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(54) LONGITUDINAL PLATE ASSEMBLY HAVING AN ADJUSTABLE LENGTH

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(57) **ABSTRACT**

An orthopedic device including a longitudinal plate assembly having an adjustable length and two ends. Each of the ends includes a feature that can be used to couple the end to a body structure, such as, for example, a vertebral bone. Preferably, the assembly includes two longitudinal plates that can translate longitudinally with respect to one another through a plurality of positions and be secured with respect to one another at one of the positions, thereby enabling the length of the assembly to be adjusted. Inasmuch as the length of the plate assembly can be adjusted, the surgeon can set the length to the most clinically appropriate length for effective coupling of the plate assembly to the body structure.

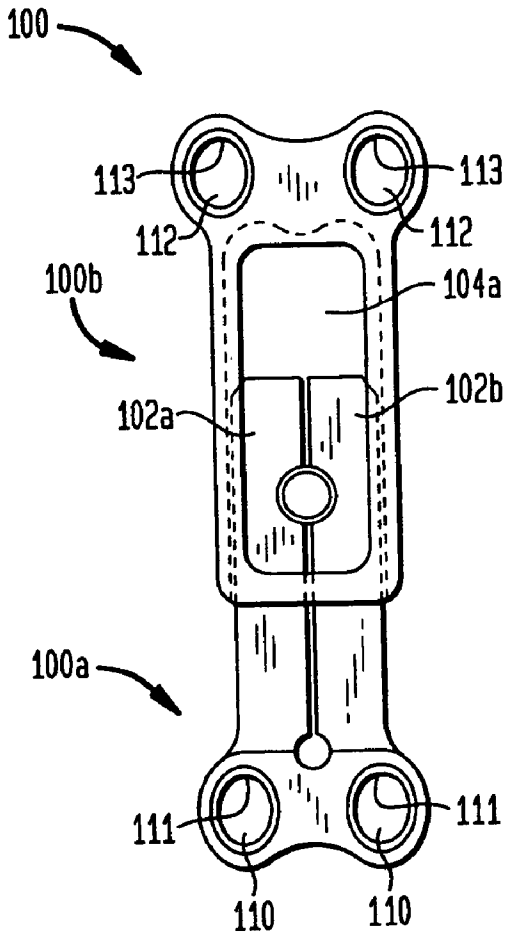


FIG. 1

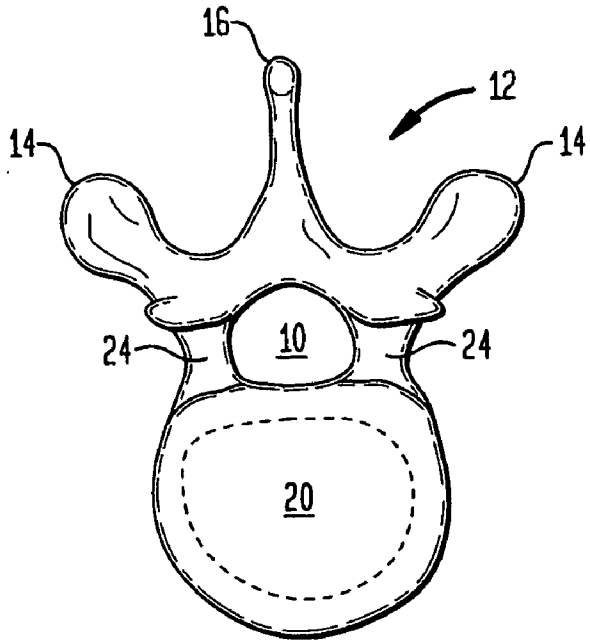


FIG. 2

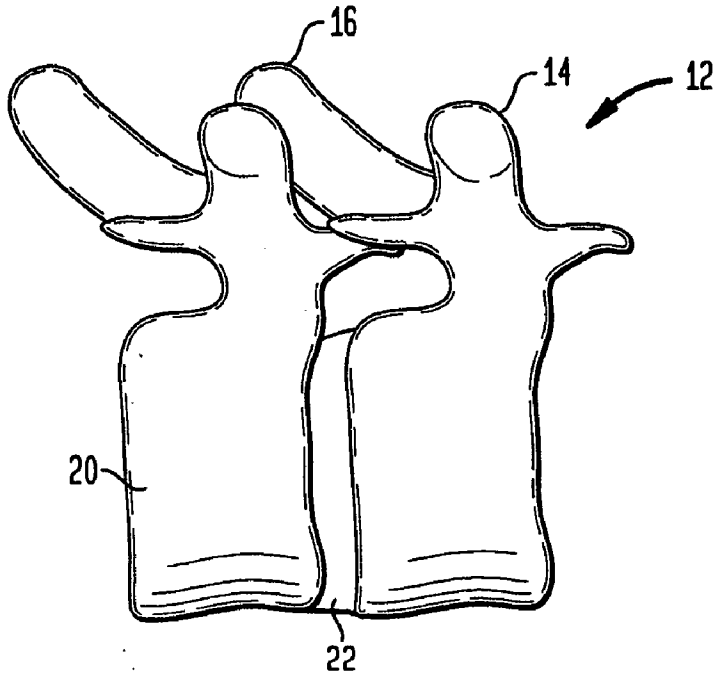


FIG. 4

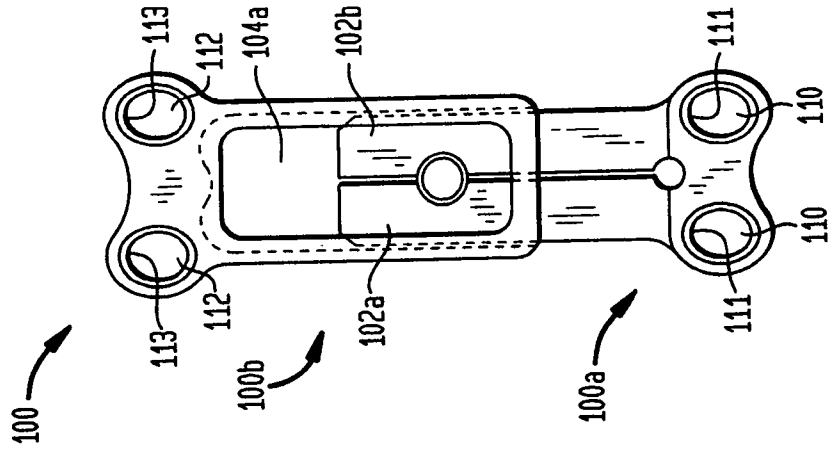


FIG. 3B

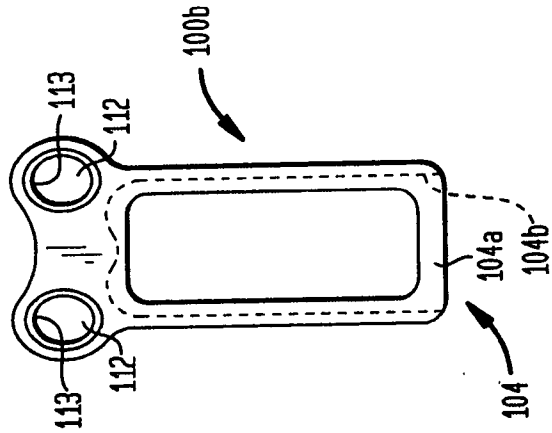


FIG. 3D

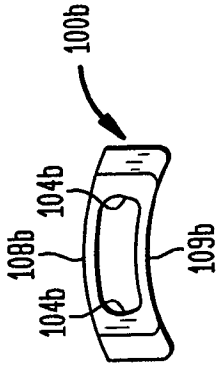


FIG. 3A

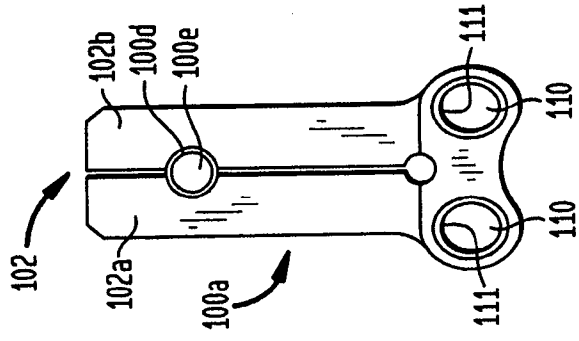


FIG. 3C

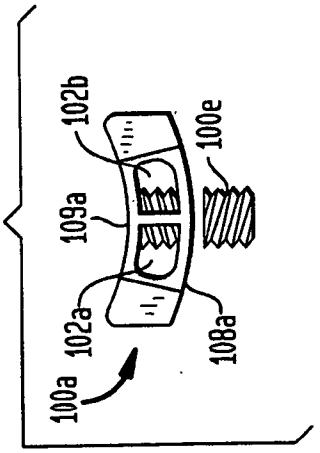


FIG. 5

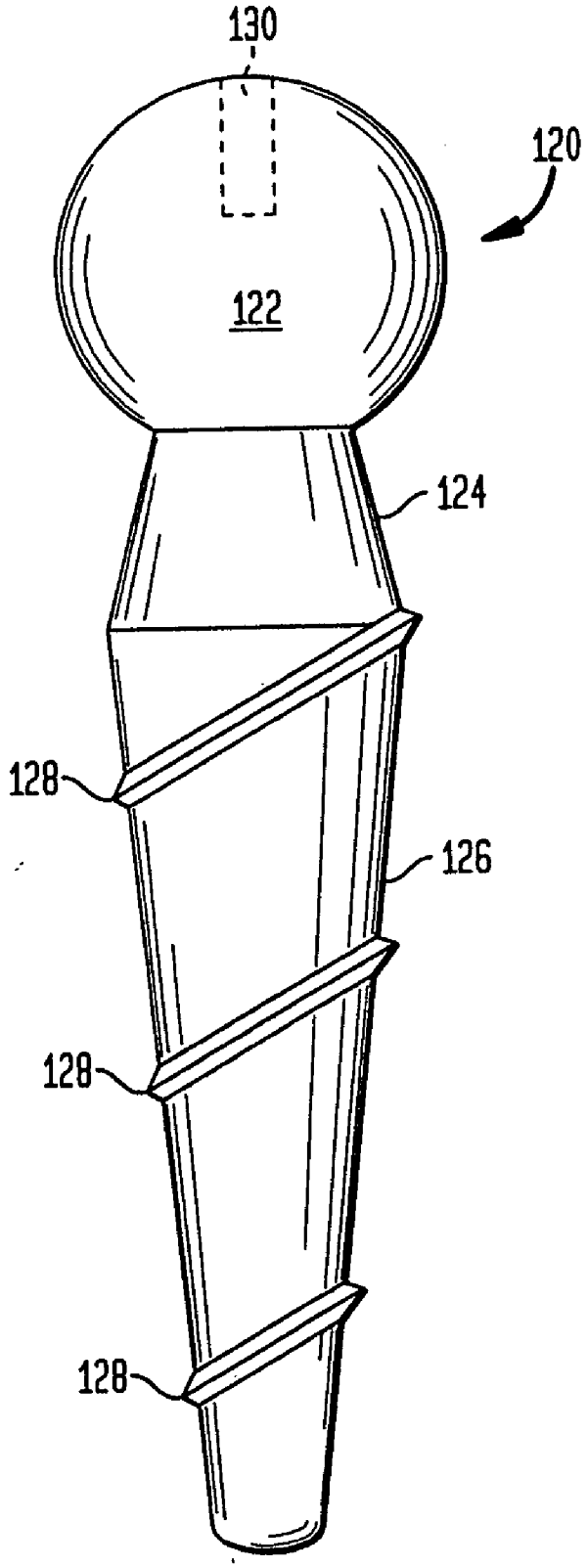


FIG. 6

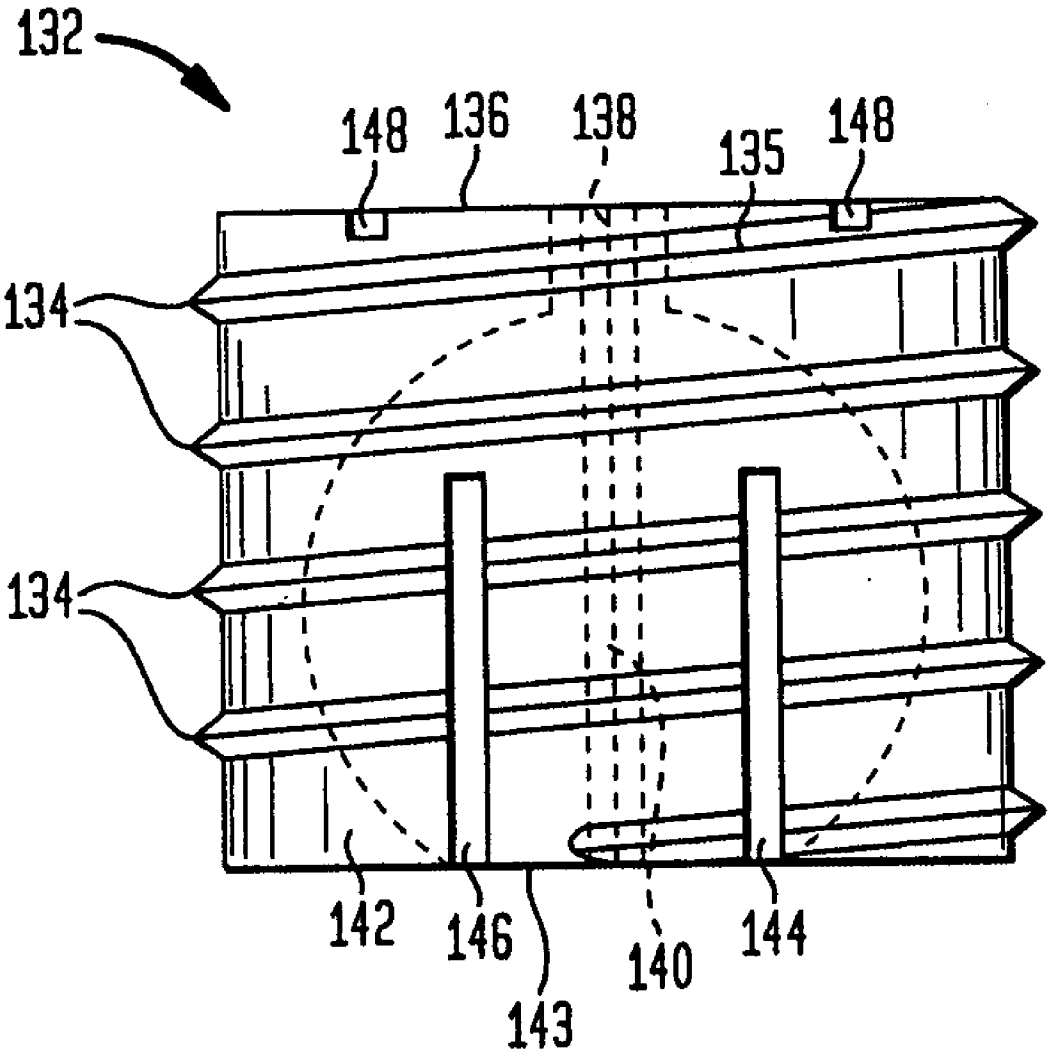


FIG. 7

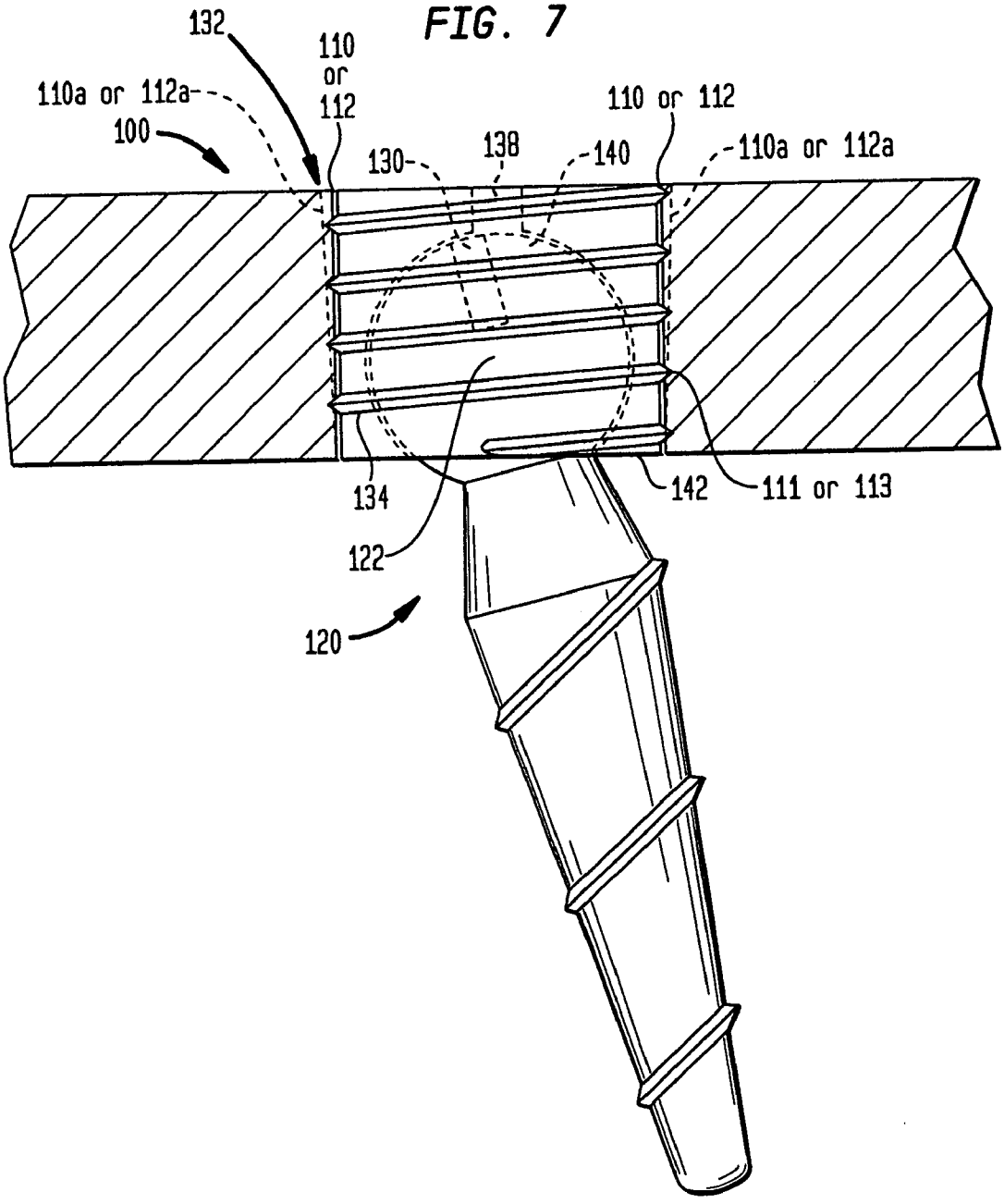

132
110
or
112
110a or 112a
100
130
138
140
110 or 112
110a or 112a
134
142
111 or 113
122
120

