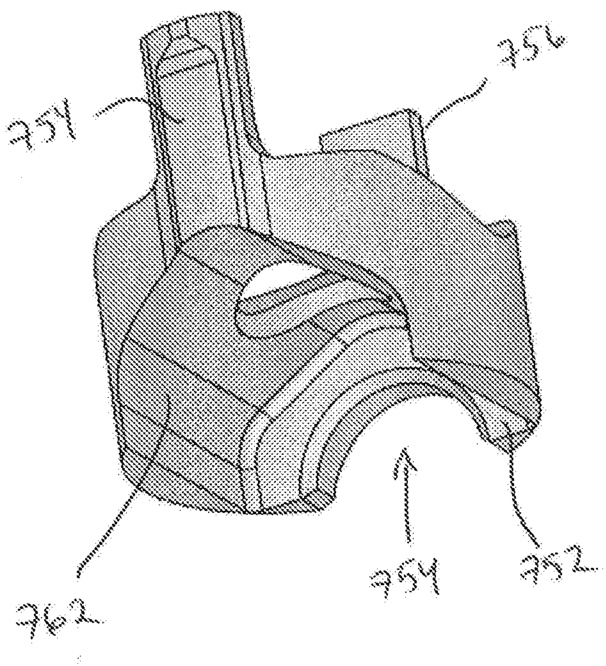


FIG. 7K

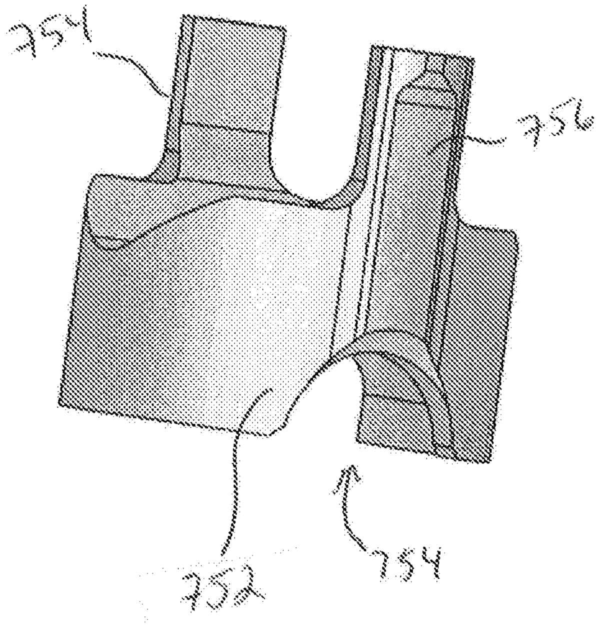


