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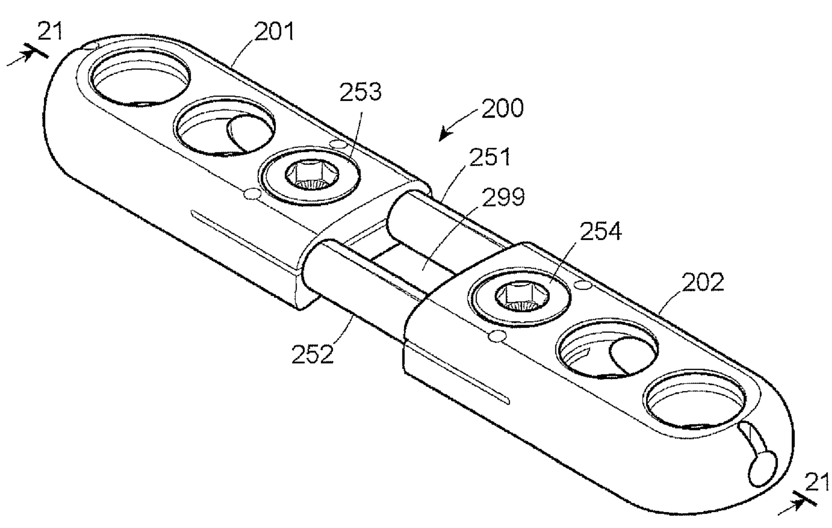

(57) Abstract: A longitudinally curved adjustable bone plate comprising a first plate having an end defined by at least two spaced prongs, and an end having means to fasten the plate to a body structure, e.g., the bone; and a second plate having an end defined by at least two straight bores for receiving the prongs, and an end having means to fasten the plate to a body structure, e.g., a bone; and a locking assembly for locking the prongs in the bores and fixing the overall length of the plate. Also, longitudinal plates and center plates which can be releasably joined using connecting rods to form slidable bone plate assemblies comprising one or more windows, and methods for applying such longitudinal plates, center plates, connecting rods and assemblies to broken bones of a patient.

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ADJUSTABLE BONE PLATE

CROSS-REFERENCE TO RELATED APPLICATION

This is a Continuation-in-part of U.S. Patent Application No. 10/975,296 filed October 28, 2004. U.S. Patent Application No. 10/975,296 is incorporated herein in its entirety by reference.

FIELD OF THE INVENTION

The invention relates to bone plates for holding body structures, such as the bones affixed relative to one another. More particularly this invention relates to longitudinal bone plate assemblies wherein the length of the plate is adjustable.

BACKGROUND OF THE INVENTION

Bone plates come in many sizes and shapes. The typical bone plate has a fixed dimension, and multiple holes for accommodating bone screws. In use, the surgeon brings together the fractured bone, places the bone plate atop the fracture, and inserts bone screws through the holes in the plate which overlie the healthy part of the bone, securing the bone about the fracture. Bone plates of many sizes are provided for the surgeon, and each is supplied with a number of holes so that the surgeon can arrange the plate over the fracture and have bone screw holes available above the healthy bone.

U.S. Patent 6,666,867 describes a bone plate having an adjustable length. The adjustable length bone plate consists of a two parts, a first plate and a second plate, which are secured to the bone on opposite sides of the fracture. The first plate has laterally adjacent prongs which are inserted into the bore of a second plate. Bone screw holes are provided at the ends of the first and second plates to fasten them to the bone. The sliding bone plate has a locking mechanism, comprising a set screw passing through the second plate, and between the prongs of the first plate, fixing the length of the overall plate atop the fracture. The laterally adjacent prongs do not permit the surgeon to see the fracture surfaces coming together under the bone plate. Further, the use of only one locking screw permitted the assembled plate to twist longitudinally, permitting an unacceptable movement of the bone.

Orthopedic surgeons have also used DCP plates to stabilize fracture bone. The DCP plates also have openings for bone screws, and angulated openings, through which screws are "toed" into the bone, the tightening of the toed screws operating to move the bone, slightly, under the DCP plate. DCP plates have been used to move the bones on either side of the fracture closer together. This movement, however, was slight, and not easily controllable. Literally, the underlying bone is being pulled into place by the threads of a screw, providing no control over the twisting or turning of the bone, and the bending of the plate. In addition, the bone is pulled at an angle to the attached plates, resulting in a cocked bone, or an angle to longitudinal direction of the bone. This angulation, together with the micromotion in the bone, has lead to backing out of the screws.

Object of the Invention

It is the object of the present invention to substantially overcome or at least ameliorate one or more of the disadvantages of the prior art, or to provide a useful alternative.

Summary of the Invention

In a first aspect the present invention relates to a bone plate assembly having an adjustable length and comprising:

a first longitudinal plate having a longitudinal curvature, a lateral curvature, an upper surface and a lower surface,

a first plate inner end comprising at least two spaced, straight longitudinal prongs,

a first plate outer end, and disposed proximate the first plate outer end at least one bone screw aperture passing through the upper surface and the lower surface and adapted to receive a bone screw for fastening the first plate to a bone, and

a second longitudinal plate having a longitudinal curvature, a lateral curvature, a length, a width, an upper plate surface and a lower plate surface,

a second plate inner end comprising at least two straight longitudinal bores, each straight longitudinal bore having an inner surface extending into and terminating within the second longitudinal plate and being adapted to receive one straight longitudinal prong,

a second plate outer end, and disposed proximate the second plate outer end at least one bone screw aperture passing through the upper plate surface and the lower plate surface and adapted to receive a bone screw for fastening the second plate to the bone, said straight longitudinal prongs being smoothly translatable within said straight longitudinal bores to adjust the length of the bore plate assembly, and defining an observation window between the prongs and the plates, said bone plate assembly further comprising:

a locking mechanism to fix the length of the bone plate assembly the locking mechanism comprising:

at least one threaded set screw aperture disposed between the bores, the second plate inner end and the bone screw aperture, and

a set screw disposed in the set screw aperture,

wherein, when the set screw is tightened in the set screw aperture the prongs are pressed against the inner surfaces of the bores locking the prongs in place.

In a second aspect the present invention relates to a bone plate assembly having an adjustable length and comprising two longitudinal plates, each plate having:

a longitudinal curvature, a lateral curvature, an upper plate surface and a lower plate surface,

a plate inner end comprising at least two straight longitudinal bores, each straight longitudinal bore having an inner surface extending into and terminating within the plate and being adapted to receive a straight longitudinal prong,

a plate outer end, and disposed proximate the plate outer end at least one bone screw aperture passing through the upper plate surface and the lower plate surface and adapted to receive a bone screw for fastening the plate to a bone,

at least two straight longitudinal prongs, said straight longitudinal prongs being smoothly translatable within said straight longitudinal bores to adjust the length of the bone plate assembly, and defining an observation window between the prongs and the plate inner ends, said bone plate assembly further comprising:

a locking mechanism in each plate to fix the length of the bone plate assembly, the locking mechanism comprising:

at least one threaded set screw aperture disposed between the bores, the plate inner end and the bone screw aperture, and

a set screw disposed in each set screw aperture,

wherein, when the set screw is tightened in the set screw aperture, the prongs are pressed against the inner surfaces of the bores locking the prongs in place.

The present invention at least in a preferred embodiment which comprises a sliding bone plate assembly having an adjustable length and a longitudinal curvature. The sliding bone plate assembly comprises at least two plates, a first longitudinal plate, having at least two spaced longitudinal prongs at one end, and means for fastening the plate to a body structure at the other end; and a second longitudinal plate having at least two straight longitudinal bores at one end, each bore adapted for receiving one prong, and means for fastening the plate to a body structure at the other end. The means for fastening the plates to the body structure comprises a pair of threaded through holes adapted for receiving bone screws for making a fastening to the underlying bones.

In this embodiment, the plates are constructed such that the prongs may be smoothly translated longitudinally within the straight bores to adjust the length of the plate assembly. The plate assembly further comprises a locking mechanism to fix the length of the overall plate assembly. The bores have an inner surface and the locking mechanism presses the prongs against the inner surface to fix the plates with respect to each other. The set screw forces the prongs against the respective inner surfaces of their bores.

In a further embodiment, the plate has two longitudinal prongs and two longitudinal bores, and the locking mechanism comprises a threaded bore in the second plate and a set screw passing between the prongs and into the threaded bore. In addition, both the first and second plates have a longitudinal curvature yielding a convex upper longitudinal surface and concave lower longitudinal surface, and first and second plates have a lateral curvature yielding a convex upper lateral surface and a concave lower lateral surface.

The present invention at least in a preferred embodiment further comprises a method of attaching at least two pieces of bone across a break, said method comprising placing the plate assembly over the break in the bone, such that the first longitudinal plate overlies the bone on one side of the break and the second longitudinal plate overlies the bone on the over side of the break; attaching the first longitudinal plate to the bone; moving the second longitudinal plate to translate the prongs out of the bores; and attaching the second longitudinal plate to the bone on the other side of the break, inserting the prongs of the first longitudinal plate into the bores of the second longitudinal plate, while observing the break through the window created by the spaced prongs, translate the prongs through the bores to bring together the two pieces of bone at the break, and locking the prongs in the bores to fix the length of the plate and position of the bones at the break. In an embodiment, the prongs of the first longitudinal plate may be inserted into the prongs of the second longitudinal plate before the bone plate assembly is placed over and secured to the broken bone.

In a further embodiment of the invention, the bone plate assembly is comprised of at least two longitudinal plates each having one or more, preferably two or more rod bores and one or more, preferably two or more connecting rods which are capable of longitudinal movement within the rod bores. In this embodiment, the bone plate assembly comprises locking means which functions to restrict or preclude longitudinal movement of the connecting rods within the rod bores and/or restrict translation or longitudinal movement of the longitudinal plates through the connecting rods. This fixes a desired distance of one longitudinal plate to another, (i.e. setting the longitudinal length of the bone plate).

The locking means may comprise one or more locking means bores, which are capable of receiving one or more screws, such as large top set screws. Each longitudinal plate may optionally comprise one or more slits and one more retaining pin bores each of which may receive a retaining pin. The bone plate assembly in this embodiment, may be assembled by placing the connecting rods within the rod bores, and the applying the locking means to fix the longitudinal length of the bone plate. For example, each longitudinal plate may comprise one or more rod bores and one end of the connecting rods are placed within the rod bores of a first longitudinal plate with the other end of the connecting rods placed within rod bores of another longitudinal plate. A large top set screw can be inserted into a locking means bore and the large top screw is tightened to lock the longitudinal plates and connecting rods in place.

In a further embodiment, one connecting rod may be inserted into the distal or forward rod bore of a first longitudinal plate and a second connecting rod may be placed in the opposite rod bore of a second longitudinal plate, then the first longitudinal plate and second longitudinal plate may be joined by translating the connecting rods within the rod bores which are vacant in the first longitudinal plate and second longitudinal plate. For example, a connecting rod may be placed in a distal rod bore of the first longitudinal plate leaving a forward rod bore vacant and a second connecting rod may be placed in a forward rod bore of the second longitudinal plate leaving a distal rod bore vacant, and when the longitudinal plates are brought together, the connecting rod in the distal rod bore of the first longitudinal plate is slid into the distal rod bore of the second longitudinal plate and the connecting rod in the forward rod bore of the second longitudinal plate is slid into the forward rod bore of the first longitudinal plate, and, likewise, a connecting rod can be placed in the forward rod bore of the first longitudinal plate and a second connecting rod can be placed in the distal rod bone of second longitudinal plate to similarly assemble the bone plate. In these, and other, embodiments, one or more ends of the connecting rod may be threaded to mate with a threaded rod bore and, also, the connecting rod may have one or more retaining pin holes to mate with retaining pins which translate through retaining pin bores in the longitudinal plates and/or center plates, and the retaining pins and retaining pin holes and retaining pin bores may be threaded.

In an embodiment of the invention, the slit in the longitudinal plate functions in conjunction with the locking means allowing the lateral movement of the top portion and/or a bottom portion of the longitudinal plate which effectively compresses or crushes the longitudinal plate to have the rod bore walls apply pressure to outer surfaces of the connecting rods which restricts or precludes movement of the connecting rods and/or the longitudinal plates. Also, the rods may be moved by the bone screws to apply further pressure locking the longitudinal plates in place.

Further, in embodiments of the invention wherein the longitudinal plates comprise retaining pin bores, slots in the connecting rods can be aligned with the retaining pin bores and the retaining pins can be inserted through the retaining pin bores and slots to facilitate placement and adjustment of the bone plate assembly over the bone. Also, as discussed above, the connecting rods may have one or more retaining pin holes, either in place of or in addition to the slots, and also one or more ends of the connecting rods may be threaded.

The invention also comprises an embodiment wherein one or more longitudinal plates may be used with one or more center plates. The center plate generally has a first end and a second end, and each end comprises one or more connecting rod bores which are capable of translating with the connecting rods of one or more longitudinal plates and/or other center plates. The center plate will optionally comprise a slit at each end, locking means bores and bone screw bores, having features the same or similar to those described above for the longitudinal plates. The sliding bone plate assembly in this embodiment will have more than one observation window and is useful for treatment of multiple fractures in the bone.

The invention further comprises a method of attaching at least two pieces of a bone across a break. The method comprises placing the bone plate assembly across the break such that each longitudinal plate and other plates, such as one or more center plates, overlies a bone on each side of the break. For example, when a bone plate assembly having two longitudinal plates is used, a first longitudinal plate is placed on one side of the break and a second longitudinal plate is placed of the other side of the break. The longitudinal plates may be secured to the bone by bone screws which are placed through bone screw bores in each longitudinal plate, and any center plates. The longitudinal plates and center plates may then be moved to bring the break together, with the longitudinal plates and, optionally, center plate, translating with the connecting rods, and then the locking means can be used to lock the longitudinal plates and any center plates against the connecting rods thus establishing a longitudinal length of the bone plate assembly with the broken pieces of the bone proximate to one another for healing. The connecting rods have an axial dimension that is not completely within the rod bores and, thus, the connecting rods and ends of the longitudinal plates and center plates define one or more windows within the bone plate assembly which allows the surgeon to see the bone surface coming together under the plate when applying the bone plate to a patient.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a top plane view of the sliding bone plate assembly of a preferred embodiment of the present invention.

Figure 2 is a top plan view of the first longitudinal bone plate 102 of Figure 1.

Figure 3 is a side view of the longitudinal plate 104 of Figure 2.

Figure 4 is a cross section of the longitudinal plate 104 of Figure 2 taken along lines 4-4.

Figure 5 is a cross section of the longitudinal plate 106 of Figure 2 taken along lines 5-5.

Figure 6 is a cross-section of the first longitudinal bone plate 102 taken along lines 6-6 of Figure 1.

Figure 6A is an enlarged view of detail D of Figure 6.

Figure 6B is an end view of the longitudinal plate 102, illustrating the locking slot, 126, on end, 112, of the plate, 102

Figure 7 is a top plane view in partial cross-section of the second longitudinal bone plate 104 of Figure 1, with the prongs of the first longitudinal plate shown by dotted lines.

Figure 8 is cross-sectional view of the sliding bone plate assembly pictured in Figure 7, taken along lines 8-8, illustrating the prongs of plate 104 within the bores of the plate 104.

Figure 9 is a partial cross-section of the prong plate of Figure seven taken along lines 9-9.

Figure 10 is a top plan view of an alternative embodiment of the sliding bone plate according to the present invention.

Figure 11 is a top perspective view of a longitudinal plate according to an embodiment of the invention.

Figure 12 is a bottom perspective view of the longitudinal plate of Figure 11.

Figure 13 is a top perspective view of a large-top set screw in accordance with an embodiment of the invention.

Figure 13A is side elevation of the large-top set screw of Figure 13.

Figure 14 is a top perspective view of a connecting rod in accordance with an embodiment of the invention that may be incorporated into the bone plate assembly of the invention.

Figure 15 is a top perspective view of a bone plate assembly according to an embodiment of the invention.

Figure 16 is a perspective exploded view of the bone plate assembly of figure 15.

Figure 17 is a side view of a bone plate assembly according to an embodiment of the invention.

Figure 18 is a top view of a bone plate assembly according to an embodiment of the invention.

Figure 19 is a bottom view of a bone plate assembly according to an embodiment of the invention.

Figure 20 is an end view of a bone plate assembly according to an embodiment of the invention.

Figure 21 is a cross section view of a bone plate assembly along line A-A of figure 15.

Figure 22 is a top perspective view of a bone plate assembly according to an embodiment of the invention.

Figure 23 is a perspective exploded view of the bone plate assembly of figure 22.

Figure 24 is a top view of a bone plate assembly according to an embodiment of the invention.

Figure 25 is a bottom view of a bone plate assembly according to an embodiment of the invention.

Figure 26 is a cross section view of a bone plate assembly along line A-A of figure 22.

Figure 27 is a perspective side view of a center plate of a bone plate assembly according to an embodiment of the invention.

Figure 28 is a perspective top view of a center plate of a bone plate assembly according to an embodiment of the invention.

Figure 29 is a top view of a center plate of a bone plate assembly according to an embodiment of the invention.

Figure 30 is a bone plate assembly having a longitudinal plate according to an embodiment of the invention.

Figure 31 is a bone plate assembly having a longitudinal plate according to an embodiment of the invention.

Figure 32 is a bone plate assembly having a longitudinal plate according to an embodiment of the invention.

Figure 33 is an exploded perspective view of the bone plate assembly in accordance with an embodiment of the invention wherein the connecting rods comprise retaining pin holes.

Figure 34 is an exploded perspective view of the bone plate assembly in accordance with an embodiment of the invention wherein the connecting rods have threaded ends.

Description of the Preferred Embodiments

As shown in Figure 1 in an embodiment of the invention, the sliding bone plate assembly, 100, of the present invention is comprised of a first longitudinal plate, 102, and a second longitudinal plate, 104. The first longitudinal plate has an end, defined by at least two spaced prongs, 108. The spacing of the prongs permits an observation window, 110, between the prongs and the plates. As may be seen in Figure 1, the prongs 108 are located at the lateral edges of the plate to open up the window, 110.

