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(54) **SPINAL FIXATION CONSTRUCTS AND RELATED METHODS**

(52) **U.S. Cl.**  
CPC ..... *A61B 17/7001* (2013.01); *A61B 17/7035* (2013.01); *A61B 17/7022* (2013.01); *A61B 17/7019* (2013.01); *A61B 17/7043* (2013.01); *A61B 17/7023* (2013.01); *A61B 17/7032* (2013.01)

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(57) **ABSTRACT**

(21) Appl. No.: **16/294,555**

(22) Filed: **Mar. 6, 2019**

**Related U.S. Application Data**

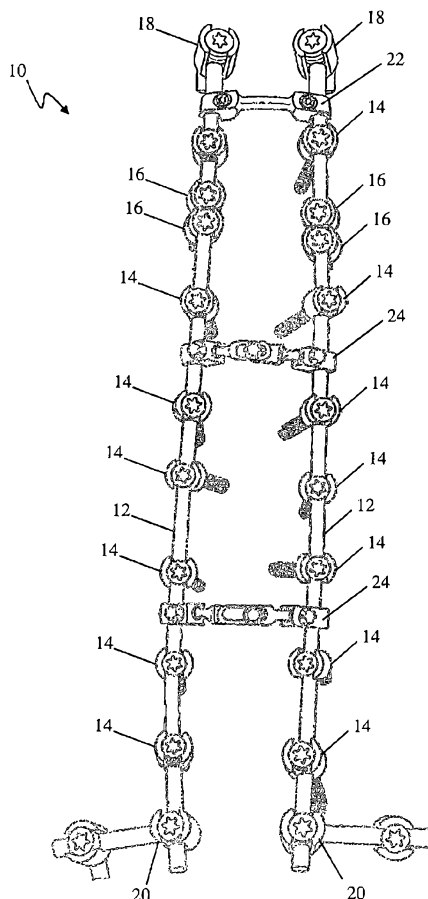
(63) Continuation of application No. 14/703,852, filed on May 4, 2015, now abandoned.

(60) Provisional application No. 61/988,066, filed on May 2, 2014.

**Publication Classification**

(51) **Int. Cl.**  
*A61B 17/70* (2006.01)

This disclosure describes a variety of transitional or terminal components that may be implanted as part of a spinal fixation construct to decrease the potential for subsequent development of junctional disease. The fixation construct may extend any number of levels from a single level construct to a long construct spanning multiple spinal levels and multiple spinal regions from the lumbosacral to cervical regions, and with any variety of combination of anchors, rods, and connectors. Terminal and/or transitional components may be utilized at the caudal and or cephalad ends of the fixation construct to reduce stresses endured by the construct adjacent pathology and prevent or reduce incidence and degree of junctional disease.



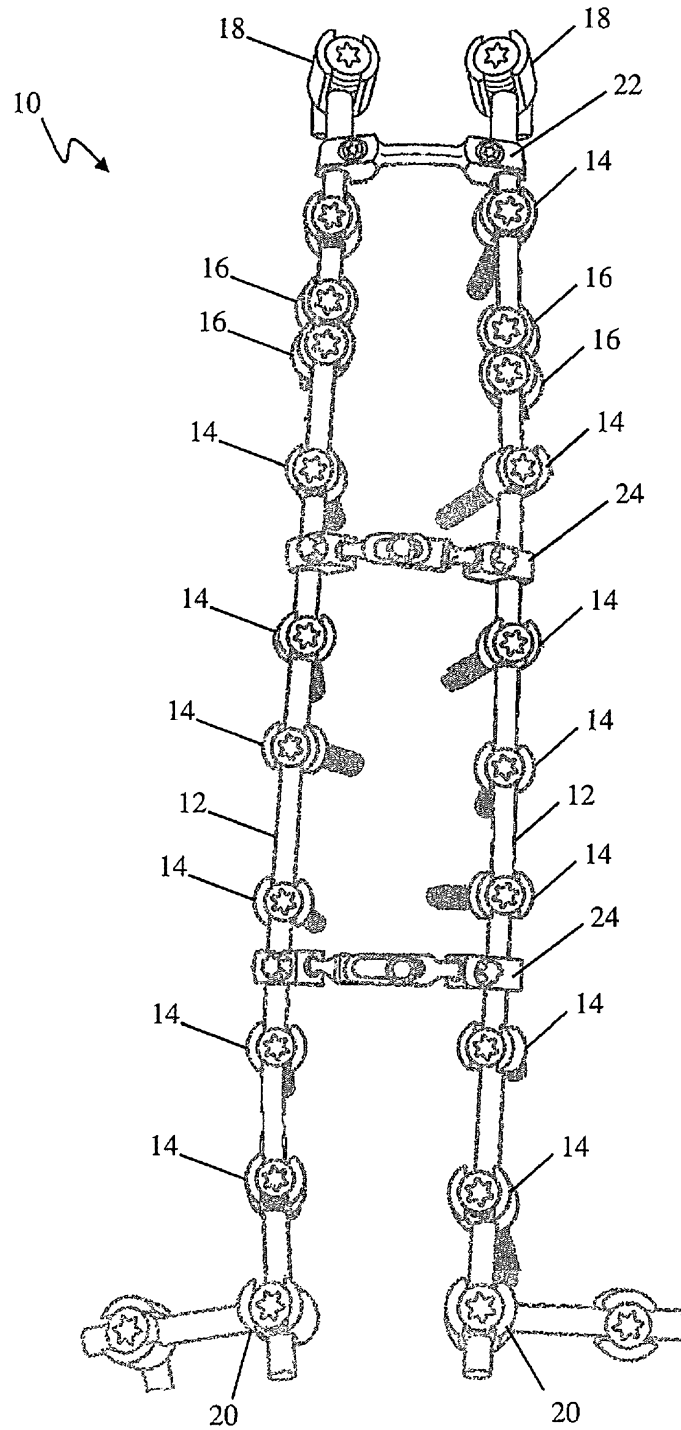


Fig. 1

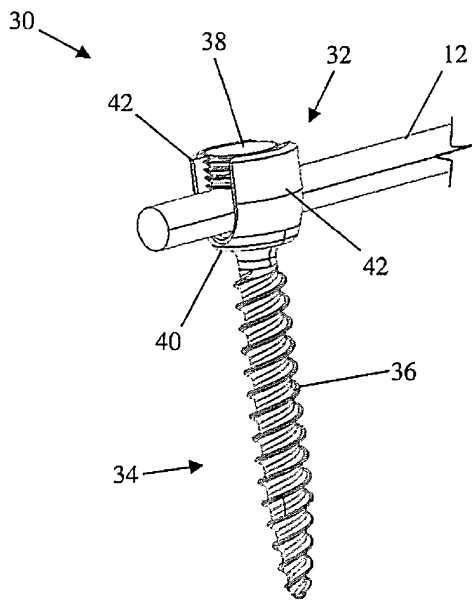


Fig. 2

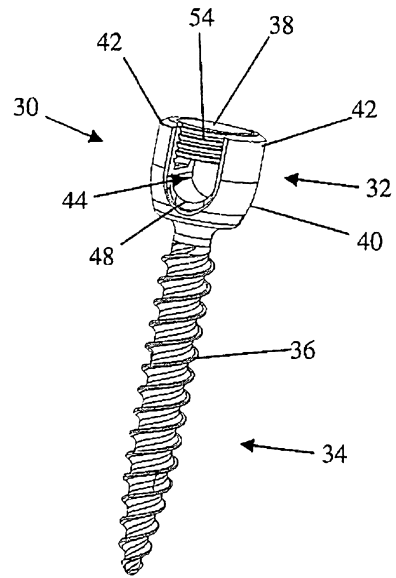


Fig. 3

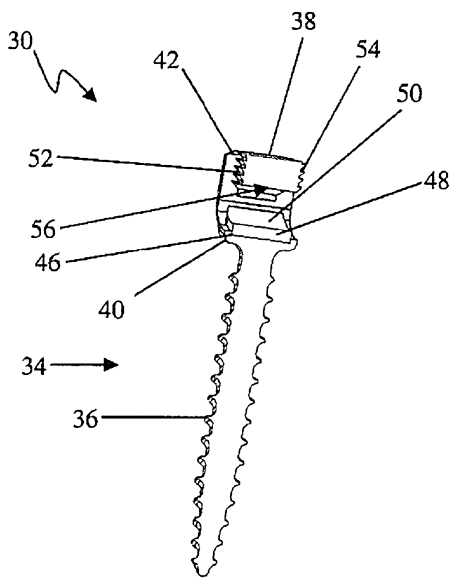


Fig. 4

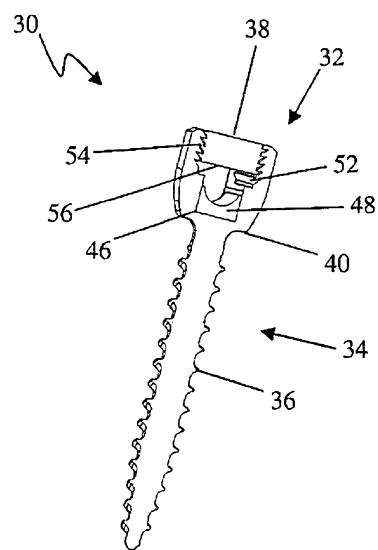
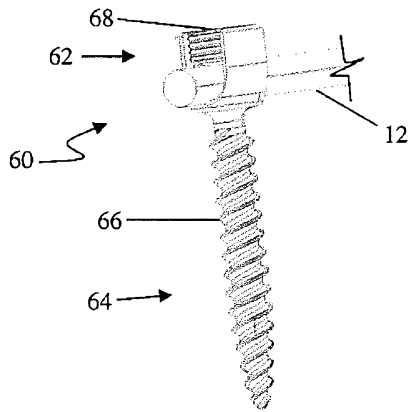
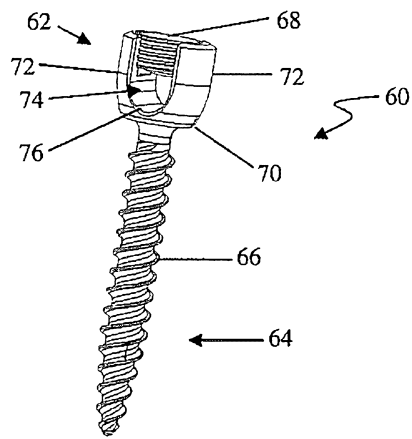


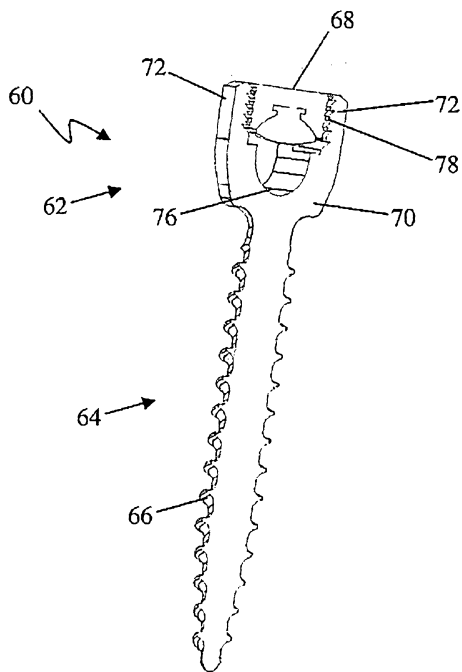
Fig. 5



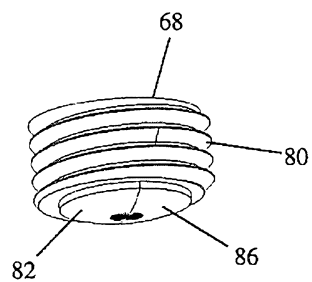
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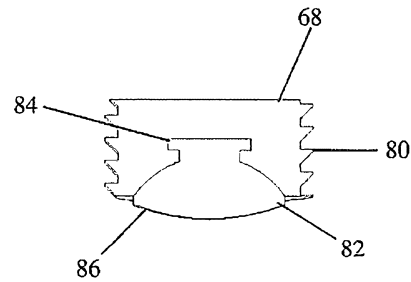
**Fig. 7**



**Fig. 8**



**Fig. 9**



**Fig. 10**

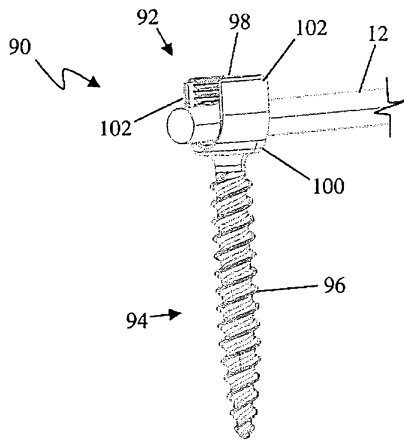


Fig. 11

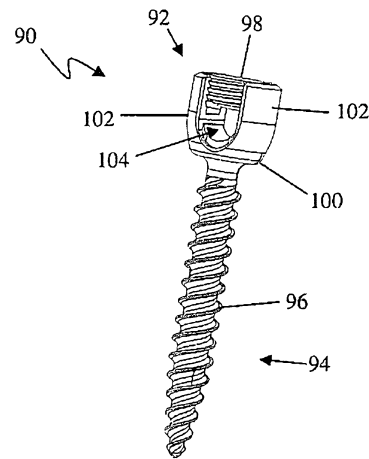


Fig. 12

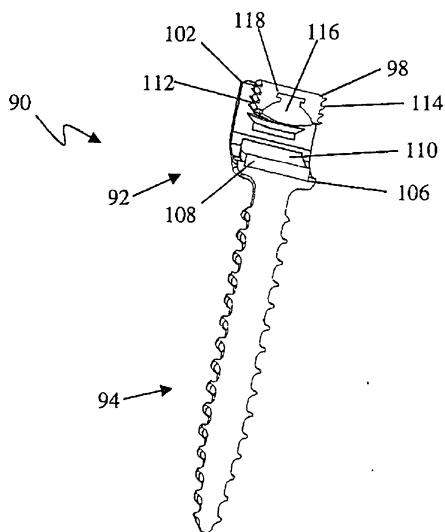


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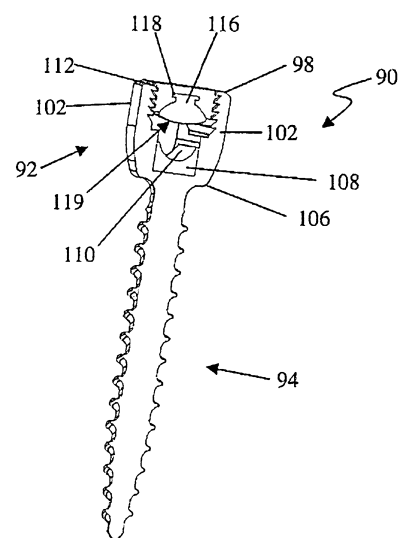
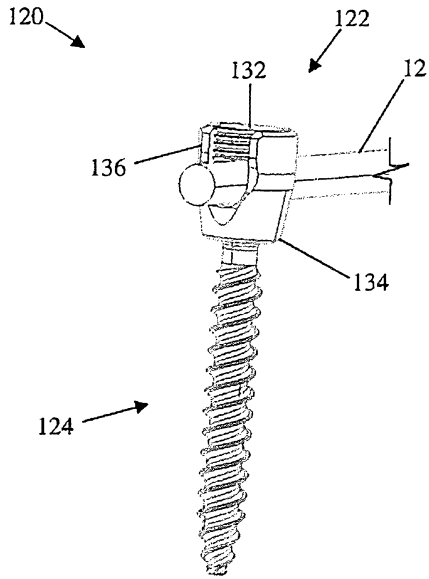
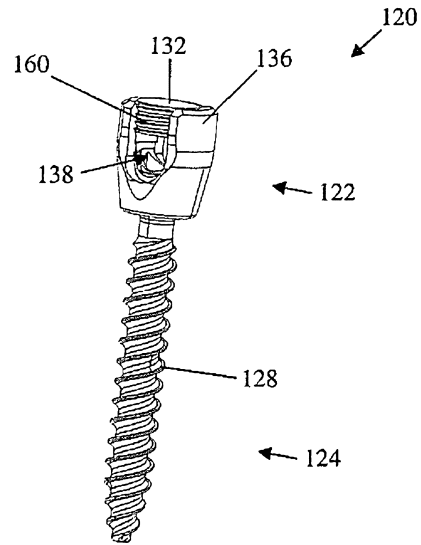


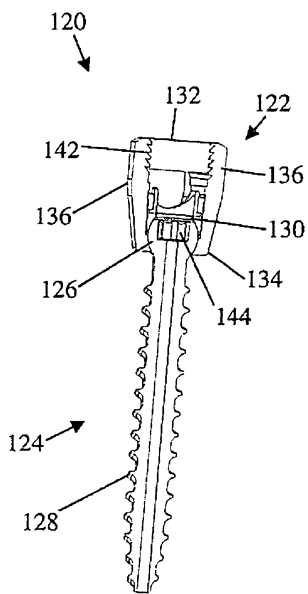
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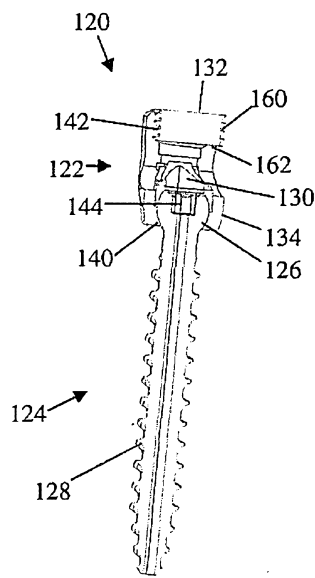
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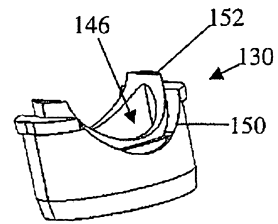
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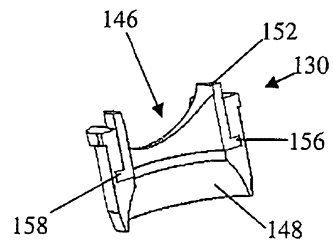
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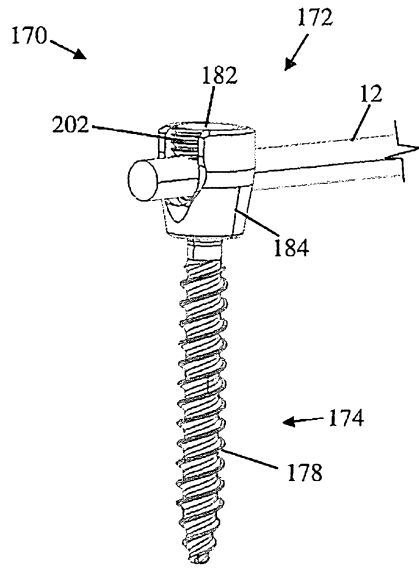
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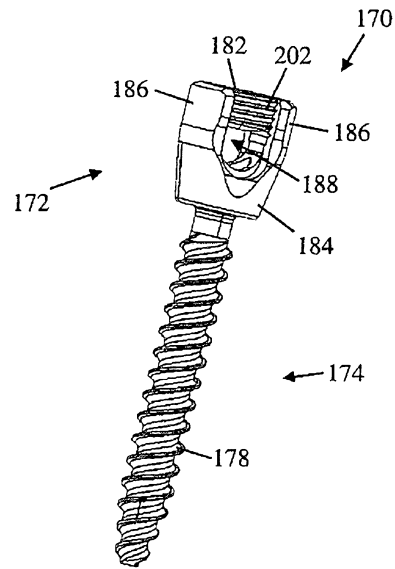
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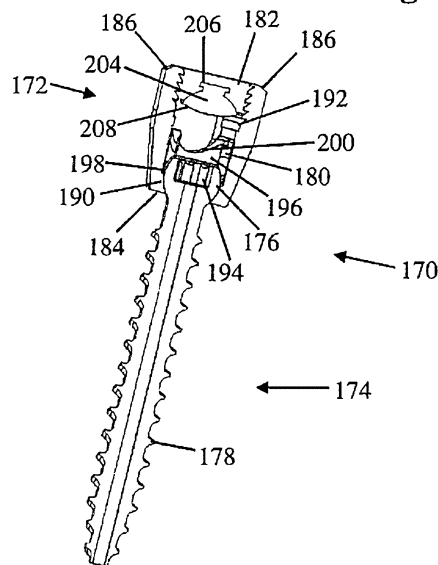
**Fig. 20**