FIG. 7L

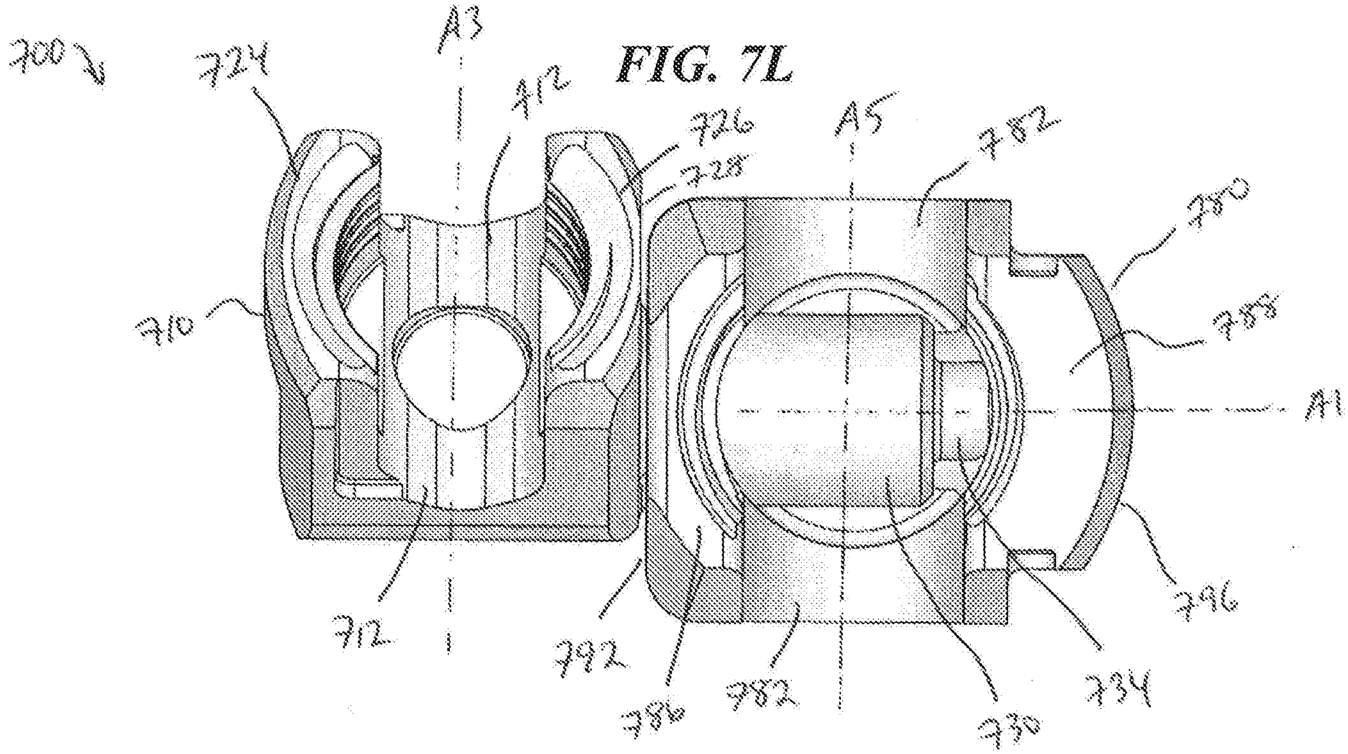
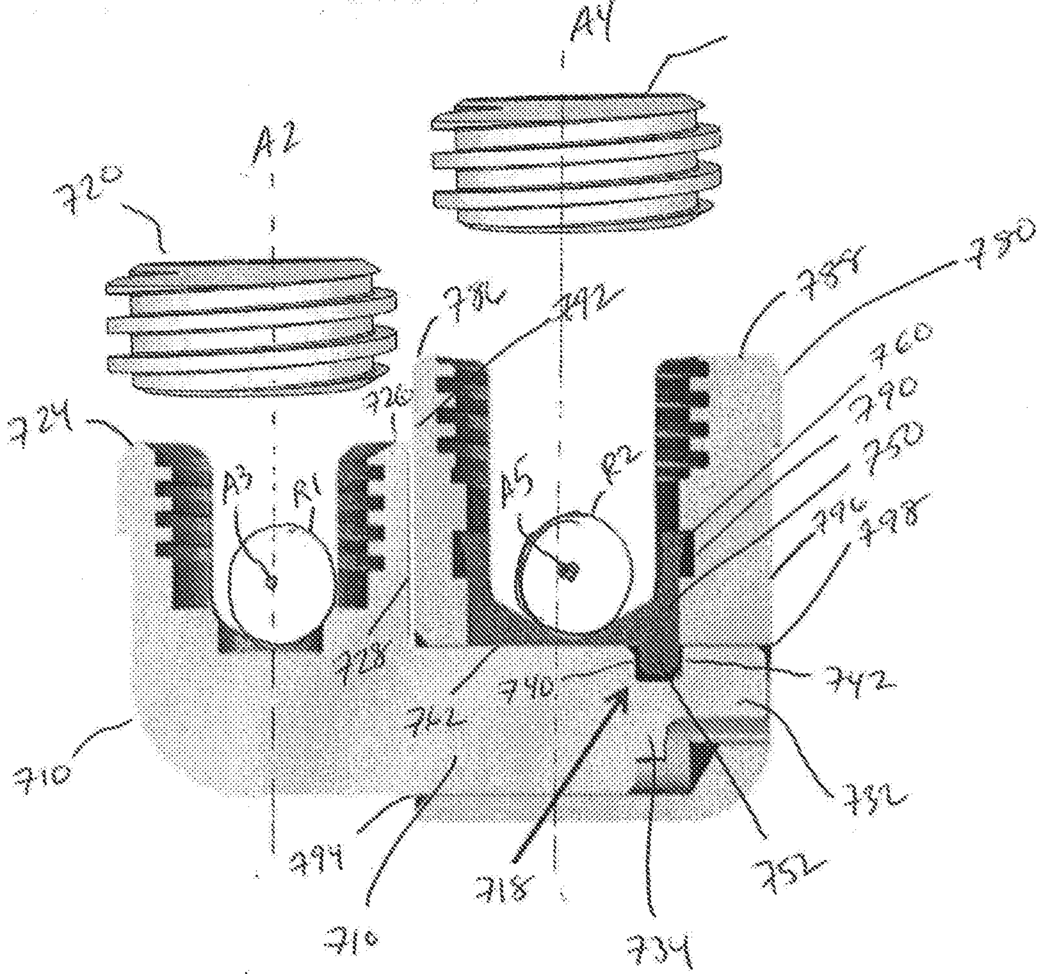