FIG. 8

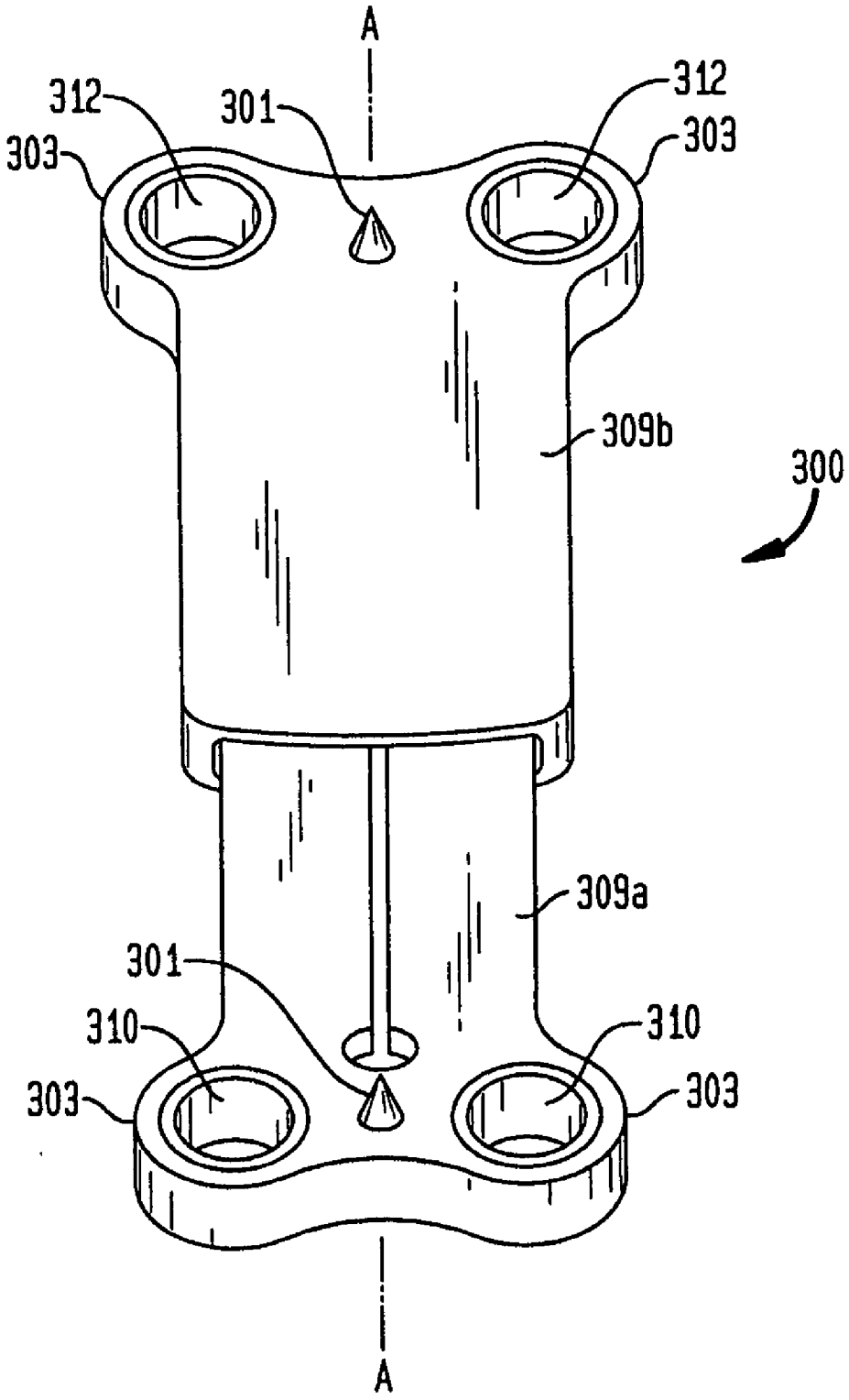


FIG. 10

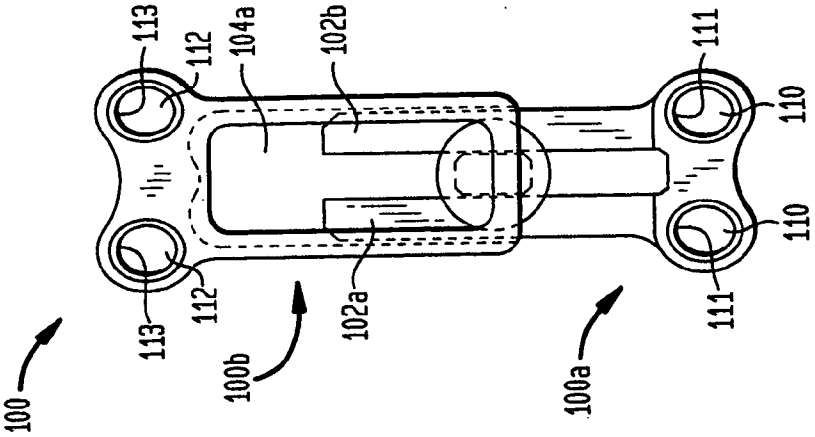


FIG. 9B

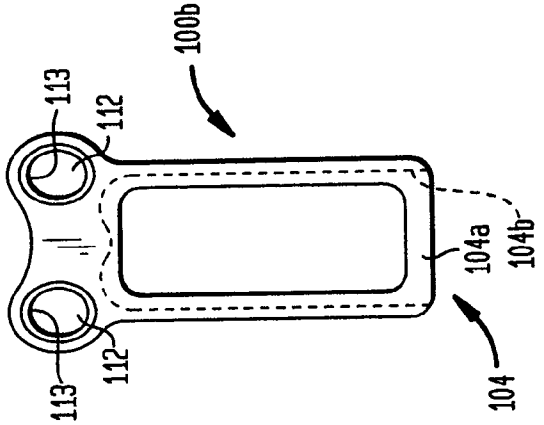


FIG. 9A-2

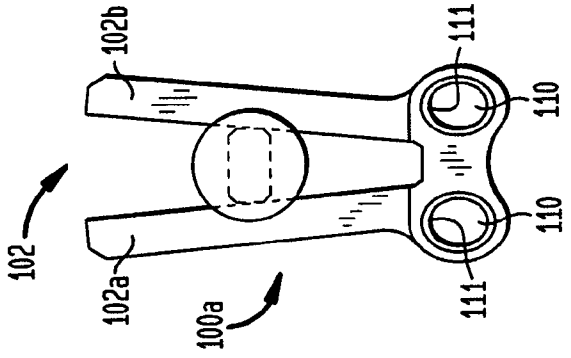


FIG. 9D

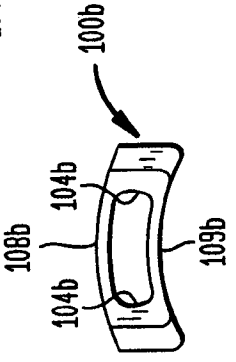


FIG. 9A-1

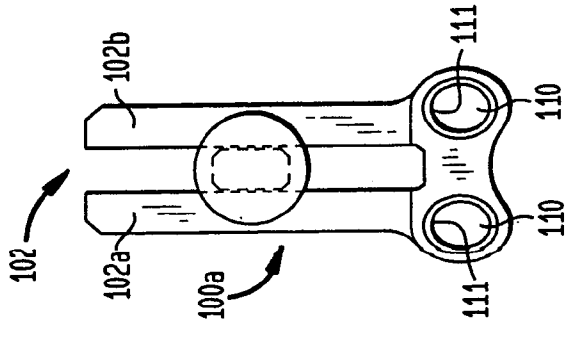
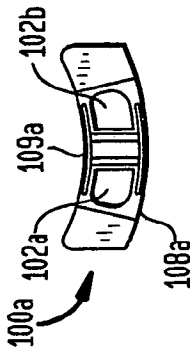


FIG. 9C



LONGITUDINAL PLATE ASSEMBLY HAVING AN ADJUSTABLE LENGTH

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuing application of U.S. patent application Ser. No. 10/075,689 filed Feb. 13, 2002 entitled "Longitudinal Plate Assembly Having an Adjustable Length", which is a continuing application U.S. patent application Ser. No. 09/789,938 entitled "Longitudinal Plate Assembly Having An Adjustable Length".

FIELD OF THE INVENTION

[0002] The invention relates generally to a spinal implant assembly for holding vertebral bones fixed relative to one another. More particularly, the invention relates to a longitudinal plate assembly having an adjustable length and two ends that each can be coupled to a body structure, such as a vertebral bone, for use in surgical procedures for stabilizing the relative motion of, or permanently immobilizing, the body structures.