**Fig. 21**



**Fig. 22**



**Fig. 23**

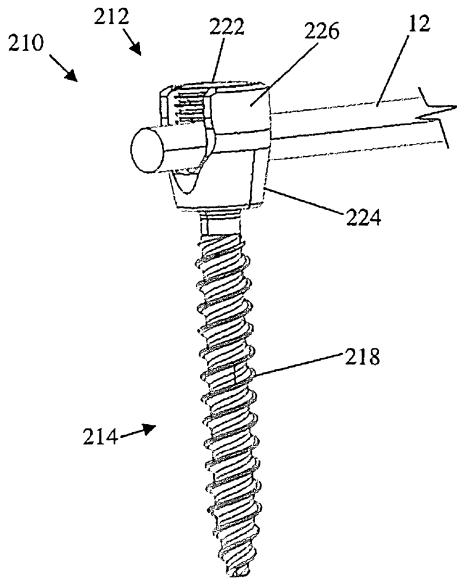


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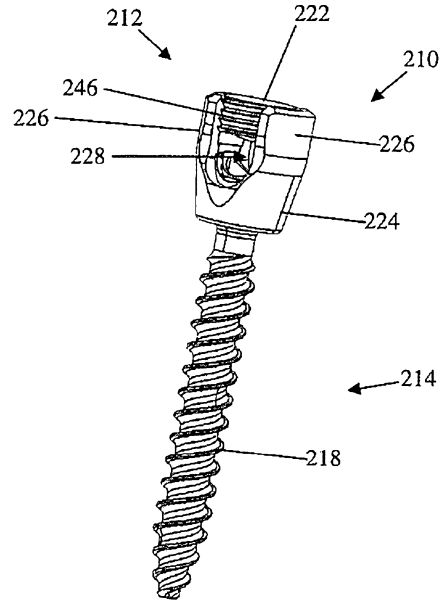


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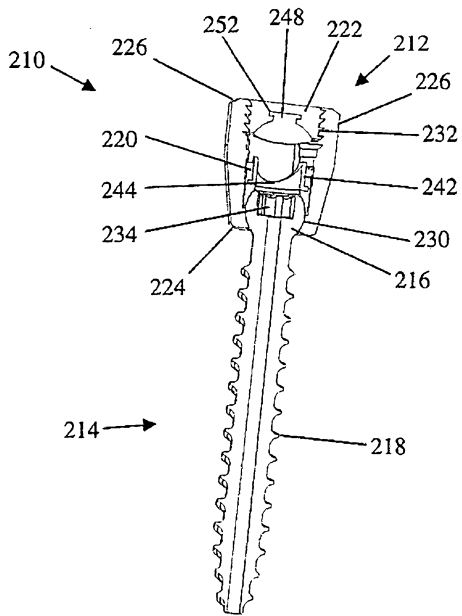


Fig. 26

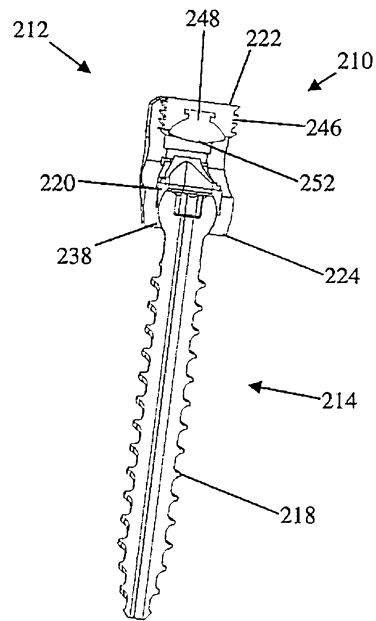


Fig. 27



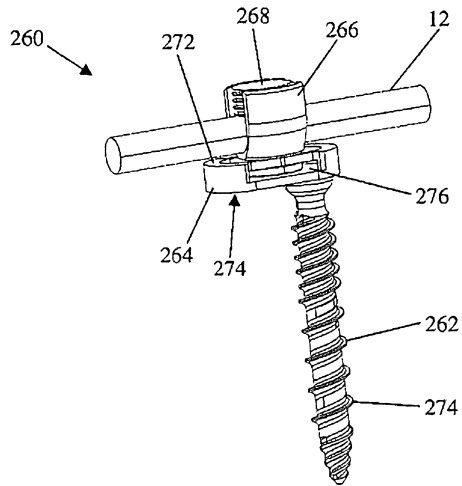


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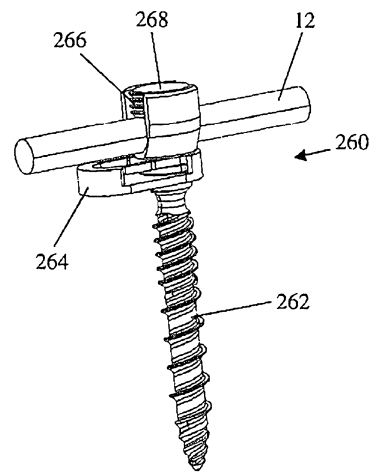


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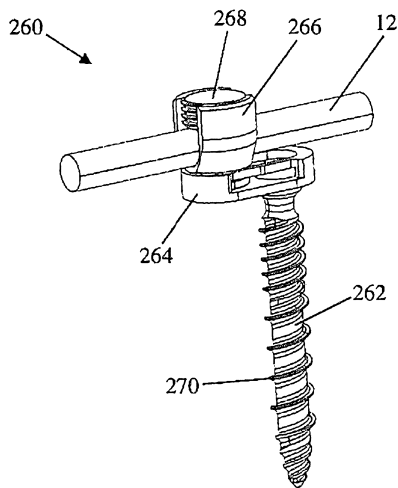


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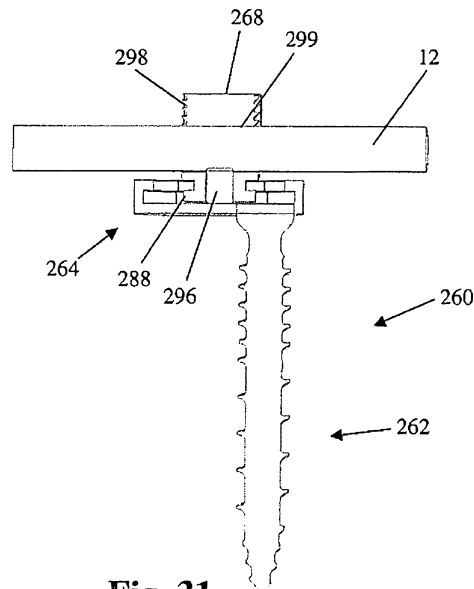
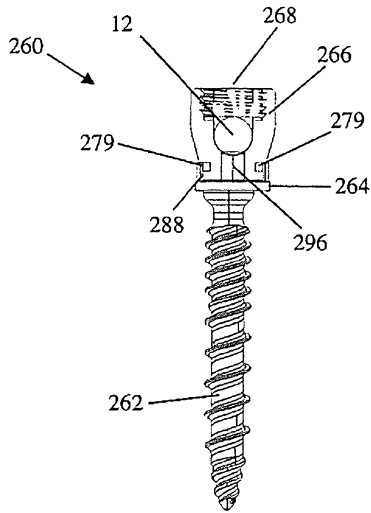
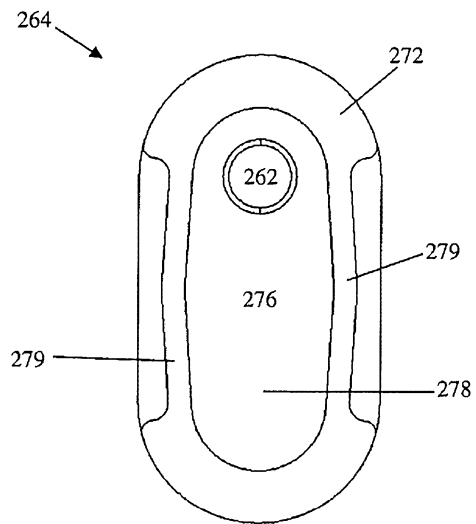


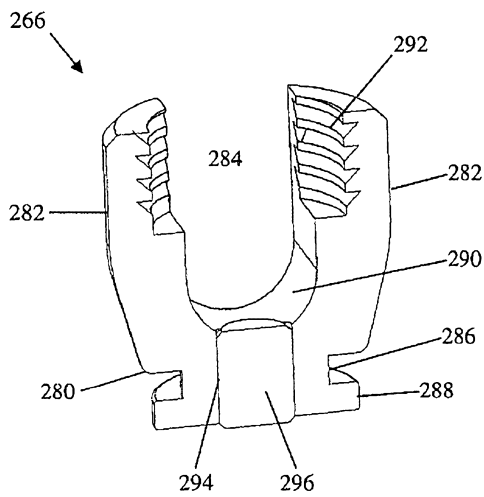
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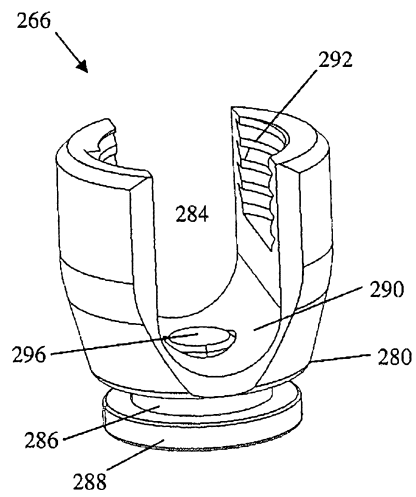
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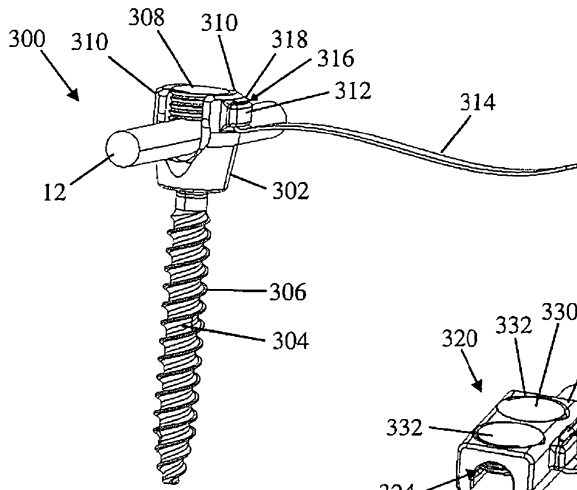
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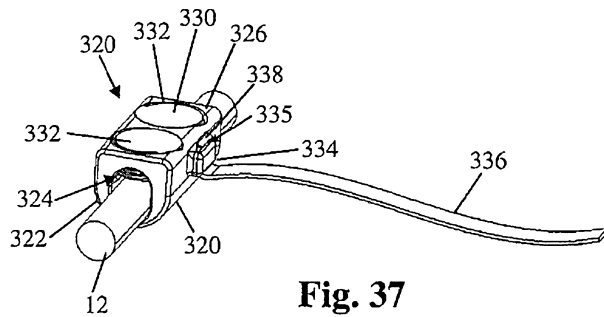
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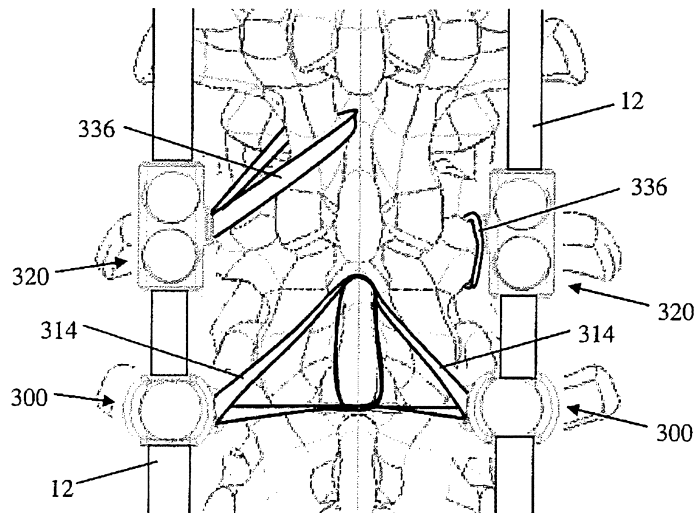
**Fig. 35**



**Fig. 36**



**Fig. 37**



**Fig. 38**

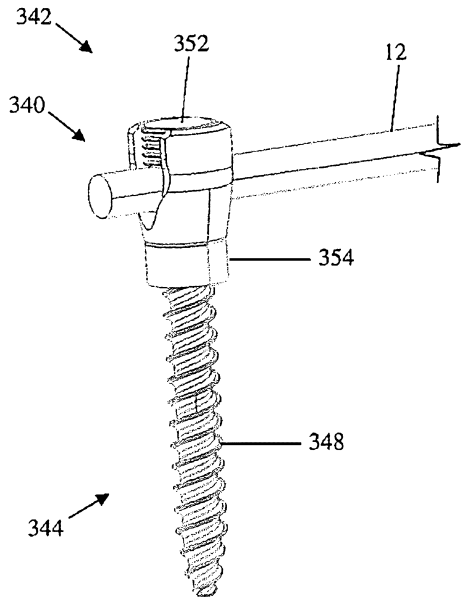


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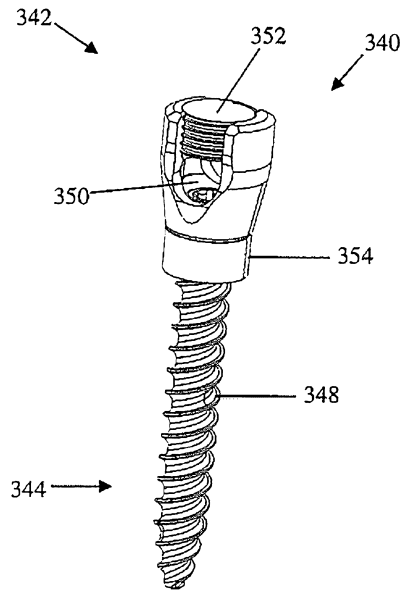


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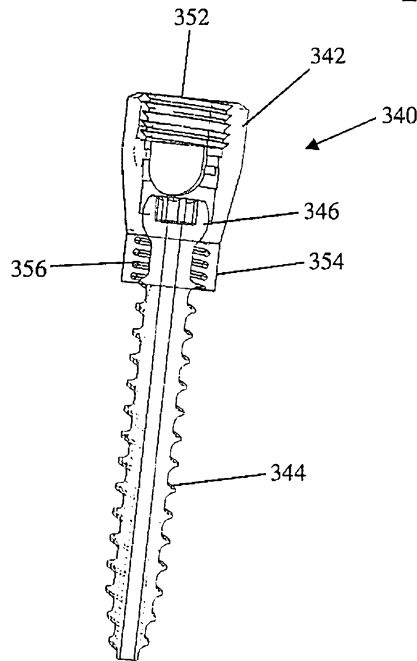


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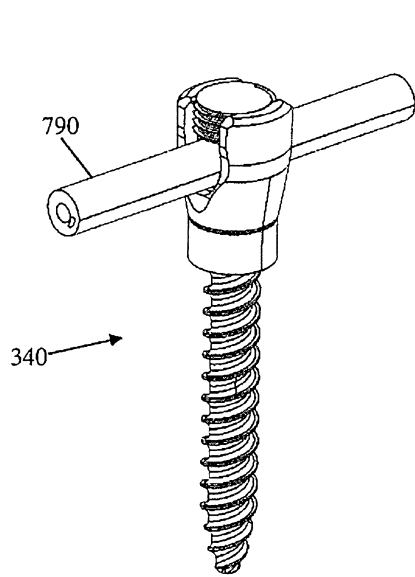


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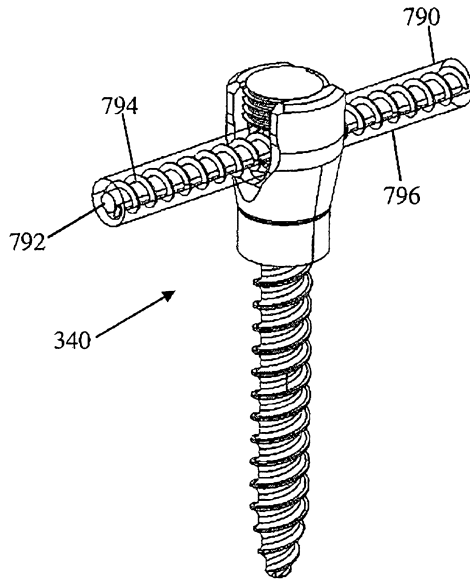


Fig. 43

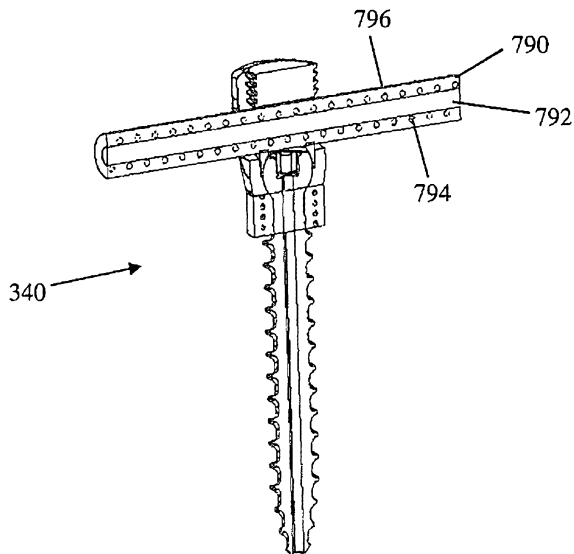


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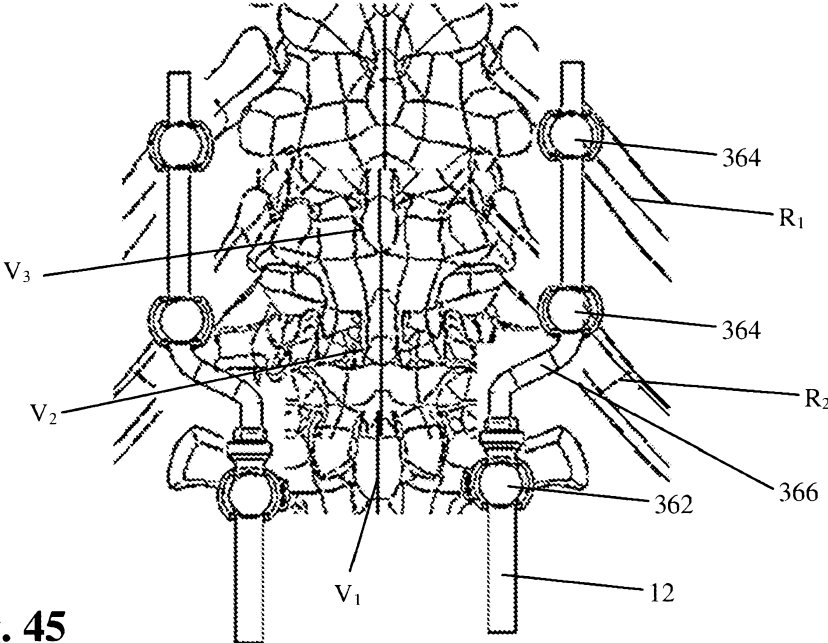


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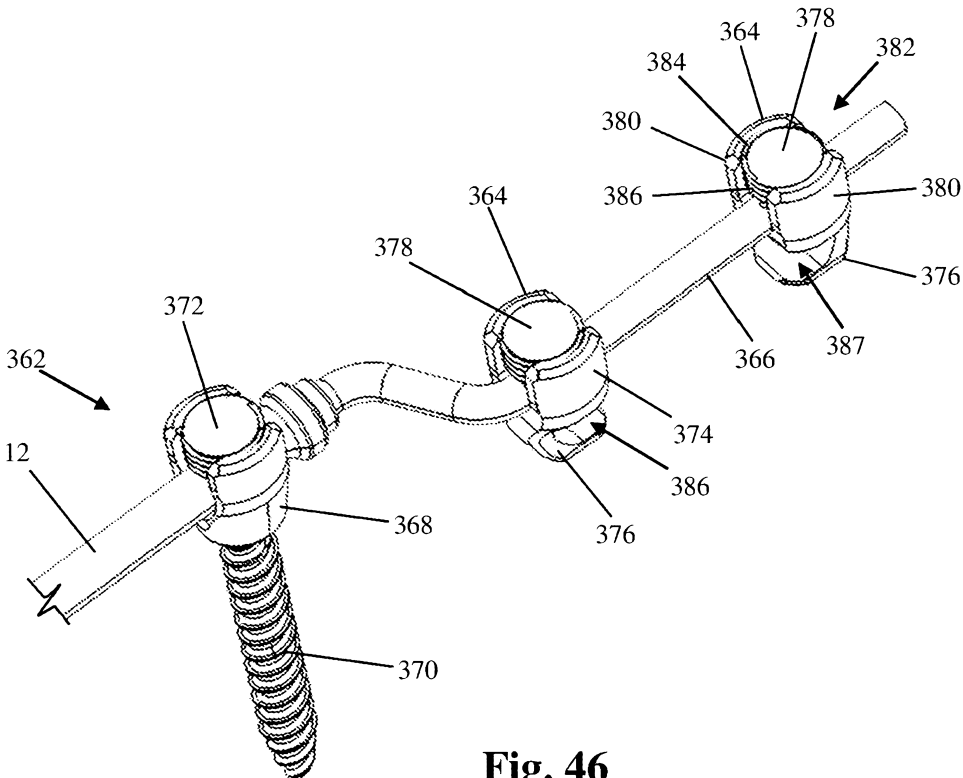