700
724
A3
412
726
728
A5
782
780
710
788
A1
796
712
792
786
782
730
734

FIG. 7M


A4
A2
720
788
780
786
792
760
724
726
790
750
A3
R1
A5
R2
796
798
728
742
740
742
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732
794
718
752
710
734

FIG. 7N

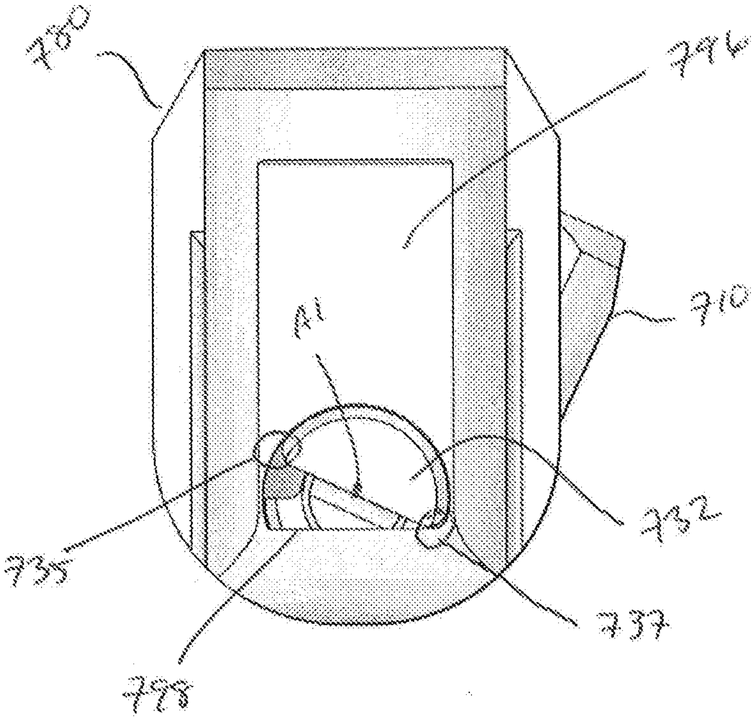


FIG. 7O

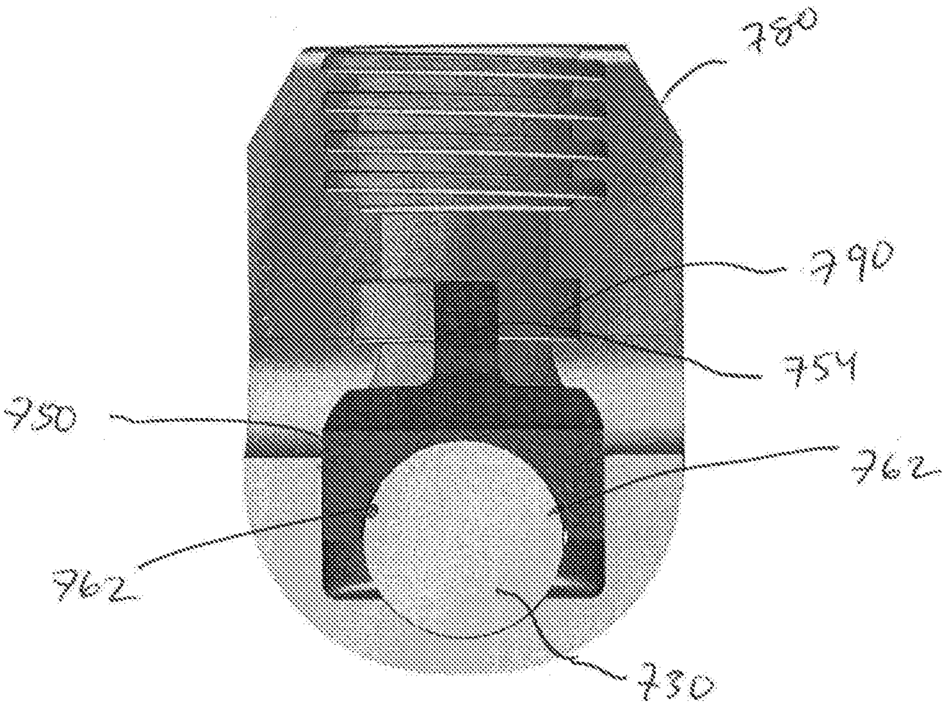
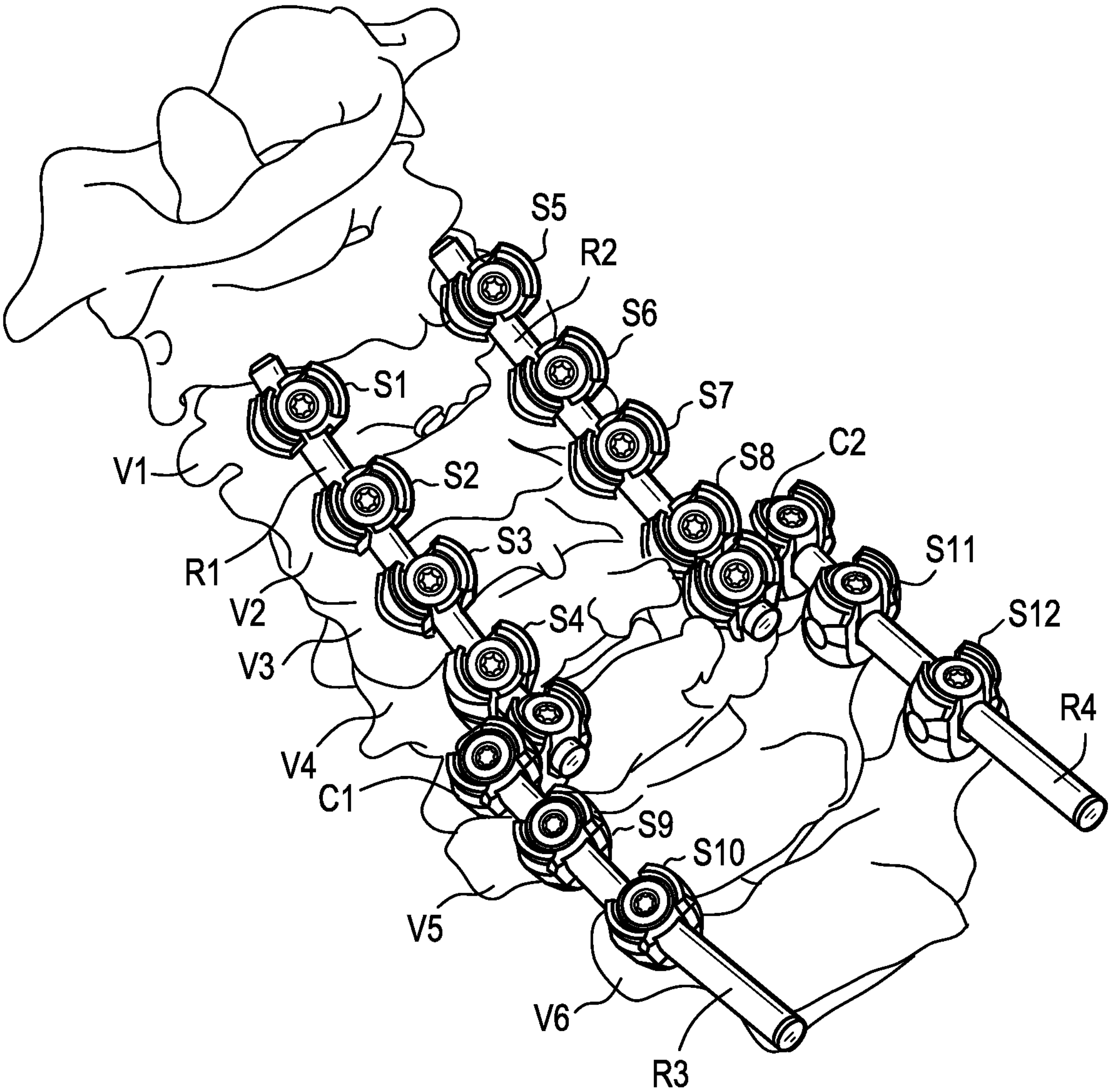