The other end, 112, of the first longitudinal plate comprises means for fastening the plate to a body structure, such as, for example, a bone. In this particular embodiment the means comprises threaded through holes, 114, for receiving bone screws, not shown. The assembly may further include a bone screw having a shaft that can be inserted into the through hole and into a bone. The shaft can be threaded to cooperate with the threading in the through holes. The threading and shaft portion of the bone screws may be of a variety of standard designs, or a particular design which may be found more secure than the standard ones. The means, however, may comprise holes which are not threaded and holes which are spherical to allow angulation of the bone screws.

As may best be seen in reference to Figures 2, 4 and 6, the holes, 114, for the bone screws include a recessed pocket having an upper edge, 116, and a lower edge, 118. The recessed pocket contains the head of the bone screw, and any coupling therefore, such as disclosed in US Patent No. 4,689,134, so that neither protrudes from the surface of the bone plate to irritate the surrounding tissues.

Bone plates in general are constructed with both a longitudinal and lateral curvature so that the plates fit snugly against the curvature of the body structure. The first longitudinal plate, 102 has an upper longitudinally curved surface, 120, as well as a lower longitudinally curved surface, 122. The second longitudinal plate has similar upper longitudinally curved surface, 130, and lower longitudinally curved surface, 128, to lend an uninterrupted longitudinal curve to the sliding bone plate assembly.

As shown in Figure 2 of the prongs and plate of the first longitudinal plate may be reinforced, as by reinforcing rod, or tube, 124, which may be constructed of titanium, stainless steel, or other material to reinforce and strengthen the prong and/or plate.

As illustrated in Figure 7, the second longitudinal plate, 104, has an end, 132, defined by at least two straight prong bores, 134. These bores do not follow the longitudinal curvature of the second longitudinal plate, but begin near the lower surface of the second plate and rise towards the upper surface. The straight prong bores make the second longitudinal plate easier and less expensive to manufacture. The straight prong bores also make the first longitudinal plate easier and less expensive to manufacture, as the prongs need not have a longitudinal, or lengthwise, curvature. In addition the straight prong bores permit the prongs to be readily translated longitudinally through the bores, to adjust the length of the plate assembly.

At the other end, 140, of the second longitudinal plate 104, are means for fastening the plate to a body structure, such as, for example, bone. The means illustrated are holes, 142, which may be threaded, for receiving e.g. bone screws. Is preferred that the holes, 142, be recessed, as shown, the recessed beginning at the upper edge, 148, and curving to the lower edge 150, to form a pocket for receiving the head of the bone screw and any coupling means included therewith.

As may be seen in Figure 8, the combination of the prong bores, 134, the recessed pockets for the bone screws, and the holes, 152, for set screws, to be described late, result in columnar structures, 138, which lend strength to the plate overall, and to the fastenings made by the bone screws and the set screws.

Located adjacent end, 132, of the second longitudinal plate, is a locking mechanism. In this embodiment, the locking mechanism comprises at least one threaded hole, 152, for a set screw. As shown, the threaded set screw hole, 152, is also recessed within a pocket defined by upper edge, 154, and lower edge, 156. As may be seen in Figure 9, the prong bores, 134, have inner surfaces, 135. When the prongs are placed in the prong bores, and a set screw rotated into the threaded set screw hole, 152, the set screw separates the prongs, presses against each prong and forces them against the inner surfaces, 135, locking the prongs in the bores, and fixing the longitudinal length of the assembled bone plate. This fastening may be easily adjusted by backing out the set screw and readjusting the position of the prong in the bore. Preferably, the head of the set screw includes a recess that can be mated with a standard tool, such as a screw driver, to rotate the screw to fasten or readjust the fastening.

As shown in Figures 1, 6A, 6B, and 7, the ends of the plate are supplied with means such as the locking slots, 126, which may be engaged by closure means provided with plate assembly, to assist in moving of the plates together.

In use, the surgeon places the assembled bone plate atop a fracture in the bone, to determine where the bone screws should be placed. Thereafter the surgeon may fasten one of the longitudinal plates to one side of the fracture, and then open up the plate assembly, moving the prongs out of the bores, and freeing the other plate. The other plate may then be placed atop the bone of the other side of the fracture and bone screws or other means used to screw the plate to the bone. Thereafter the bone surfaces may be brought together by inserting the prongs in the prong bores, and moving the two longitudinal plates together. During this process the surgeon may carefully observe the edges of the fracture coming together, by viewing the edges of the fracture through the observation window between the prongs.

Figure 10 illustrates an alternative embodiment of the sliding bone plate according to the present invention. In Figure 10, the threaded holes, 114, in the first longitudinal plate are located at an angle to the longitudinal direction of the plate, and spaced wider apart from each other, by using a dog bone plate configuration. The threaded holes, 142, for the bone screws in the second longitudinal plate are similarly oriented. This configuration permits the surgeon to "toe" the bone screws at each end of the plate towards each other, to provide greater assurance that the bone screws will not pull out.

As may be seen in Figure 8, with respect to the embodiment of Figures 1-9, the prong bores, 134, intersect with the pockets of the bone screw holes 142. To lock the plate 104a with a plate 102, the prongs, 108 are inserted into the bores, when the threads, 162 of the screw 160, engage the threads of set screw hole 152a, further rotation of the screw crushes the top 144, and bottom, 146, of the plate, locking down the prongs in the bores.

Figure 14 illustrates a rod which may be used to create a pronged plate, like plate 102, from a plate with a slit and set screw holes 152a and 104a, using the locking mechanism described above. The rod, 166 may be provided with a curved surface 168, which mimics the curved surface 135 of the prongs of plate 102. Using two plates, 104a, two large-top set screws, 160 and two rods, 166, one can assemble an interlocking, adjustable length bone plate, as, for example, by placing the two prongs into the bores of one plate, 104a, and locking them in with a large-top set screw. If the prongs have the curvature, 168, they should be placed in the bores such that the curvature, 168, of the extending prongs will align with the curve of the recessed pocket for the bone screw holes, 142, once the prongs are inserted into the bores of the second plate.

In the preferred embodiments shown, in the first longitudinal plate has two prongs, however it should be understood that more than two prongs may be utilized. In the embodiment shown in Figures 1-9, only one threaded set screw hole, 152, is shown, and in Figure 10, two locking holes are shown. It should be understood that the locking mechanism of the sliding bone plate of the present invention may comprise any number of threaded set screw holes, 152, for use by the surgeon. In addition, any number of bone screw holes, 114, and 142 may be provided in the first and second longitudinal plates, respectively, for use by the surgeon as he/she sees fit. Other variations on design will be obvious to those skilled in the art.

Figures 11 to 34 illustrate further embodiments of the invention. As shown, for example, in figures 15-21, this bone plate assembly (i.e., sliding bone plate assembly) 200 comprises a first longitudinal plate 201 and a second longitudinal plate 202. Representative longitudinal plates are more particularly shown in Figs. 11 and 12. In this embodiment, each longitudinal plate, 201/202 has a first end 203, a second end 204, a forward side 205 and a distal side 206.

As shown in figures 11 and 12, and also in figures 15-21, the first end 203 may have lateral curvature having an upper arc point 207 about equidistant from the forward side 205 and distal side 206 of the longitudinal plates. The first end comprises the locking slot 126 at about the upper arc point 207. In addition, the first end comprises a first end upper longitudinally curved surface 208 and a first end lower longitudinally curved surface 209.

The forward side 205 of each longitudinal plate comprises a forward side upper longitudinally curved surface 210 and a forward side lower longitudinally curved surface 211. Also, the distal side 206 of each longitudinal plate comprises a distal side upper longitudinally curved surface 212 and a distal side lower longitudinally curved surface 211. The forward side upper longitudinally curved surface 210, forward side lower longitudinally curved surface 211, the distal side upper longitudinally curved surface 212 and distal side lower longitudinally curved surface 211, together with the first end upper longitudinally curved surface 208 and a first end lower longitudinally curved surface 209 provide each longitudinal plate, and the bone plate assembly, with an uninterrupted longitudinal curve. Also, as discussed above, the longitudinal and lateral surfaces allow the bone plates, to fit snugly against the curvature of the bone structure. Each longitudinal plate, particularly as shown in figures 11 and 12, has an upper surface 236 and a lower surface 237. The lower surface generally comprises a concave arcuate section 238 which further facilitates the snug fit of the bone plate against the curvature of the bone structure.

The second end may be flush, but is preferably concave shaped. Each longitudinal plate comprises two or more rod bores which are defined by rod bore walls and rod bore ends. For example, in the embodiment of the invention shown in figures 11-12 and 15 - 21, the second end has a forward rod bore 212 defined by a forward rod bore wall 212a and a forward rod bore end 212b and a distal rod bore 213 defined by a distal rod bore wall 213a and a distal rod bore end 213b. The two or more rod bores, i.e. the forward rod bore 212 and distal rod bore 213 extend longitudinally from the second end to a point between the second end and the first end of each longitudinal plate. In an embodiment of the invention one, or both, rod bores in each longitudinal plate may be threaded.

Each longitudinal plate optionally comprises a slit 214 which, as shown in figures 11-12 and 16-21, has a slit opening 215 proximate to the second end and extends longitudinally from the slit opening at the second end to a point between the second end and the first end of each longitudinal plate. The slit 214 has a slit upper wall 216 and a slit lower wall 217, and the gap between the slit upper wall 216 and a slit lower wall 217 to the slit end 250 defines the slit 214. The slit optionally, as shown in drawings 11-12 and 15-21, has three sections. One is a forward section 218 which has a forward opening at the lateral side 205 and extends to a point on the forward bore wall thereby providing a gap in the forward bore wall with the gap between the slit upper wall 216 and a slit lower wall 217 from the forward side to the forward rod bore to the slit end 250 defining the forward section 218 of the slit 214. The second section is the central section which extends from an opening on the forward rod bore, opposite to the point where the forward section intersects the forward rod bore, to a point on the distal rod bore. Thus, the gap between the slit upper wall 216 and a slit lower wall 217 from the forward rod bore to the distal rod bore to the slit end 250 defines the central section 219 of the slit 214. The third section, the distal section 220 of the slit 214, extends from an opening on the distal rod bore, opposite to the point where the central section intersects the distal rod bore, to a point on the distal wall. Thus, the gap between the slit upper wall 216 and a slit lower wall 217 from the distal rod bore to the distal side of the longitudinal plate to the slit end 250 defines the distal section 220 of the slit 214. The slit 214 is preferably along the midline of each longitudinal plate, the midline being the point about halfway between the top surface and a longitudinal plane of the lowest point on the lower surface of each longitudinal plate.

Each longitudinal plate may further comprise one or more locking means bores and one or more bone screw bores, both of which may be threaded. However, in an embodiment of the invention the bone screw bores have smooth surfaces and are not threaded. As shown in figures 11-12 and 15-21, each longitudinal plate comprises one locking means bores 221 and two bone screw bores 222. The slit of each longitudinal plate extends from the second end through the locking means bores and terminates proximate to one of the bone screw bores preferably the bone screw bore proximate to the locking means bore.

The bone plate assembly further comprises one or more connecting rods 223 which are generally shown in figure 14 but more specifically shown in figures 16, 33 and 34. The connecting rods are generally cylindrical in shape having a curved continuous outer surface, a first end 224 and an opposite second end 225. Each connecting rod, at both the first end 224 and second end 225, has a recessed section, i.e. a first end recessed section 226 and a second end recessed section 227. Each recessed section generally has a concave section 228a and 228b and an adjacent cut in section 229a and 229b. The connecting rods may have different longitudinal length. As shown in figure 34 one end, either the first and or second end, may be threaded, i.e., comprise threading 3301, to mate with threaded rod bores 3303 in the longitudinal plates and/or the center plates discussed below. It should be understood that the connecting rods may be threaded at either or both ends.

The connecting rods may optionally comprise one or more slots. The slots generally extend from a point on the surface of each rod to an opposite point on the surface and are an opening within the rod defined by a slot inner surface. As shown in the drawings, each rod optionally has a first slot 230a and 230b and a second slot 231a and 231b. The slots may be aligned at a defined angle to the plane of the recessed sections. As shown particularly in figure 33, the connecting rods may have one or more retaining pin holes, such as, as shown in figure 33, a retaining pin hole 3302 proximate to one end of the connecting rod defined by retaining pin hole walls which extend completely through the connecting rod, i.e., from one side of the continuous rod to a point on the opposite side, and may be angulated. The retaining pin hole 3302 may be threaded. It should be understood that the connecting rods may have retaining pin holes at either end of the connecting rod, or at both ends.

The bone plate assembly may optionally comprise one or more retaining pins. As shown in Fig. 16, the retaining pins 232 are cylindrical elements having a first end 233, a second end 234 and a continuous outer surface 235 between the ends. The retaining pins may have threaded sections. For example, the continuous outer surface of the retaining pin may be smooth or may have threads either at the first end or second end of the retaining pin, at both the first end and second end of the retaining pin or along the entire continuous outer surface of the retaining pin.

Threading of the retaining pin facilitates intermixing of the longitudinal plates and/or center plates by the surgeon when treating a patient with broken bone(s) and in certain embodiments may be used to affix one or more connecting rods to a center plate or longitudinal plate.

Each longitudinal plate may optionally, as shown in figures 11-12 and 15-21, comprise one or more retaining pin bores 239 which are defined by retaining pin bore walls which extend vertically from the top of each longitudinal plate to the bottom surface of each longitudinal plate. The retaining pin bores are proximate to the locking means bores, and in this embodiment the bone plate assembly comprises four retaining pin bores, a first retaining pin bore 240, a second retaining pin bore, 241, a third retaining pin bore 242 and a fourth retaining pin bore 243. The retaining pin bores may be threaded either at each end, both ends or along the entire retaining pin bore wall to interact with threaded retaining pins. In the embodiment of the invention, such as that shown in figure 33 wherein the connecting rod has one or more retaining pin holes defined by retaining pin hole walls, the retaining pin holes are aligned with the retaining bores when the connecting rod is translated through the connecting rods and then the retaining pin can be applied through the retaining pin bore of the longitudinal plate (or center plate which is discussed below) and the retaining pin hole of the connecting rod. In the embodiment of the invention wherein the retaining pin, retaining pin bore and retaining pin hole are threaded, this effectively secures, or affixes, the connecting rod to the longitudinal plate (or center plate) which precludes movement of the connecting rod within the particular rod bore of the longitudinal plate (or center plate).

Figs. 13 and 13a show a locking means which may be used in accordance with an embodiment of the invention. The locking means comprises a large-top set screw, 160 having a top section 164 and a threaded section 162. The top section 164 which has a breadth, i.e. diameter, greater than the diameter of the threaded section 162. The top section has an upper surface 164a, an upper section 164b having a diameter and a frustoconical section 164c which has a diameter that tapers from the diameter of the upper surface and upper section to the diameter of the threaded section. The locking means may further have a recessed section 164d to accommodate a tool for tightening the locking means.

In the embodiment of the invention shown in figures 15-21, the bone plate assembly comprises a first longitudinal plate 201, a second longitudinal plate 202, two connecting rods (a distal rod 251 and forward rod 250) and two large top set screws (a first large top set screw 253 and a second large top set screw 254). The bone plate assembly may also, optionally, comprise four retaining pins. The bone plate may be assembled by inserting the first ends of the connecting rods into the bore holes of the first longitudinal plate and the second ends of the connecting rods into the second longitudinal plate of the bone plate. When the optional retaining pins are used, slots in the connecting rods are proximate to the retaining pin bores to allow the retaining pins to be inserted into the retaining pin bores and through the slots. When the connecting rods have retaining pin holes, the connecting rods may be effectively secured within the forward rod bore and distal rod bore of the first longitudinal plate or second longitudinal plate and then the opposite ends of the connecting rods may be slid into the rod bores of the corresponding plate to which the connecting rods are not effectively secured. Alternatively, one end of one of the connecting rods may be effectively secured within the distal rod bore of the first longitudinal plate and one end of the other connecting rod may be effectively secured within the forward rod bore of the second longitudinal plate, or vice versa, and then the free ends of the connecting rods can be slid in the vacant rod bores of the opposite longitudinal plate, and similar sequencing can be used when the bone plate assembly comprises center plates which are discussed below. When assembled, as shown in figures 15 and 18, for example, the bone plate assembly has the first longitudinal plate and second longitudinal plate with opposed second ends, and the gap between the opposed second ends framed by the connecting rods defines the observation window 299.

In a particular embodiment of the invention, the longitudinal plates and center plates do not necessarily require the slit and/or locking means bore. In embodiments of the invention wherein both the distal connecting rod and forward connecting rod are both affixed to the same longitudinal plate or center plate by either threaded connecting rods and/or connecting rods which comprise retaining pin holes for alignment with retaining pin bores in longitudinal plates or center plates which interact with retaining pins, all preferably threaded, there is no need to use the locking means to releasably secure the connecting rods to the longitudinal plate or center plate and, thus, the locking means bore and slit, as well as the locking means, are not necessary for those particular longitudinal plates or center plates. However, in embodiments wherein one connecting rod is affixed, either through threaded ends or with the use of the retaining pin hole and the other rod bore of the longitudinal plate or center plate is vacant, then the longitudinal plate and/or center plate should comprise slit and locking means bore.