BACKGROUND OF THE INVENTION

[0003] The bones and connective tissue of an adult human spinal column consists of more than twenty discrete bones coupled sequentially to one another by a tri-joint complex which consist of an anterior disc and the two posterior facet joints, the anterior discs of adjacent bones being cushioned by cartilage spacers referred to as intervertebral discs. These more than twenty bones are anatomically categorized as being members of one of four classifications: cervical, thoracic, lumbar, or sacral. The cervical portion of the spine, which comprises the top of the spine, up to the base of the skull, includes the first seven vertebrae. The intermediate twelve bones are the thoracic vertebrae, and connect to the lower spine comprising the five lumbar vertebrae. The base of the spine includes the sacral bones (including the coccyx). The component bones of the cervical spine are generally smaller than those of the thoracic spine, which are in turn smaller than those of the lumbar region. The sacral region connects laterally to the pelvis. While the sacral region is an integral part of the spine, for the purposes of fusion surgeries and for this disclosure, the word spine shall refer only to the cervical, thoracic, and lumbar regions.

[0004] Referring now to **FIGS. 1 and 2**, a typical vertebral body is shown in a top view and a side view. The spinal cord is housed in the central canal **10**, protected from the posterior side by a shell of bone called the lamina **12**. The lamina **12** has three large protrusions, two of which extend laterally from the shell and are referred to as the transverse process **14**. The third extends back and down from the lamina and is called the spinous process **16**. The anterior portion of the spine comprises a set of generally cylindrically shaped bones which are stacked one on top of the other. These portions of the vertebrae are referred to as the vertebral bodies **20**, and are each separated from the other by the intervertebral discs **22**. Pedicles **24** are bone bridges which couple the anterior vertebral body **20** to the corresponding lamina **12** and posterior elements **14**, **16**.

[0005] The spinal column of bones is highly complex in that it includes over twenty bones coupled to one another, housing and protecting critical elements of the nervous system which have innumerable peripheral nerves and circulatory bodies in dose proximity. In spite of these complications, the spine is a highly flexible structure, capable of a high degree of curvature and twist in nearly every direction.

[0006] Genetic or developmental irregularities, trauma, chronic stress, tumors, and disease are a few of the causes which can result in spinal pathologies for which permanent immobilization of multiple vertebral bodies may be necessary. A variety of systems have been disclosed in the art which achieve this immobilization by implanting artificial assemblies in or on the spinal column. These assemblies may be classified as anterior, posterior, or lateral implants. As the classification suggests, posterior implants are attached to the back of the spinal column, generally hooking under the lamina and entering into the central canal, attaching to the transverse process, or coupling through the pedicle bone. Lateral and anterior assemblies are coupled to the vertebral bodies.

[0007] The region of the back which needs to be immobilized, as well as the individual variations in anatomy, determine the appropriate surgical protocol and implantation assembly. The use of screw plate assemblies for stabilization and immobilization via lateral or anterior entrance is, however, common.

[0008] Because spinal injuries vary with regard to the number of vertebral bodies affected, the proximity of the affected vertebral bodies with respect to one another, and the proximity of the unaffected or stable vertebral bodies with respect to one another, it is necessary for the treatment of a given spinal injury to use a plate assembly having a length that can be used effectively to immobilize, with respect to one another, those vertebral bodies that must be so immobilized to achieve clinically desirable results. For example, depending on the spinal injury, it may be necessary to immobilize two adjacent vertebral bodies. Or, for example, it may be necessary to immobilize two vertebral bodies on either side of one or more unstable or damaged vertebral bodies. Potentially, each spinal injury therefore requires a plate assembly having a different length.

[0009] In addition, the vertebral bodies of the spine are not all equal in length or identical in shape. Some are smaller than others, and are therefore shorter and, for example, have smaller transverse processes, spinous processes, and/or smaller pedicles. Therefore, depending on the location of the spinal injury along the spine, it is again necessary to select a plate assembly having a length that can be used effectively to immobilize, with respect to one another, those vertebral bodies that must be so immobilized to achieve clinically desirable results. For example, in the cervical portion of the spine, the immobilization of two adjacent vertebral bodies will require a plate assembly of a given length, while the immobilization of two adjacent vertebral bodies in the lumbar region will typically require a plate assembly that is longer. And, of course, the selection of the plate assembly of appropriate length must take into account the specific location of the bone structures to which the a plate assembly will be coupled, as these specific locations vary depending on the spinal injury and the damage caused thereby.

[0010] Further, because the spine is routinely subject to high loads which cycle during movement, one of the primary concerns of physicians performing spinal implantation surgeries, as well as of the patients in whom the implants are

placed, is the risk of screw pull-out. Screw pull-out occurs when the cylindrical portion of the bone which surrounds the inserted screw fails. A bone screw which is implanted perpendicular to the plate is particularly weak because the region of the bone which must fail for pull-out to occur is only as large as the outer diameter of the screw threads. It has been found that for pull-out to occur for a pair of screws which are angled inward, "toe nailed", or ones which diverge within the bone, the amount of bone which must fail increases substantially as compared to pairs of screws which are implanted in parallel along the axis that the loading force is applied. It has, therefore, been an object of those in the art to provide a screw plate assembly which permits the screws to be entered into the vertebral body at angles other than 90 degrees.

[0011] A great concern, however, with screws being implanted in the anterior portion of the spine, most particularly in the cervical spine, is that there are important internal tissue structures which, because of their proximity to the implant, may be damaged by a dislocated screw. In the cervical spine, the esophagus is located directly in front of the anterior surface of the vertebral body, and therefore, in potential contact with an implanted cervical plate assembly. Breaches of the esophageal wall permit bacterial contamination of the surrounding tissues, including the critical nerves in and around the spinal cord. Such contamination can be fatal. Because screw pull-out represents one of the largest risks of esophageal perforation, it has been an object of those in the art to produce a cervical screw plate assembly having a locking means which couples, not only the plate assembly to the bone, but locks the screw to the plate assembly. In such a design, it is intended that, even if the bone holding the screw fails, the screw will not separate from the plate assembly.

[0012] In addition to pull-out, however, it has been observed that if the screw plate assembly includes screw heads which protrude beyond the exterior surface of the plate assembly, long term wearing of surrounding tissues may occur, leading to the development of abscesses and holes, which, once again, can have grave consequences. With respect to cervical plate assemblies, which are necessarily thin, on the order of a few millimeters, unless the system is designed to specifically accommodate non-perpendicular screw-in directions, the heads of the screws which are desirably toe-nailed in are a considerable risk.

[0013] Similar concerns exist in the thoracic and lumbar regions with respect to anterior and lateral fixation implants as their are proximally located organs as well as a plurality of major blood vessels which may be compromised by either catastrophic screw pull-out and/or long term wearing of non-flush surface protrusions.

[0014] One screw plate design which has been offered to provide physicians and patients with a reduced risk of pull-out or damage to proximal tissues is the Orion™ Anterior Cervical Plate System of Sofamor Danek USA, 1800 Pyramid Place, Memphis, Tenn. 38132. The Orion™ system teaches a plate having two pair of guide holes through which the screws are inserted to fix the plate to the vertebral body. The plate further includes external annular recessions about each of the guide holes which are radially non-symmetric in depth. More particularly, the annular recessions serve as specific angle guides for the screws so that they may be inserted non-perpendicularly with respect to the overall curvature of the plate. In addition, the Orion™ plate includes an additional threaded hole disposed between each of the pairs of guide holes so that a corresponding set screw may be inserted to lock the bone screws to the plate.

[0015] Although the Orion™ system achieved certain advantages over prior cervical screw plate assemblies, it is not without failures. Specifically, a given plate can accommodate only one screw-in angulation per hole, preferably in accordance with the angle of the annular recession. This is undesirable, in that physicians often must inspect the vertebral bodies during the implantation procedure before making the decision as to which screw-in angle is the ideal. By forcing the physician to chose from a limited set of angles, it is unavoidable that physicians will be forced to implant plates having screws which were positioned non-ideally. While providing a variety of plates having different angle guide holes and annular recession orientations is possible, the complexity and expense of providing a full spectrum of plates available in the operating room for the surgeon to choose from is undesirable. It is a failure of the system that one plate cannot accommodate a variety of different screw-in angles.

[0016] It is an additional failure of the system that an extra set screw is required to lock the screw to the plate. Plates for use in the cervical spine are very thin, and if the screw head already rests in an annular recess, and there is to be enough room for the head of the set screw to rest on top of the head of the bone screw, the thickness of the remaining plate must be reduced even further. The thinner the plate is at the load bearing points—the guide holes—the weaker the plate is overall.

[0017] It is a further failure of the system that one plate cannot accommodate a variety of lengths. Specifically, a given plate can accommodate only one length, preferably the length that is needed for the specific injury. This is undesirable, in that physicians often must inspect the vertebral bodies during the implantation procedure before making the decision as to which plate length is the ideal. By forcing the physician to chose from a limited set of lengths, it is unavoidable that physicians will be forced to implant plates having a length that is non-ideal for the application. This problem is compounded by the limited set of angles discussed above, in that the physician may be forced to use an angle other than the one most clinically appropriate simply because the fixed length of the plate, while being the closest clinically appropriate length available, is slightly too long or too short to allow the desired angle to be used. While providing a variety of plates having different lengths is possible, the complexity and expense of providing a full spectrum of plates available in the operating room for the surgeon to choose from is undesirable.