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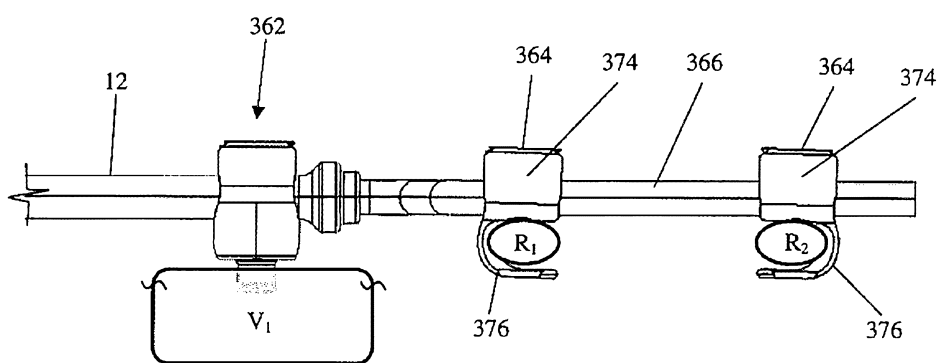
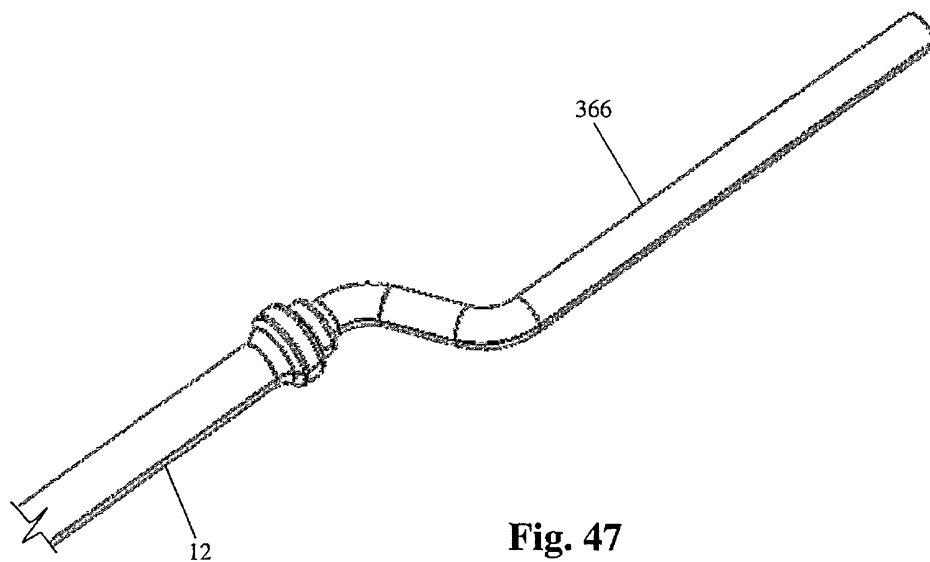
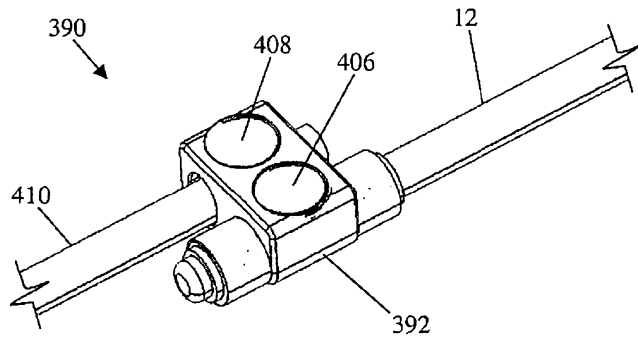
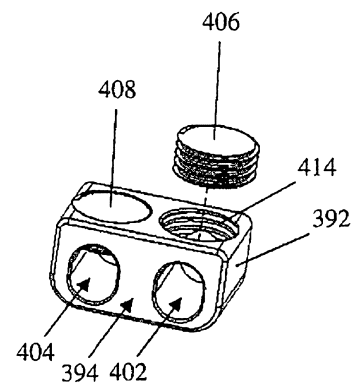


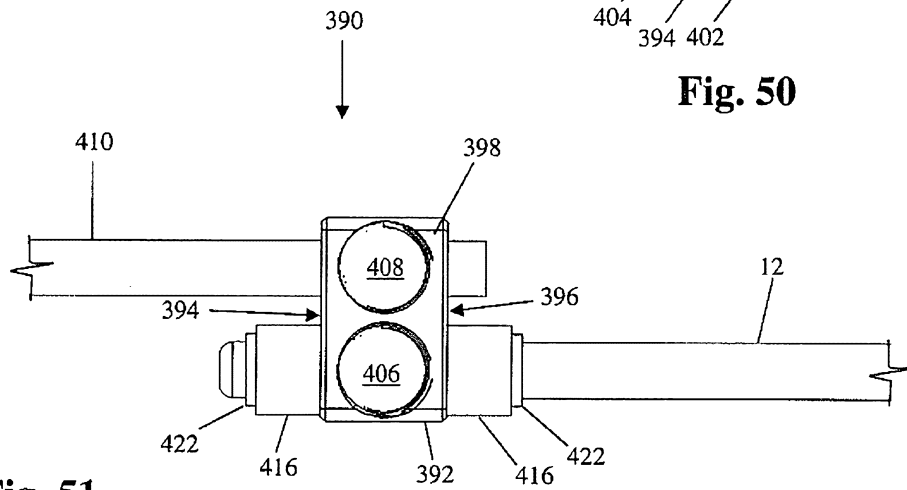
Fig. 48



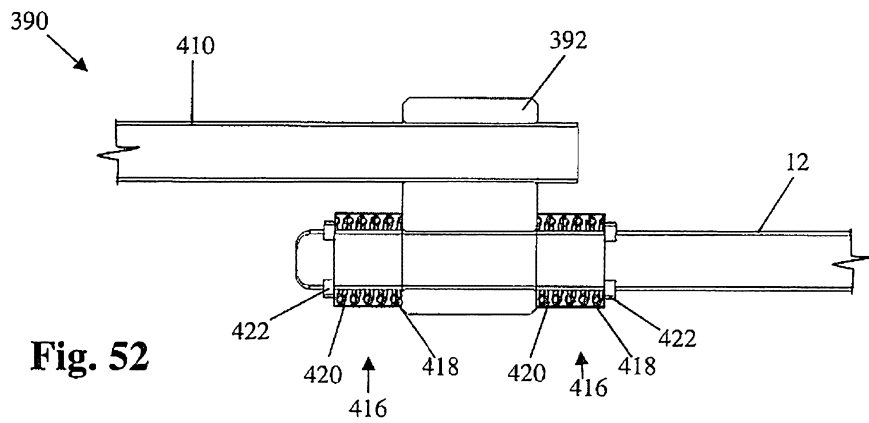
**Fig. 49**



**Fig. 50**

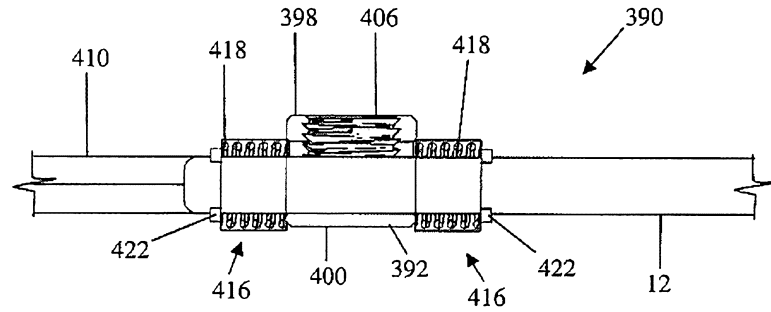


**Fig. 51**

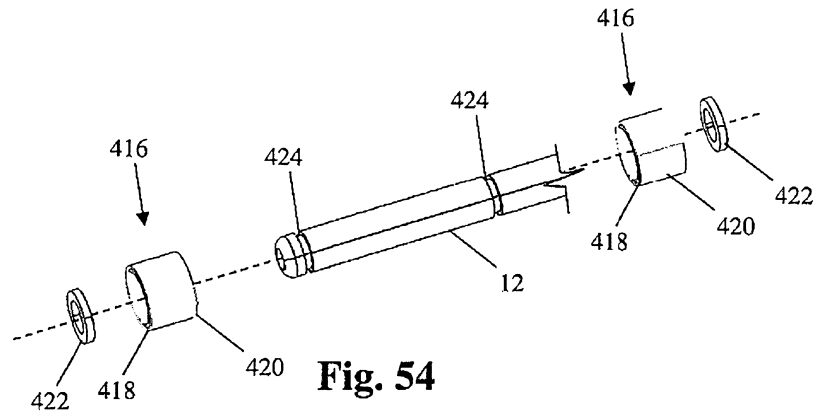


**Fig. 52**

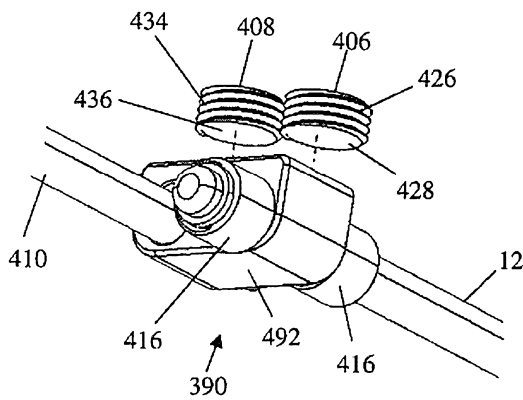




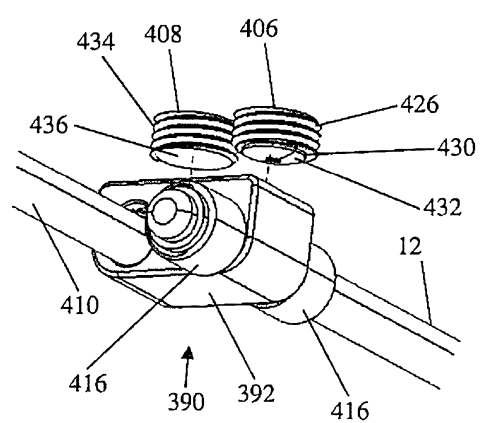
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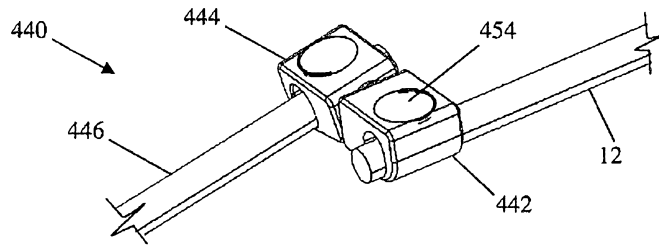
**Fig. 54**



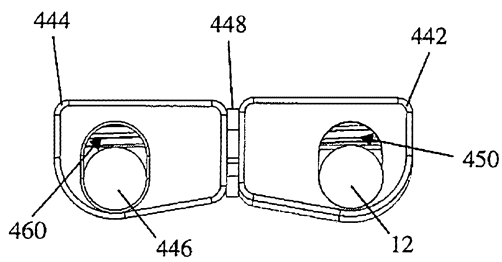
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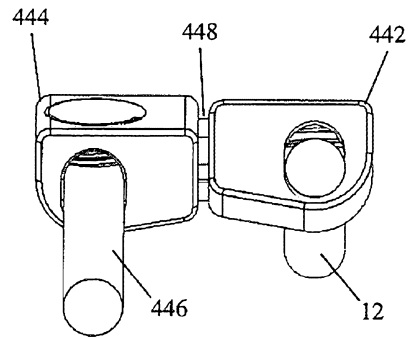
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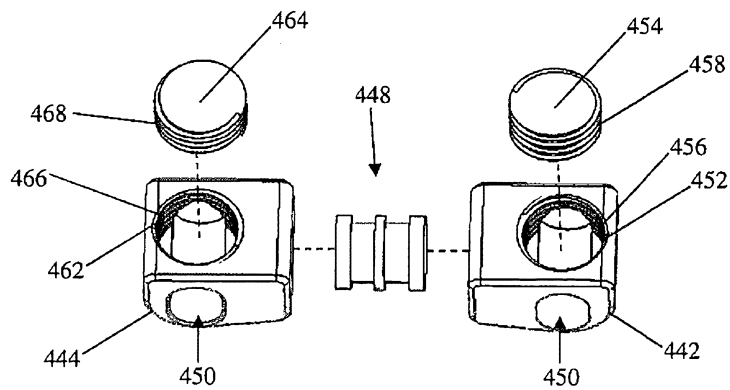
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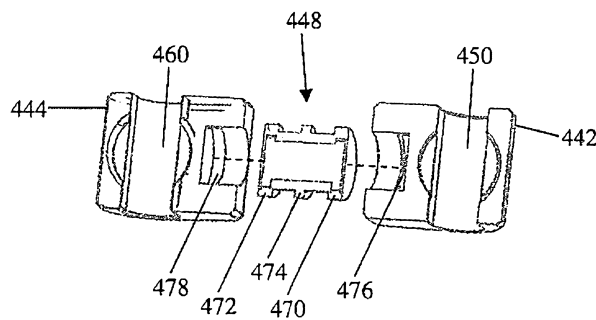
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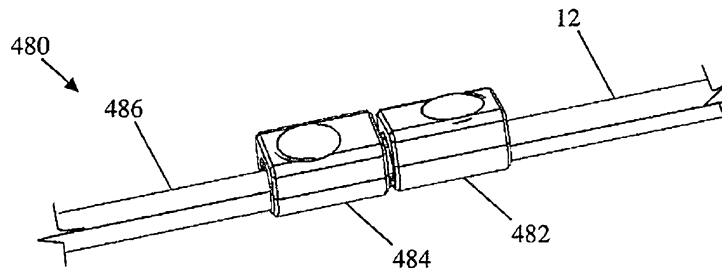
**Fig. 59**