Particularly as shown in figure 21, the locking means bores in the longitudinal plates each have an upper segment 244 and a threaded segment 245 and further comprise a frustoconical segment 246 that tapers from the diameter of the upper segment to the diameter of the threaded segment. The locking means bores are generally spherical and are defined by locking means bore walls, including walls of the segments as described below. Each longitudinal plate and each bone plate may comprise one or more locking means to interact with the locking means bores. The dimensions of the upper segment 244, frustoconical segment 246 and lower segment 245 complement the dimensions of the large top set screw such that the upper segment corresponds to the upper section of the large top set screw, the frustoconical segment corresponds to the frustoconical section of the large top set screw and the threaded segment corresponds to the threaded section of the large top set screw so that the large top set screws when secured into the locking means bores, are about flush with the top surface of the longitudinal plate, i.e. the large top set screw is recessed into the longitudinal plate. Likewise, as shown in Figure 21, each bone screw bore is defined by bone screw bore walls, including walls of the segments in that each bone screw bore has an upper segment 247, frustoconical segment 248 and lower segment 249, with the diameter of the frustoconical segment tapering from the diameter of the upper segment to that of the lower segment, which complements the shape of the bone screw similar to that discussed above for the large top set screw and locking means bore so that, when inserted into the bone screw bore, the top surface of the bone screw is flush, or about flush, with the upper surface of the longitudinal plate such that the bone screws are recessed into the longitudinal plate. Also, the bone screws will lock with the bone screw bores and also the bone of the patient.

A further embodiment of the invention is shown in figures 22 – 29. In this embodiment, the bone plate assembly 300 comprises a center plate 301 for receiving the ends of one or more connecting rods 223 or connecting rods from other center plates. In this embodiment, the bone plate 300 also comprises the first longitudinal plate and second longitudinal plate and other elements associated therewith, i.e., the locking means, optional retaining pins and such, as depicted, which are described above with respect to the embodiment of the invention shown in Figs. 11 – 21. The center plate may comprise one or more, such as two or more, rod bores defined by at least rod bore walls. For example, the center plate comprises two or more first end rod bores which may extend from the first end to a point between the first end and second end, which are defined by first end rod bore inner walls and a first end rod bore end walls, and two or more second end rod bores which may extend from the second end to a point between the first end and second end which are defined by second end rod bore inner walls and second end rod bore end walls. Also, in place of two or more first end rod bones and two or more second end and rod bones, the center plate may comprise two or more continuous rod bores which extend from the first end to the second end each defined by continuous rod bore walls and each having a first opening at the first end of the center plate and a second opening at the second end of the center plate. One or more of the rod bores may be threaded to mate with threaded connecting rods, for example one rod bore at the first end of the center plate may be threaded and one rod bore at the second end of the center plate may be threaded, or all the rod bores of the center plate may be threaded, including embodiments comprising threaded continuous rod bores.

As particularly shown in figures 27 and 28, for example, the center plate has a first end 302 and a second end 303. As shown in figures 24 and 25, the center plate 300 has a top surface 304 and a bottom surface 305. The center plate further comprises a forward longitudinal side 306 and distal longitudinal side 307. Similar to the sides of the longitudinal plates, the forward longitudinal side of the center plate comprises a forward center plate upper longitudinally curved surface 308 and a forward center plate lower longitudinally curved surface 309, and the distal longitudinal side of the center plate comprises a distal center plate upper longitudinally curved surface 310 and a distal center plate lower longitudinally curved surface 311. As discussed above, the curved shape of the longitudinal and lateral surfaces allow the bone plates to fit snugly against the curvature of the bone structure. The lower surface of the center plate also generally comprises a concave arcuate section which further facilitates the snug fit of the bone plate against the curvature of the bone structure.

In the embodiment of the invention comprising a center plate, as shown in figures 22-29, the center plate may comprise at least two, such as two, locking means bores, a first locking means bore 312 proximate to the first end 302 and a second locking means bore 313 proximate to the second end 303. The first and second locking means bores of the center plate are the same shape and have similar features as the locking means bores described above with respect to the longitudinal plates. The center plate further comprises one or more, such as three bone screw bores 314a, 314b and 314c which are laterally between the first bone screw bore and second bone screw bore and have the same shape and configuration as described above with respect to the bone screw bores of the longitudinal plates.

The center plates may optionally comprise a slit at both ends of the center plate or a slit at one end. Referring particularly to figure 27, the center plate comprises a first slit 315 at the first end of the center plate. The center plate further comprises a first end forward rod bore 317 which extends from the first end of the center plate longitudinally proximate to the bone screw bore 314a next to the first locking means bore 312 and a first end distal rod bore 318 which also extends from the first end of the center plate longitudinally proximate to the bone screw bore 314a next to the first locking means bore 312. The first slit and second slit have the same shape, configuration and defining elements as described above with respect to the slit in the longitudinal plates. For example, the first slit has a first slit opening 390 at the first end and is defined by first slit upper wall 321 and a first slit lower wall 322 and a first slit end 323 and comprises three sections, the first a forward section 319 which has a forward opening at the forward longitudinal side 306 and extends to a point on the first end forward rod bore 317, the second a central section 320 which extends from an opening on the first end forward rod bore, opposite to the point where the forward section intersects the first end forward rod bore 317 to a point on the first end distal rod bore 318, and third, a distal section which extends from an opening on the first end distal rod bore 318, opposite to the point where the central section intersects the first end distal rod bore, to a point on the distal longitudinal side 307. The gap between the first slit upper wall 321 and first slit lower wall 322 and the first slit end 323 defines the first slit 315. The first slit 315 is preferably along the midline of each center section, the midline being the point about halfway between the top surface and a longitudinal plane of the lower surface of the center plate.

Referring particularly to figure 28, the center plate comprises a second slit 316 at the second end 303 of the center plate. The center plate further comprises a second end forward rod bore 324 which extends from the second end of the center plate longitudinally proximate to the bone screw bore 314c next to the second locking means bore 313 and a second end distal rod bore 325 which is also from the second end of the center plate longitudinally proximate to the bone screw bore 314c next to the second locking means bore 313. As mentioned above, the first slit and second slit have the same shape, configuration and defining elements as described above with respect to the slit in the longitudinal plates. For example, the second slit has a second slit opening 391 at the second end and is defined by second slit upper wall 326 and a second slit lower wall 327 and a second slit end 328 and comprises three sections, the first a forward section 329 which has a forward opening at the forward longitudinal side 306 and extends to a point on the second end forward rod bore 324, the second a central section 330 which extends from an opening on the second end forward rod bore 324, opposite to the point where the forward section intersects the second end forward rod bore 324 to a point on the second end distal rod bore 325, and third, a distal section 331 which extends from an opening on the second end distal rod bore 325, opposite to the point where the central section intersects the second end distal rod bore, to a point on distal longitudinal side 307. The gap between the second slit upper wall 326 and second slit lower wall 327 and the second slit end 329 defines the second slit 316. The second slit 316 is preferably along the midline of each center section, the midline being the point about halfway between the top surface and a longitudinal plane of the lower surface of the center plate.

As discussed above, the center plate may comprise continuous rod bores in lieu of rod bores at each end. Thus, in an embodiment of the invention, the center plate may comprise a forward continuous rod bore proximate to the forward longitudinal side 306 having a first opening at the first end and a second opening at the second end and is defined by a forward continuous rod bore wall, generally cylindrical in shape, which extends from the first opening to the second opening of the forward continuous rod bore. Likewise, the center plate, in this embodiment, also comprises a distal forward rod bore proximate to distal longitudinal side 307 of the center plate having a first opening at the first end and a second opening at the second end and is defined by a distal continuous rod bore wall, generally cylindrical in shape, which extends from the first opening to the second opening of the distal continuous rod bore. In this embodiment, the sections of the first slit and second slit would be defined as discussed above, but with respect to the forward continuous rod bore and distal continuous rod bore as opposed to the first end forward rod bore, first end distal rod bore, second end forward rod bore and second end distal rod bore.

As shown in figure 23, the center plate may optionally comprise one or more, preferably four, retaining pin bores 331 and one or more, preferably four, retaining pins 332. These retaining pin bore holes 331 and retaining pins 332 function the same as discussed above with respect to the longitudinal plates. As mentioned above, one or more, including two, three or four, of the retaining pin bores may be threaded.

In the embodiments of the invention discussed above wherein two connecting rods are affixed to rod bores at one end, or both ends, of the center plate by threaded connecting rods and/or the use of retaining pins with retaining pin bores and retaining pin holes, no slit or locking means bore may be necessary. For example, when the rods at both ends are affixed, then the center plate need not comprise slits or locking means bores and when the connecting rods at one end are affixed at either the first end or second end, the end where the connecting rods are affixed does not comprise a slit or a locking means bore proximate thereto, however there should be a slit and locking means bore at or proximate to the opposite end. When only one connecting rod is affixed at either or both ends of center plate with one or more rod bores vacant at both ends, then a slit and locking means bore is necessary proximate to each the first end and second end of the center plate.

As shown in figures 23-24, the center plate may be used in conjunction with longitudinal plates to make up a bone plate. In the embodiment of the invention shown in figures 23-24, ends of connecting rods extending from the longitudinal plates are inserted into and translate within the connecting rod bore holes of the center plate to form a bone plate 333, shown in figure 24 for example, having dual observation windows 334 and 335. This embodiment comprises the use of a second distal connecting rod and second forward connecting rod which connect between the center plate at the second end and the second longitudinal plate. It should be understood that one or more center plates may be used in which case the bone plate would have three or more windows. Thus, the invention encompasses plates having more than one center plate with two longitudinal plates which comprise two or more windows, or a number of windows equal to one plus the number of center plates. Bone plates having more than one center plate are particularly useful when used to treat multiple fractures by providing a window over each fracture area. Also, the connecting rods may have at least one threaded end to mate with threaded rod bores in the longitudinal plates or center plates, and may have at least one retaining pin hole, which correspond to retaining pin bores in the longitudinal plates or center plates, and the retaining pin hole may be threaded.

For example, when a bone is fractured in two places, the surgeon will place one longitudinal plate over one side of one of the breaks, the center plate over the bone between breaks and the other longitudinal plate over the bone on the other side of the second break. The plates would be secured to the bone with one or more bone screws in each of the longitudinal plates and in the center plate. The breaks can be brought together by moving the longitudinal plates and/or center plates in a direction to move the bone together, and then the longitudinal plates and/or center plates can be fixed in location by applying the large top set screw. The surgeon then applies more bone screws through available bone screw bores, if desired. Various lengths of connecting rods may be used to further accommodate breaks in two or more places in the bone of a patient, and also to accommodate use of the center plates comprising continuous connecting rod bores.

In an embodiment of the invention, the bone screws may further set the longitudinal plates, and when used, the center plate, in place by urging the connecting rods towards the distal side and/or forward side of the longitudinal plate or center plate. The recessed section of the connecting rods may be placed adjacent to, or, preferably partially within one or more of the bone screws bores, preferably the upper segment 247 and/or frustoconical segment 248 such that the recessed section partially overlays the bone screw bore and when the bone screw is inserted into the bone screw bore and translates through the bone screw bore, the connecting rod proximate to the lateral side is urged towards lateral side and the connecting rod proximate to the distal side is urged towards the distal side thereby increasing frictional forces between the connecting rods and the inner surfaces of the connecting rod bores. For example, in figure 16, bone screw bores 250 and 251 show the recessed section of the connecting rods overlaying the upper segment 247 and/or frustoconcial segment 248 of the bone screw bore. As such, when the bone screw is inserted into the bone screw bore the distal connecting rod is urged towards the distal side of the longitudinal plate and the forward connecting rod is urged towards the forward side of the longitudinal plate, thus increasing the frictional forces between the connecting rods and the inner surfaces of the connecting rod bores. Figure 24 shows bone screw bores 336, 337, 338 and 339 as having the recessed section of connecting rode partially overlaying the bone screw bores, as discussed above.

Also, with respect to the large top set screws and bone screws, because the structure of the locking means bores and bone screws bores compliment the configuration of the large top set screws and bone screws, as discussed above, the large top set screw and bone screws are flush with the upper surface of the longitudinal plates and, when used, the center plate. Thus, the large top set screw and bone screw counter sink within the longitudinal plates and center plate and are recessed into the longitudinal plates and/or center plate(s). This will aid in precluding toggle and bone twisting.

Although the invention is described above with respect to bone plates having connecting rods which can translate within connecting rod bores, it should be understood that the connecting rods may be secured to or integral with the longitudinal plates and/or center plates at one or both end(s). In an embodiment of the invention this may be achieved by use of connecting rods with at least one end being threaded to mate with a threaded connecting rod bore in the longitudinal plate or center plate. In a further embodiment, this may be achieved with connecting rods comprising at least one retaining pin hole and translating a retaining pin, possibly threaded, within the retaining pin bore of the longitudinal plate or center plate and the retaining pin hole of the connecting rod and; retaining pin bore and retaining pin hole may, optionally, be threaded. As such, the longitudinal plates and/or center plates would have one or more rods, which cannot slide within one or more connecting rod bores of the longitudinal plates and/or center plate. As discussed above, if the connecting rods are both affixed to or integral with one of the longitudinal plates or one or both ends of a center plate, then no locking means or slit is needed for at least one of the longitudinal plates and/or center plate, or one end of the center plate. In these embodiments, the rods are permanently affixed and work with center plates and/or longitudinal plates having rod bore holes with the locking means to provide adjustability to the bone plate.

Figure 30 shows a further embodiment of the invention wherein the longitudinal plate has an "L-shaped" configuration. In this embodiment the longitudinal plate has a first end 401, a second end 402, a forward side 403, a distal side 405 and a bump out 406. As with the other bone plates described herein, the ends and sides of this longitudinal plate have upper and lower longitudinally curved surfaces. The forward side 403 extends from the second end to the first end 401 and the first end 401 extends about perpendicularly from the forward side 403 to the bump out 406. The bump out 406 comprises curvature 407 which extends from the distal termination point 408 of the first end to the distal termination point 409 of the distal wall 405. The distal wall extends from the second end 402 to the bump out 406 and generally has a lateral section 412 which is parallel or about parallel to the forward side 403 and a perpendicular section 411 which extends at an angle, preferably perpendicular or about perpendicular, from the lateral section 412 and a curved piece 411 which is between the lateral section 412 and perpendicular section 410 providing smooth curvature between these sections. The bone plate in this embodiment of the invention may comprise a bone screw hole 413 from a top surface to a bottom surface of the longitudinal plate proximate to the bump out 407 and about perpendicular to the other bone screw bores (shown as 414 in figure 30) and locking means bores (shown as 415 on figure 30).

Figure 31 shows another embodiment of the invention. In this embodiment, the longitudinal plate 500 has a "t-shaped" configuration. The longitudinal plate has a first end 501 and a second end 502. The second end 502 has the same configuration and features as discussed above with respect to the longitudinal plates in the other embodiments of the invention. The "t-shaped" longitudinal plates comprise mutually opposed lobes, the forward lobe 503 and distal lobe 504. The "t-shaped" longitudinal plate also comprises a forward side 505 and a distal side 506. As with the other bone plates described herein, the ends and sides of this longitudinal plate 500 have upper and lower longitudinally curved surfaces.

The first end 501 has a forward termination point 508 and a distal termination point 509. The forward side extends generally longitudinally from the second end to a forward side termination point 510 and the distal side extends generally longitudinally from the second end to the distal side termination point 511. The forward lobe 503 is adjacent to the first end and forward side and extends from the forward termination point 508 of the first end to the termination point 509 of the forward side. The forward lobe comprises a forward lobe first curved section 507 which is concave and adjacent thereto a forward lobe second curved section 512 which is convex. The forward lobe first curved section 507 and forward lobe second curved section 512 form a continuous curved surface. The distal lobe 504 is adjacent to the first end and distal side and extends from the distal termination point 509 of the first end to the termination point 511 of the distal side. The distal lobe 504 comprises a distal lobe first curved section 513 which is concave and adjacent thereto a distal lobe second curved section 514 which is convex. The distal lobe first curved section 513 and distal lobe second curved section 514 form a continuous curved surface.

The longitudinal plate 500 has an upper surface 515 and a lower surface 516, and the longitudinal plate is curved such that the upper surface has convex curvature and the lower surface has concave curvature with the uppermost point of the upper surface proximate to a centerline 519 of the longitudinal plate. A forward lobe bone screw bore 517 which extends from the upper surface to the lower surface is proximate to the forward lobe, and a distal lobe bone screw bore 518 which extends from the upper surface to the lower surface is proximate the distal lobe. The curvature of the longitudinal plate 500 allows the surgeon to place the longitudinal plate over the curvature of a broken bone. Because the longitudinal plate has curvature, when bone screws are inserted into the forward lobe bone screw bore 517 and distal lobe bone screw bore 518, the ends of the bone screws within the bone point towards each other, e.g., toe, which inhibits twisting of the bone plate and provides greater assurance that the bone screws will not pull out of the bone.

The longitudinal plate 500 further comprises at least one locking means bore (shown in figure 31 as 520) proximate to the second end at about the centerline 519 of the longitudinal plate and, optionally, two or more retaining pin bores and retaining pins (shown in figure 31 as a distal retaining pin bore 521a and a forward retaining pin bore 521b) proximate to the locking means bore. In addition, the longitudinal plate 500 may optionally comprise a supplemental bone screw bore 522 proximate to the locking means bore 510 at about the centerline 519 of the longitudinal plate.

Figure 32 shows another embodiment of a longitudinal plate of the invention. In this embodiment, the longitudinal plate 600 comprises a first end 601 which is comprised of a forward circular element 602 and a distal circular element 603 joined by a center section 604 having curvature. The forward circular element has a continuous side which extends from a first forward termination point 605 to a second forward termination point 604 such that the side is circular or semi-circular in orientation. Likewise, the distal circular element has a continuous side which extends from a first distal termination point 607 to a second forward termination point 608. The center section is adjacent to the second forward termination point 604 and the first distal termination point 607, and extends from the second forward termination point 604 to the first distal termination point 607. In a preferred embodiment, the second forward termination point 604 and the first distal termination point 607 oppose each other and the side 609 of the center section 604 has curvature creating a void between the forward circular element 602 and distal circular element 603 having semicircular surface which is such that the sides of the forward circular element, center section and distal circular element represent a continuous curved surface as shown in figure 32.