[0018] While the preceding discussion has focused on a specific cervical screw plate system and its failures, the same failures apply to the art of vertebral immobilizing screw plate systems which are presently available as well. There are no presently available screw plate assemblies which present a flush surface and provide for means of preventing both screw pull-out from the bone and screw backout from the plate, while simultaneously providing for a wide range of angulation for the bone screws and for a wide range of plate lengths.

[0019] An additional concern for physicians who implant screw plates for spinal fixation is proper alignment for pre-drilling of the holes into which the bone screws are driven to hold the plate. As suggested above with respect to the angulation of the annular recesses of the Orion™ system, the process of forming the holes generally involves placing the plate against the appropriate vertebral bodies and using a guide to hold the proper angle with respect to the plate and bone as a drill is used. The difficulty in this process involves slippage at the interface between the unsecured plate and the bone. To avoid slippage, the surgeon is generally required to use, simultaneously, a plate holding mechanism, which may be removably affixed to the plate, to maintain the plate in its proper position, a drill guide to set the desired angulation (which is set by the thread angle of the plate), and the drill itself. It is understood that simultaneous manipulation of these three tools by the surgeon is tedious and difficult.

[0020] Therefore, there is a need for a new and novel cervical, thoracic, and/or lumbar screw plate assembly having a polyaxial coupling of the screw to the plate assembly, whereby a single plate assembly is compatible with a wide range of screw-in angles and a wide range of plate assembly lengths. There is also a need for a screw plate assembly having a flush exterior while being fixed to the vertebral bodies which it immobilizes, having no screw head protrusion despite non-perpendicular angulation. There is also a need for a spinal implant assembly which is more sturdy and more versatile than previous designs. There is also a need for a screw plate assembly which provides the surgeon with the greatest freedom to choose the most desirable angle in which to direct the bone screw. There is also a need for an orthopedic screw plate assembly which has a simple and effective locking mechanism for locking the bone screw to the plate assembly. There is also a need for an orthopedic screw plate assembly which has a simple and effective means of holding the plate assembly in position for the pre-drilling of screw holes.

SUMMARY OF THE INVENTION

[0021] The invention provides an orthopedic device including a longitudinal plate assembly having an adjustable length and two ends. Each of the ends includes a feature that can be used to couple the end to a body structure, such as, for example, a vertebral bone. Preferably, the assembly includes two longitudinal plates that can translate longitudinally with respect to one another through a plurality of positions and be secured with respect to one another at one of the positions, thereby enabling the length of the assembly to be adjusted. Inasmuch as the length of the plate assembly can be adjusted, the surgeon can set the length to the most clinically appropriate length for effective coupling of the plate assembly to the body structure or structures.

[0022] In an embodiment, the invention provides a plate assembly including a first longitudinal plate having an end defined by longitudinal prongs; a second longitudinal plate having a longitudinal bore, the longitudinal bore being adapted to receive the prongs for longitudinal translation therein through a plurality of positions; and a lock assembly for locking the prongs within the bore at one of the positions. Each plate comprises a feature that can be used to couple the plate to a body structure.

[0023] In an aspect, the bore has an inner surface and the lock assembly presses the prongs against the inner surface. Preferably, the prongs are laterally adjacent one another and the lock assembly separates the prongs to press them against the inner surface. The lock assembly can include a threaded bore and a set screw passing between the prongs and into the threaded bore. Alternatively, the lock assembly can include a cam that when placed in a first position, does not press the prongs against the inner surface, allowing the prongs to longitudinally translate freely within the bore through the plurality of positions, and when placed in a second position (e.g., rotated 90 degrees with respect to the first position), separates the prongs to press them against the inner surface, preventing longitudinal translation of the prongs within the bore.

[0024] In another aspect, a lateral curvature is imparted to the plate assembly. The lateral curvature is preferably contoured to the curved roughly cylindrical surface of the vertebral bodies to which it can be secured.

[0025] In yet another aspect, at least one of the features comprises a through hole. Preferably, each feature comprises a pair of through holes. Preferably, there are two threaded holes at each end of the plate assembly extending through the plate assembly, positioned so that they are aligned in pairs with the vertebral bodies to which the plate assembly is to be attached.

[0026] In this aspect, the assembly can 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. Preferably, the head is not standard in that it comprises a semi-spherical section.

[0027] In this aspect, the assembly can further include a coupling element that has a semi-spherical interior volume and that can be inserted into the through hole. The bone screw can have a semi-spherical head that can be rotationally freely mounted within the semi-spherical interior volume prior to insertion of the coupling element into the through hole. The shaft and the coupling element can be inserted into the through hole and the shaft can be inserted into the bone at a selected angle within a predetermined range of angles, including non-perpendicular angles, relative to the respective plate, thereby locking the coupling element and the head to the respective plate at the selected angle as the head and the coupling element are advanced into the through hole. For example, the first step in a process of implanting such an embodiment of the invention is to position the plate assembly against the vertebral bodies and to align the entry points for the screws. The next step in such a process is to pre-drill holes into the vertebral bones at desired angles, into which the screws will be inserted. With the plate assembly in place, the screws may be screwed into the drilled holes in the vertebral bodies.

[0028] In this aspect, the head of the bone screw can have a recess to which a screwdriving tool can be mated for inserting the screw into the through hole and into the bone. The recess can be a slot, phillips, star, hexagonal or other shape that is ideally suited for mating to an appropriate screwdriving tool. When the head of the bone screw is semi-spherical for use with a coupling element in the manner described above, however, the recess should not alter the semi-spherical shape of the head.

[0029] Accordingly, the coupling element can have a top surface recess through which the screwdriving tool may be inserted. The top surface recess can be aligned with the recess in the head of the bone screw. This allows the bone screw to be inserted into the bone using the screwdriver. Alternatively, instead of a recess, the coupling element may be partially opened so that the screw and the coupling may be manipulated easily so that the recess in the head of the screw is accessible. In either variation, once the screw has been fully inserted into the vertebral bone, at the desired angle, the coupling element, via its rotationally free mating of the socket to the inserted screw, is realigned so that it may be locked down into the plate assembly. Screwing down the coupling element provides the locking of the screw to the plate assembly, whereby the screw can be angled non-perpendicularly (or perpendicularly, if desired) with respect to the plate assembly, while the coupling element is flush with a bottom surface of one of the plates of the plate assembly, without the need for a set screw.

[0030] In this aspect, the interior semi-spherical interior volume of the coupling element can be defined by a curved interior surface which forms a receiving socket into which the semi-spherical head is inserted, whereby the head is rotationally freely mounted in the semi-spherical interior volume. The curved interior surface can include slots which permit the interior semi-spherical volume to expand to facilitate the insertion of the semi-spherical head of the bone screw therein. The through hole can be tapered inwardly to cause, upon insertion of the coupling element into the through hole, the slots to be compressed, which causes the curved interior surface to lock the semi-spherical head of the screw at a definite insertion angle. Therefore, the coupling element may be crush-locked to the head of the screw by the application of a radial force. The tapering has the effect of applying a radial force to the slotted socket portion of the coupling element. This circumferential reduction has the desirable effect of locking the screw at the insertion angle. In this way, the coupling element serves as an additional support for keeping the screw in the vertebral bone at the proper angle.

[0031] It is understood that variations in the coupling element (with respect to its recessed or open top) can be used without departing from the scope of the invention so that polyaxial screws may be used with cervical, thoracic, and lumbar plates, despite the considerable variation in plate thicknesses.

[0032] In still another aspect, at least one of the plates has a bottom surface and the assembly further includes at least one feature protruding from the bottom surface for removable and temporary fixation of the plate assembly to the body structure. Preferably, the feature comprises a spike. The spike can interface with the vertebral bones to hold the plate assembly in position during the pre-drilling step. For example, the plate assembly may be held firmly in place by simply positioning the plate assembly and applying enough pressure to drive the spikes into the vertebral bone. The spikes will hold the plate assembly in position, thereby freeing the hands of the surgeon to easily and accurately pre-drill the ideally angled holes. The spikes also provide supplementary gripping and holding strength for the plate assembly, in addition to the screws, once the plate assembly has been implanted securely.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] **FIG. 1** is a top view of a vertebral bone, the stabilization of which an embodiment of the invention is directed.

[0034] **FIG. 2** is a side view of sequentially aligned vertebral bones.

[0035] **FIG. 3*a*** is a top view of a first plate of an embodiment of the invention.

[0036] **FIG. 3*b*** is a top view of a second plate of an embodiment of the invention.

[0037] **FIG. 3*c*** is an end view of a first plate of an embodiment of the invention.

[0038] **FIG. 3*d*** is an end view of a second plate of an embodiment of the invention.

[0039] **FIG. 4** is a top view of cooperating first and second plates of an embodiment of the invention.

[0040] **FIG. 5** is a side view of a bone screw of a plate assembly of an embodiment of the invention.

[0041] **FIG. 6** is a side view of a coupling element of a plate assembly of an embodiment of the invention.

[0042] **FIG. 7** is a partial side cross sectional view of an assembled embodiment of the invention.

[0043] **FIG. 8** is a perspective view of a plate assembly of another embodiment of the invention.

[0044] **FIG. 9*a*1** is a top view of a first plate of a second embodiment of the invention showing prongs closed.

[0045] **FIG. 9*a*2** is a top view of a first plate of a second embodiment of the invention showing prongs open.

[0046] **FIG. 9*b*** is a top view of a second plate of a second embodiment of the invention.