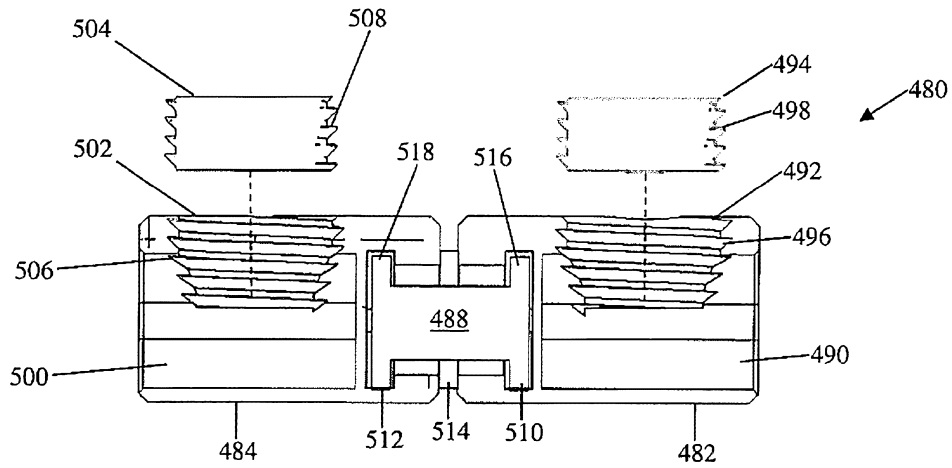
**Fig. 60**



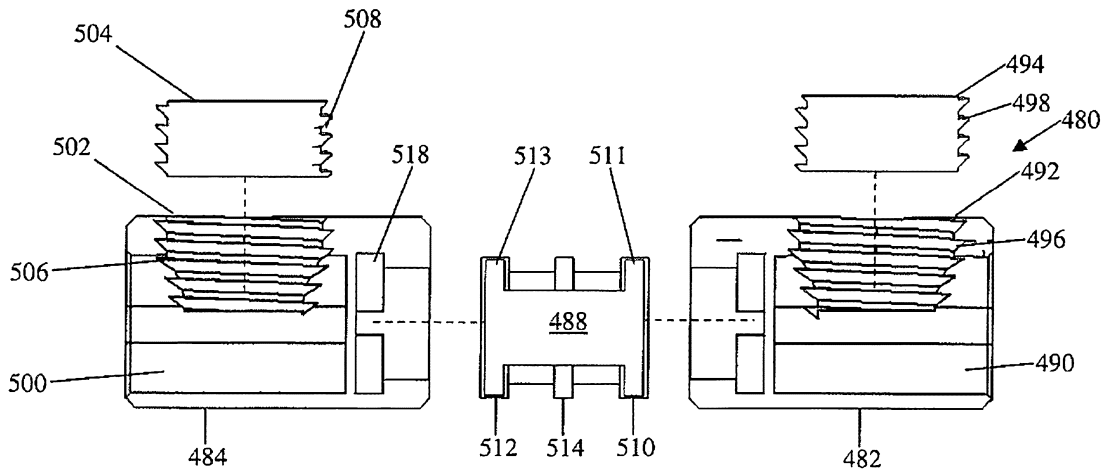
**Fig. 61**



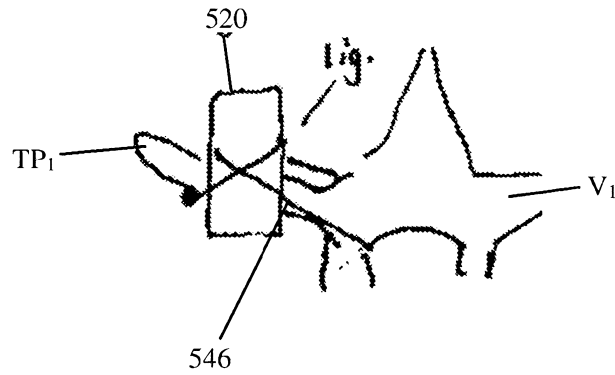
**Fig. 62**



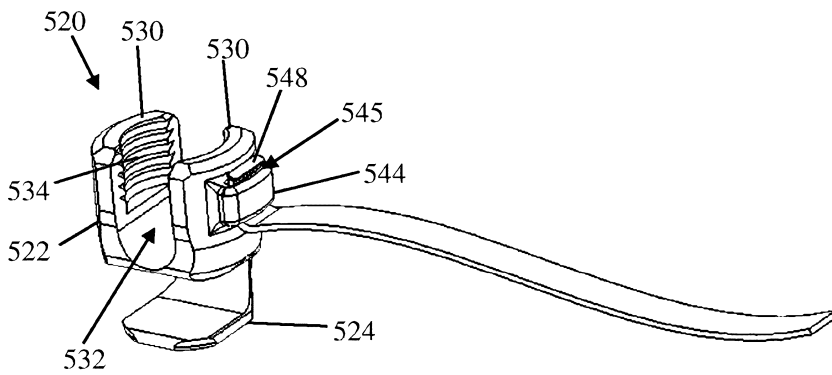
**Fig. 63**



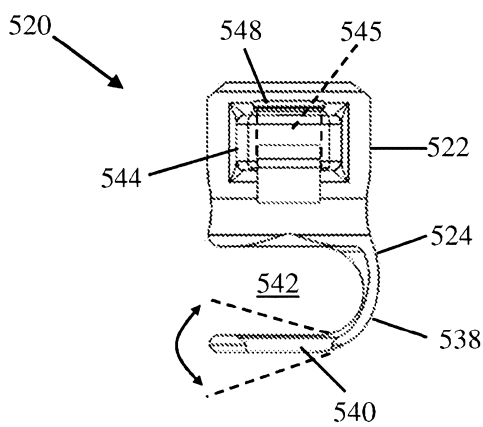
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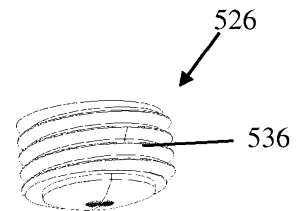
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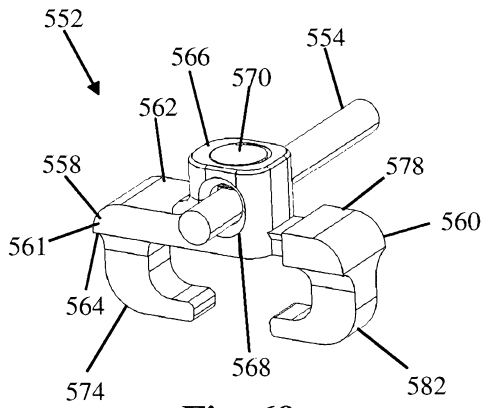
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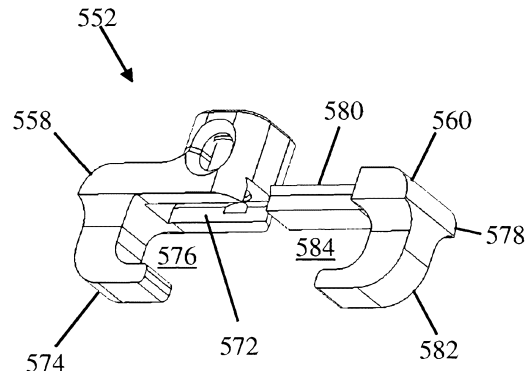
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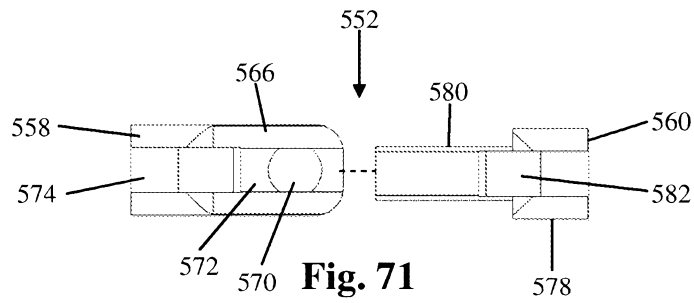
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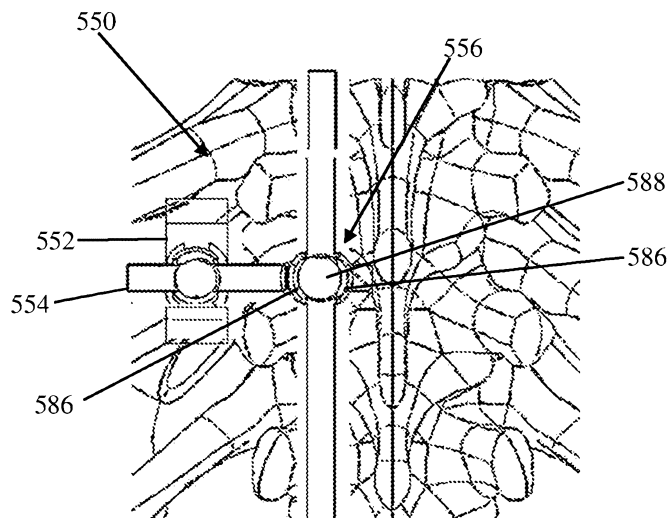
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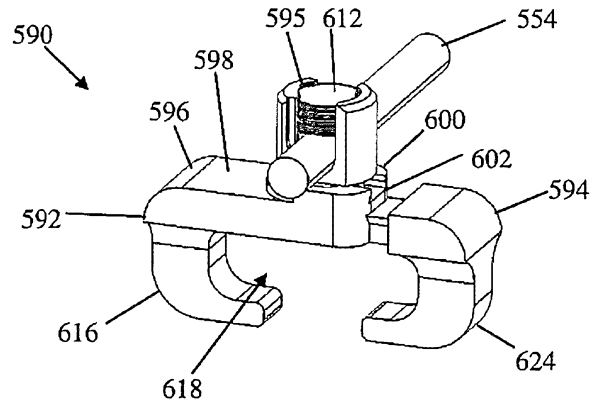
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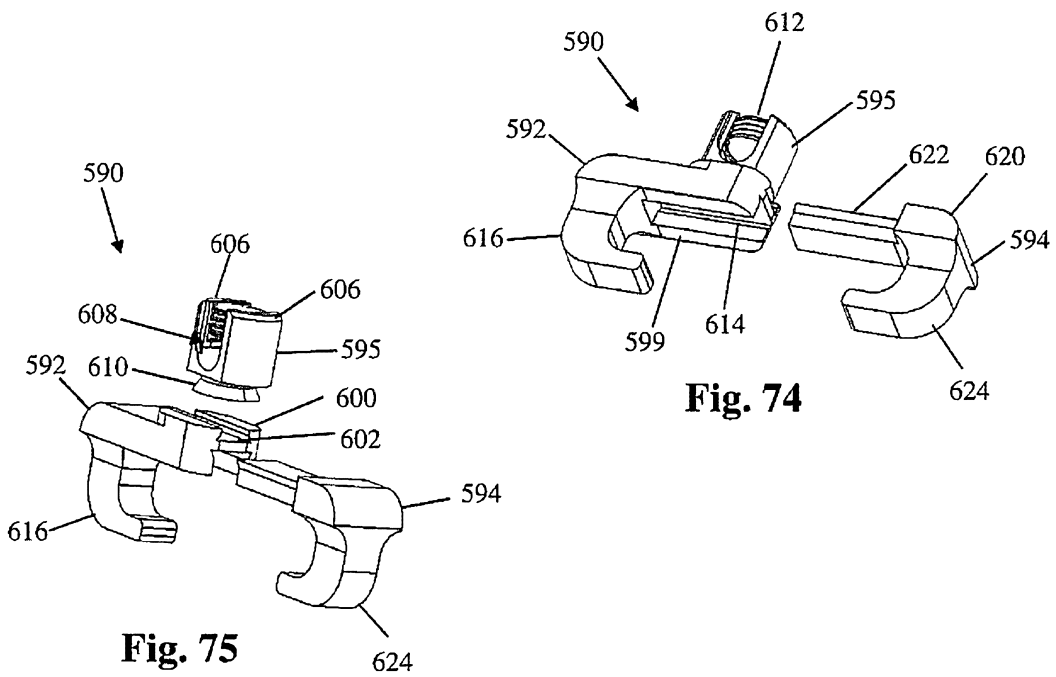
**Fig. 71**



**Fig. 72**

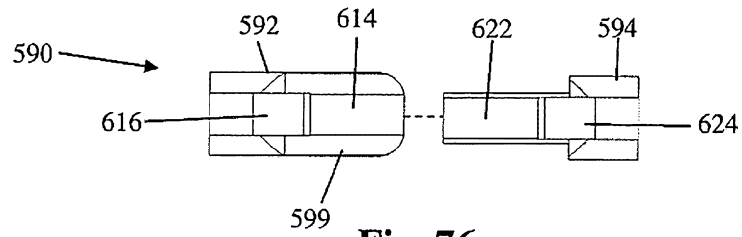


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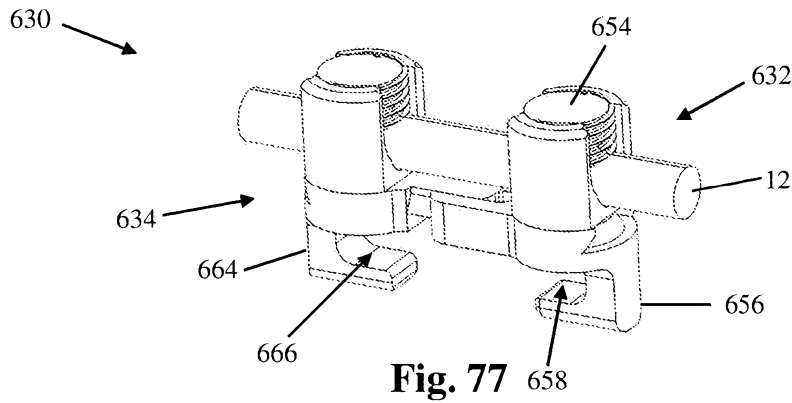


**Fig. 74**

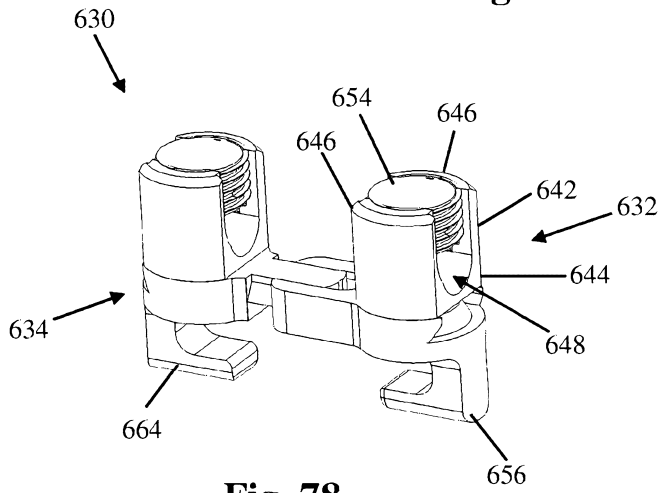
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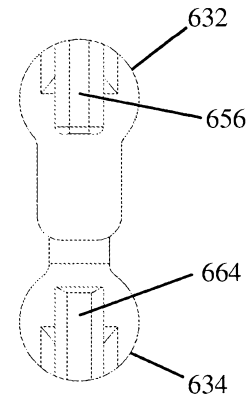
**Fig. 76**



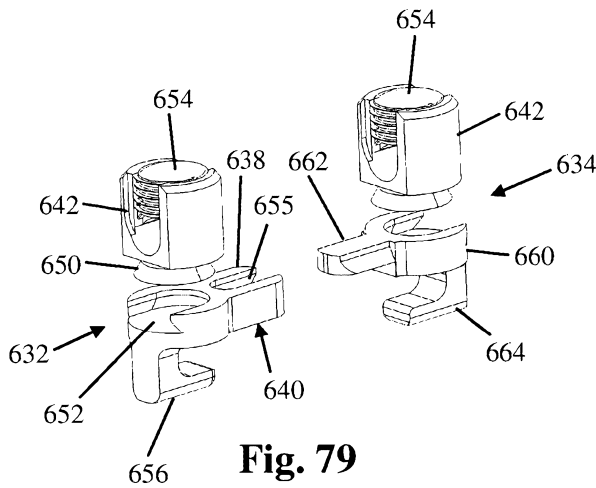
**Fig. 77**



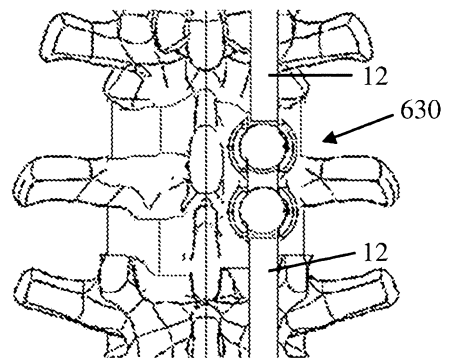
**Fig. 78**



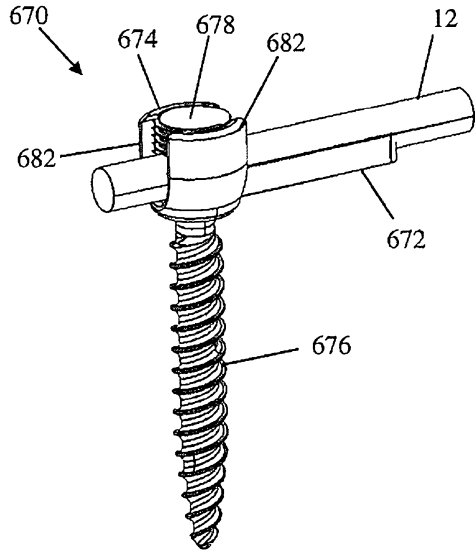
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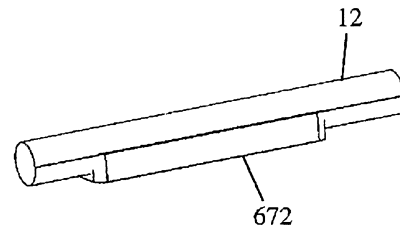
**Fig. 79**