The longitudinal plate 600 further comprises a forward side edge 610 extending from the first forward termination point 605 opposite the first forward circular piece to a second end 612. Preferably, the forward side edge comprises first forward edge section 613 adjacent to the first forward termination point 605 and extending to a point more proximate to the second end and may be slanted from a forward position at the first forward termination point 605 to a more distal position at a third forward termination point 614, i.e., slanted towards the centerline 618 of the longitudinal plate. Adjacent to the first forward edge section 613 is a second forward edge section 615, which extends to a fourth forward termination point 616. Adjacent to the second forward edge section 615 is a third forward edge section 617 which is generally parallel to the centerline 618. In a preferred embodiment, because the first forward edge section 613 is slanted with respect to the centerline of the longitudinal plate and the third forward edge section is generally parallel to the centerline, the second forward edge section 615 may have curvature to provide a curved surface to join the first forward edge section 613 and a third forward edge section 617 such that the forward side edge has a continuous curved surface without any sharp edges joining the sides.

The longitudinal plate 600 further comprises a distal side edge 611 extending from the second distal termination point 608 opposite the distal circular piece to a second end 612. Preferably, the distal side edge comprises first distal edge section 619 adjacent to the second distal termination point 608 and extending to a point more proximate to the second end and may be slanted from a distal position at the second distal termination point 608 to a more forward position at a third distal termination point 620, i.e. slanted towards the centerline 618 of the longitudinal plate. Adjacent to the first distal edge section 613 is a second distal edge section 621, which extends to a fourth distal termination point 623. Adjacent to the second distal edge section 621 is a third distal edge section 622 which is generally parallel to a centerline 618. In a preferred embodiment, because the first distal edge section 619 is slanted with respect to the centerline of the longitudinal plate and the third distal edge section 622 is generally parallel to the centerline, the second distal edge section 621 may have curvature to provide a curved surface to join the first distal edge section 619 and a third distal edge section 617 such that the distal side has a continuous curved surface without any sharp edges joining the sides.

As in the other embodiments of the longitudinal plates described above, the ends and sides of longitudinal plate 600 have upper and lower longitudinal curved surfaces. The longitudinal plate 600 has an upper surface 624 and a lower surface 625, and the longitudinal plate is, optionally, curved such that the upper surface has convex curvature and the lower surface has concave curvature with the uppermost point of the upper surface proximate to a centerline 618 of the longitudinal plate. A forward bone screw bore 626, proximate to the forward circular element 602, extends from the upper surface to the lower surface, and a distal bone screw bore 627, proximate to the distal circular element 603, extends from the upper surface to the lower surface. The curvature of the longitudinal plate 600 allows the surgeon to place the longitudinal plate over the curvature of a broken bone. Because the longitudinal plate has curvature, when bone screws are inserted into the forward bone screw bore 626 and distal bone screw bore 627, the ends of the bone screws within the bone point towards each other, e.g., toe, which inhibits twisting of the bone plate and provides greater assurance that the bone screws will not pull out of the bone.

The longitudinal plate 600 further comprises at least one locking means bore (shown in figure 32 as 628) proximate to the second end about the centerline 618 of the longitudinal plate and, optionally, two or more retaining pin bores and retaining pins (shown in figure 32 as a distal retaining pin bore 629a and a forward retaining pin bore 629b) proximate to the locking means bore.

In the embodiments of the longitudinal plates 400, 500 and 600 (as shown in Figs. 30-32), the longitudinal plates will generally have the same features described above, such as the connecting rod bores, connecting rods and slits in order to secure the longitudinal plates to connecting rods and other longitudinal plates or center plates. Also, all of the longitudinal plates described herein, as well as center plates, are interchangeable and, thus the longitudinal plates and center plates can be formed into a number of different variations of the bone plate assembly using the connecting rods and locking means. For example, the longitudinal plate 600 could be used in conjunction with longitudinal plate 200, 400 or 500 with the use of the connecting rods, and further one or more center plates could be used in conjunction with such longitudinal plates. Any number of variations of longitudinal plates and center plates can be used together with connecting rods to form the bone plate assembly with one or more observation windows.

In any embodiment of the invention comprising locking means and locking means bores, the locking means is inserted into the locking means bores and rotated such that the threaded section of the locking means mates with the threaded segment of the locking means bore causing the locking means to recess into the locking means bore as the locking means is moved in a direction. As the large top set screw moves downward, the upper wall of the slit is caused to move towards the lower wall of the slit thus creating a frictional force between the bore hole walls and the connecting rods which restricts and precludes longitudinal movement of the longitudinal plates and center plates and/or the connecting rods thereby setting an longitudinal length of the bone plate. The lower wall of the slit may also be caused to move towards the upper wall fully or partially creating the frictional force. In effect, the locking mechanism crushes the slit and the locking means bores together to hold the longitudinal plates in fixed relationship to the rods. Because there is a gap between the ends of the longitudinal plates, and, if applicable, between the longitudinal plates and the center plates, these one or more gaps provide the surgeon with one or more windows to view the bone as he or she moves the bone plate together prior to selecting the appropriate therapeutic length.

The invention comprises a method for setting the broken bone of a patient. The method comprises providing one or more longitudinal plates and, optionally one or more center plates, providing one or more connecting rods, optionally providing one or more locking means and providing one or more bone screws. The method further comprises securing at least a first longitudinal plate to the first side of the break in a bone of a patient by translating a bone screw through a bone screw bore and connecting the bone screw to the bone, inserting connecting rods into the connecting rod bores of the first longitudinal plate, placing a second longitudinal plate over the bone on the second side of a break in the bone of a patient and translating connecting rods through the bore holes in the second longitudinal plate securing the second longitudinal plate to the bone by translating bone screws through a bone screw bore and connecting the bone screw to the bones, moving the longitudinal plates toward one another and providing and applying the locking means to set the length of the slidable bone plate assembly. The method further comprises applying more bone screws by translating bone screws through further bone screw bores on the longitudinal plates. Optionally, the method may further comprise the steps of aligning slots in the connecting rods with the retaining pin bores and inserting retaining pins in the retaining pin bores and slots. Another optional embodiment of the invention involves translating one or more connecting rods having at least one end that threaded into one or more threaded rod bores of one or more longitudinal plates and/or center plates. Yet a further embodiment comprises the step of aligning retaining pin holes in one or more connecting rods with retaining pin bores in one or more longitudinal plates and/or center plates and translating a retaining pin within the retaining pin bore and retaining pin hole. Preferably the bone screws used prior to the step of applying the locking means are placed into and translated through bone screw bores which are not proximate to the connecting rods, i.e., bone screw bores in the longitudinal plates (or center plates) which are not adjacent to the recessed sections of the connecting rods and/or do not have the recessed section partially within the bone screw bores, then the bone screw bores adjacent to connecting rods and/or having connecting rods within may be used for the bone screws applied after the locking means is applied.

The method may further comprise applying one or more center plates. In this embodiment, one center plate is placed over the second side of the break and additional connecting rods are used and inserted into the connecting rod bores on the second end of the center plate and then either additional center plates or the second longitudinal plate may be applied by translating the connecting rods from the second end of the center plate within the connecting rod bores of further center plates or the second longitudinal plate of the bone plate assembly. For example, the step of applying the center plate and additional connecting rods can be repeated over sides of broken bone by inserting the connecting rods, from the second end of the center plate into the first end of another center plate. The surgeon may either move and secure the longitudinal plate and center plate combination, or center plate and center plate combination either as each combination of pieces applied to the bone or after all pieces of the bone assembly are applied but before the locking means are applied. In any event, after the center plate is over the bone, the center plate may be secured to the bone by bone screws.

Methods wherein the connecting rods are permanently affixed to one or more longitudinal plates and/or center plates are also within the scope of the invention.

Thus, rather than attaching longitudinal plates and/or center plates, then inserting connecting rods and then other longitudinal plates and/or center plate(s), the surgeon may attach a longitudinal plate and/or center plate with permanently affixed connecting rod then place a second center plate and/or a second longitudinal plate over the other side of the break and translate the permanently affixed connecting rods within the connecting rod bores of this adjoining center plate and/or longitudinal plate or may attach a first longitudinal plate and/or center plate to one side of the break and then translate the permanently affixed connecting rods of a second longitudinal plate and/or center plate within the connecting rod bores of the first longitudinal plate or center plate and then affix the second longitudinal plate or center plate on the bone on the opposite side of the break. In a preferred method, the surgeon affixes a connecting rod with either a threaded end or a retaining pin hole to either the forward rod bore or distal rod bore of a longitudinal plate or one end of a center plate leaving either the forward rod bore or distal rod bore of the longitudinal plate or end of a center plate vacant. The surgeon then affixes a connecting rod with either a threaded end or a retaining pin hole in the forward rod bore or distal rod bore of a second longitudinal plate or end of a center plate leaving the forward rod bore or distal rod bore of the second longitudinal plate and/or end of center plate vacant. The surgeon can then place the first longitudinal plate or center plate over one side of the broken bone and the second longitudinal plate or center plate over another side of the broken bone and translate the connecting rod from one longitudinal plate or center plate in the vacant rod bore of the opposite longitudinal plate or center plate. For example, when the bone plate assembly comprises a first longitudinal plate and a second longitudinal plate, a connecting rod would be affixed to the forward rod bore of the first longitudinal plate and a connecting rod would be affixed to the distal rod bore of the second longitudinal plate or the connecting rod would be affixed to the distal rod bore of the first longitudinal plate and the forward rod bore of the second longitudinal plate.

In these methods, the surgeon moves the longitudinal plates and/or center plates to move the broken bones together for healing. The surgeon shall observe the bone pieces through the one or more observation windows, such as the observation windows defined by the connecting rods and all or some of 1) the second ends of the longitudinal plates, 2) the second end of a longitudinal plate and first end of a center plate, 3) the second end of a longitudinal plate and second end of a center plate and 4) the first end of a center plate and second end of a center plate.

The sliding bone plate and the longitudinal plates and center plates of the present invention may be constructed of any suitable biocompatible material, known to have sufficient structural strength and durability, such as stainless-steel, or titanium or titanium alloys. One example of such a material is ASTM F-136 titanium alloy (Ti 6AL-4V), which is a titanium alloyed with vanadium, or all ASTM materials. In addition the sliding bone plates and the longitudinal plates and center plates of the present invention may be made of polymeric material such as PEEK (poly ethyl ethylketone), either separately, with other polymers or with other materials, such as reinforcing members. The material should have sufficient flex to mimic the micromotion of normal bone, to stimulate bone growth; ceramic filled biocompatible polymers, or other biocompatible materials of sufficient strength to stabilize the bone during healing, or correct a fracture of the bone.

The bone plate assembly, the longitudinal plates and/or center plates may further comprise bioabsorbable drug delivery devices, such as implantable modular drug delivery devices. Examples of bioabsorbable drug delivery devices which may be used in the bone plate assembly, longitudinal plates and/or center plates are described in the co-pending application, U.S. Serial Number 11/135,256 filed May 23, 2005, IMPLANTABLE PROSTHETIC DEVICES CONTAINING TIMED RELEASE THERAPEUTIC AGENTS, which is incorporated herein in its entirety by reference. Such devices, for example, may be placed within a dedicated bore, such as a drug delivery bore or pockets for drug or nano release, in one or more of the longitudinal plates and/or center plates, or within a bone screw bore or locking means bore of one or more of the longitudinal plates and/or center plates.

Bioabsorbable surgical fasteners or bone screws made from bioabsorbable materials may be used to apply the bone plate assembly, i.e. to apply the longitudinal plates and/or center plates, to the bone of a patient. For example, the materials described in the co-pending patent application, U.S. Serial No. 11/025,231, filed December 29, 2004, SURGICAL FASTENERS AND RELATED IMPLANT DEVICES HAVING BIOABSORBABLE COMPONENTS, which is incorporated herein in its entirety by reference, may be used for the bone screws and the bone screws may be the surgical fasteners described in this co-pending patent application.

The present invention at least in a preferred embodiment provides a two piece bone plate which is easy and inexpensive to manufacture.

The present invention at least in a preferred embodiment provides separate longitudinal plates, optionally, center plates, connecting rods, and locking means to provide the surgeon with components of bone plates that can be assembled around the time of surgery into a bone plate for application to a patient.

The present invention at least in a preferred embodiment provides a two piece bone plate which permits an observation window allowing the surgeon to see the bone surface coming together under the plate.

The present invention at least in a preferred embodiment provides a two piece bone plate which provides a strong locking mechanism for fixing the overall length of the plate, and resisting bending of the plate.

The present invention at least in a preferred embodiment provides a bone plate which has an adjustable length, to permit the surgeon to fix the clinically effective length of the plate, permitting a better reconstruction or re-growth of bone at the fracture.

The present invention at least in a preferred embodiment provides a bone plate which resists bending, and thereby permits the surgeon better control of the movement of the underlying bone while adjusting the length of the plate.

The present invention at least in a preferred embodiment provides a controlled method for bringing together the pieces of bone using a two piece bone plate, while controlling the turning of the bone.

There has thus been shown and described a novel bone plate, e.g., sliding bone plate assembly which fulfills all the objects and advantages sought therefore. Many changes, modifications, variations and other uses and applications of the subject invention, will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawings which disclose the preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention, which is to be limited only by the claims which follow.

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Editorial Note

Please note that the following claims pages have been inadvertently numbered 10-13.

The claims defining the invention are as follows:

1. A bone plate assembly having an adjustable length and comprising:

a first longitudinal plate having a longitudinal curvature, a lateral curvature, an upper surface and a lower surface,

a first plate inner end comprising at least two spaced, straight longitudinal prongs,

a first plate outer end, and disposed proximate the first plate outer end at least one bone screw aperture passing through the upper surface and the lower surface and adapted to receive a bone screw for fastening the first plate to a bone, and

a second longitudinal plate having a longitudinal curvature, a lateral curvature, a length, a width, an upper plate surface and a lower plate surface,

a second plate inner end comprising at least two straight longitudinal bores, each straight longitudinal bore having an inner surface extending into and terminating within the second longitudinal plate and being adapted to receive one straight longitudinal prong,

a second plate outer end, and disposed proximate the second plate outer end at least one bone screw aperture passing through the upper plate surface and the lower plate surface and adapted to receive a bone screw for fastening the second plate to the bone,

said straight longitudinal prongs being smoothly translatable within said straight longitudinal bores to adjust the length of the bore plate assembly, and defining an observation window between the prongs and the plates, said bone plate assembly further comprising:

a locking mechanism to fix the length of the bone plate assembly the locking mechanism comprising:

at least one threaded set screw aperture disposed between the bores, the second plate inner end and the bone screw aperture, and

a set screw disposed in the set screw aperture,

wherein, when the set screw is tightened in the set screw aperture the prongs are pressed against the inner surfaces of the bores locking the prongs in place.

2. The bone plate assembly of claim 1, further comprising a locking slot in the first plate outer end and a locking slot in the second plate outer end.

3. The bone plate assembly of claim 1, wherein the locking mechanism further comprises:

a slit at the second plate inner end extending laterally across the width between the upper plate surface and the lower plate surface and extending longitudinally from the second plate inner end partially along the length and at least through the set screw aperture, the slit having an upper slit surface and a lower slit surface,

wherein, when the set screw is tightened in the set screw aperture, the upper slit surface and lower slit surface are caused to move toward one another and press the inner surfaces of the bores against the prongs locking them in place.

4. The bone plate assembly of claim 1 or claim 5, wherein the first and second plates have a convex upper longitudinal surface, a concave lower longitudinal surface, a convex upper lateral surface and a concave lower lateral surface.

5. The bone plate assembly of claim 1 or claim 4, further comprising a locking slot in the first plate outer end and a locking slot in the second plate outer end.

6. A bone plate assembly having an adjustable length and comprising two longitudinal plates, each plate having:

a longitudinal curvature, a lateral curvature, an upper plate surface and a lower plate surface,

a plate inner end comprising at least two straight longitudinal bores, each straight longitudinal bore having an inner surface extending into and terminating within the plate and being adapted to receive a straight longitudinal prong,

a plate outer end, and disposed proximate the plate outer end at least one bone screw aperture passing through the upper plate surface and the lower plate surface and adapted to receive a bone screw for fastening the plate to a bone,

at least two straight longitudinal prongs, said straight longitudinal prongs being smoothly translatable within said straight longitudinal bores to adjust the length of the bone plate assembly, and defining an observation window between the prongs and the plate inner ends, said bone plate assembly further comprising:

a locking mechanism in each plate to fix the length of the bone plate assembly, the locking mechanism comprising:

at least one threaded set screw aperture disposed between the bores, the plate inner end and the bone screw aperture, and

a set screw disposed in each set screw aperture,

wherein, when the set screw is tightened in the set screw aperture, the prongs are pressed against the inner surfaces of the bores locking the prongs in place.

7. The bone plate assembly of claims 1 or 6, wherein each set screw separates the prongs and is in direct contact with the prongs.

8. The bone plate assembly of claims 1 or 6 wherein the at least one threaded set screw aperture passes through the upper plate surface and the lower plate surface.

9. The bone plate assembly of claim 6, wherein each plate has a convex upper longitudinal surface, a concave lower longitudinal surface, a convex upper lateral surface and a concave lower lateral surface.

10. The bone plate assembly of claims 1 or 6, wherein the bone screw apertures are threaded.

11. The bone plate assembly of claims 1 or 6, wherein the bone screw apertures are adapted for receiving bone screws for making a removeable and temporary fastening to the underlying bones.

12. The bone plate assembly of claim 6 further comprising a locking slot in each plate outer end.

13. The bone plate assembly of claim 6 wherein the locking mechanism further comprises:

a slit at the plate inner end extending laterally across the width between the upper plate surface and the lower plate surface and extending longitudinally from the plate inner end partially along the length and at least through the set screw aperture, the slit having an upper slit surface and a lower slit surface,

wherein, when the set screw is tightened in the set screw aperture, the upper slit surface and the lower slit surface are caused to move toward one another and press the inner surfaces of the bores against the prongs locking them in place.