[0047] **FIG. 9*c*** is an end view of a first plate of a second embodiment of the invention.

[0048] **FIG. 9*d*** is an end view of a second plate of a second embodiment of the invention.

[0049] **FIG. 10** is a top view of cooperating first and second plates of a second embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0050] While the invention will be described more fully hereinafter with reference to the accompanying drawings, in which particular embodiments and methods of fabrication are shown, it is to be understood at the outset that persons skilled in the art may modify the invention herein described while achieving the functions and results of this invention. Accordingly, the descriptions which follow are to be understood as illustrative and exemplary of specific structures, aspects and features within the broad scope of the invention and not as limiting of such broad scope. Like numbers refer to similar features of like elements throughout.

[0051] **FIGS. 3*a*, 3*b*, 3*c*, 3*d*** and **4**, illustrate elements of a plate assembly **100** of an embodiment of the invention. **FIG. 3*a*** illustrates a top view of a first longitudinal plate **100*a*** of the plate assembly **100**. The first plate **100*a*** has an end **102** defined by longitudinal prongs **102*a*, 102*b*** that are

laterally adjacent one another. While two prongs are shown in this embodiment, and are shown as laterally adjacent one another, it is understood that a greater number of prongs and/or prongs that are adjacent one another in other configurations can be used without departing from the scope of the invention.

[0052] **FIG. 3***b* illustrates a top view of a second longitudinal plate **100***b* of the plate assembly **100**. The second plate **100***b* has an end **104** that has a longitudinal bore **104***a* that is adapted to receive the prongs **102***a*, **102***b* for longitudinal translation therein through a plurality of positions. **FIG. 4** illustrates a top view of the plate assembly **100** when the prongs **102***a*, **102***b* of the first plate **100***a* are received within the bore **104***a* of the second plate **100***b*. The prongs **102***a*, **102***b* can be inserted into the bore **104***a* and translated longitudinally therein through one or more of the plurality of positions until the desired length of the plate assembly **100** is achieved by stopping the translation at one of the positions, such position establishing the desired relative position of the first plate **100***a* to the second plate **100***b* to achieve the desired length of the plate assembly **100**.

[0053] The plates **100***a*, **100***b* may be constructed of any suitably biocompatible material which has the structural strength and durability to withstand the cyclical loading associated with long term fixation to the spine. Materials which would be suitable for such applications include titanium alloys and steels. A specific titanium material which has been utilized in implants of the prior art include ASTM F-136 titanium alloy (Ti 6AL-4V). This material has enhanced mechanical properties including fatigue endurance and tensile strength, as compared with pure titanium.

[0054] In order to secure the plates **100***a*, **100***b* in the selected position, the plate assembly **100** further includes a lock assembly for locking the prongs **102***a*, **102***b* within the bore **104***a* at the selected position. Activation of the lock assembly secures the relative position of the plates **100***a*, **100***b* so that the desired length of the plate assembly **100** is fixed.

[0055] **FIG. 3***c* illustrates an end view of the first plate **100***a*. In this embodiment, as shown in **FIG. 3***c*, the lock assembly includes a threaded bore **100***d* between the prongs **102***a*, **102***b* and a set screw **100***e* passing between the prongs **102***a*, **102***b* and into the threaded bore **100***d*. Rotation of the set screw **100***e* advances the set screw **100***e* into the threaded bore **100***d*, causing the prongs **102***a*, **102***b* to separate as the set screw **100***e* passes between them as it advances. Preferably, a head of the set screw **100***e* includes a recess that can be mated with a screwdriving tool and the screwdriving tool can be used to rotate the set screw **100***e* within the threaded bore **100***d* to advance the set screw **100***e* until the prongs **102***a*, **102***b* separate.

[0056] **FIG. 3***d* illustrates an end view of the second plate **100***b*. It can be seen that the bore **104***a* has an inner surface **104***b*.

[0057] **FIG. 4** illustrates a plan view of the plate assembly **100** when the prongs **102***a*, **102***b* are received within the bore **104***a*. The prongs **102***a*, **102***b* are laterally adjacent one another and the lock assembly separates the prongs **102***a*, **102***b* to press them against the inner surface **104***b* as described above. The compression of the prongs **102***a*, **102***b* against the inner surface **104***b* secures the position of the plates **100***a*, **100***b* relative to one another, thereby fixing the length of the plate assembly **100**.

[0058] **FIGS. 9***a***1**, **9***a***2**, **9***b*, **9***c*, **9***d* and **10** will now be discussed as describing a second embodiment of the present invention that is similar to the first embodiment shown in **FIGS. 3***a-d* and **4** in all material respects (and like elements are accordingly like numbered in **FIGS. 9***a***1**, **9***a***2**, **9***b*, **9***c*, **9***d* and **10**) except that this second embodiment has a different lock assembly. The discussion will then continue with respect to other aspects of the present invention, which apply to both embodiments, except where specifically noted.

[0059] **FIG. 9***c* illustrates an end view of the first plate **100***a* of the second embodiment, in which the lock assembly includes a cam assembly having a cam **900** that when placed in a first position (e.g., as shown in **FIG. 9***a***1** which is a plan view of the plate assembly **100** of this second embodiment), does not press the prongs **102***a*, **102***b* against the inner surface **104***b*, allowing the prongs **102***a*, **102***b* to longitudinally translate freely within the bore **104***a* through a plurality of positions, and when placed in a second position (e.g., rotated 90 degrees with respect to the first position as shown in **FIG. 9***a***2** which is a plan view of the plate assembly **100** of this second embodiment), separates the prongs **102***a*, **102***b* to press them against the inner surface **104***b*, preventing longitudinal translation of the prongs **102***a*, **102***b* within the bore **104***a*.

[0060] For example, a suitable cam **900** would have an elongated cross-section at that portion **908** of the cam **900** that engages the prongs **102***a*, **102***b* for separation, such that, e.g., the width of the cam **900** at that portion **908** is smaller than the resting distance between the prongs **102***a*, **102***b* (the distance between the prongs **102***a*, **102***b* when they are not engaged by the cam **900**), and the length of the cam **900** at that portion **908** is greater than the combination of the resting distance between the prongs **102***a*, **102***b* and the resting distances between each prong **102***a*, **102***b* and the inner surface **104***b* (the distances between the prongs **102***a*, **102***b* and the inner surface **104***b* when the prongs **102***a*, **102***b* are not engaged by the cam **900**).

[0061] Also, for example, a suitable cam **900** would have at least one feature that maintains the cam **900** within the plate assembly **100**. One example of a suitable feature comprises flanges **906** that prevent the cam **900** from slipping out from between the prongs **102***a*, **102***b*. Preferably, the flanges **906** have a greater cross-section than the length of the portion **908** of the cam **900**, as shown. Another example of a suitable feature comprises a rotatable mounting **902** of the cam **900** to the second plate **100***b* and such that the cam **900** is located between the prongs **102***a*, **102***b* when the prongs **102***a*, **102***b* are longitudinally translated in the bore **104***a*. Although it need not be in some embodiments, such a cam **900** could be made longitudinally translatable in the bore **104***a*, e.g., on a track, so that it can be slid between the prongs **102***a*, **102***b* to any desired location therebetween, and so positionable at any desired prong separation location suitable for the length to which the plate assembly **100** has been adjusted. The mounting to the second plate **100***b* would also serve to maintain the cam **900** within the plate assembly **100**, and therefore would not require the cam **900** to have flanges **906** to maintain it within the plate assembly **100**.

[0062] Accordingly, when the cam **900** is in the first position, it preferably can be slid between the prongs **102***a*,

102*b* to any desired location therebetween, and so is positionable at any desired prong separation location suitable for the length to which the plate assembly **100** has been adjusted. Once the desired prong separation location has been reached, rotation of the cam **900** engages the portion **908** with the prongs **102***a*, **102***b* to maintain them against the inner surface **104***b*.

[**0063**] It should be understood that other cam types and other rotatable mountings can be used, and fall within the scope of the present invention.

[**0064**] **FIG. 9***d* illustrates an end view of the second plate **100***b* of this second embodiment, showing that the bore **104***a* has the inner surface **104***b*.

[**0065**] **FIG. 10** illustrates a plan view of the plate assembly **100** of this second embodiment when the prongs **102***a*, **102***b* are received within the bore **104***a*. The prongs **102***a*, **102***b* are laterally adjacent one another and when the cam **900** is in the first position (e.g., as shown in **FIG. 9***a***1**), the prongs **102***a*, **102***b* are not pressed against the inner surface **104***b*, allowing the prongs **102***a*, **102***b* to longitudinally translate freely within the bore **104***a* through a plurality of positions. Once a desired position of the prongs **102***a*, **102***b* is reached, the cam **900** can be slid between the prongs **102***a*, **102***b* to the most advantageous position for engaging the prongs **102***a*, **102***b*, and can be turned. The turning can be made possible, e.g., by a rotatable mounting of the cam **900** between the prongs **102***a*, **102***b* (e.g., the dimensions of the cam **900** discussed above make it possible to rotate the cam **900** between the prongs **102***a*, **102***b*, and an engageable feature **904** on the cam **900** that when rotated rotates the cam **900**. One example of a suitable engageable feature **904** is a screwdriver-receiving recess as shown. When the cam **900** is turned enough to be placed in the second position (e.g., rotated 90 degrees with respect to the first position as shown in **FIG. 9***a***2**), the cam **900** separates the prongs **102***a*, **102***b* and presses them against the inner surface **104***b*, preventing longitudinal translation of the prongs **102***a*, **102***b* within the bore **104***a*, effectively locking the prongs **102***a*, **102***b* at the desired position.