FIG. 8


S5
R2
S6
S1
S7
V1
S2
S8
C2
R1
S3
S11
V2
S4
S12
V3
R4
V4
C1
S9
S10
V5
V6
R3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/024731

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 24-27, 50-56
because they relate to subject matter not required to be searched by this Authority, namely:
see FURTHER INFORMATION sheet PCT/ISA/210

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/024731

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B17/70
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2009/157120 A1 (MARINO JAMES F [US] ET AL) 18 June 2009 (2009-06-18) paragraph [0028]; figures 1,2 paragraph [0037]; figures 4A, 4B	1-3,5,6,12,18-20 4,7-11,13-17
X A	US 2006/039750 A1 (THOMKE ROLAND [CH] ET AL) 23 February 2006 (2006-02-23) paragraph [0063] - paragraph [0069]; figures 11, 12 paragraph [0070] - paragraph [0074]; figures 13-14	1-3,6,18-20 4,5,7-17
X	US 2012/232593 A1 (PREDICK DANIEL [US]) 13 September 2012 (2012-09-13) paragraph [0022] - paragraph [0029]; figures 1-3	2,21,23,28-34,40,41,46

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 2018	02/07/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Filali, Salima

2

International application No
PCT/US2018/024731

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 2 319 436 A1 (ORTHOFIX SRL [IT]) 11 May 2011 (2011-05-11) paragraph [0052] - paragraph [0060]; figures 2, 2A	1-20, 35-39, 47-49
A	US 2010/274286 A1 (BLAIN JASON [US] ET AL) 28 October 2010 (2010-10-28) paragraph [0027] - paragraph [0029]; figures 5-7 figure 10	35-39, 47-49

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2018/024731

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009157120 A1	18-06-2009	US 2009157120 A1	18-06-2009
		US 2012004688 A1	05-01-2012
		WO 2009076107 A1	18-06-2009
US 2006039750 A1	23-02-2006	AT 430523 T	15-05-2009
		AU 2005203737 A1	09-03-2006
		EP 1627608 A1	22-02-2006
		ES 2326269 T3	06-10-2009
		JP 4959160 B2	20-06-2012
		JP 2006055647 A	02-03-2006
		US 2006039750 A1	23-02-2006
US 2012232593 A1	13-09-2012	NONE	
EP 2319436 A1	11-05-2011	AR 081307 A1	08-08-2012
		AU 2010241221 A1	26-05-2011
		BR PI1004592 A2	26-02-2013
		CA 2719980 A1	06-05-2011
		CO 6290085 A1	20-06-2011
		EP 2319436 A1	11-05-2011
		ES 2414532 T3	19-07-2013
		HK 1155630 A1	30-08-2013
		IL 209002 A	29-02-2012
		JP 5654320 B2	14-01-2015
		JP 2011098201 A	19-05-2011
		KR 20110050392 A	13-05-2011
		US 2011112533 A1	12-05-2011
US 2010274286 A1	28-10-2010	AU 2010239230 A1	10-11-2011
		CA 2759249 A1	28-10-2010
		EP 2421454 A2	29-02-2012
		JP 2012524623 A	18-10-2012
		US 2010274286 A1	28-10-2010
		US 2014336707 A1	13-11-2014
		WO 2010124032 A2	28-10-2010

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 24-27, 50-56

Re Item III
Non-establishment of opinion with regard to novelty, inventive step and industrial applicability Claims 24-27 and 50-56 relate to a method for treatment of the human or animal body surgery, because they implicitly comprise the step of expelling bone cement into the patient. This is evidenced by the expressions "securing the first and second rods to an anatomy of a patient" as read in the claims and the context of the description. This Authority is not required to search the present application with respect to the aforementioned claims (Article 17(2)?(b) PCT and Rule 39.1(iv) PCT)?. Consequently, no International Search Report and no Written Opinion (Rule 67.1 PCT in combination with Rule 43bis.1(b) PCT) have been established with respect to them.