14. The bone plate assembly of claim 3 or 13, wherein the at least one threaded set screw aperture passes through the upper plate surface and the lower plate surface.

15. The bone plate assembly of claim 13, wherein each plate has a convex upper longitudinal surface, a concave lower longitudinal surface, a convex upper lateral surface and a concave lower lateral surface.

16. The bone plate assembly of claim 3 or 13, wherein the bone screw apertures are threaded.

17. The bone plate assembly of claim 16, wherein the bone screw apertures are adapted for receiving bone screws for making a removeable and temporary fastening to the underlying bones.

18. The bone plate assembly of claim 6, further comprising a lock slot in each plate outer end.

19. A bone plate assembly substantially as hereinbefore described with reference to the accompanying drawings.

Dated 4 August, 2009

Biodynamics L.L.C.

Patent Attorneys for the Applicant/Nominated Person

SPRUSON & FERGUSON

FIG. 1

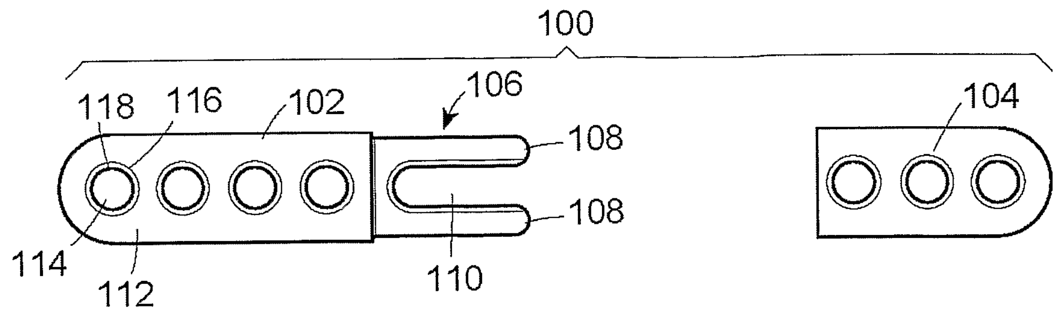

FIG. 6

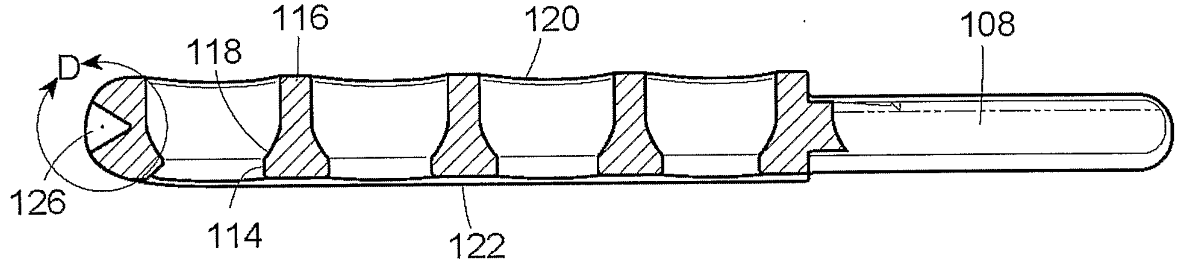

FIG. 6A

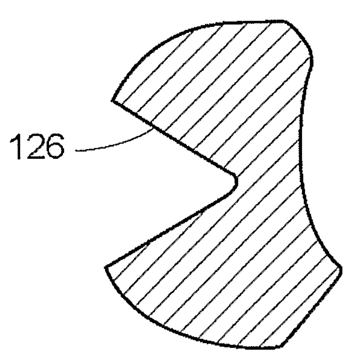

FIG. 6B

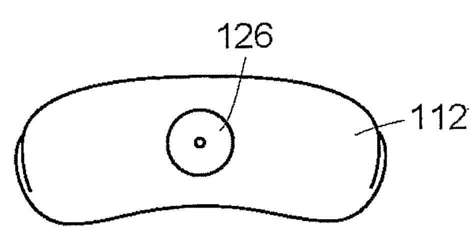

FIG. 2

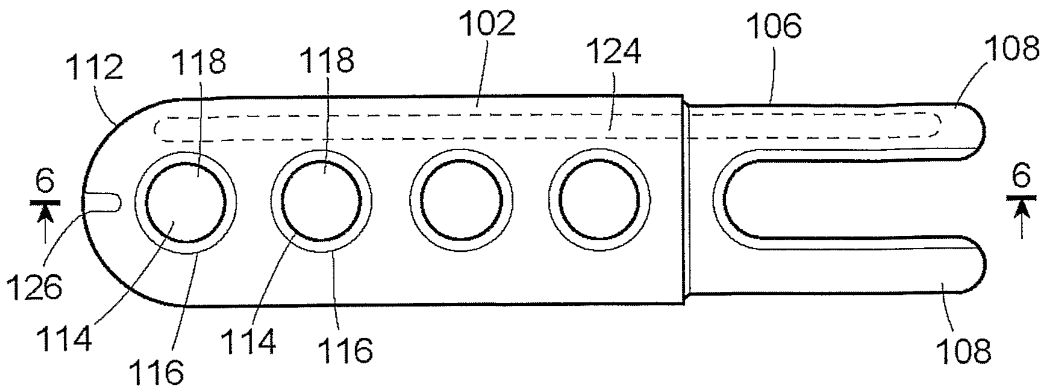

FIG. 3

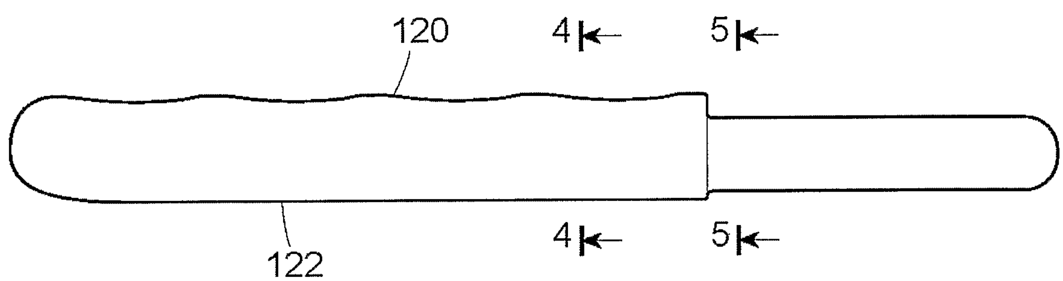

FIG. 4

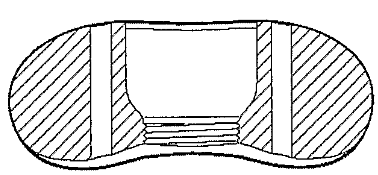

FIG. 5

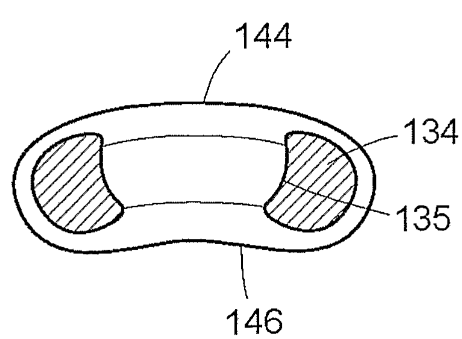

FIG. 7

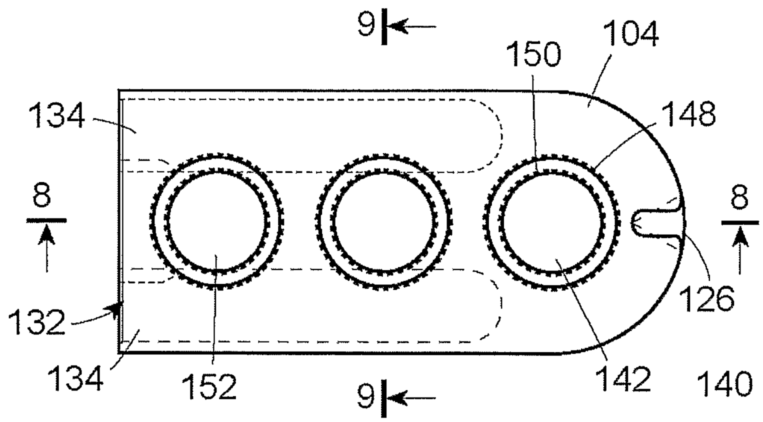

FIG. 8

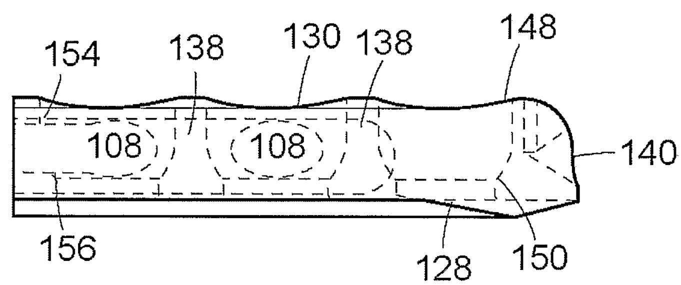

FIG. 9

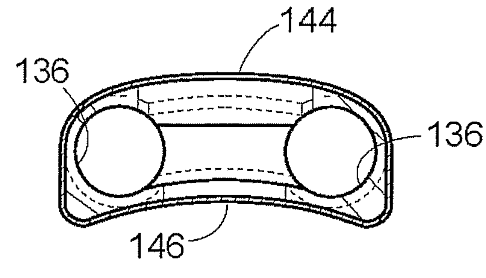

FIG. 10

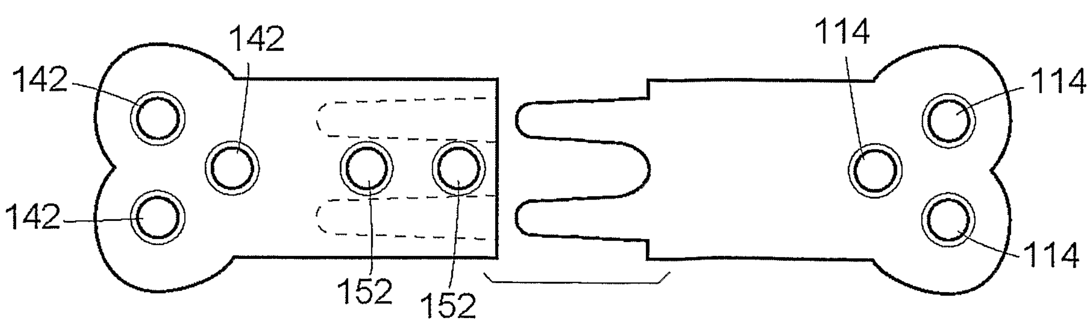

FIG. 11

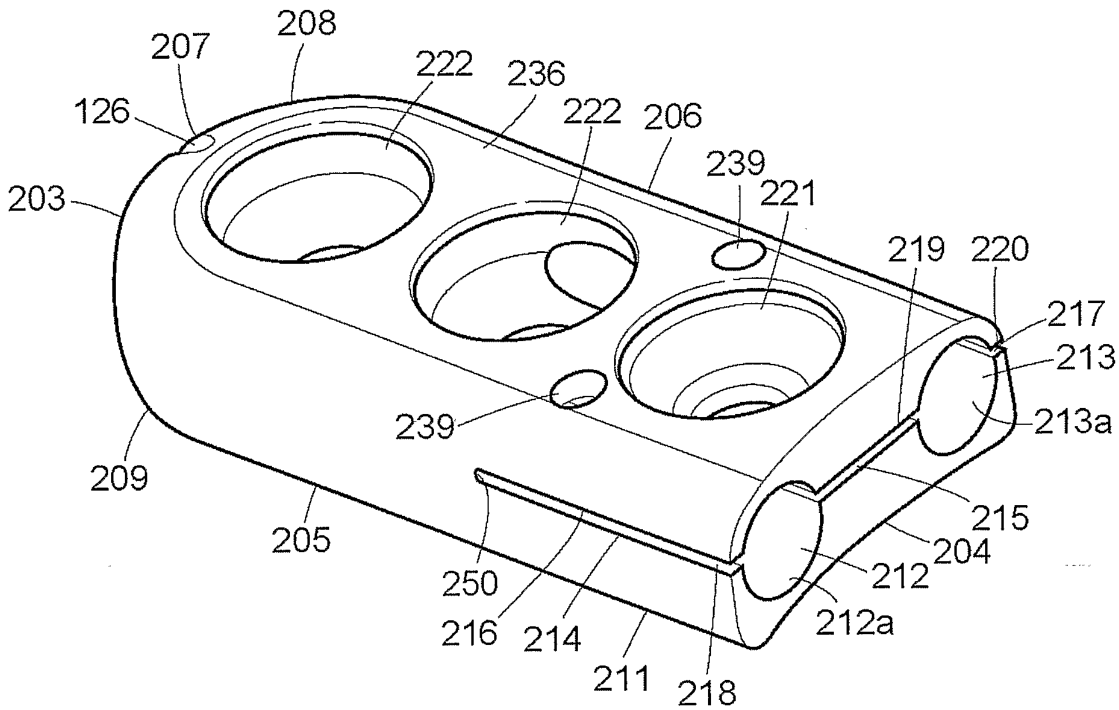
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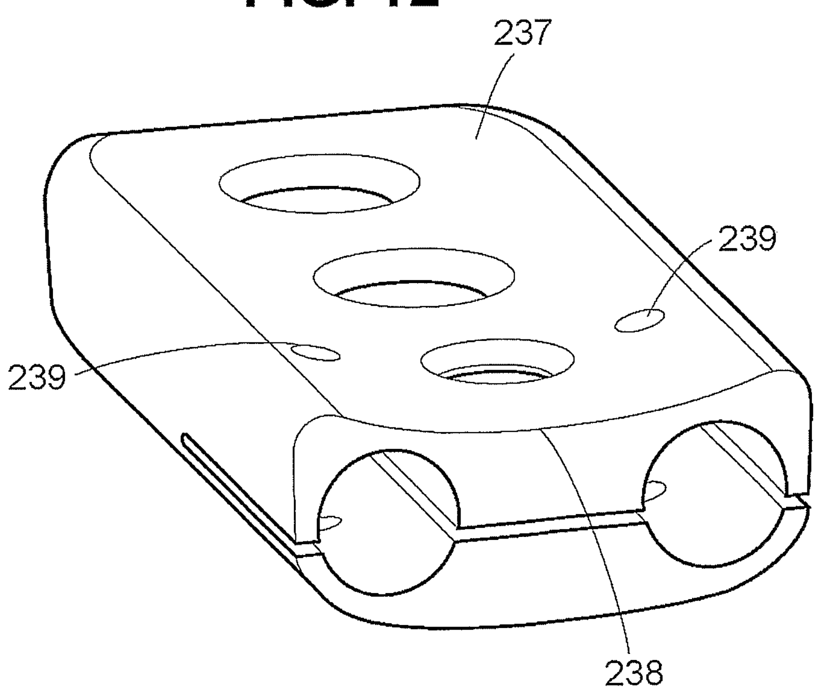
FIG. 12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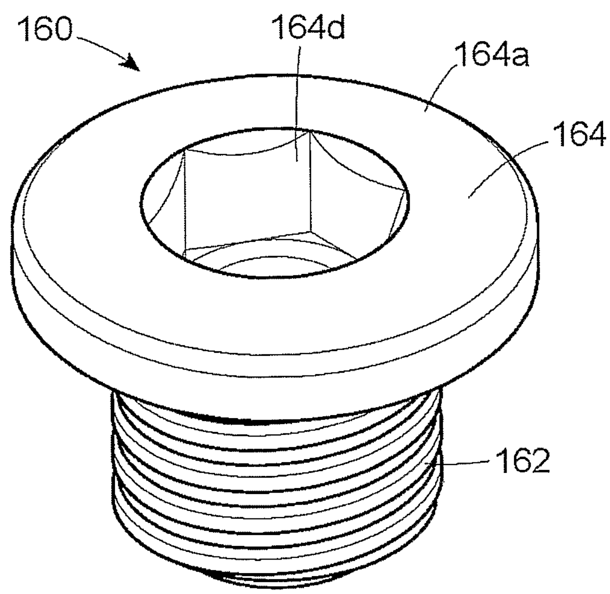


FIG. 13

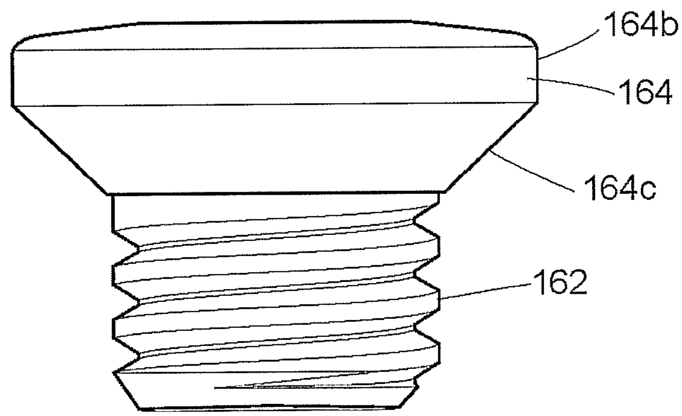
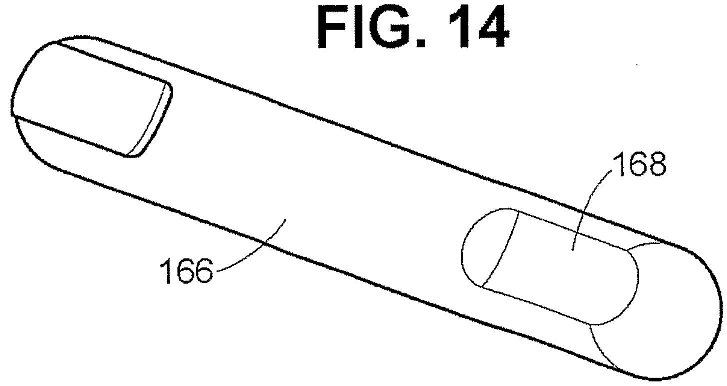