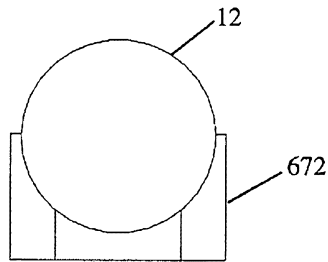
**Fig. 81**



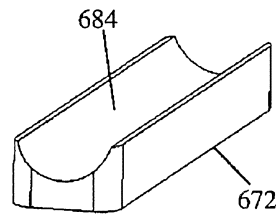
**Fig. 82**



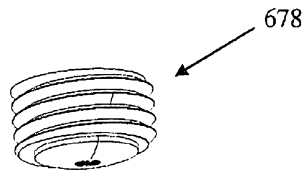
**Fig. 83**



**Fig. 84**

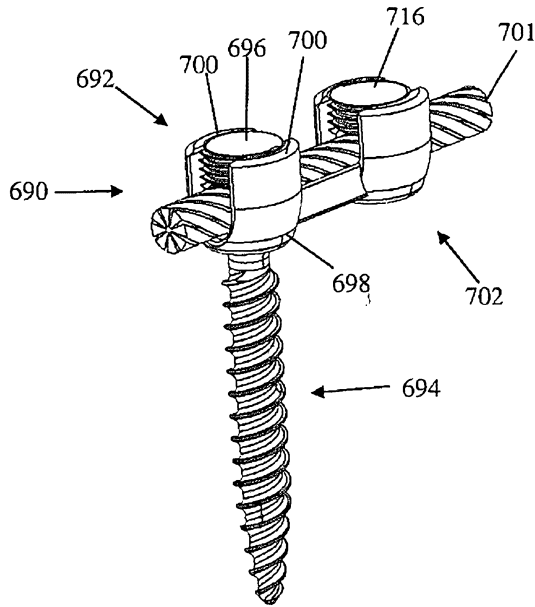


**Fig. 85**

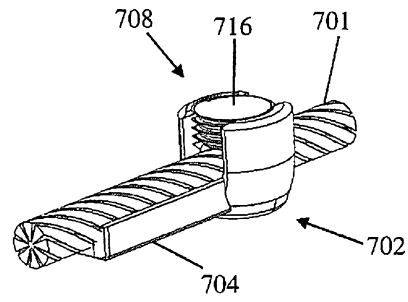


**Fig. 86**

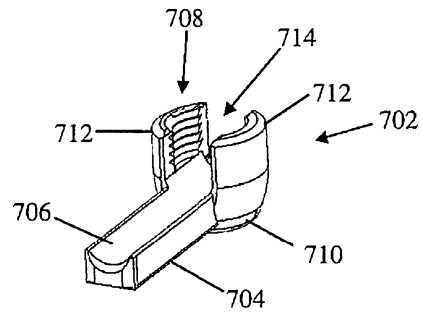




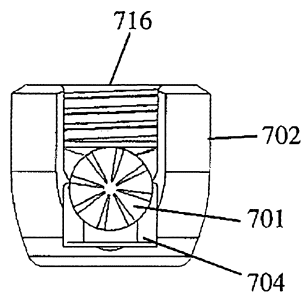
**Fig. 87**



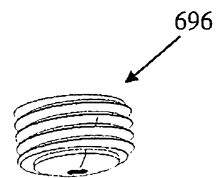
**Fig. 88**



**Fig. 89**



**Fig. 90**



**Fig. 91**

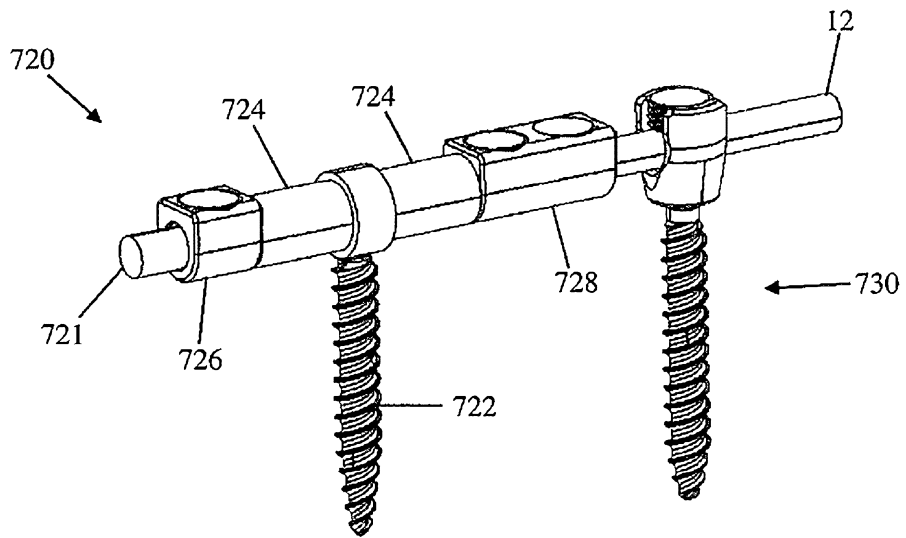


Fig. 92

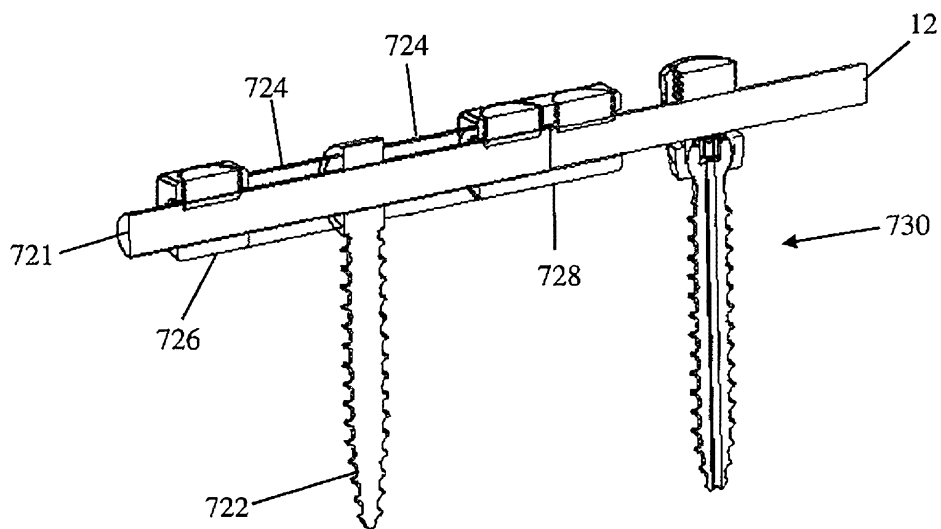


Fig. 93

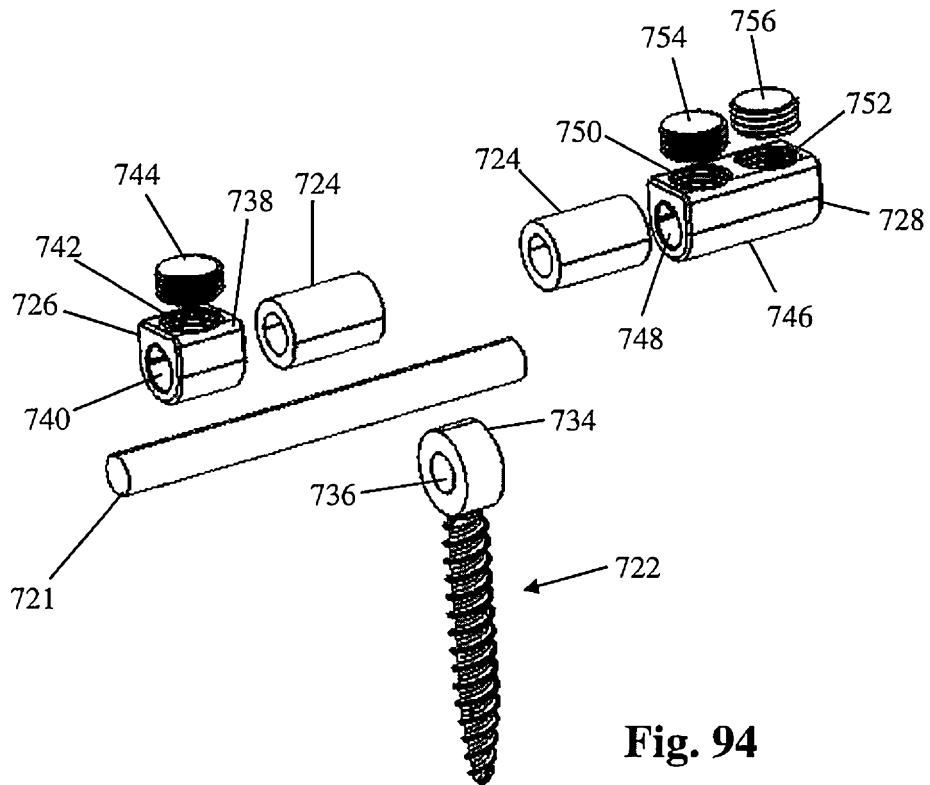


Fig. 94

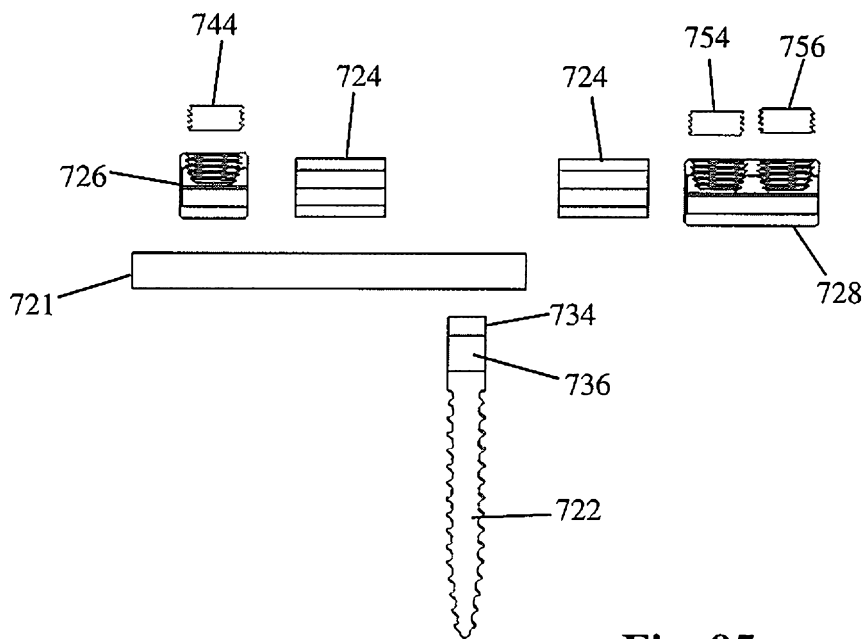
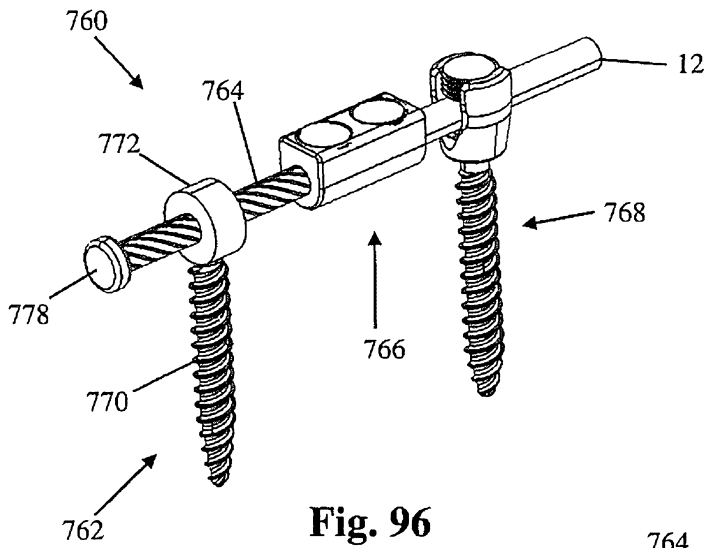
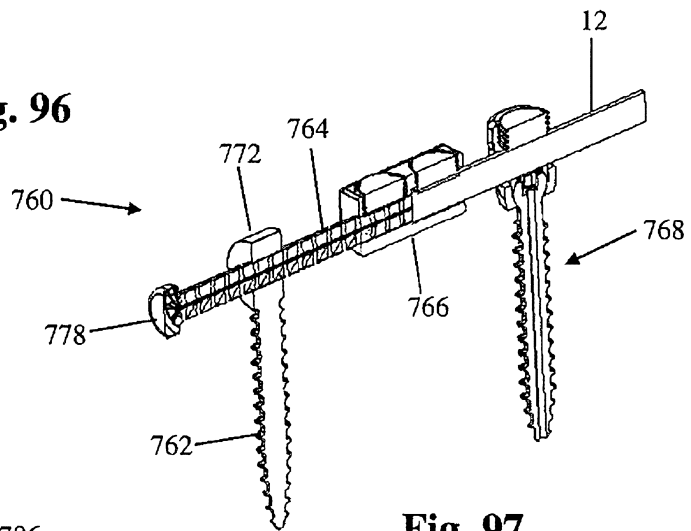


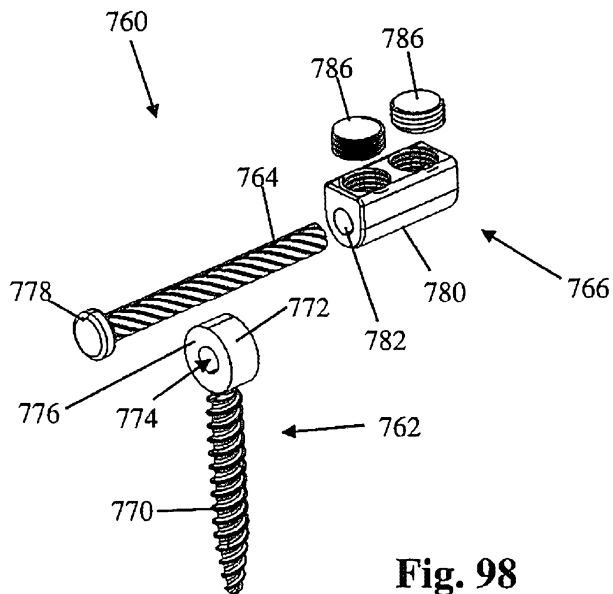
Fig. 95



**Fig. 96**



**Fig. 97**



**Fig. 98**

## SPINAL FIXATION CONSTRUCTS AND RELATED METHODS

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is continuation of U.S. patent application Ser. No. 14/703,852 filed on May 4, 2015, which claims the benefit of priority under 35 U.S.C. § 119(e) to U.S. Provisional Application 61/988,066, filed on May 2, 2014, the entire contents of which are incorporated by reference into this disclosure as if set forth in its entirety herein.

### FIELD

[0002] The present application relates generally to implants and methods used with, or forming part of, a spinal fixation construct and directed at preventing the occurrence of or reducing the degree of adjacent segment pathology and failures occurring at either the distal junction (DJK) or proximal junction (PJK).

### BACKGROUND

[0003] The spine is formed of a column of vertebra that extends between the cranium and pelvis. The three major sections of the spine are known as the cervical, thoracic and lumbar regions. There are 7 cervical vertebrae (C1-C7), 12 thoracic vertebrae (T1-T12), and 5 lumbar vertebrae (L1-L5), with each of the 24 vertebrae being separated from each other by an intervertebral disc. A series of about 9 fused vertebrae extend from the lumbar region of the spine and make up the sacral and coccygeal regions of the vertebral column. The natural curvature of the spine includes a combination of lordosis and kyphosis. Specifically, the cervical and lumbar portions of the spine exhibit a natural lordotic curvature, meaning that they are set in a curve that is anteriorly convex (and posteriorly concave). The thoracic portion of the spine has a naturally kyphotic curvature, meaning that it is set in a curve that is anteriorly concave (and posteriorly convex).

[0004] The main functions of the spine are to provide skeletal support and protect the spinal cord. Even slight disruptions to either the intervertebral discs or vertebrae can result in serious discomfort as well as compression of nerve fibers either within the spinal cord or extending from the spinal cord. If a disruption to the spine becomes severe enough, severe pain, disability and damage to a nerve or part of the spinal cord may occur and can result in partial to total loss of bodily functions (e.g., walking, talking, breathing, etc.). Therefore, it is of great interest and concern to be able to both correct and prevent any ailments of the spine.

[0005] Fixation systems are often surgically implanted to stabilize or immobilize a portion of the spine. They are generally utilized during spinal fusion procedures to immobilize the applicable vertebrae until bone growth occurs to effect the fusion and/or to correct vertebral alignment issues. Fixation systems often use a combination of rods, plates, pedicle screws, and bone hooks to attach a fixation construct to the affected vertebrae. The configuration required for each procedure and patient varies due to the ailment being treated, the specific method of treatment (e.g. surgical approach, etc. . . .) and the patient's specific anatomical characteristics.

[0006] Depending upon the pathology presented, correction of spinal ailments may involve only one vertebral level

(i.e. a single intervertebral disc and the two vertebral bodies adjacent that intervertebral disc) or multiple spinal levels. An extreme example of a multiple level treatment relates to deformity correction (e.g. scoliosis correction) in which a screw and rod construct is implanted along a significant length of the spine in an attempt to forcibly correct or maintain a desired spinal alignment.

[0007] Whatever the treatment, the goal remains to improve the quality of life for the patient. In the vast majority of cases this goal is achieved, however in some instances patients who receive implants to treat the primary pathology develop a secondary condition called junctional disease. Most commonly this occurs at the proximal or cephalad area of spinal instrumentation and is then termed adjacent segment pathology. Clinical Adjacent Segment Pathology (CASP) refers to clinical symptoms and signs related to adjacent segment pathology. Radiographic Adjacent Segment Pathology (RASP) refers to radiographic changes that occur at the adjacent segment. A subcategory of CASP and RASP that occurs at the proximal end of the instrumentation is termed proximal junctional kyphosis (PJK). PJK may be defined in several manners and commonly is specified as kyphosis measured from one segment cephalad to the upper end instrumented vertebra to the proximal instrumented vertebra with abnormal value defined as 10 degrees or greater. In practice this often means that the patient's head and/or shoulders tend to fall forward to a greater degree than should normally occur. Sometimes the degree is significant.

[0008] Adjacent segment pathology can occur as either a degenerative, traumatic or catastrophic condition and sometimes as a result from a combination of factors. Degenerative conditions are ones that occur over a period of time, normally 5 or 6 years but can occur at an accelerated rate particularly with altered mechanics related to spinal fusion. As a result the patient's head and/or shoulder region(s) fall forward gradually over time. Traumatic and catastrophic conditions occur as a generally sudden shifting of the vertebral body immediately cephalad to the upper end instrumented vertebra and can lead to sudden changes in spinal alignment with marked symptoms noted by the patient.

[0009] Whether the condition is degenerative, traumatic or catastrophic, the exact cause of adjacent segment pathology is uncertain. Generally, it is believed that adjacent segment pathology and more specifically PJK is a result of excess strain and stress on the proximal instrumented spinal segment which is then at least partially transferred to the bone structures, disc, ligaments and other soft tissues, causing a loss of normal structural integrity and mechanical properties. The resultant effect can be a forward (i.e. kyphotic) shift of the adjacent non-instrumented vertebral body. One such theory is that this strain and stress is caused by suboptimal alignment and/or balance of the screw and rod construct. Another theory is that the rigidity of the screw and rod construct causes the problem in that the transition from a motion-restrained segment to a motion-unrestrained segment is too much for the non-instrumented (unrestrained) segment to handle over time. Yet another theory speculates that the specific level at which the proximal instrumented vertebra is located is of vital importance in that some levels may be better suited to handle a proximal termination of a fixation construct than others.

[0010] Thus there remains a need for continued improvements and new systems for spinal fixation with a specific goal of preventing the occurrence of or reducing the degree of adjacent segment pathology and failures occurring at either the distal junction (DJK) or proximal junction (PJK). The implants and techniques described herein are directed towards overcoming these challenges and others associated with posterior spinal fixation.

#### BRIEF DESCRIPTIONS OF THE DRAWINGS

[0011] Many advantages of the present invention will be apparent to those skilled in the art with a reading of this specification in conjunction with the attached drawings, wherein like reference numerals are applied to like elements and wherein:

[0012] FIG. 1 is a perspective view of one example of a vertebral fixation system including various elements described in this disclosure;

[0013] FIGS. 2 and 3 are perspective views of one example of a fixed angle bone anchor forming part of the vertebral fixation system of FIG. 1;

[0014] FIGS. 4 and 5 are perspective sectional views of the bone anchor of FIG. 2;

[0015] FIGS. 6 and 7 are perspective views of another example of a fixed angle bone anchor forming part of the vertebral fixation system of FIG. 1;

[0016] FIG. 8 is a perspective sectional view of the bone anchor of FIG. 6;

[0017] FIGS. 9 and 10 are perspective and sectional views, respectively, of a locking element forming part of the bone anchor of FIG. 6;

[0018] FIGS. 11 and 12 are perspective views of still another example of a fixed angle bone anchor forming part of the vertebral fixation system of FIG. 1;

[0019] FIGS. 13 and 14 are perspective sectional views of the bone anchor of FIG. 11;

[0020] FIGS. 15 and 16 are perspective views of one example of a polyaxial bone anchor forming part of the vertebral fixation system of FIG. 1;

[0021] FIGS. 17 and 18 are perspective sectional views of the bone anchor of FIG. 15;

[0022] FIGS. 19 and 20 are perspective and sectional views, respectively, of a rod seat insert forming part of the bone anchor of FIG. 15;

[0023] FIGS. 21 and 22 are perspective views of another example of a polyaxial bone anchor forming part of the vertebral fixation system of FIG. 1;

[0024] FIG. 23 is a perspective sectional view of the bone anchor of FIG. 21;

[0025] FIGS. 24 and 25 are perspective views of another example of a fixed angle bone anchor forming part of the vertebral fixation system of FIG. 1;

[0026] FIGS. 26 and 27 are perspective sectional views of the bone anchor of FIG. 24;

[0027] FIGS. 28-30 are perspective views of an example of a bone anchor having a translating tulip configured for use with and forming part of the vertebral fixation system of FIG. 1;

[0028] FIGS. 31 and 32 are sectional views of the bone anchor of FIG. 28;

[0029] FIG. 33 is a plan view of a translation base forming part of the bone anchor of FIG. 28;

[0030] FIGS. 34 and 35 are sectional and perspective views, respectively, of a rod-receiving member forming part of the bone anchor of FIG. 28;

[0031] FIG. 36 is a perspective view of an example of a bone anchor with attached tether configured for use with and forming part of the vertebral fixation system of FIG. 1;

[0032] FIG. 37 is a perspective view of an example of a rod attachment with attached tether configured for use with and forming part of the vertebral fixation system of FIG. 1;

[0033] FIG. 38 is a plan view of the bone anchor of FIG. 36 and the rod attachment of FIG. 37 in use on a human spine;

[0034] FIGS. 39 and 40 are perspective view of still another example of a bone anchor suitable for use with the vertebral fixation system of FIG. 1;

[0035] FIG. 41 is a sectional view of the bone anchor of FIG. 39;

[0036] FIGS. 42 and 43 are perspective view, respectively, of the bone anchor of FIG. 39 in use with an example of a flexible rod suitable for use with the vertebral fixation system of FIG. 1;

[0037] FIG. 44 is a sectional view of the bone anchor and flexible rod combination of FIG. 42;

[0038] FIG. 45 is a plan view of a portion of a spine with an implanted transition apparatus suitable for use with the vertebral fixation system of FIG. 1;

[0039] FIG. 46 is a perspective view of the transition apparatus of FIG. 45;

[0040] FIG. 47 is a perspective view of a rod-cord hybrid forming part of the transition apparatus of FIG. 45;

[0041] FIG. 48 is a side plan view of the transition apparatus of FIG. 45;

[0042] FIG. 49 is a perspective view of another example of a transition apparatus suitable for use with the vertebral fixation system of FIG. 1;

[0043] FIG. 50 is a perspective view of a housing unit forming part of the transition apparatus of FIG. 49;

[0044] FIGS. 51 and 52 are plan and top sectional views, respectively, of the transition apparatus of FIG. 49;

[0045] FIG. 53 is a side sectional view of the transition apparatus of FIG. 49;

[0046] FIG. 54 is an exploded view of a spinal rod terminus forming part of the transition apparatus of FIG. 49;

[0047] FIGS. 55 and 56 are perspective views of the transition apparatus of FIG. 49;

[0048] FIG. 57 is a perspective view of yet another transition apparatus suitable for use with the vertebral fixation system of FIG. 1;

[0049] FIGS. 58 and 59 are plan views of the transition apparatus of FIG. 57;

[0050] FIG. 60 is an exploded perspective view of the transition apparatus of FIG. 57;

[0051] FIG. 61 is an exploded sectional view of the transition apparatus of FIG. 57;

[0052] FIG. 62 is a perspective view of another example of a transition apparatus suitable for use with the vertebral fixation system of FIG. 1;

[0053] FIG. 63 is a partially exploded sectional view of the transition apparatus of FIG. 62;

[0054] FIG. 64 is an exploded sectional view of the transition apparatus of FIG. 62;

[0055] FIG. 65 is a plan view of a partial spine with another example of a bone anchor suitable for use with the vertebral fixation system of FIG. 1 attached thereto;

[0056] FIG. 66 is a perspective view of the bone anchor of FIG. 65;

[0057] FIG. 67 is a side plan view of the bone anchor of FIG. 65;

[0058] FIG. 68 is a perspective view of a locking element forming part of the bone anchor of FIG. 65;

[0059] FIGS. 69 and 70 are perspective views of an example of a rib clamp forming part of a bone anchor suitable for use with the vertebral fixation system of FIG. 1;

[0060] FIG. 71 is an exploded plan view of the rib clamp of FIG. 69;

[0061] FIG. 72 is a plan view of the bone anchor of FIG. 69 implanted within a human spine;

[0062] FIGS. 73-75 are perspective views of an alternative example of a rib clamp forming part of the bone anchor of FIG. 72;

[0063] FIG. 76 is an exploded plan view of the rib clamp of FIG. 73;

[0064] FIGS. 77 and 78 are perspective views of another example of a bone anchor forming part of the vertebral fixation system of FIG. 1;

[0065] FIG. 79 is an exploded perspective view of the bone anchor of FIG. 77;

[0066] FIG. 80 is a plan view of the bone anchor of FIG. 77;

[0067] FIG. 81 is a plan view of the bone anchor of FIG. 77 implanted within a human spine;

[0068] FIG. 82 is a perspective view of an example of a bone anchor having a rod bumper configured for use with the spinal fixation system of FIG. 1;

[0069] FIGS. 83 and 84 are perspective and plan views, respectively, of the spinal rod and rod bumper of FIG. 82;

[0070] FIG. 85 is a perspective view of the rod bumper of FIG. 82;

[0071] FIG. 86 is a perspective view of a locking element forming part of the bone anchor of FIG. 82;

[0072] FIG. 87 is a perspective view of an alternative example of a bone anchor and rod bumper combination configured for use with the spinal fixation system of FIG. 1;

[0073] FIGS. 88 and 89 are perspective and plan views, respectively, of the spinal rod and rod bumper of FIG. 87;

[0074] FIG. 90 is a perspective view of the rod bumper of FIG. 87;

[0075] FIG. 91 is a perspective view of a locking element forming part of the bone anchor of FIG. 87;

[0076] FIGS. 92 and 93 are perspective and sectional views, respectively, of an example of a fixation assembly including an elastomeric bumper configured for use with the spinal fixation system of FIG. 1;

[0077] FIG. 94 is an exploded view of the fixation assembly of FIG. 92;

[0078] FIG. 95 is an exploded perspective view of the fixation assembly of FIG. 92;

[0079] FIGS. 96 and 97 are perspective and sectional views, respectively, of another example of a fixation assembly including cable and a flexion stop configured for use with the spinal fixation system of FIG. 1; and

[0080] FIG. 98 is an exploded view of the fixation assembly of FIG. 96.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

[0081] Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of

an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure. The vertebral fixation system and methods described herein boast a variety of inventive features and components that warrant patent protection, both individually and in combination.