[**0066**] With reference again to **FIGS. 3***c* and **3***d*, in order to enable the plate assembly **100** to at least grossly conform to the cylindrical morphology of the vertebral bodies which it couples, a slight lateral curvature preferably is imparted to the plate assembly **100**. More specifically, the first plate **100***a* has a convex top surface **108***a* and a concave bottom surface **109***a*. Similarly, the second plate **100***b* has a convex top surface **108***b* and a concave bottom surface **109***b* and the bore **104***a* has a corresponding curvature so that it can receive the prongs **102***a*, **102***b* of the first plate **100***a*.

[**0067**] In order to secure the plate assembly **100** to the desired body structure or structures, each plate **100***a*, **100***b* includes a feature that can be used to couple the plate **100***a*, **100***b* to a body structure. In this embodiment, each feature comprises a pair of through holes. However, it should be understood that in other embodiments, additional or alternative features may be appropriate, including, for example, one or more hooks, rings, recesses, clips, and adhesives.

[**0068**] Accordingly, in this embodiment, with reference again to **FIGS. 3***a*, **3***b* and **4**, a first pair of through holes **110**, having internal threading **111**, extend fully through the first plate **100***a*, from the top surface **108***a* of the plate **100***a* through to the bottom surface **109***a* of the plate **100***a*. A second pair of through holes **112**, having internal threading **113**, extend fully through the second plate **100***b*, from the top surface **108***b* of the plate **100***b* through to the bottom surface **109***b* of the plate **109***b*.

[**0069**] The embodiment shown further includes elements that can be used in conjunction with the features of the plates **100***a*, **100***b* to couple the plates **100***a*, **100***b* to the body structure. In this embodiment, the elements include screws and cooperative coupling elements. It should be understood that elements or tools other than the ones herein described can alternatively or additionally be used with the described or suggested features of the plates **100***a*, **100***b* to couple the plates **100***a*, **100***b* to the body structures.

[**0070**] Accordingly, in this embodiment, with reference also to **FIG. 5, a** screw of a type which is ideally suited for coupling the plates **100***a*, **100***b* to vertebral bones is shown in a side view. The screw **120** comprises a head portion **122**, a neck **124**, and a shaft **126**. In **FIG. 5**, the shaft **126** is shown as having a tapered shape with a high pitch thread **128**. It shall be understood that a variety of shaft designs are interchangeable with the present design. The specific choice of shaft features, such as thread pitch, or shaft diameter to thread diameter ratio, or overall shaft shape, etc. should be made by the physician with respect to the conditions of the patient's bone, however, the invention is compatible with a wide variety of shaft designs.

[**0071**] The head portion **122** of the screw **120** is semi-spherical and has a recess **130**. It is understood that the semi-spherical shape is necessarily a section of a sphere, greater in extent than a hemisphere, and exhibits an external contour which is equidistant from a center point of the head. In a preferred embodiment, the major cross-section of the semi-spherical head **122** (as shown in the two dimensional illustration of **FIG. 5**) includes at least 270 degrees of a circle.

[**0072**] The recess **130** defines a receiving locus for the application of a torque for driving the screw **120** into the bone. The specific shape of the recess **122** may be chosen to cooperate with any suitable screwdriving tool. For example, the recess **130** may comprise a slot for a flat-headed screwdriver, a crossed recess for a phillips head screwdriver, or most preferably, a hexagonally shaped hole for receiving an allen wrench. It is further preferable that the recess **130** be co-axial with the general elongate axis of the screw **120**, and most particularly with respect to the shaft **126**. Having the axes of the recess **130** and the shaft **126** co-linear facilitates step of inserting the screw **120** into the bone.

[**0073**] The semi-spherical head **122** is connected to the shaft **126** at a neck portion **124**. While it is preferable that the diameter of the shaft **126** be less than the radius of the semi-spherical head **122**, it is also preferable that the neck **124** of the screw **120** be narrower than the widest portion of the shaft **126**. This preferable dimension permits the screw to be inserted at a variety of angles while still permitting a coupling element (as described with respect to **FIG. 6**) to be screwed into the appropriate hole **110** or **112** of the plate assembly **100** and remain coupled to the head **122**.

[**0074**] As noted above, this embodiment further includes additional elements that can be used in conjunction with the features of the plates **100***a*, **100***b* to couple the plates **100***a*,

100*b* to the body structure or structures. Accordingly, referring now also to **FIG. 6, a** coupling element of the invention is shown in side view, wherein phantom lines show the interior structure of the element along a diametrical cross section. The coupling element **132** comprises a cylindrical socket having an external threading **134**. The external threading **134** and the diameter of the exterior of the cylindrical socket is designed to mate with threading **111** or **113** of the holes **110** or **112** of the plate assembly **100**, so that the coupling element **132** may be screwed into the plate assembly **100**. It is preferable that the uppermost thread **135** be designed to crush-lock the coupling element **132** into the hole **110** or **112**. Once screwed into the plate assembly **100**, and locked down, the top surface **136** of the coupling element **132** and the respective top surface **108***a*, **108***b* of the plate assembly **100** present a flush external surface.

[**0075**] The top surface **136** of the coupling element **132** which is shown in **FIG. 6** further comprises a through hole **138**, which extends from the top surface **136** to an interior semi-spherical volume **140**. This through hole **138** is designed such that the screwdriving tool which is used to insert the screw **120** into the body structure may access and rotate the screw **120** through the coupling element **132**.

[**0076**] The interior semi-spherical volume **140** is ideally suited for holding the head **122** of the screw **120**, and permitting the screw **120** to rotate through a range of angles. The coupling element **132** has a bottom **142** which has a circular hole (enumerated as **143** on the bottom surface of the side view of the coupling element in **FIG. 6**) which forms the bottom entrance into the interior semi-spherical volume **140**. It is understood that the head **122** of the screw **120** is held within the interior semi-spherical volume **140** by the annular rim, or support lip, **144** of the bottom **142** of the coupling element **132**. This annular support lip **144** defines the circular opening **143** which has a diameter less than the diameter of the semi-spherical head **122** of the screw **120**.

[**0077**] It is therefore preferred that the lower portion of the coupling element **132** comprise slots **146** so that the physician may insert the head **122** into the interior volume **140**. These slots **146** permit the lower portion of the coupling element **132** to expand to accept the inserted head **122**, but is secured from releasing the head **122** once the coupling element **132** is screwed into the plate assembly **100**. In an alternative variation, the holes **110***a* or **112***a* (as shown in phantom in **FIG. 7**) of the plate assembly **100** are tapered inward with respect to insertion direction. In such a variation, the step of screwing the coupling element **132** into the hole **110***a* or **112***a* causes the slots **146** to be compressed and, correspondingly, for the bottom entrance **143** and the annular lip **144** to lock the screw head **122** into position.

[**0078**] In the alternative, it is also possible for the coupling element **132** to be formed in a manner whereby the lower portion does not have to include an expanding entrance **143**. In such a variation, the coupling element **132** would necessarily be formed of two separate pieces which would be joined together about the head **122** of the screw **120**. In either design, however, it is preferred than the top surface **136** of the coupling element **132** have features, such as holes **148**, allowing a second screwdriving tool to easily insert the element **132** into the threaded holes **110**, **100***a* or **112**, **112***a* of the plate assembly **100**.

[**0079**] Referring now to **FIG. 7, a** partial side cross sectional view of a plate assembly **100** of the invention is shown. With reference to the relative positions of the screw **120**, plate assembly **100**, and coupling element **132**, the operative steps of implanting this plate assembly **100** and affixing it to, for example, a pair of vertebral bones, begins with preparing the bones through surgical tissue resection and exposure.

[**0080**] Next, the prongs **102***a*, **102***b* of the first longitudinal plate **100***a* are inserted into the bore **104***a* of the second longitudinal plate **100***b* and translated therein until the desired length of the plate assembly **100** is achieved. More specifically, the surgeon determines, after inspection of the vertebral bones to be secured, how far apart the holes **110** of the first longitudinal plate **100***a* must be spaced from the holes **112** of the second longitudinal plate **100***b* in order for the plate assembly **100** to be properly coupled to the vertebral bones to be clinically effective.

[**0081**] Once the surgeon makes this determination, he secures the plates **100***a*, **100***b* in the selection position by locking the lock assembly. More specifically, with regard to the first embodiment (having the lock assembly shown in **FIGS. 3***a-d* and **4**), the surgeon uses a screwdriving tool to rotate the set screw **100***e* within the threaded bore **100***d* to advance the set screw **100***e* until the prongs **102***a*, **102***b* separate and press against the inner surface **104***b* of the bore **104***a*. The compression of the prongs **102***a*, **102***b* against the inner surface **104***b* secures the position of the plates **100***a*, **100***b* relative to one another, thereby fixing the length of the plate assembly **100**. It should be noted that preferably, the surgeon is able to use the screwdriving tool to reverse rotate the set screw **100***e* within the threaded bore **100***d* to retract the set screw **100***e* and thereby return the prongs **102***a*, **102***b* back together so that they no longer press against the inner surface **104***b* of the bore **104***a* so that the prongs **102***a*, **102***b* may again freely translate within the bore **104***a*. This functionality allows the surgeon to readjust the length of the plate assembly **100** if the surgeon's first setting of the length is not correct or is undesirable.