FIG. 13A

FIG. 14



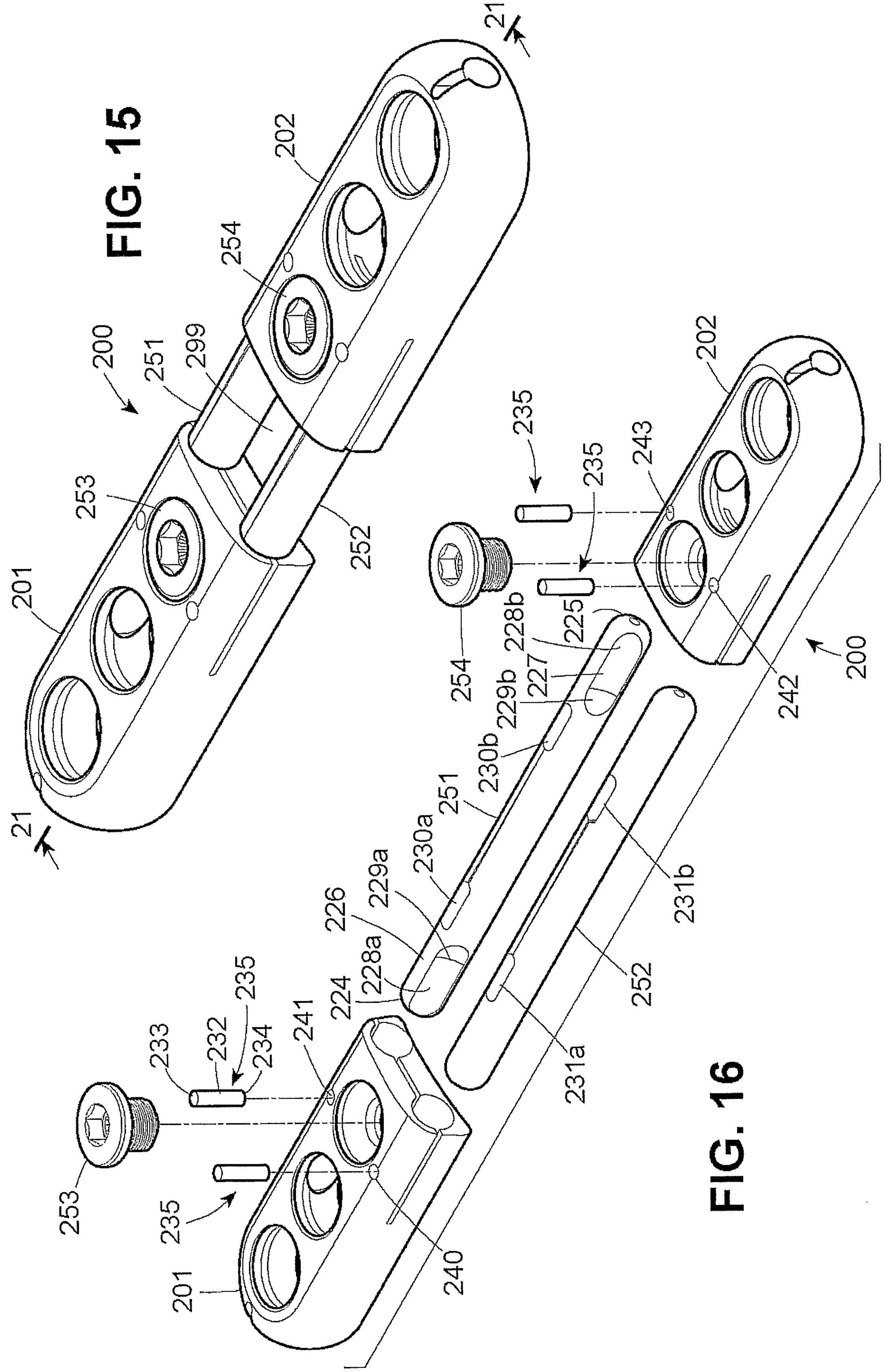

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FIG. 15

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FIG. 16

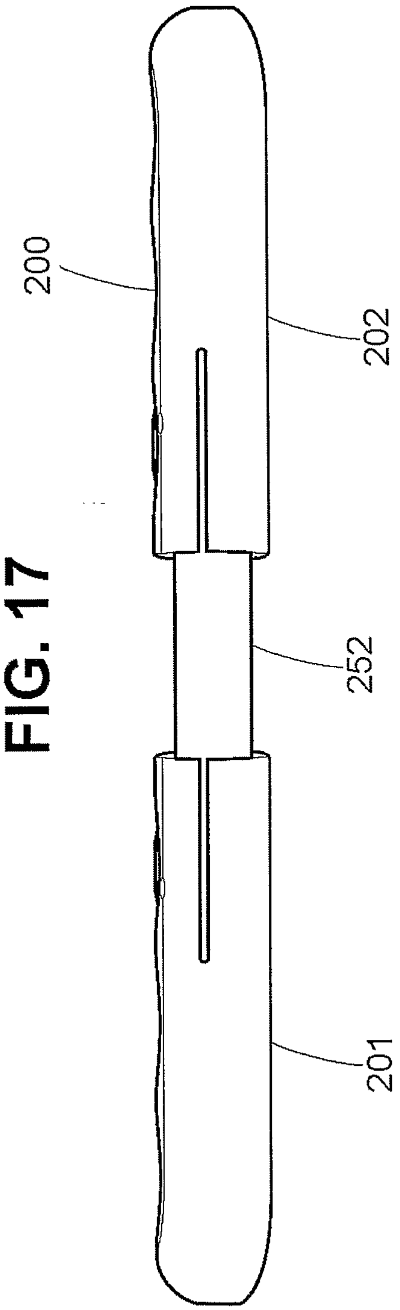

FIG. 17

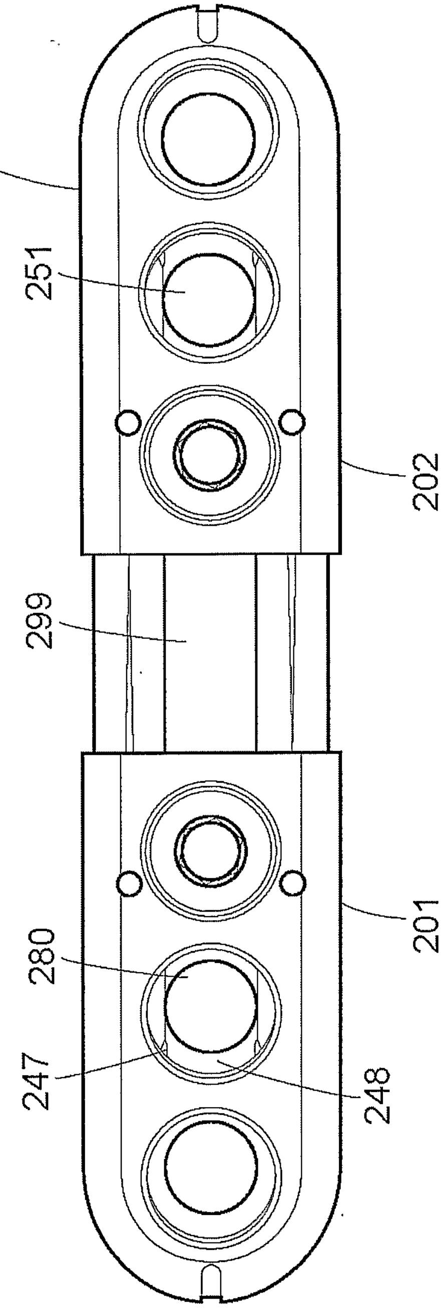

FIG. 18

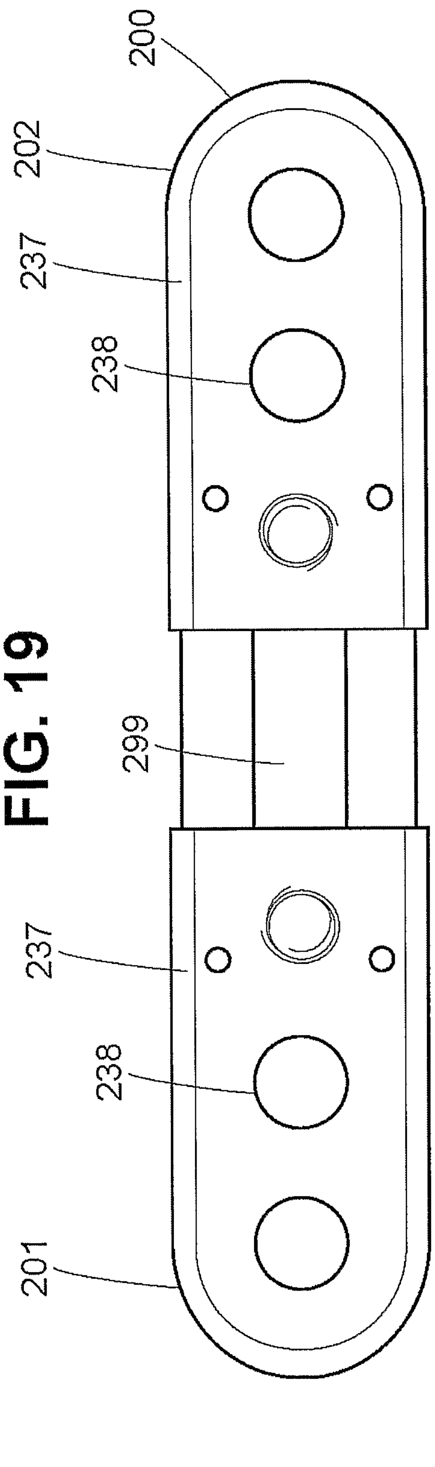

FIG. 19

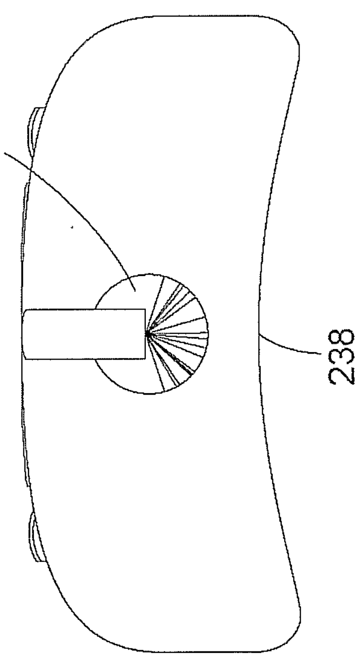

FIG. 20

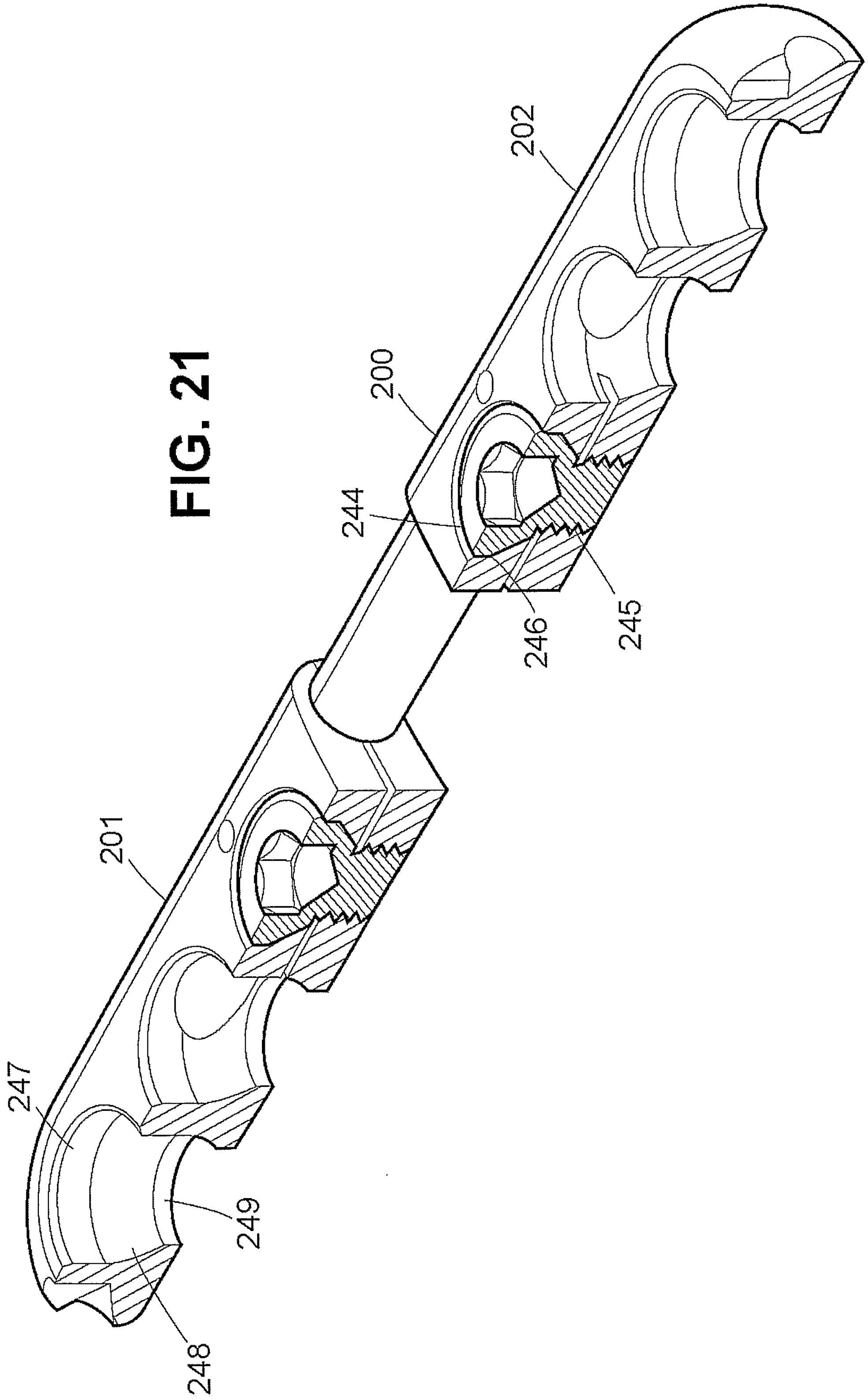

FIG. 21

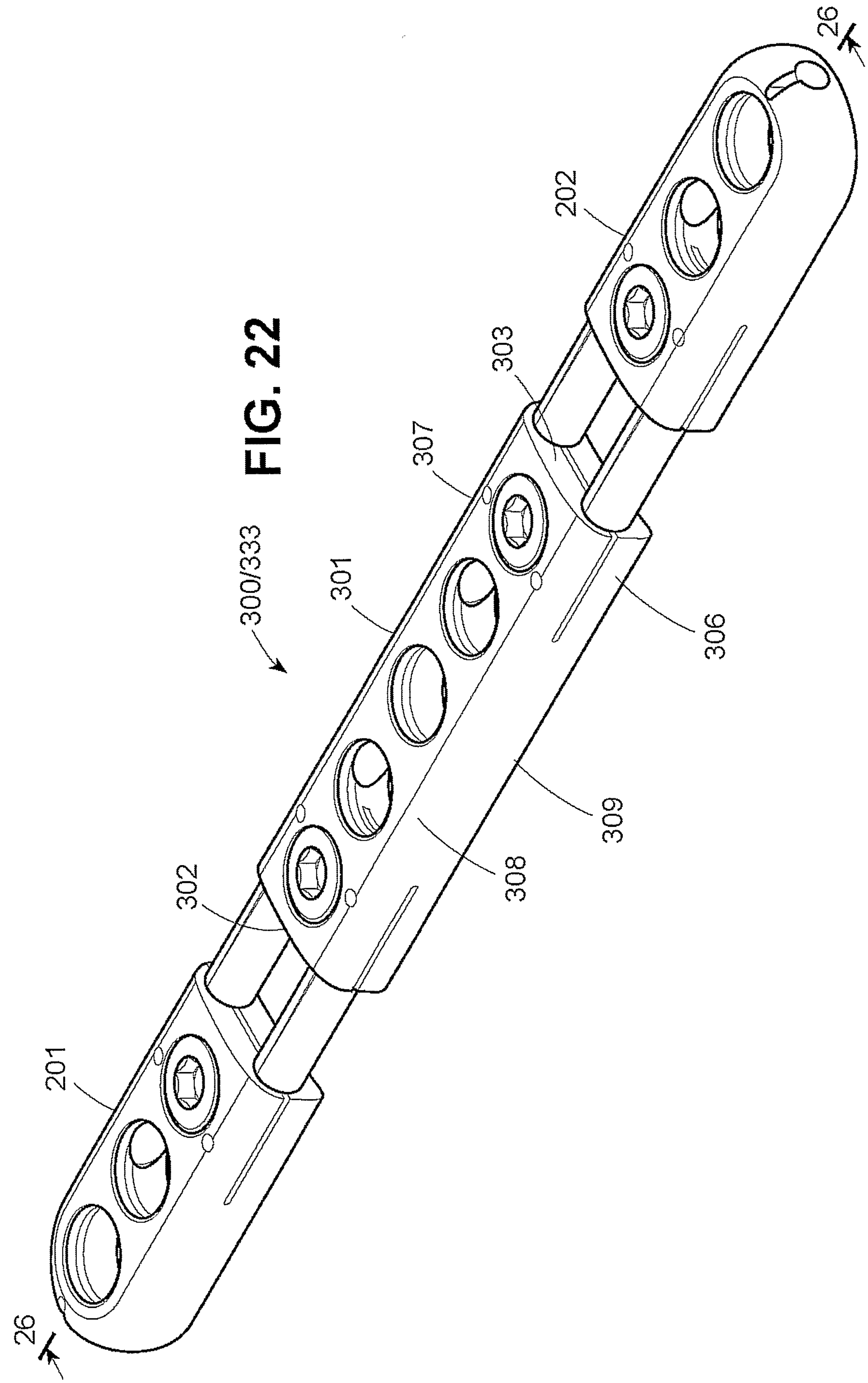

FIG. 22