[0082] This disclosure describes a variety of transitional or terminal components that may be implanted as part of a spinal fixation construct to decrease the potential for subsequent development of junctional disease or failure. In the examples shown only the cephalad most level (for terminal hardware) or levels (for multilevel transitional hardware) of the fixation construct (e.g. those utilizing the exemplary components described herein) are illustrated. It should be appreciated, however, that the entire fixation construct may extend any number of levels from a single level construct to a long construct spanning multiple spinal levels and multiple spinal regions from the lumbosacral to cervical regions (such as the example construct illustrated in FIG. 1), and with any variety of combinations of known anchors, rods, and connectors. It should also be appreciated that the exemplary terminal and/or transitional components may additionally or alternatively be utilized at the caudal end of the fixation construct. Moreover, although the vertebral fixation systems described herein may be used along any aspect of the spine (e.g. anterior, posterior, antero-lateral, posterolateral) they are particularly suited for implantation along a posterior aspect of the spine.

[0083] FIG. 1 illustrates an example of a vertebral fixation system 10 of the type that is used with the devices and methods described in this disclosure. By way of example, the vertebral fixation system 10 is a screw-and-rod construct adapted for implantation along the posterior aspect of the human spinal column. The vertebral fixation system 10 includes a pair of elongate rods 12 dimensioned to span multiple vertebral levels, a plurality of threaded bone anchors 14, a plurality of hook-type bone anchors 16, and a plurality of transverse connectors 22, 24 dimensioned to rigidly engage each of the elongate rods 12 so as to hold each rod in place relative to the other. The transverse connectors 22, 24 may be provided as fixed connectors 22 or adjustable connectors 24, in any quantity that is required by the surgeon performing the implantation surgery. Proximal bone anchors 18 are provided at the proximal (cephalad) terminus of the assembly. Distal bone anchors 20 are provided at the distal (caudal) terminus of the assembly. It is contemplated that any of the examples of bone anchors and other transition assemblies described herein may be substituted for the proximal bone anchors 18 and/or distal bone anchors 20 which are traditionally rigid and identical to the other bone anchors used throughout the construct. It is also contemplated that the examples of flexible transition segments described herein may replace existing hardware at the proximal and/or distal terminus of the vertebral fixation system 10 such that there is no additional surgical footprint realized. It is further contemplated that the examples of flexible transi-

tion segments described herein may augment existing hardware at the proximal and/or distal terminus of the vertebral fixation system **10** such that there is additional added surgical footprint realized. This may be more applicable with the various embodiments to that can be installed with minimal disruption of additional muscle tissue and/or ligament structure. Finally, as previously noted junctional disease or failure can be a problem at either the proximal terminus or the distal terminus (or both) of vertebral fixation systems. Therefore, although the various examples disclosed herein may be described in terms of proximal terminus and proximal joint disease (for ease of disclosure) it is to be understood that any of the example embodiments are also applicable and may be used at the distal terminus of the vertebral fixation system without deviating from the scope of this disclosure.

[0084] FIGS. 2-5 illustrate a first example of a bone anchor configured for use with the vertebral fixation system **10** described above. By way of example, the bone anchor **30** is a fixed angle screw having a housing **32** for capturing and locking therein a spinal rod **12**, a shank **34** including a thread feature **36** suitable for stable fixation to vertebral bone, and a locking element **38** configured for locking the spinal rod **12** within the housing **32**.

[0085] The housing **32** has a base **40** that mates (or is integrally formed) with the shank **34** and a pair of upstanding arms **42** separated by and partially defining a rod channel **44** sized and configured to receive the spinal rod **12** therein. The base includes a recess **46** formed within the rod channel and configured to receive a rod seat **48**. The rod seat **48** is a block of material sized and dimensioned to snugly fit within the recess **46** and having a concave surface **50** that forms the lower portion of the rod channel **44**. The concave surface **50** is configured to engage the generally cylindrical spinal rod **12** and provide a seat for the spinal rod **12**. Significantly, the rod seat **48** of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod **12** within the housing **32** while maintaining a frictional association with the spinal rod **12** (and thus preventing unrestricted movement of the rod). The upstanding arms **42** include a locking element engagement feature **52** disposed on the interior face of each arm **42**. The locking element engagement feature **52** mates with a complementary housing engagement feature **54** on the locking element **38**, described in further detail below.

[0086] The locking element **38** is attachable to the housing **32** after the spinal rod **12** has been seated within the rod channel **44**. In the example presently described, the locking element **38** comprises a setscrew having a housing engagement feature **54** and a rod engagement surface **56**. The housing engagement feature **54** complementarily engages the locking element engagement feature **46** of the upstanding arms **42**. The rod engagement surface **56** is configured to engage the spinal rod **12** and may be planar, convex, or concave. By way of example, the locking element **38** is made of a rigid material (e.g. titanium).

[0087] In use, after the spinal rod **12** has been seated within the rod channel **44**, the locking element **38** is inserted between the upstanding arms **42** such that the housing engagement feature **54** on the locking element **38** engages the locking element engagement features **46** on each of the upstanding arms **42**. The locking element **38** is then advanced via rotation to exert a force on the spinal rod **12**

and frictionally lock the spinal rod **12** within the housing **32** (and between the locking element **38** and the rod seat **48**). After implantation, the semi-rigid nature of the elastomeric rod seat **48** will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0088] In the instant example (and others described below), the housing **32** and shank **34** are provided in a fixed relationship so that no relative movement is possible between them. This may be achieved by way of example through secure mating of separate parts or by a single part having an integral housing **32** and shank. Alternatively, the housing **32** and shank **34** may be mated with a polyaxial engagement such that the housing **32** can pivot relative to the shank **34** in any direction. The engagement may also be such that the pivoting movement may be inhibited in one or more directions. By way of example, the housing **32** and shank **34** may be mated with a uniplanar engagement such that the housing **32** pivots relative to the shank **34** in a single plane. Many of these alternative examples are described in further detail below.

[0089] FIGS. 6-8 illustrate another example of a bone anchor configured for use with the vertebral fixation system **10** described above. By way of example, the bone anchor **60** is a fixed angle screw having a housing **62** for capturing and locking therein a spinal rod **12**, a shank **64** including a thread feature **66** suitable for stable fixation to vertebral bone, and a locking element **68** configured for locking the spinal rod **12** within the housing **62**.

[0090] The housing **62** has a base **70** that mates (or is integrally formed) with the shank **64** and a pair of upstanding arms **72** separated by and partially defining a rod channel **74** sized and configured to receive the spinal rod **12** therein. The base includes a rod seat **76** comprising an upward-facing concave surface that forms the lower portion of the rod channel **74**. The rod seat **76** is configured to engage the generally cylindrical spinal rod **12** and provide a seat for the spinal rod **12**. In the instant example, the rod seat **76** is composed of the same rigid material as the bone anchor **60** (e.g. titanium). The upstanding arms **72** include a locking element engagement feature **78** disposed on the interior face of each arm **72**. The locking element engagement feature **78** mates with a complementary housing engagement feature **80** on the locking element **68**, described in further detail below.

[0091] FIGS. 9 and 10 illustrate the locking element **68** in greater detail. The locking element **68** is attachable to the housing **62** after the spinal rod **12** has been seated within the rod channel **74**. In the example presently described, the locking element **68** comprises a set screw having a housing engagement feature **80** and a rod engagement insert **82**. The housing engagement feature **80** complementarily engages the locking element engagement feature **78** of the upstanding arms **72**. The rod engagement insert **82** is a block of material sized and dimensioned to snugly fit within a recess **84** formed within the locking element **68** and having a convex surface **86** that forms the upper boundary of the rod channel **74** when the locking element **68** is mated with the housing **62**. The convex surface **86** is configured to engage the generally cylindrical spinal rod **12** and exert a force on the spinal rod **12** to enable the frictional lock. By way of example, the locking element **68** is made of a rigid material (e.g. titanium). Significantly, the rod engagement insert **82**



of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 62 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). The rod engagement insert 82 is secured within the recess 84 via a physical barrier (i.e. flange and lip interaction) however other methods of securing the rod engagement insert 82 within the recess 84 are possible.

[0092] In use, after the spinal rod 12 has been seated within the rod channel 74, the locking element 68 is inserted between the upstanding arms 72 such that the housing engagement feature 80 on the locking element 68 engages the locking element engagement features 78 on each of the upstanding arms 72. The locking element 68 is then advanced via rotation to exert a force on the spinal rod 12 and frictionally lock the spinal rod 12 within the housing 62 (and between the locking element 68 and the rod seat 76). After implantation, the semi-rigid nature of the elastomeric rod engagement insert 82 will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0093] FIGS. 11-14 illustrate another example of a bone anchor configured for use with the vertebral fixation system 10 described above. By way of example, the bone anchor 90 is a fixed angle screw having a housing 92 for capturing and locking therein a spinal rod 12, a shank 96 including a thread feature 96 suitable for stable fixation to vertebral bone, and a locking element 98 configured for locking the spinal rod 12 within the housing 92.

[0094] The housing 92 has a base 100 that mates (or is integrally formed) with the shank 94 and a pair of upstanding arms 102 separated by and partially defining a rod channel 104 sized and configured to receive the spinal rod 12 therein. The base includes a recess 106 formed within the rod channel and configured to receive a rod seat 108. The rod seat 108 is a block of material sized and dimensioned to snugly fit within the recess 106 and having a concave surface 110 that forms the lower portion of the rod channel 104. The concave surface 110 is configured to engage the generally cylindrical spinal rod 12 and provide a seat for the spinal rod 12. Significantly, the rod seat 108 of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 92 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). The upstanding arms 102 include a locking element engagement feature 112 disposed on the interior face of each arm 102. The locking element engagement feature 112 mates with a complementary housing engagement feature 114 on the locking element 98, described in further detail below.

[0095] The locking element 98 is attachable to the housing 92 after the spinal rod 12 has been seated within the rod channel 104. In the example presently described, the locking element 98 comprises a setscrew having a housing engagement feature 114 and a rod engagement insert 116.

[0096] The housing engagement feature 114 complementarily engages the locking element engagement feature 112

of the upstanding arms 102. The rod engagement insert 116 is a block of material sized and dimensioned to snugly fit within a recess 118 formed within the locking element 98 and having a convex surface 119 that forms the upper boundary of the rod channel 104 when the locking element 98 is mated with the housing 92. The convex surface 119 is configured to engage the generally cylindrical spinal rod 12 and exert a force on the spinal rod 12 to enable the frictional lock. By way of example, the locking element 98 is made of a rigid material (e.g. titanium). Significantly, the rod engagement insert 116 of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 92 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). The rod engagement insert 116 is secured within the recess 118 via a physical barrier (i.e. flange and lip interaction) however other methods of securing the rod engagement insert 116 within the recess 118 are possible.

[0097] In use, after the spinal rod 12 has been seated within the rod channel 104, the locking element 98 is inserted between the upstanding arms 102 such that the housing engagement feature 114 on the locking element 98 engages the locking element engagement features 112 on each of the upstanding arms 102. The locking element 98 is then advanced via rotation to exert a force on the spinal rod 12 and frictionally lock the spinal rod 12 within the housing 92 (and between the locking element 98 and the rod seat 108). After implantation, the semi-rigid nature of both the elastomeric rod seat 108 and the rod engagement insert 116 will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0098] FIGS. 15-20 illustrate another example of a bone anchor configured for use with the vertebral fixation system 10 described above. By way of example, the bone anchor 120 is a polyaxial screw having a housing 122 for capturing and locking therein a spinal rod 12, a shank 124 including a generally spherical head 126 and a thread feature 128 suitable for stable fixation to vertebral bone, a seat member 130, and a locking element 132 configured for locking the spinal rod 12 within the housing 122.

[0099] The housing 122 has a base 134 that mates with the shank 124 and a pair of upstanding arms 136 separated by and partially defining a rod channel 138 sized and configured to receive the spinal rod 12 therein. The base 134 includes a recess 140 having a concave surface sized and dimensioned to receive the spherical head 126 of the shank 124. The spherical head 126 is able to rotate and pivot within the recess 140 such that the shank 124 may be disposed at any number of a plurality of angles relative to the housing 122. The upstanding arms 136 include a locking element engagement feature 142 disposed on the interior face of each arm 136. The locking element engagement feature 142 mates with a complementary housing engagement feature 160 on the locking element 132, described in further detail below.

[0100] The shank 124 further includes a driver recess 144 positioned at the top of the head 126 such that the driver recess 144 is accessible from the rod channel 138 prior to insertion of the locking element 132. The driver recess 144

is configured to engage a driver instrument (not shown) to enable implantation of the bone anchor 120 into a vertebral bone.

[0101] Referring to FIGS. 19 and 20, the seat member 130 is generally cylindrical in shape and has a lumen 146 extending longitudinally therethrough to allow passage of a driver instrument so that the driver instrument may engage the driver recess 144 of the shank 124. The lower portion of the lumen 146 has a concave surface 148 configured to receive and engage at least a portion of the generally spherical head 126 of the shank 124. The seat member 130 also includes a pair of opposing concave recesses 150 on the upper portion of the seat member 130. When properly assembled, the concave recesses 150 are aligned with and form part of the rod channel 138 for receiving the spinal rod 12.

[0102] The seat member 130 further includes a rod seat 152 disposed within the upper portion of the lumen 146. The rod seat 152 is a block of material sized and dimensioned to snugly fit within the lumen 146 and having a pair of concave surfaces 154 that form part of the lower portion of the rod channel 138. The concave surfaces 154 are configured to engage the generally cylindrical spinal rod 12 and provide a seat for the spinal rod 12. Significantly, the rod seat 152 of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 122 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). By way of example, the rod seat 152 is secured within the lumen 146 via a physical barrier interaction (i.e. a flange 156 on the rod seat 152 that is received within a recess 158 disposed within the lumen 146).

[0103] The locking element 132 is attachable to the housing 122 after the spinal rod 12 has been seated within the rod channel 138. In the example presently described, the locking element 132 comprises a setscrew having a housing engagement feature 160 and a rod engagement surface 162. The housing engagement feature 160 complementarily engages the locking element engagement feature 142 of the upstanding arms 136. The rod engagement surface 162 is configured to engage the spinal rod 12 and may be planar, convex, or concave. By way of example, the locking element 38 is made of a rigid material (e.g. titanium).

[0104] In use, after the spinal rod 12 has been seated within the rod channel 138, the locking element 132 is inserted between the upstanding arms 136 such that the housing engagement feature 160 on the locking element 132 engages the locking element engagement features 142 on each of the upstanding arms 136. The locking element 132 is then advanced via rotation to exert a force on the spinal rod 12 and frictionally lock the spinal rod 12 within the housing 122 (and between the locking element 132 and the rod seat 152). After implantation, the semi-rigid nature of the elastomeric rod seat 152 will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0105] FIGS. 21-23 illustrate another example of a bone anchor configured for use with the vertebral fixation system 10 described above. By way of example, the bone anchor

170 is a polyaxial screw having a housing 172 for capturing and locking therein a spinal rod 12, a shank 174 including a generally spherical head 176 and a thread feature 178 suitable for stable fixation to vertebral bone, a seat member 180, and a locking element 182 configured for locking the spinal rod 12 within the housing 172.

[0106] The housing 172 has a base 184 that mates with the shank 174 and a pair of upstanding arms 186 separated by and partially defining a rod channel 188 sized and configured to receive the spinal rod 12 therein. The base 184 includes a recess 190 having a concave surface sized and dimensioned to receive the spherical head 176 of the shank 174. The spherical head 176 is able to rotate and pivot within the recess 190 such that the shank 174 may be disposed at any number of a plurality of angles relative to the housing 172. The upstanding arms 186 include a locking element engagement feature 192 disposed on the interior face of each arm 186. The locking element engagement feature 192 mates with a complementary housing engagement feature 202 on the locking element 182, described in further detail below.

[0107] The shank 174 further includes a driver recess 194 positioned at the top of the head 176 such that the driver recess 194 is accessible from the rod channel 138 prior to insertion of the locking element 182. The driver recess 194 is configured to engage a driver instrument (not shown) to enable implantation of the bone anchor 170 into a vertebral bone.

[0108] The seat member 180 is generally cylindrical in shape and has a lumen 146 extending longitudinally therethrough to allow passage of a driver instrument so that the driver instrument may engage the driver recess 194 of the shank 174. The lower portion of the lumen 196 has a concave surface 198 configured to receive and engage at least a portion of the generally spherical head 176 of the shank 174. The seat member 180 also includes a rod seat 200 in the form of a pair of opposing concave recesses on the upper portion of the seat member 180. The concave surfaces 200 are configured to engage the generally cylindrical spinal rod 12 and provide a seat for the spinal rod 12.

[0109] The locking element 182 is attachable to the housing 172 after the spinal rod 12 has been seated within the rod channel 188. In the example presently described, the locking element 182 comprises a setscrew having a housing engagement feature 202 and a rod engagement insert 204. The housing engagement feature 202 complementarily engages the locking element engagement feature 192 of the upstanding arms 186. The rod engagement insert 204 is a block of material sized and dimensioned to snugly fit within a recess 206 formed within the locking element 182 and having a convex surface 208 that forms the upper boundary of the rod channel 188 when the locking element 182 is mated with the housing 172. The convex surface 208 is configured to engage the generally cylindrical spinal rod 12 and exert a force on the spinal rod 12 to enable the frictional lock. By way of example, the locking element 182 is made of a rigid material (e.g. titanium). Significantly, the rod engagement insert 204 of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 172 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). The rod engagement insert 204 is secured within the recess 206

via a physical barrier (i.e. flange and lip interaction) however other methods of securing the rod engagement insert 204 within the recess 206 are possible.

[0110] In use, after the spinal rod 12 has been seated within the rod channel 188, the locking element 182 is inserted between the upstanding arms 186 such that the housing engagement feature 202 on the locking element 182 engages the locking element engagement features 192 on each of the upstanding arms 186. The locking element 182 is then advanced via rotation to exert a force on the spinal rod 12 and frictionally lock the spinal rod 12 within the housing 172 (and between the locking element 182 and the rod seat 200). After implantation, the semi-rigid nature of the elastomeric rod engagement insert 204 will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0111] FIGS. 24-27 illustrate another example of a bone anchor configured for use with the vertebral fixation system 10 described above. By way of example, the bone anchor 210 is a polyaxial screw having a housing 212 for capturing and locking therein a spinal rod 12, a shank 214 including a generally spherical head 216 and a thread feature 218 suitable for stable fixation to vertebral bone, a seat member 220, and a locking element 222 configured for locking the spinal rod 12 within the housing 212.

[0112] The housing 212 has a base 224 that mates with the shank 214 and a pair of upstanding arms 226 separated by and partially defining a rod channel 228 sized and configured to receive the spinal rod 12 therein. The base 224 includes a recess 230 having a concave surface sized and dimensioned to receive the spherical head 216 of the shank 214. The spherical head 216 is able to rotate and pivot within the recess 230 such that the shank 214 may be disposed at any number of a plurality of angles relative to the housing 212. The upstanding arms 226 include a locking element engagement feature 232 disposed on the interior face of each arm 226. The locking element engagement feature 232 mates with a complementary housing engagement feature 246 on the locking element 222, described in further detail below.

[0113] The shank 214 further includes a driver recess 234 positioned at the top of the head 216 such that the driver recess 234 is accessible from the rod channel 228 prior to insertion of the locking element 222. The driver recess 234 is configured to engage a driver instrument (not shown) to enable implantation of the bone anchor 210 into a vertebral bone.

[0114] The seat member 220 is identical to the seat member 130 described in reference to FIGS. 19 and 20. The seat member 220 is generally cylindrical in shape and has a lumen extending longitudinally therethrough to allow passage of a driver instrument so that the driver instrument may engage the driver recess 234 of the shank 214. The lower portion of the lumen has a concave surface 238 configured to receive and engage at least a portion of the generally spherical head 216 of the shank 214. The seat member 220 also includes a pair of opposing concave recesses on the upper portion of the seat member. When properly assembled, the concave recesses are aligned with and form part of the rod channel 228 for receiving the spinal rod 12.

[0115] The seat member 220 further includes a rod seat 242 disposed within the upper portion of the lumen. The rod seat 242 is a block of material sized and dimensioned to snugly fit within the lumen and having a pair of concave surfaces 244 that form part of the lower portion of the rod channel 228. The concave surfaces 244 are configured to engage the generally cylindrical spinal rod 12 and provide a seat for the spinal rod 12. Significantly, the rod seat 242 of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 212 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). By way of example, the rod seat 242 is secured within the lumen via a physical barrier interaction (i.e. a flange on the rod seat that is received within a recess disposed within the lumen).