[**0082**] Use of the second embodiment (having the lock assembly shown in **FIGS. 9***a***1**, **9***a***2**, **9***b*, **9***c*, **9***d* and **10**) by the surgeon is similar in all material respects to use of the first embodiment as noted above, except that locking of the lock assembly involves use of a screwdriving tool to rotate the cam **900** between the prongs **102***a*, **102***b* until the prongs **102***a*, **102***b* separate and press against the inner surface **104***b* of the bore **104***a*. The compression of the prongs **102***a*, **102***b* against the inner surface **104***b* secures the position of the plates **100***a*, **100***b* relative to one another, thereby fixing the length of the plate assembly **100**. It should be noted that preferably, the surgeon is able to use the screwdriving tool to reverse rotate the cam **900** between the prongs **102***a*, **102***b* to return the prongs **102***a*, **102***b* back together so that they no longer press against the inner surface **104***b* of the bore **104***a* so that the prongs **102***a*, **102***b* may again freely translate within the bore **104***a*. This functionality allows the surgeon to readjust the length of the plate assembly **100** if the surgeon's first setting of the length is not correct or is undesirable.

[**0083**] Once the desired length of the plate assembly **100** is fixed, the plate assembly **100** is positioned against the bones and pre-drill holes are made at the desired insertion angle for the screw **120**. Screw **120** and coupling element **132** are then placed together so that the head **122** is within

the interior volume **140**, whereby the two elements are able to rotate freely with respect to one another, but are nonetheless coupled.

[**0084**] The recess **130** in the screw **120** and the through hole **138** of the coupling element **132** are aligned at first, and an appropriate screwdriving tool is used to insert the screw **120** through the proper hole **110** or **112** (**110***a* or **112***a*) and into the pre-drilled hole in the bone. Once the screw **120** has been screwed down to the point that the bottom surface of the coupling element **142** contacts the plate **100***a* or **100***b*, the first threads **134** of the coupling element are mated to the threading **111** or **113** of the hole **110** or **112** (**110***a* or **112***a*), respectively.

[**0085**] Complete insertion of the coupling element **132** to the plate assembly **100** preferably locks the element **132** to the plate assembly **100**, in addition to locking the screw **120** and plate assembly **100** to the bone. In the variation of the embodiment in which the coupling element **132** has slots (elements **146** of **FIG. 6**) and an expanding bottom entrance **143**, corresponding holes **110** or **112** (**110***a* or **112***a*) may be tapered; the complete insertion of the coupling element **132** into the hole **110** or **112** therein having the additional benefit of locking the angle of the screw **120**.

[**0086**] Referring now to **FIG. 8, a** variation of the plate assembly **100** of the invention is shown in perspective view. This plate assembly **300** comprises a first plate **300***a* corresponding to the first plate **100***a* of the plate assembly **100** and a second plate **300***b* corresponding to the second plate **100***b* of the plate assembly **100**. The first plate **300***a* has through holes **310** and a bottom surface **309***a* and the second plate **300***b* has through holes **312** and a bottom surface **309***b*. The plate assembly **300** further includes at least one feature protruding from one of the bottom surfaces **309***a*, **309***b* for removable and temporary fixation of the plate assembly **300** to a vertebral bone. In this embodiment, the feature is a spike. However, it should be understood that other features can additionally or alternatively be used to achieve this functionality without departing from the scope of the invention.

[**0087**] Accordingly, in this embodiment, as shown in **FIG. 8**, one spike element **301** protrudes from each of the bottom surfaces **309***a*, **309***b*. Preferably, each spike **301** is positioned between the pair of holes **310** or **312**, on center line A-A. These spikes allow the plate assembly **300** to be temporarily, and easily removably, fixed to vertebral bones during the steps of pre-drilling and insertion of the screws **120** through the holes **310**, **312** and into the vertebral bones. This is a desirable operational advantage, as it frees one hand of the surgeon and/or removes extra tools from the surgical site.

[**0088**] It is preferred to have the spikes **301** positioned along the center line A-A for plate assemblies **300** which have a radius of curvature which is equal to or greater than that of the vertebral bodies such as, for example, vertebral bones (i.e., not as curved as the bone). Having the spikes **301** along the center line ensures that the plate assembly **300** can be removably fixed to the bone by simply applying an insertion force against the plate assembly **300** and driving the spikes **301** into the bone. It is understood that for implants wherein the plate assembly **300** has a smaller radius of curvature than the bone, it would be desirable to position the spikes **301** at edges **303** of the plate assembly **300**.

[**0089**] While there has been described and illustrated implantation devices for stabilizing and immobilizing regions of the spine by affixing a plate assembly having an adjustable length to the anterior portion of the vertebral bones, it will be apparent to those skilled in the art that variations and modifications are possible without deviating from the broad spirit and principle of the invention which shall be limited solely by the scope of the claims appended hereto.

What is claimed is:

1. A plate assembly, comprising:

a first longitudinal plate having an end defined by longitudinal prongs;

a second longitudinal plate having a longitudinal bore, the longitudinal bore being adapted to receive the prongs for longitudinal translation therein through a plurality of positions; and

a lock assembly for locking the prongs within the bore at one of the positions; wherein

each plate comprises a feature that is usable to couple the plate to a body structure; and wherein

the bore has an inner surface and the lock assembly presses the prongs against the inner surface; and wherein

the prongs are laterally adjacent one another and the lock assembly separates the prongs to press them against the inner surface; and wherein

the lock assembly comprises a multi-positionable cam between the prongs.

2. The plate assembly of claim 1, wherein the cam is alternately positionable in a first position, in which the cam permits the prongs to longitudinally translate within the bore, and a second position, in which the cam maintains the prongs against the inner surface.

3. The plate assembly of claim 2, wherein when the cam is in the first position, it is longitudinally translatable between the prongs through a plurality of longitudinal translation positions.

4. The plate assembly of claim 1, wherein the cam is a rotatable cam.

5. The plate assembly of claim 4, wherein the cam is rotatable into a first position, in which the cam permits the prongs to longitudinally translate within the bore, and a second position, in which the cam maintains the prongs against the inner surface.

6. The plate assembly of claim 5, wherein in the second position, the cam is rotated ninety degrees with respect to the first position.

7. The plate assembly of claim 5, wherein when the cam is in the first position, it is longitudinally translatable between the prongs through a plurality of longitudinal translation positions.

8. The plate assembly of claim 1, wherein the cam has a portion that engages the prongs for separation, the portion having a width smaller than a resting distance between the prongs and a length greater than the resting distance between the prongs and resting distances between each prong and the inner surface, wherein the resting distance between the prongs is a distance between the prongs when the prongs are not engaged by the cam, and each of the resting distances

between each prong and the inner surface is a distance between each prong and the inner surface when the prongs are not engaged by the cam.

9. The plate assembly of claim 8, wherein the cam has flanges that maintain the cam in the plate assembly, each of the flanges having a cross-section greater than the length of the portion of the cam.

10. An orthopedic device comprising a longitudinal plate assembly having an adjustable length and two ends, each of the ends comprising a feature that can be used to couple the end to a body structure; wherein

the assembly comprises two longitudinal plates that can translate longitudinally with respect to one another through a plurality of positions and be secured with respect to one another at one of the positions, thereby enabling the length of the assembly to be adjusted; and wherein

one of the plates has an end defined by longitudinal prongs and the other of the plates has a longitudinal bore, the longitudinal bore being adapted to receive the prongs for longitudinal translation therein; and wherein

the assembly further comprises a lock assembly for locking the prongs within the bore at one of the positions; and wherein

the bore has an inner surface and the lock assembly presses the prongs against the inner surface; and wherein

the prongs are laterally adjacent one another and the lock assembly separates the prongs to press them against the inner surface; and wherein

the lock assembly comprises a multi-positionable cam between the prongs.

11. The plate assembly of claim 10, wherein the cam is alternately positionable in a first position, in which the cam permits the prongs to longitudinally translate within the bore, and a second position, in which the cam maintains the prongs against the inner surface.

12. The plate assembly of claim 11, wherein when the cam is in the first position, it is longitudinally translatable between the prongs through a plurality of longitudinal translation positions.

13. The plate assembly of claim 10, wherein the cam is a rotatable cam.

14. The plate assembly of claim 13, wherein the cam is rotatable into a first position, in which the cam permits the prongs to longitudinally translate within the bore, and a second position, in which the cam maintains the prongs against the inner surface.

15. The plate assembly of claim 14, wherein in the second position, the cam is rotated ninety degrees with respect to the first position.

16. The plate assembly of claim 14, wherein when the cam is in the first position, it is longitudinally translatable between the prongs through a plurality of longitudinal translation positions.

17. The plate assembly of claim 10, wherein the cam has a portion that engages the prongs for separation, the portion having a width smaller than a resting distance between the prongs and a length greater than the resting distance between the prongs and resting distances between each prong and the inner surface, wherein the resting distance between the prongs is a distance between the prongs when the prongs are not engaged by the cam, and each of the resting distances between each prong and the inner surface is a distance between each prong and the inner surface when the prongs are not engaged by the cam.

18. The plate assembly of claim 17, wherein the cam has flanges that maintain the cam in the plate assembly, each of the flanges having a cross-section greater than the length of the portion of the cam.

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