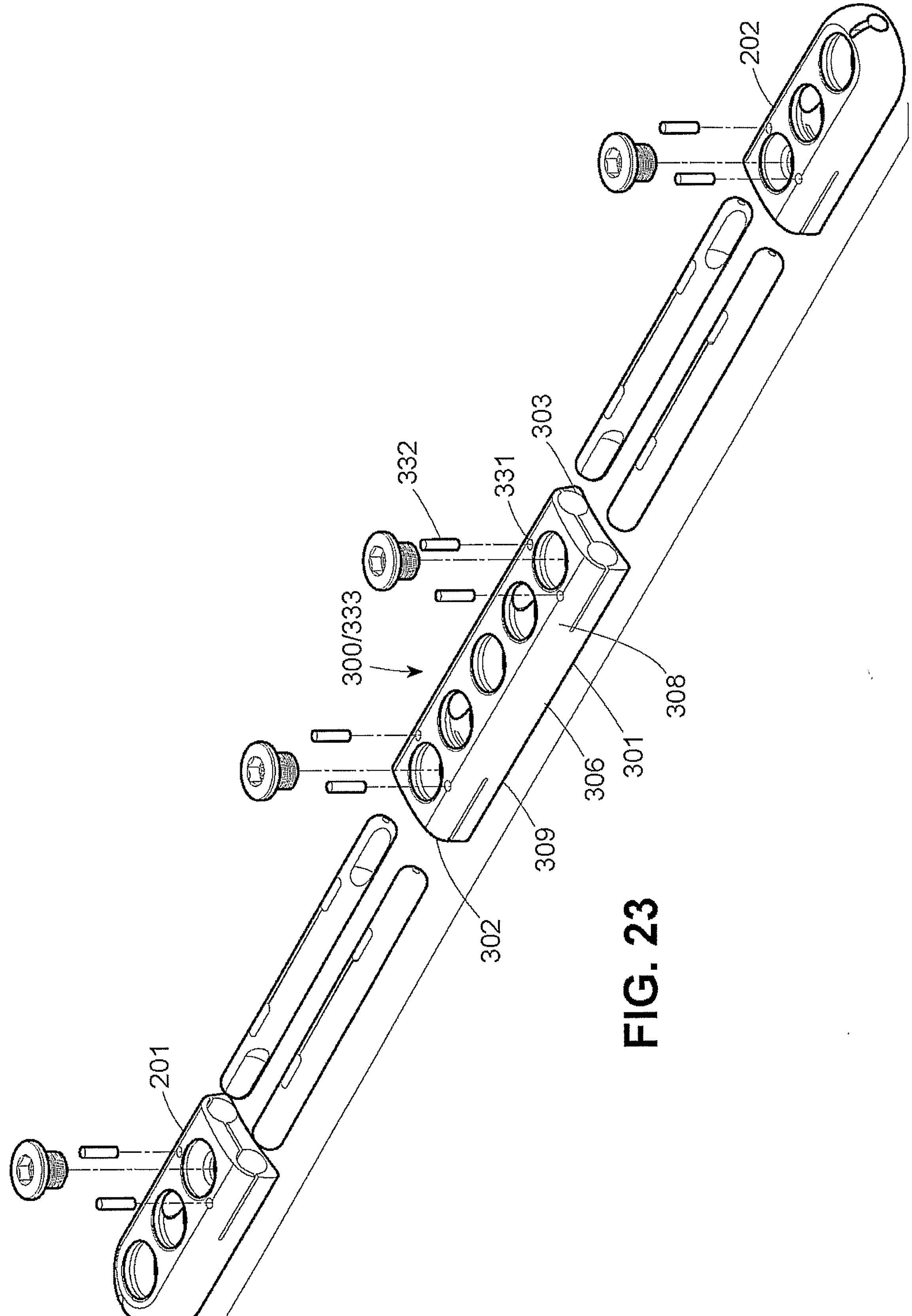

FIG. 23

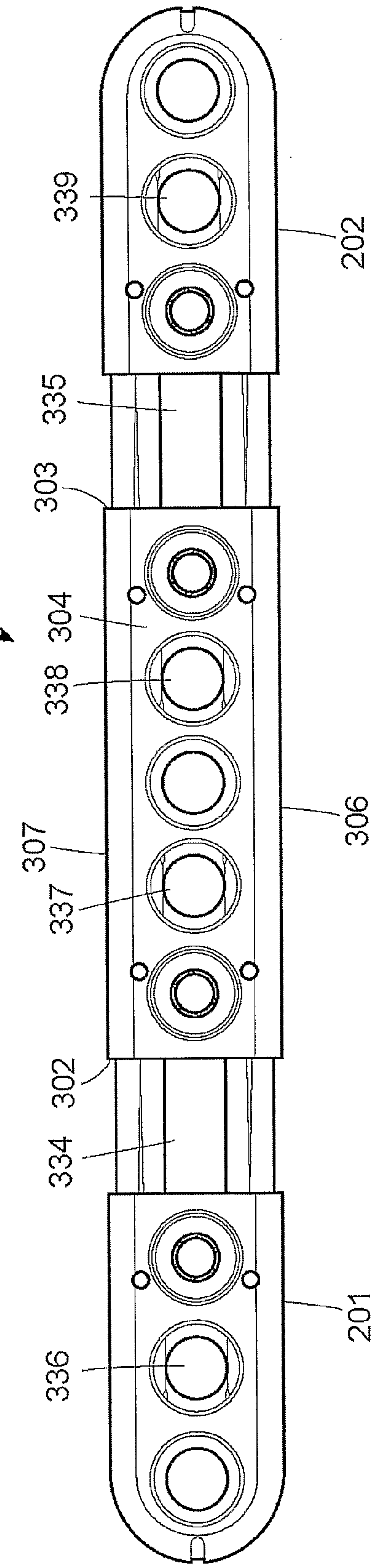
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FIG. 24

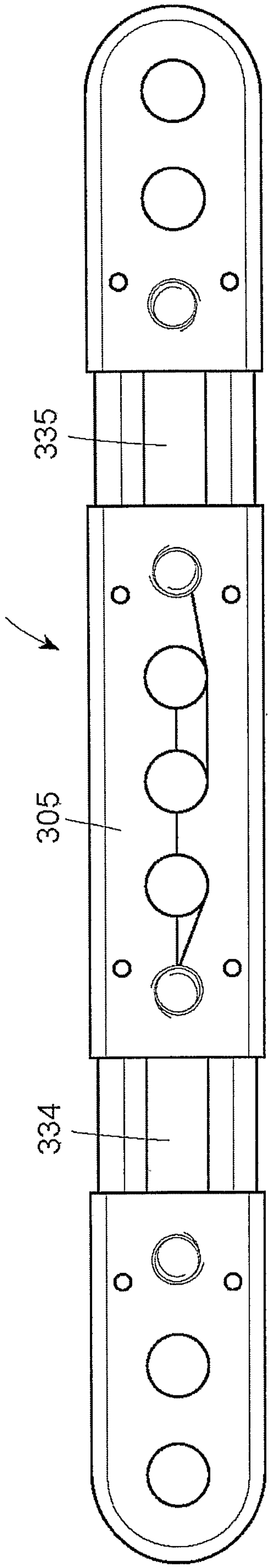
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FIG. 25

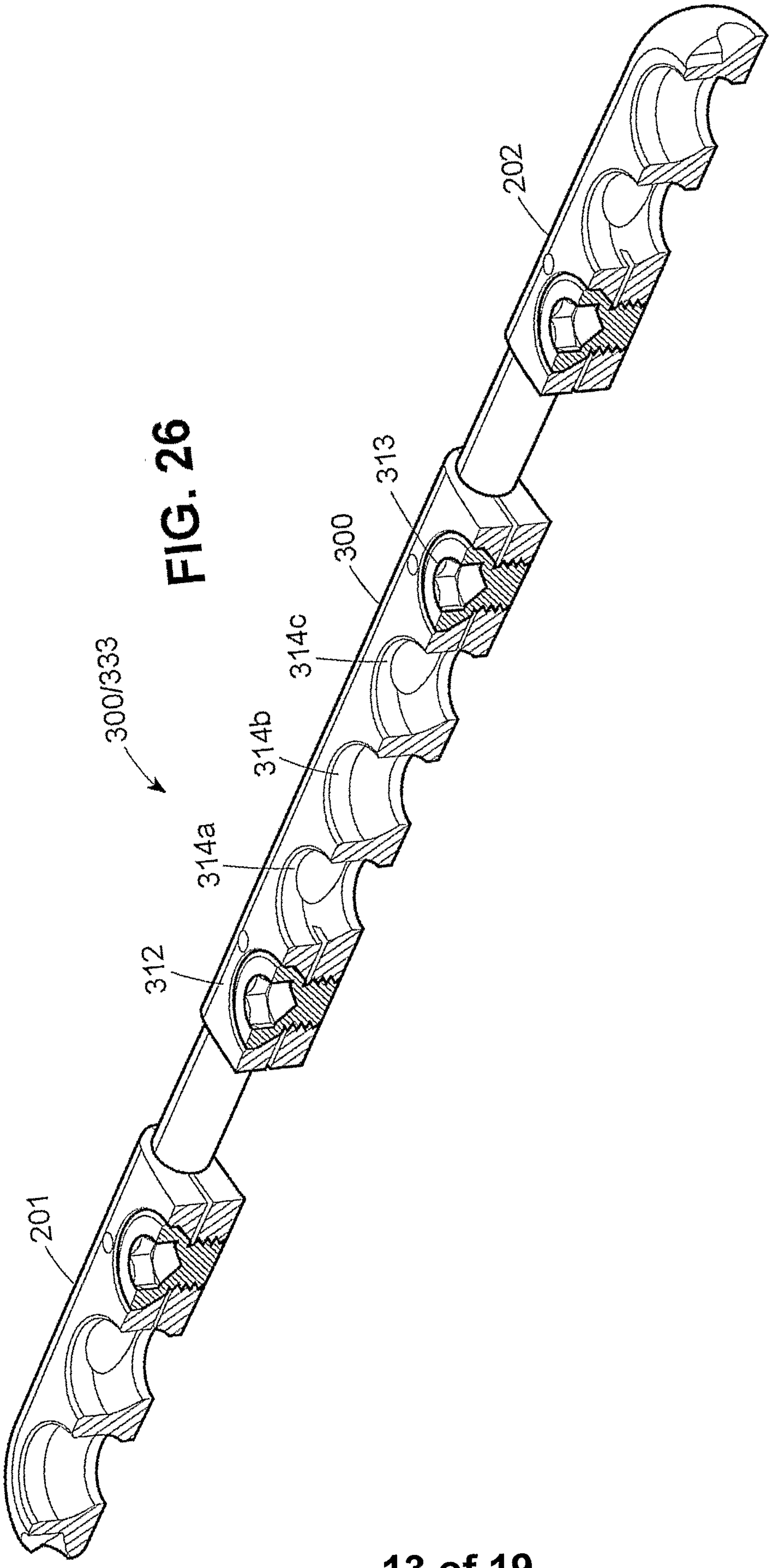
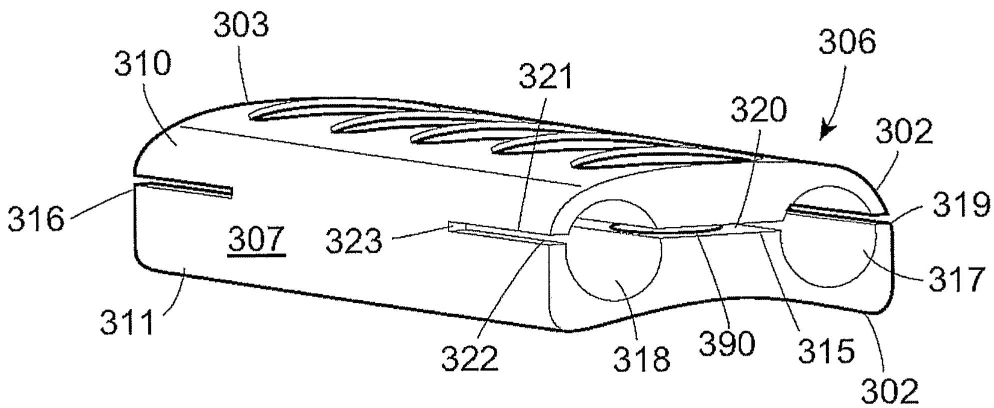


FIG. 26

FIG. 27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315
302

FIG. 28

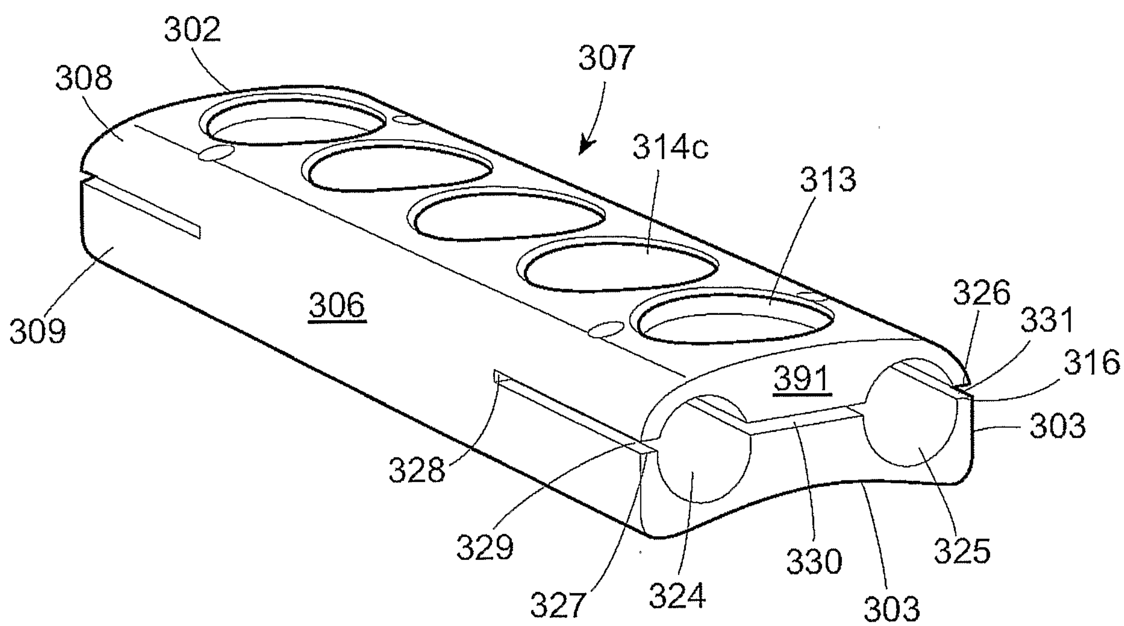
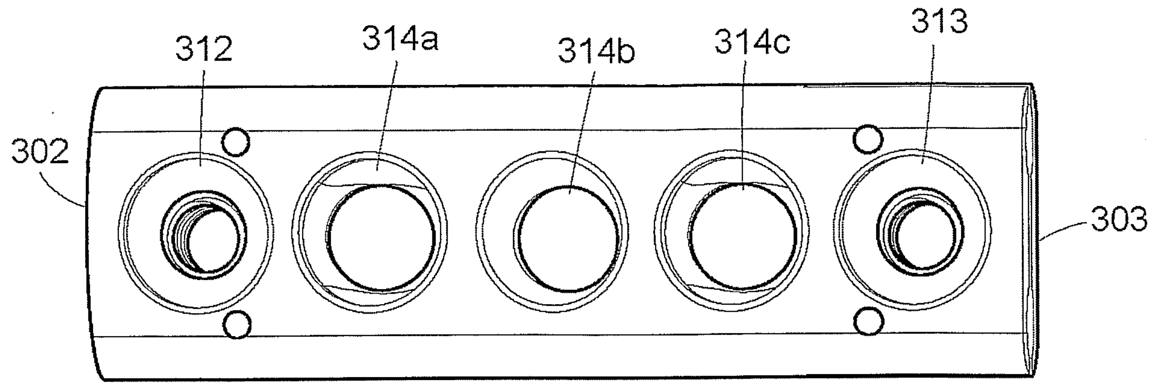