[0116] The locking element 222 is attachable to the housing 212 after the spinal rod 12 has been seated within the rod channel 228. In the example presently described, the locking element 222 comprises a setscrew having a housing engagement feature 246 and a rod engagement insert 248. The housing engagement feature 246 complementarily engages the locking element engagement feature 232 of the upstanding arms 226. The rod engagement insert 248 is a block of material sized and dimensioned to snugly fit within a recess 250 formed within the locking element 222 and having a convex surface 252 that forms the upper boundary of the rod channel 188 when the locking element 222 is mated with the housing 212. The convex surface 252 is configured to engage the generally cylindrical spinal rod 12 and exert a force on the spinal rod 12 to enable the frictional lock. By way of example, the locking element 222 is made of a rigid material (e.g. titanium). Significantly, the rod engagement insert 248 of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod 12 within the housing 212 while maintaining a frictional association with the spinal rod 12 (and thus preventing unrestricted movement of the rod). The rod engagement insert 248 is secured within the recess 250 via a physical barrier (i.e. flange and lip interaction) however other methods of securing the rod engagement insert 248 within the recess 250 are possible.

[0117] In use, after the spinal rod 12 has been seated within the rod channel 228, the locking element 222 is inserted between the upstanding arms 226 such that the housing engagement feature 246 on the locking element 222 engages the locking element engagement features 232 on each of the upstanding arms 226. The locking element 222 is then advanced via rotation to exert a force on the spinal rod 12 and frictionally lock the spinal rod 12 within the housing 212 (and between the locking element 222 and the rod seat 242). After implantation, the semi-rigid nature of the elastomeric rod seat 242 and the elastomeric rod engagement insert 248 will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0118] FIGS. 28-35 illustrate another example of a bone anchor assembly configured for use with the vertebral fixation system 10 described above. By way of example, the bone anchor assembly 260 includes a bone anchor 262, a

translation body 264, a rod-receiving member 266, and a locking element 268. As will be explained below, the bone anchor assembly 260 is semi-adjustable after implantation (e.g. allows for controlled motion) in that the rod-receiving member 266 has some freedom to translate and/or rotate relative to the translation body 264 to accommodate natural shifting that may occur. By way of example, FIGS. 28-30 illustrate the bone anchor assembly 260 with the rod-receiving member 266 in three different translational positions.

[0119] The bone anchor 262 extends generally perpendicularly from the bottom surface of the translation body 264 and has a thread feature 270 suitable for stable fixation to vertebral bone. The translation body 264 has a generally elliptical footprint (illustrated in FIG. 33) however other shapes are possible. The translation body 264 has a top surface 272, a bottom surface 274, and a translation surface 276 configured to engage the rod-receiving member 266 and allow translation in a proximal-distal direction. The top surface 272 is generally planar however other shapes including but not limited to convex are possible. The top surface 272 has an elongated recess 278 having a T-shaped cross-section formed therein that limits the degree of translation. By way of example, the elongated recess 278 may be generally elliptical in shape but may also be tapered in that it is wider in the center of the recess than it is at either end. This tapered shaped functions to provide greater resistance to incremental translation as the rod-receiving member 266 approaches the outer ends of the recess 278 in either direction. The recess 278 further includes a pair of overhangs 279 that give the recess 278 its T-shaped cross-section and also function to retain the cylindrical flange 288 of the rod-receiving member 266 within the recess 278. The translation surface 276 comprises the bottom surface of the elongated recess 278 and may be planar or slightly convex.

[0120] Referring to FIGS. 34 and 35, the rod-receiving member 266 includes a base 280 and a pair of upstanding arms 282 separated by a rod channel 284. The base 280 includes a protrusion 286 extending away from the base 280 and a cylindrical flange 288 positioned at the end of the protrusion 286. The protrusion 286 has a generally cylindrical shape and has a diameter that is less than the diameter of the cylindrical flange 288. The result is that the protrusion 286 and flange 288 when taken together have a generally T-shaped cross section. The protrusion 286 and flange 288 fit within the recess 278 of the fixation body 264 and are configured to allow multiple degrees of movement of the rod-receiving member 266 relative to the fixation body 264. More specifically, the cylindrical shapes of both the protrusion 286 and flange 288 allow axial rotation of the rod-receiving member, and a generally planar bottom surface 290 of the flange 288 allows for smooth translation of the flange 288 (and thus the rod-receiving member 266) within the recess 264. The upper surface 290 of the base 280 is a concave, semi-cylindrical surface having a generally arcuate cross-section. The upper surface 290 forms the distal end of the rod channel 284 and forms a cradle that receives the spinal rod 12 during implantation. The upstanding arms 282 are equipped with a locking element engagement feature 292 disposed on the interior face of each arm 282. The locking element engagement feature 292 mates with a housing engagement feature 298 on the locking element 268.

[0121] The base 280 has a hollow lumen 294 formed therein and configured to receive an elastomeric plug

therein. In the example shown in FIGS. 34 and 35, both the hollow lumen 294 and the elastomeric plug 296 have generally cylindrical cross sections, however other shapes are possible. The elastomeric plug 296 has a length that is at least slightly greater than the length of the hollow lumen 294 so that the ends of the elastomeric plug 296 are in continuous contact with both the spinal rod 12 and the translation surface 276 of the translation body 264. After implantation, the semi-rigid nature of the elastomeric plug 296 will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0122] The locking element 268 is attachable to the upstanding arms 282 after the spinal rod 12 has been seated within the rod channel 284. In the example presently described, the locking element 268 comprises a setscrew having a housing engagement feature 298 and a rod engagement surface 299. The housing engagement feature 298 complementarily engages the locking element engagement feature 292 of the upstanding arms 282. The rod engagement surface 299 is configured to engage the spinal rod 12 and may be planar, convex, or concave. By way of example, the locking element 268 is made of a rigid material (e.g. titanium).

[0123] FIGS. 36-38 illustrate an example utilizing tethers connected to bone anchors and/or rods to strengthen, reconstruct, and/or otherwise emulate ligaments that may have been damaged or removed during implantation of the vertebral fixation system 10. For example, a tether connected to a bone anchor may be wrapped around the facet, transverse process, lamina, rib and/or spinous process to provide further stability to the construct. As another example, a tether may be attached to a rod at or near the proximal terminus of the vertebral fixation system 10 in lieu of bone screws to alleviate or eliminate factors that may cause junctional disease or failure (e.g. PJK, DJK, etc.).

[0124] FIG. 36 illustrates an example of a bone anchor 300 with an attached tether suitable for use with the vertebral fixation system 10. By way of example, the bone anchor 300 may be either a fixed angle screw or polyaxial screw. The bone anchor 300 includes a housing 302 for capturing and locking therein a spinal rod 12, a shank 304 including a thread feature 306 suitable for stable fixation to vertebral bone, and a locking element 308 configured for locking the spinal rod 12 within the housing 302. The bone anchor 300 is substantially similar to the various examples of bone anchors described throughout this disclosure such that repeat description of the housing 302, shank 304, and locking element 308 beyond what is necessary to describe the additional tether feature specific to this example embodiment is not necessary. It is to be understood that any feature of any other example embodiment described herein may be included in this (and any other) example embodiment without reservation either alone or in combination.

[0125] The housing 302 has a pair of upstanding arms 310 separated by and partially defining a rod channel sized and configured to receive the spinal rod 12 therein. At least one of the upstanding arms 310 includes a tether connector 312 extending outwardly away from the arm 310 and configured to fixedly receive a tether 314 therein. By way of example, the tether connector 312 comprises a post member having a lumen 316 formed therein that is sized to receive at least a

portion of the tether **314**. The tether **314** may be formed of any material suitable for medical use. For example, the tether may be made from allograft tendon, autograft tendon, braided, woven, or embroidered polyethylene, braided, woven, or embroidered polyester, PEEK, or PEKK. In some instances the tether **314** may be formed of elastic material. The tether **314** of the instant example has a stop element **318** attached to or otherwise forming the proximal end of the tether **314**. The stop element **318** buffers against the tether connector **312** and acts as a physical barrier to prevent the proximal end of the tether **314** from passing through the lumen **316**. In this way the tether **314** is secured to the tether connector **312**. By way of example, the stop element may be formed by a knot, a clamp, or a crimp. Additionally the stop element may be in the form of a connection loop created when the proximal end of the tether is reattached to itself (e.g. via clamp, crimp, adhesive, braiding, weaving, and/or embroidery) distal of the tether connector **312**. Other attachment methods of securing the tether **314** to the tether connector **312** are possible, including but not limited to adhesive, spot welding, set screw, and the like. The tether **314** may be formed of any length necessary to secure the bone anchor **300** to surrounding bone structure. By way of example, the tether may be wrapped around (or, through a hole formed therein) one or more of a lamina(s), transverse process(s), spinous process(s), and rib(s). After wrapping around the bone, the tether may be attached back to itself (e.g. via knot, clamp, crimp, etc. . . .), a second tether connector on the housing **302**, or a tether connector on another bone anchor (e.g. a contralateral anchor) or alternate connector, such as the rod connector **320** described below. Alternatively, the tether may be anchored directly to the lamina(s), transverse process(s), spinous process(s), or rib(s) (for example, with a suture anchor, staple, or similar device).

[0126] FIG. 37 illustrates an example of a rod attachment **320** with attached tether suitable for use with the vertebral fixation system **10**. The rod attachment **320** includes a housing **322** having a lumen **324** extending longitudinally therethrough configured to receive at least a portion of the spinal rod **12**. By way of example, the housing **322** includes one side comprising a generally planar surface **326** and another side comprising a generally arcuate surface **328**. The generally planar surface **326** includes at least one aperture **330** for receiving a locking element **332**. In the instant example, the generally planar surface **326** includes a pair of apertures **330** and thus the rod attachment **320** has a pair of locking elements **332**. The locking elements **332** are substantially similar to the locking elements described in the various examples above and further description need not be repeated. The rod attachment **320** further includes a tether connector **334** extending outwardly and configured to fixedly receive a tether **336** therein. The tether connector **334** comprises a post member having a lumen **335** formed therein that is sized to receive at least a portion of the tether **336**. The tether **336** of the instant example has a stop element **338** attached to or otherwise forming the proximal end of the tether **336**. By way of example, the stop element may be formed by a knot, a clamp, or a crimp. Additionally the stop element **338** may be in the form of a connection loop created when the proximal end of the tether is reattached to itself (e.g. via clamp, crimp, adhesive, braiding, weaving, and/or embroidery) distal of the tether connector **334**. Other attachment methods of securing the tether **336** to the tether connector **334** are possible, including but not limited to

adhesive, spot welding, set screw, and the like. The tether **336** may be formed of any length necessary to secure the rod, via rod connector **320**, to surrounding bone structure. By way of example, the tether may be wrapped around (or, through a hole formed therein) one or more of a lamina(s), transverse process(s), spinous process(s), and rib(s). After wrapping around the bone, the tether may be attached back to itself (e.g. via knot, clamp, crimp, etc. . . .), a second tether connector on the housing **322**, or a tether connector on another bone anchor or rod connector connector, such as the rod connector **320** described below. Alternatively, the tether may be anchored directly to the lamina(s), transverse process(s), spinous process(s), or rib(s) (for example, with a suture anchor, staple, or similar device).

[0127] FIG. 38 illustrates the bone anchor **300** and rod attachment **320** in use after implantation in a human spine. By way of example, as shown the tethers are wrapped around a lamina, transverse process, and a spinous process. It will be appreciated that the tether may be wrapped around one of, or any combination of, one or more lamina, transverse processes, spinous processes, and ribs.

[0128] FIGS. 39-44 illustrate another example of a bone anchor **340** suitable for use with the vertebral fixation system **10**. In the embodiment shown by way of example in the attached Figs., the bone anchor **340** is substantially similar to any of the polyaxial bone screw example embodiments described above such that features described above may be applied to this example without reservation either alone or in combination. The bone anchor **340** includes a housing **342** for capturing and locking therein a spinal rod **12**, a shank **344** including a generally spherical head **346** and a thread feature **348** suitable for stable fixation to vertebral bone, a seat member **350**, and a locking element **352** configured for locking the spinal rod **12** within the housing **342**. The bone anchor **340** further includes a collar **354** positioned at the top of the shank **344** just below the head **346** such that the collar **354** is flushly engaged with the housing **342**. By way of example only, the collar **354** may be composed of an elastomeric material and may also have a spring **356** disposed therein that is biased toward the housing **342**. The collar **354** functions to convert the otherwise fixed relationship between shank and head upon locking of a rod with a setscrew into a limited range permanent polyaxial bone screw. Once the bone anchor **340** has been implanted into the spine as a part of the vertebral fixation system **10** it may experience realignment pressure (of the type that causes DJK and PJK). Under such a circumstance, the elastomeric collar **354** and/or spring **356** are capable of allowing controlled movement of the housing **342**, for example adjustment of the angle formed between the housing member **342** and shank **344**, controlled minimal translation along the spinal rod **12**, and/or further compression of the collar **354** if adjustment is needed in that direction.

[0129] In some instances it may be beneficial if the spinal rod itself was capable of compression, distraction, and/or rotation in response to realignment pressure. FIGS. 42-44 illustrate the bone anchor **340** used with one example of a flexible rod **790**. By way of example, the flexible rod **790** includes an interior rod **792**, a spring coil **794**, and an elastomeric sheath **796**. The interior rod **792** has a narrow diameter and may be composed of any material that allows for some flexibility (e.g. Nitinol, PEEK, PEKK, etc.). The spring coil **794** is disposed around the interior rod **792** and may extend beyond the proximal terminus of the interior rod

**792.** The elastomeric sheath **796** is disposed around the interior rod **792** and the spring coil **794** and may extend the same length as the spring coil **794**. The interior rod **792** gives the flexible rod **790** some rigidity, while the spring coil **794** functions to allow for compression, distraction and rotational movement of the flexible rod **790**. The elastomeric sheath **796** holds the spring coil **794** in place and also allows for controlled compression, distraction, and rotational movement of the flexible rod **790**. It should be noted that the locking element **352** locks the flexible rod **790** within the housing **342** but does not exert pressure to the point of compressing the spring coil **794** within the flexible rod **790**.

[0130] FIGS. 45-48 illustrate an example of a transition apparatus **360** configured for use with the vertebral fixation system **10** described herein. The purpose of the transition apparatus **360** is to gradually reduce the rigidity of the fixation construct as it transitions from instrumented to non-instrumented vertebra. One advantage associated with the transition apparatus **360** is it reduces the need for muscle stripping along the patient's back and therefore may leave intact those anatomical structures that naturally help to prevent outcomes such as DJK or PJK.

[0131] FIG. 45 illustrates the transition apparatus **360** implanted in a segment of the spine. The transition apparatus **360** includes a bone anchor **362**, one or more bone hooks **364**, and a flexible cord **366**. The bone anchor **362** includes a housing **368** for receiving the spinal rod **12**, a shank **370**, and a locking element **372** for securing the spinal rod **12** within the housing **368**. The bone anchor **362** may be one of any of the bone screw example embodiments described above such that any and all features described above may be applied to this example without reservation either alone or in combination, and further discussion of the bone screw **362** is not necessary.

[0132] The bone hook **364** includes a housing **374**, a generally curved hook member **376** extending from the base of the housing **374**, and a locking element **378**. The housing **374** includes a pair of upstanding arms **380** separated by and forming part of a rod channel **382**. The upstanding arms **380** include a locking element engagement feature **384** disposed on the interior face of each arm **380**. The locking element engagement feature **384** mates with a complementary housing engagement feature **386** on the locking element **378** to secure the flexible cord **366** within the rod channel **382**. The generally curved hook member **376** has a concave curvature that forms a cavity **386** dimensioned to receive a bone segment. By way of example only, the bone hooks **364** of the present example are configured to be used with rib bone, however other configurations are possible.

[0133] The flexible cord **366** may be composed of any material medically suitable for implantation into a human and sufficiently flexible to serve as a transition medium, including but not limited to autograft tendon, allograft tendon, braided polyethylene, PEEK, and PEKK. The flexible cord **366** is secured to the distal end of the spinal rod **12** via an attachment member **388**.

[0134] In use, the bone anchor **362** is implanted into the proximal-most fully instrumented vertebral level  $V_1$ . The bone anchor **362** may have one or more of the features described above (e.g. elastomeric inserts in one or more of the rod seat and locking element, flexible collar, and the like). The spinal rod **12** terminates just proximally of the bone anchor **362** and transitions to a flexible cord **366**. The path of the flexible cord **366** is directed laterally away from

the spinal column and continues along a path determined by the placement of the bone hooks **364**. For example, a first bone hook **364** may be secured to a rib  $R_1$  associated with the first non-instrumented vertebral body  $V_2$ . A second bone hook **364** may be secured to a rib  $R_2$  associated with the second non-instrumented vertebral body  $V_3$ . Since the cord path is away from the spine, less muscle tissue would need to be disturbed. And since the flexible cord **366** is flexible, it may be better suited to handle alignment shifts than a rigid construct.

[0135] FIGS. 49-56 illustrate another example of a transition apparatus configured for use with the vertebral fixation system **10** described herein. Transition apparatus **390** includes a housing **392** that generally has the form of a rectangular block having a leading surface **394**, a trailing surface **396**, a top surface **398**, and a bottom surface **400**, a first rod channel **402**, a second rod channel **404**, a first locking element **406**, and a second locking element **408**. The first rod channel **402** is sized and dimensioned to receive the proximal end of the spinal rod **12**. The second rod channel **404** is configured to receive the distal end of a transition rod **410**. The transition rod **410** is generally more flexible than the spinal rod **12** and serves to transitionally reduce the strain associated with the proximal terminus of the vertebral fixation system **10**. The transition rod **410** may be composed of any suitable medical grade material capable of establishing a flexible connection, including but not limited to plastics (e.g. PEEK) or flexible metal (e.g. Nitinol). Additionally, the transition rod **410** may be in the form of a cylindrically shaped rod, an oval shape, a fluted configuration, a cord, or a tether.

[0136] The top surface **398** further includes a pair of apertures **412** for receiving the locking elements **406**, **408** therein. The apertures **412** each have a locking element engagement feature **414** configured to engage the corresponding housing engagement features of the locking elements **406**, **408**. When inserted in the apertures **412**, the locking elements **406**, **408** are able to contact and lock in place the spinal rod **12** and transition rod **410**, respectively.

[0137] The transition apparatus **390** further includes a pair of buffer elements **416** attached to the proximal end of the spinal rod **12**, with one buffer element **416** attached to the spinal rod **12** on either side of the housing **392**. The buffer element **416** includes a spring **418** or block of elastomeric material (not pictured) positioned within a sleeve **420**. Locking rings **422** are provided within circumferential grooves **424** formed in the spinal rod **12** to provide a physical barrier for the buffer element **416** to ensure the buffer element **416** remains in place.

[0138] The first locking element **406** is attachable to the housing **392** after the spinal rod **12** has been seated within the rod channel **402**. In the example shown in FIG. 55, the locking element **406** comprises a setscrew having a housing engagement feature **426** and a rod engagement surface **428**. The housing engagement feature **426** complementarily engages the locking element engagement feature **414** of the housing **392**. The rod engagement surface **428** is configured to engage the spinal rod **12** and may be planar, convex, or concave. By way of example, the locking element **406** is made of a rigid material (e.g. titanium). In the example shown in FIG. 56, the locking element **406** includes a rod engagement insert **430** comprising a block of material sized and dimensioned to snugly fit within a recess (not shown) formed within the locking element **406** and having a convex

surface **432** that forms the upper boundary of the rod channel **402** when the locking element **406** is mated with the housing **392**. The convex surface **432** is configured to engage the generally cylindrical spinal rod **12** and exert a force on the spinal rod **12** to enable the frictional lock. By way of example, the locking element **406** is made of a rigid material (e.g. titanium). Significantly, the rod engagement insert **430** of the instant example may be formed of a semi-rigid elastomeric material that allows for some movement (e.g. vertical shifting, axial rotation, pivoting, and/or translation) of the spinal rod **12** within the housing **392** while maintaining a frictional association with the spinal rod **12** (and thus preventing unrestricted movement of the rod). The rod engagement insert may be configured such that the limited movement occurs only upon surpassing a threshold pressure.

[0139] The second locking element **408** is attachable to the housing **392** after the transition rod **410** has been seated within the rod channel **404**. The locking element **408** comprises a setscrew having a housing engagement feature **434** and a rod engagement surface **436**. The housing engagement feature **434** complementarily engages the locking element engagement feature **414** of the housing **392**. The rod engagement surface **436** is configured to engage the spinal rod **12** and may be planar, convex, or concave. By way of example, the locking element **408** is made of a rigid material (e.g. titanium).