302
307
308
314c
313
306
309
326
331
391
316
303
328
329
330
325
327
324
303

FIG. 29


312
314a
314b
314c
313
302
303

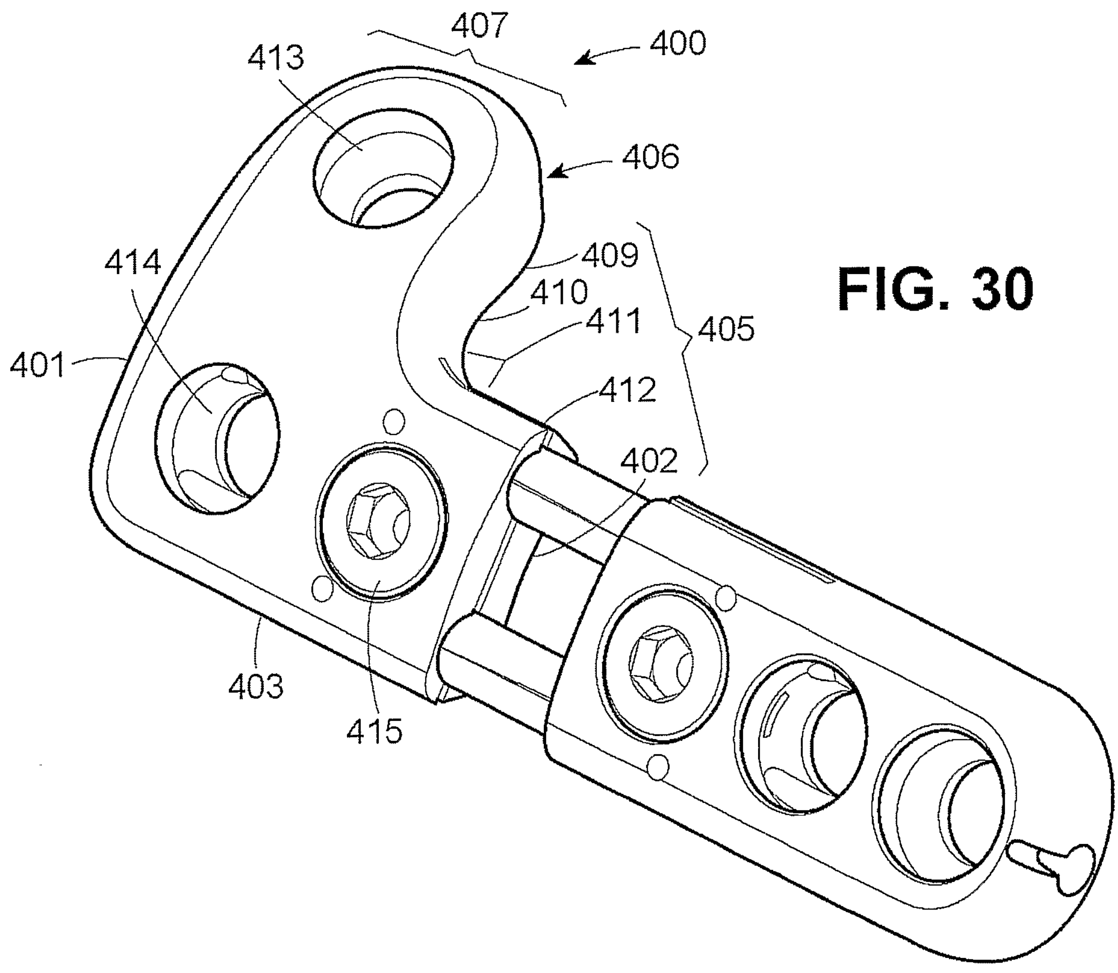

407
400
413
406
409
410
411
405
414
401
412
402
403
415

FIG. 30

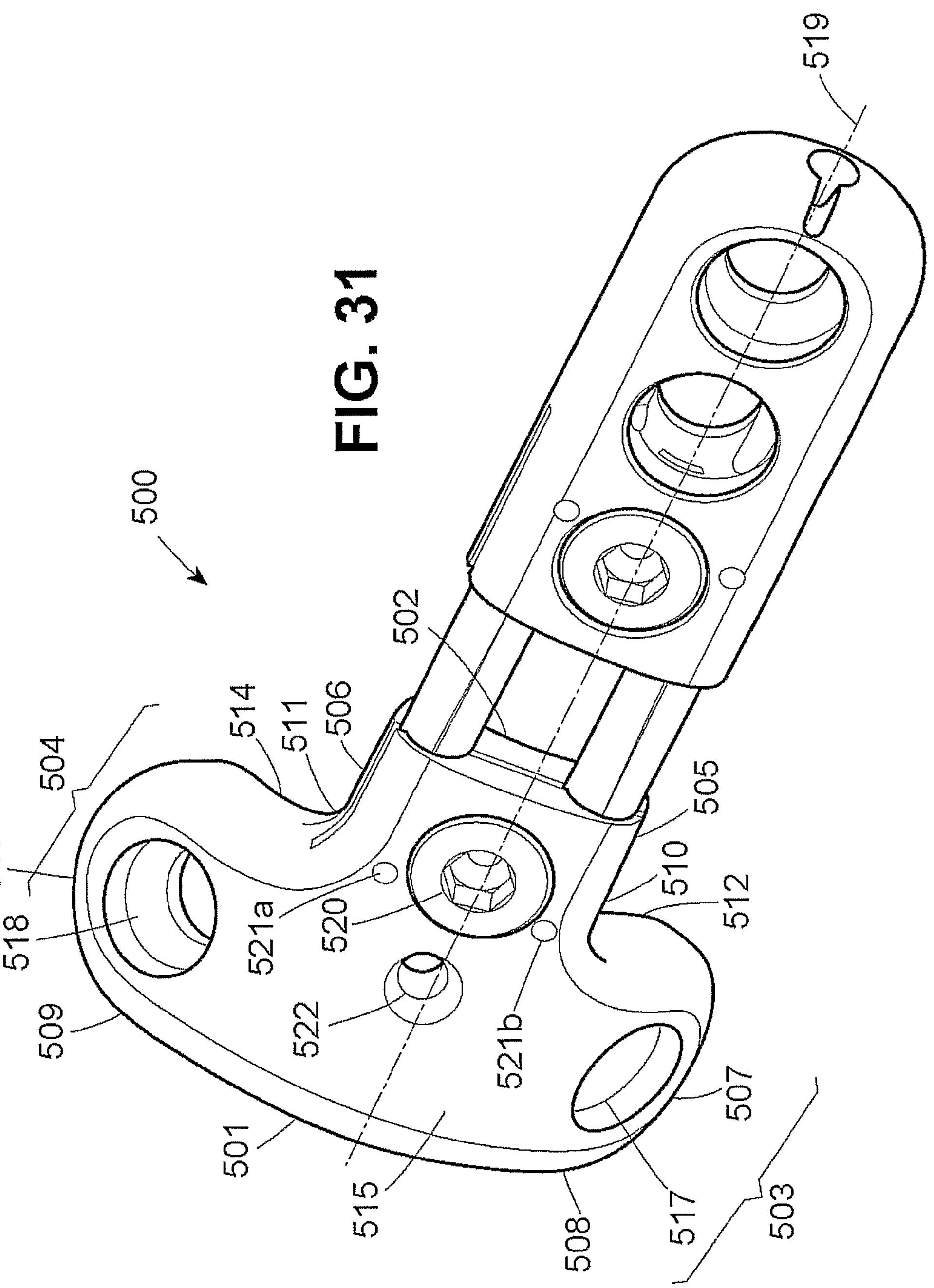

500
502
504
514
511
506
513
518
521a
520
505
510
512
509
522
521b
507
501
515
508
517
503
519

FIG. 31

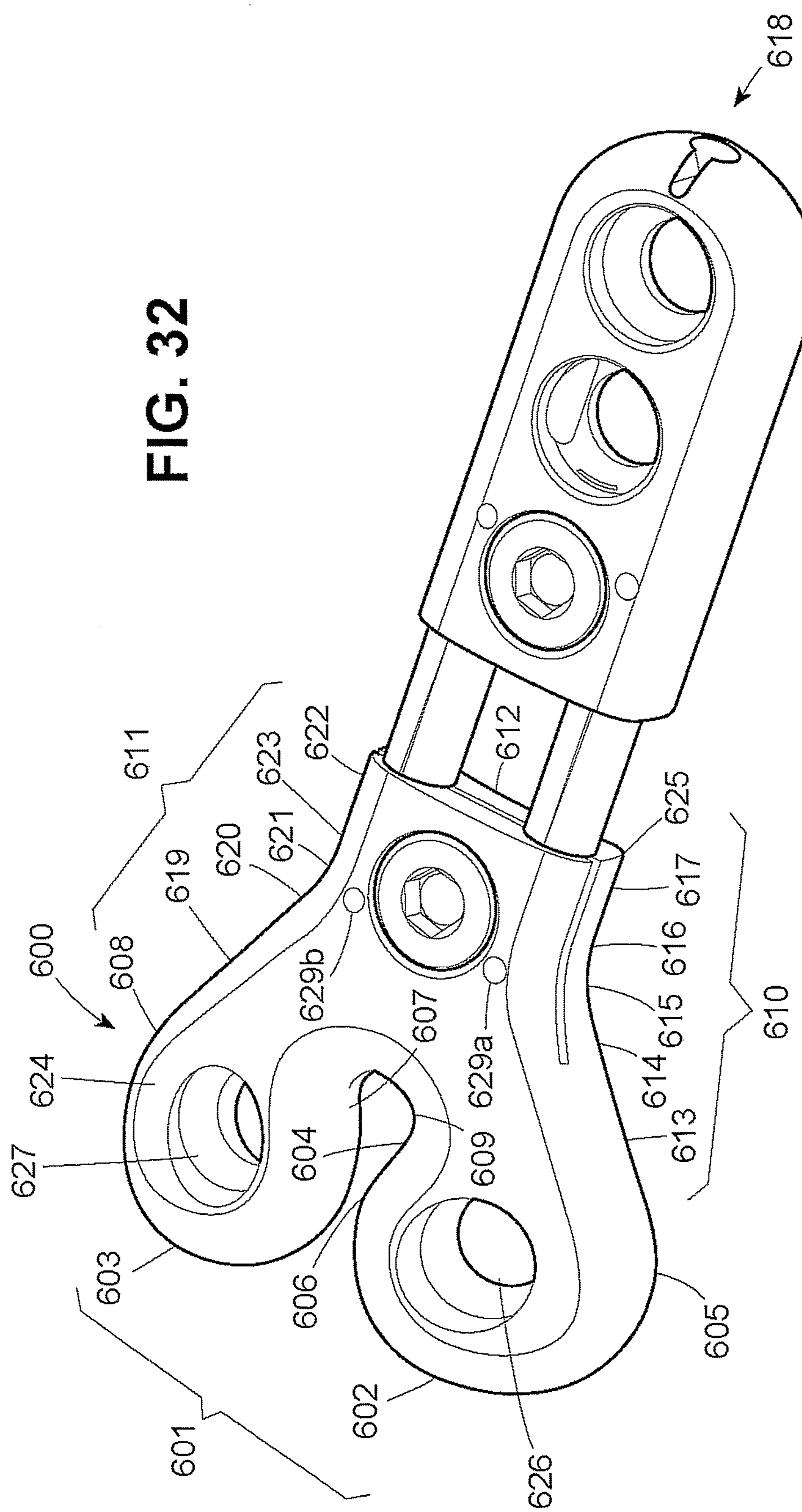

618
611
622
623
612
625
620
621
619
617
616
600
608
629b
615
610
624
607
629a
614
613
609
604
627
603
606
605
602
601
626

FIG. 32

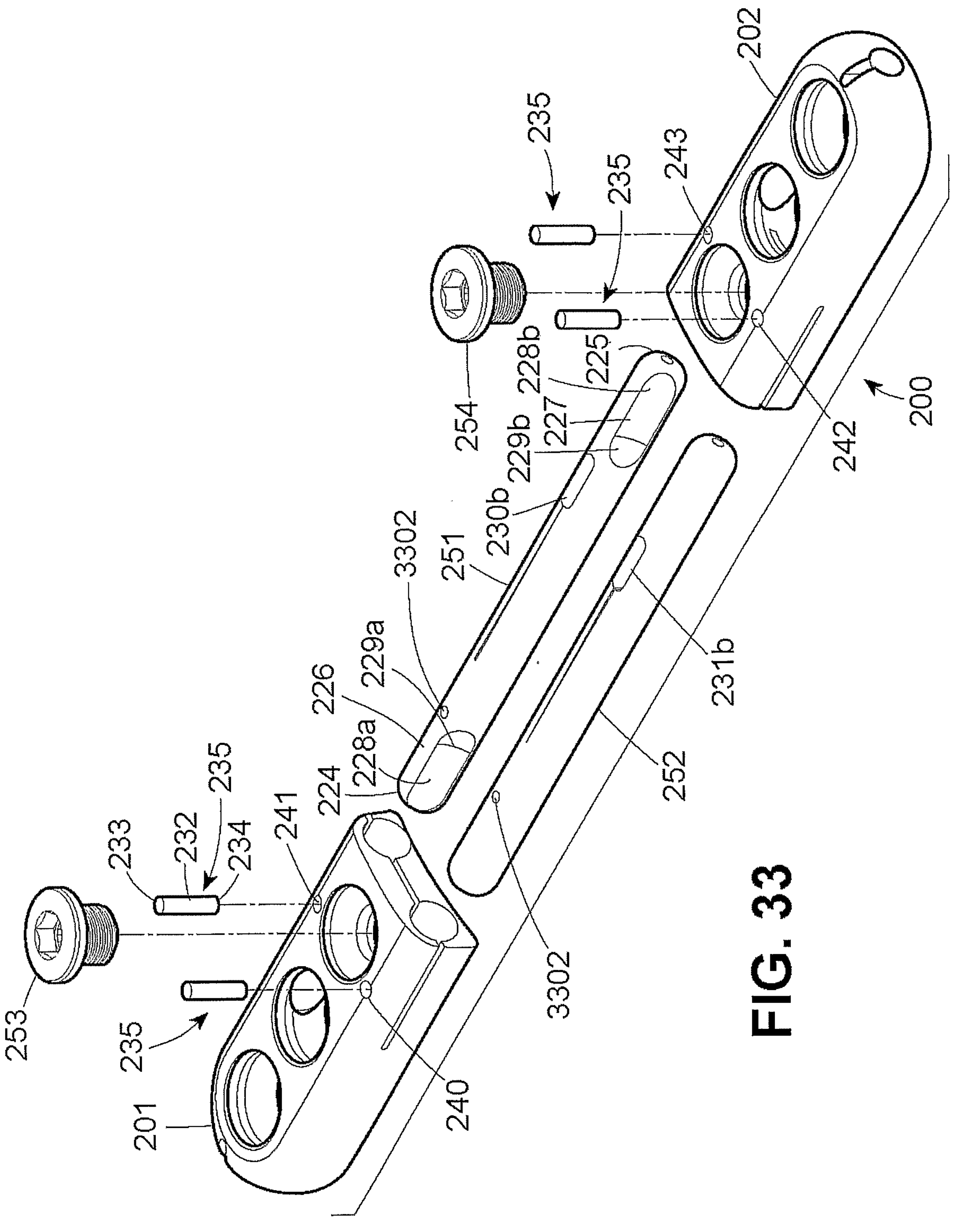

202
235
243
235
254
228b
225
227
229b
230b
3302
251
229a
226
228a
224
241
233
232
234
235
253
235
240
201
3302
252
231b
242
200

FIG. 33

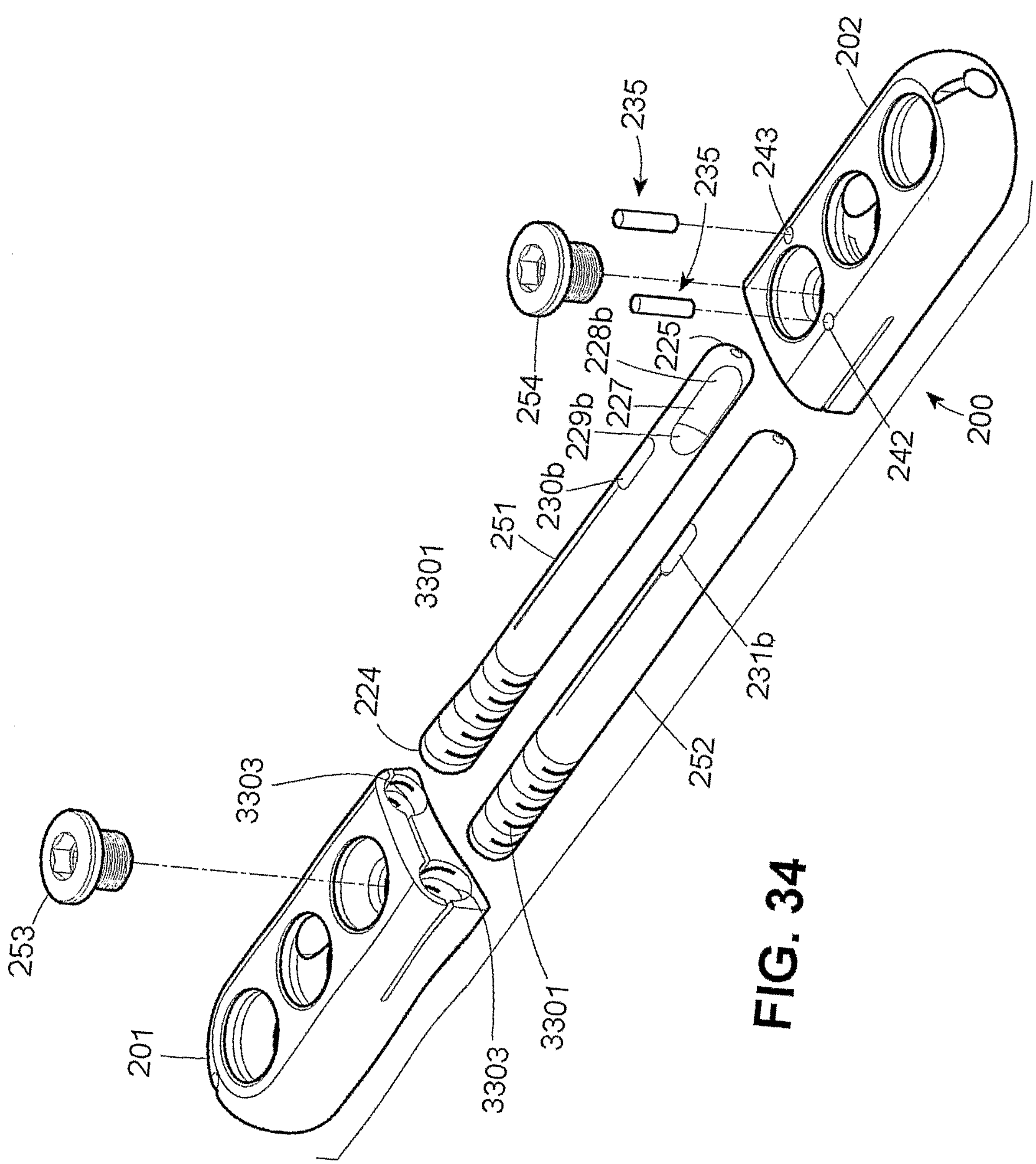

253
201
3303
3303
3301
3301
224
252
251
230b
229b
227
228b
225
254
235
235
235
243
202
242
200
231b

FIG. 34