[0140] The buffer element **416** allows for controlled translation/shifting of the spinal rod **12** within the housing **392** which will allow the construct to absorb some force and experience some potential alignment correction that may occur from natural shifting of the patient's body, thereby potentially alleviating some conditions that may lead to junctional disease or failure (e.g. PJK, DJK, etc.).

[0141] FIGS. 57-61 illustrate another example of a transition apparatus configured for use with the vertebral fixation system **10**. The transition apparatus **440** of the present example generally comprises a parallel rod connector with multiple degrees of freedom of movement. The transition apparatus **440** includes a first housing **442** configured for receiving the spinal rod **12** and a second housing **444** configured for receiving a transition rod **446**. The first housing **442** and second housing **444** are connected via a pivot connector **448**. The first housing **442** is offset from the second housing **444** such that a longitudinal axis extending through the first rod channel **450** is parallel to, but not aligned with, a longitudinal axis extending through the second rod channel **460**.

[0142] The first housing includes a first rod channel **450** extending therethrough that is sized and configured to receive the proximal portion of the spinal rod **12**. The rod channel **450** has an elliptical cross-section to allow for some constrained motion of the spinal rod **12** within the rod channel **450** after implantation. The first housing **442** further includes an aperture **452** adjacent the rod channel **450** for receiving a locking element **454**. The aperture **452** includes a locking element engagement feature **456** configured to engage the corresponding housing engagement feature **458** of the locking element **454**. When inserted in the aperture **452**, the locking element **454** is able to contact and lock in place the spinal rod **12** while allowing for some controlled movement within the rod channel **450**. The locking element **454** comprises a setscrew having a housing engagement feature **458** and a rod engagement surface. The housing engagement feature **458** that complementarily engages the

locking element engagement feature **456** of the first housing **442**. The rod engagement surface is configured to engage the spinal rod **12** and may be planar, convex, or concave. Although not shown, the locking element **454** may alternatively be equipped with a rod engaging insert comprising a block of elastomeric material (for example) as shown and described in various example embodiments disclosed above.

[0143] The second housing **444** includes a second rod channel **460** extending therethrough that is sized and configured to receive a distal portion of the transition rod **446**. The rod channel **460** has an elliptical cross-section to allow for some constrained motion of the transition rod **446** within the rod channel **460** after implantation. The second housing **444** further includes an aperture **462** adjacent the rod channel **460** for receiving a locking element **464**. The aperture **462** includes a locking element engagement feature **466** configured to engage the corresponding housing engagement feature **468** of the locking element **464**. When inserted in the aperture **462**, the locking element **464** is able to contact and lock in place the transition rod **446** while allowing for some controlled movement within the rod channel **460**. The locking element **464** comprises a setscrew having a housing engagement feature **468** and a rod engagement surface. The housing engagement feature **468** complementarily engages the locking element engagement feature **466** of the first housing **442**. The rod engagement surface is configured to engage the transition rod **446** and may be planar, convex, or concave.

[0144] The pivot connector **448** comprises a generally cylindrical member including a first end flange **470**, a second end flange **472**, and a central flange **474**. The first end flange **470** is configured to be received within a recess **476** formed in the first housing **442**. The second end flange **472** is configured to be received within a recess **478** formed in the second housing **444**. The central flange **474** is positioned between the first and second housings **442**, **444** when assembled and acts as a washer. The first and second housings **442**, **444** are allowed to pivot relative to one another. This pivoting ability may be controlled or partially restricted but is not locked.

[0145] FIGS. 62-64 illustrate another example of a transition apparatus configured for use with the vertebral fixation system **10**. The transition apparatus **480** of the present example generally comprises an inline rod connector with multiple degrees of freedom of movement. The transition apparatus **480** includes a first housing **482** configured for receiving the spinal rod **12** and a second housing **484** configured for receiving a transition rod **486**. The first housing **482** and second housing **484** are connected via a pivot connector **488**. The first housing **482** is inline with the second housing **484** such that a longitudinal axis extending through the first rod channel **490** is axially aligned with a longitudinal axis extending through the second rod channel **500**.

[0146] The first housing includes a first rod channel **490** extending therethrough that is sized and configured to receive the proximal portion of the spinal rod **12**. The rod channel **490** has an elliptical cross-section to allow for some constrained motion of the spinal rod **12** within the rod channel **490** after implantation. The first housing **482** further includes an aperture **492** adjacent the rod channel **490** for receiving a locking element **494**. The aperture **492** includes a locking element engagement feature **496** configured to engage the corresponding housing engagement feature **498**

of the locking element **494**. When inserted in the aperture **492**, the locking element **494** is able to contact and lock in place the spinal rod **12** while allowing for some controlled movement within the rod channel **490**. The locking element **494** comprises a setscrew having a housing engagement feature **498** and a rod engagement surface. The housing engagement feature **498** complementarily engages the locking element engagement feature **496** of the first housing **482**. The rod engagement surface is configured to engage the spinal rod **12** and may be planar, convex, or concave. Although not shown, the locking element **494** may alternatively be equipped with a rod engaging insert comprising a block of elastomeric material (for example) as shown and described in various example embodiments disclosed above.

[0147] The second housing **484** includes a second rod channel **500** extending therethrough that is sized and configured to receive a distal portion of the transition rod **486**. The rod channel **500** has an elliptical cross-section to allow for some constrained motion of the transition rod **486** within the rod channel **500** after implantation. The second housing **484** further includes an aperture **502** adjacent the rod channel **500** for receiving a locking element **504**. The aperture **502** includes a locking element engagement feature **506** configured to engage the corresponding housing engagement feature **508** of the locking element **504**. When inserted in the aperture **502**, the locking element **504** is able to contact and lock in place the transition rod **486** while allowing for some controlled movement within the rod channel **500**. The locking element **504** comprises a setscrew having a housing engagement feature **508** and a rod engagement surface. The housing engagement feature **508** complementarily engages the locking element engagement feature **506** of the first housing **502**. The rod engagement surface is configured to engage the transition rod **486** and may be planar, convex, or concave.

[0148] The pivot connector **488** comprises a generally cylindrical member including a first end flange **510**, a second end flange **512**, and a central flange **514**. The first end flange **510** is configured to be received within a recess **516** formed in the first housing **482**. The first end flange **510** may be equipped with an elastomeric coating **511** that allows for restrained translational movement of the first end flange **510** within the recess **516**. The second end flange **512** is configured to be received within a recess **518** formed in the second housing **484**. The second end flange **512** may be equipped with an elastomeric coating **513** that allows for restrained translational movement of the second end flange **512** within the recess **518**. The central flange **514** is positioned between the first and second housings **482**, **484** when assembled and acts as a washer. The first and second housings **482**, **484** are allowed to pivot relative to one another. This pivoting ability may be controlled but is not locked.

[0149] FIGS. **65-68** illustrate an example of another type of bone anchor configured for use with the vertebral fixation system **10**. Generally, the bone anchor **520** is configured to attach to a bone structure (e.g. a transverse process  $TP_1$  or lamina of vertebra  $V_1$ ) without puncturing or otherwise invading the bone. The bone anchor **520** may be used with the spinal rod **12** or one of the several examples of flexible transition rod (e.g. PEEK, cable) disclosed above.

[0150] The bone anchor **520** includes a housing **522**, an attachment flange **524** extending from the base of the housing **522**, and a locking element **526**. The housing **522**

includes a pair of upstanding arms **530** separated by and forming part of a rod channel **532**. The upstanding arms **530** include a locking element engagement feature **534** disposed on the interior face of each arm **530**. The locking element engagement feature **534** mates with a complementary housing engagement feature **536** on the locking element **526** to secure the transition rod within the rod channel **532**. The attachment flange **524** has a concave first portion **538** extending away from the housing **522** and a generally planar second portion **540** adjacent the first portion **538**. The concave first portion **538** and generally planar second portion **540** together form a cavity **542** (along with the bottom face of the housing **522**) dimensioned to receive a bone segment. The second portion **540** is at least slightly flexible so that it may accommodate different sizes of bone but also so that it may experience some post-surgical adjustment without dislodging from the bone. This flexibility may be achieved by varying the thickness of the material or by using more flexible/elastic materials in the manufacture of the flange **524**. By way of example only, the bone anchor **520** of the present example is sized and configured to be used with transverse process bone, however other configurations are possible.

[0151] At least one of the upstanding arms **530** includes a tether connector **544** extending outwardly away from the arm **530** and configured to fixedly receive a tether **546** therein. By way of example, the tether connector **544** comprises a post member having a lumen **545** formed therein that is sized to receive at least a portion of the tether **546**. The tether **546** may be formed of any material suitable for medical use, including but not limited to allograft tendon, autograft tendon, braided polyethylene, PEEK, or PEKK. In some instances the tether **546** may be formed of elastic material. The tether **546** may be formed of any length necessary to secure the bone anchor **520** to surrounding bone by wrapping around the bone. The tether **546** of the instant example has a stop element **548** is attached to or otherwise forms the proximal end of the tether **546**. The stop element **548** buffers against the tether connector **544** and acts as a physical barrier to prevent the proximal end of the tether **546** from passing through the lumen **545**. In this way the tether **546** is secured to the tether connector **544**. Other attachment methods of securing the tether **546** to the tether connector **544** are possible, including but not limited to adhesive, spot welding, and the like.

[0152] The locking element **526** may be any of the previously described locking element examples disclosed herein. The locking element **526** may or may not be equipped with a block of elastomeric material, depending on the type of rod element that is secured in the rod channel **532** by the locking element **526**.

[0153] FIGS. **69-72** illustrate another example of a non-screw bone anchor configured for use with the vertebral fixation system **10**. The bone anchor **550** of the instant example generally comprises a clamp-type mechanism suitable for attachment to a rib bone. The bone anchor **550** has includes a rib clamp **552**, a connecting rod **554**, and a rod connector **556**. The rib clamp **552** includes a first clamp member **558** and a second clamp member **560** that are translationally connected to each other.

[0154] The first clamp member **558** has an elongated generally rectangular base **561** having a top side **562** and a bottom side **564**. The top side **562** has a housing **566** positioned on a first end of the base **561** and protruding away



from the top side 562. The housing 566 includes a rod hole 568 configured to receive the connecting rod 554 and a locking element 570 for securing the connecting rod 554 to the housing 566. The bottom side 564 includes an elongated translation recess 572 and a curved flange 574. The translation recess 572 is formed within the bottom side 564 on the first end of the base 561 (underneath the housing 566) and is configured to slideably receive the translation arm 580 of the second clamp member 560. The curved flange 574 is positioned on the second end of the base 561 and extends away from the bottom side 564 before curving inward (i.e. toward the second clamp member 560). The bottom side 564 and curved flange 574 together form a cavity 576 sized and configured to receive at least a portion of a rib bone.

[0155] The second clamp member 560 includes a base 578 and a translation arm 580 extending laterally from the base 578. The translation arm 580 mates with the translation recess 572 of the first clamp member 558 and is capable of translation within the recess to allow the rib clamp 552 to be secured to a bone. The second clamp member 560 further includes a curved flange 582 that extends away from the bottom side of the second clamp member 560 before curving inward (i.e. toward the first clamp member 558). The translation arm 580 and curved flange 582 together form a cavity 584 sized and configured to receive at least a portion of a rib bone.

[0156] The rod connector 556 has a base and a pair of upstanding arms 586 that define a rod channel in between. The rod channel is configured to receive the spinal rod 12 or a transition rod (e.g. any of the transition rod types described herein). The rod connector 556 further has a locking element 588 (e.g. any of the locking elements described herein) configured to secure the rod connector 556 to the spinal rod 12 (or transition rod). The connecting rod 554 extends laterally from one of the upstanding arms 586.

[0157] The bone anchor 550 has multiple articulating connections to help absorb force and allow controlled movement after implantation. One articulating connection is between the rod connector 556 and the spinal rod 12. This is much the same as the interaction between the spinal rod and various examples of bone screws described above. Another articulating connection is between the connecting rod 554 and the rib clamp 552. Thus slight shifting can occur without causing dislodgement of the bone anchor 550.

[0158] FIGS. 73-76 illustrate an alternative example of a rib clamp for use with the bone anchor 550. The rib clamp 590 of the instant example is substantially similar to the rib clamp 552 described above with the significant difference being the moveable housing 595 as will be described below. The rib clamp 590 includes a first clamp member 592 and a second clamp member 594 that are translationally connected to each other, and a housing 595 for receiving the connecting rod 554.

[0159] The first clamp member 592 has an elongated generally rectangular base 596 having a top side 598 and a bottom side 599. The top side 598 has a pedestal 600 positioned on a first end of the base 596 and protruding away from the top side 598. The pedestal 600 includes a first translation recess 602 having a length dimension extending parallel to the longitudinal axis of the rib clamp 590. The first translation recess 602 is configured to receive the lower flange 610 of the housing 595. The housing 595 has a base 604 and a pair of upstanding arms 606 separated by and partially defining a rod channel 608 sized and configured to

receive the connecting rod 554 therein. The housing 595 further includes a lower flange 610 that slideably mates with the first translation recess 602 to connect the housing 595 to the first clamp member 592. A locking element 612 (e.g. any of the setscrew style locking elements described herein) mates with the housing 595 to secure the connecting rod 554 to the housing 595.

[0160] The bottom side 599 includes an elongated translation recess 614 and a curved flange 616. The translation recess 614 is formed within the bottom side 599 on the first end of the base 596 (underneath the housing 566) and is configured to slideably receive the translation arm 580 of the second clamp member 594. The curved flange 616 is positioned on the second end of the base 596 and extends away from the bottom side 599 before curving inward (i.e. toward the second clamp member 594). The bottom side 599 and curved flange 616 together form a cavity 618 sized and configured to receive at least a portion of a rib bone.

[0161] The second clamp member 594 includes a base 620 and a translation arm 622 extending laterally from the base 620. The translation arm 622 mates with the translation recess 614 of the first clamp member 592 and is capable of translation within the recess to allow the rib clamp 590 to be secured to a bone. The second clamp member 594 further includes a curved flange 624 that extends away from the bottom side of the second clamp member 594 before curving inward (i.e. toward the first clamp member 592). The translation arm 622 and curved flange 624 together form a cavity 584 sized and configured to receive at least a portion of a rib bone.

[0162] The rod connector 556 has a base and a pair of upstanding arms 586 that define a rod channel in between. The rod channel is configured to receive the spinal rod 12 or a transition rod (e.g. any of the transition rod types described herein). The rod connector 556 further has a locking element 588 (e.g. any of the locking elements described herein) configured to secure the rod connector 556 to the spinal rod 12 (or transition rod). The connecting rod 554 extends laterally from one of the upstanding arms 586.

[0163] The bone anchor 550 has multiple articulating connections to help absorb force and allow controlled movement after implantation. One articulating connection is between the rod connector 556 and the spinal rod 12. This is much the same as the interaction between the spinal rod and various examples of bone screws described above. Another articulating connection is between the connecting rod 554 and the rib clamp 590. Thus slight shifting can occur without causing dislodgement of the bone anchor 550.

[0164] FIGS. 77-81 illustrate another example of a non-screw bone anchor configured for use with the vertebral fixation system 10. The bone anchor 630 of the instant example generally comprises a clamp-type mechanism suitable for attachment to a lamina or transverse process or spinous process bone or a combination thereof. The bone anchor 630 includes a first clamp member 632 and a second clamp member 634 that are translationally mated with each other.

[0165] The first clamp member 632 has an elongated base 636 having a top side 638 and a bottom side 640. The top side 638 has a housing 642 positioned on a first end of the base 636 and protruding away from the top side 638. The housing 642 has a base 644 and a pair of upstanding arms 646 separated by and partially defining a rod channel 648 sized and configured to receive the spinal rod 12 (or tran-

sition rod) therein. By way of example, the housing 642 further includes a lower flange 650 that mates with a first recess 652 formed in the top side 638 to connect the housing 642 to the first clamp member 632. A locking element 654 (e.g. any of the setscrew style locking elements described herein) mates with the housing 642 to secure the rod 12 to the housing 642. The top side 638 further includes a second recess 655 formed on the second end of the base 636 configured to slideably receive the translation arm 662 of the second clamp member 634. The bottom side 640 includes a flange 656 positioned on the first end of the base 636 (underneath the housing 642) and extending away from the bottom side 640 before curving inward (i.e. toward the second clamp member 634). The bottom side 640 and flange 656 together form a cavity 658 sized and configured to receive at least a portion of a lamina or transverse process bone.

[0166] The second clamp member 634 includes a base 660 and a translation arm 662 extending laterally from the base 660. The translation arm 662 mates with the second recess 655 of the first clamp member 632 and is capable of translation within the recess to allow the bone anchor 630 to be secured to a bone. The second clamp member 634 also includes a housing 642 with locking element 654 that are identical to the same elements described in relation to the first clamp member 632. The second clamp member 634 further includes a flange 664 that extends away from the bottom side of the second clamp member 634 before curving inward (i.e. toward the first clamp member 632). The translation arm 662 and flange 664 together form a cavity 666 sized and configured to receive at least a portion of a lamina or transverse process bone.

[0167] The prior examples described herein have sought to address the need for reducing or preventing the occurrence of junctional disease and failures through instrumentation that aims to alleviate stress on the proximal and/or distal termini of multi-level spinal fixation systems. Another way to limit flexion in the proximal and/or distal instrumented vertebrae is to create physical barriers or countermeasures that either prevent or exert a counterforce to reverse the kyphosis. One example of such a physical barrier is a rod bumper that may be inserted between a bone anchor and spinal rod, and extends a short distance distally along the spinal rod. As flexion associated with kyphosis occurs and the upper vertebra falls forward, the bumper pushes backwards on the spinal rod. In response, the spinal rod exerts a return force on the bumper, which then causes the upper vertebra to return to a more normal position. FIGS. 82-86 illustrate one example of a bone anchor 670 with associated rod bumper 672 that may be employed as a terminal anchor in a fixation construct. The bone anchor 670 is shown by way of example as a pedicle screw with a tulip and lock screw, however the rod bumper may be used with other fixation hardware.

[0168] By way of example, the bone anchor 670 includes a housing 674, threaded shank 676, and locking element 678. The housing has a base 680 and a pair of upstanding arms 682 that form the rod channel. The locking element 678 may be any of the previously described examples of locking elements. A rod bumper 672 may be attached to the housing 674 or one end of may be inserted into the rod channel between the housing 674 and spinal rod 12. The rod bumper 672 has a concave rod engaging surface 684 so as

to reduce the profile of the spinal fixation system after implantation and prior to the occurrence of flexion.

[0169] FIGS. 87-91 illustrate another example of a bone anchor and rod bumper combination configured for use with cords or other non-traditional transition rods. The bone anchor 690 is shown by way of example as a pedicle screw with a tulip and lock screw, however the rod bumper may be used with other fixation hardware.

[0170] By way of example, the bone anchor 690 includes a housing 692, threaded shank 694, and locking element 696. The housing has a base 698 and a pair of upstanding arms 700 that form the rod channel. The locking element 696 may be any of the previously described examples of locking elements. A rod bumper 702 may be attached to the housing 692 or one end of may be inserted into the rod channel between the housing 692 and transition cable rod 701. The rod bumper 702 is has an elongated body 704 with a concave rod engaging surface 706 to reduce the profile of the spinal fixation system after implantation and prior to the occurrence of flexion. The rod bumper 702 further includes a distal housing 708 to capture the transition cable rod 701 therein. The distal housing 708 is necessary to ensure the transition cable rod 701 remains aligned with the rod bumper 702 given the flexibility of the transition cable rod 701. The distal housing 708 is similar to the previously described examples of housings in that it has a base 710 and a pair of upstanding arms 712 that act in concert to form a rod channel 714. A locking element 716 may also be included to ensure the transition cable rod 701 remains in the rod channel 714. The locking element 716 may be any of the previously described examples of locking elements. Although described herein with regard to this specific example, other configurations are possible. For example the distal housing 708 may be replaced by a loop that achieves the goal of keeping the transition cable rod 701 aligned with the rod engaging surface 706.

[0171] FIGS. 92-95 illustrate an example of another fixation assembly that works to counteract flexion at the proximal and/or distal instrumented vertebra. The fixation assembly 720 described herein forms part of the spinal fixation system 10 and is suitable for use with the spinal rod 12 and/or a transition rod 721 such as one of the several examples described above. By way of example, the fixation assembly 720 is described herein as being used with both the spinal rod 12 and a transition rod 721. The fixation assembly 720 includes a first bone anchor 722, a pair of elastomeric sheaths 724, and first and second locking rings 726, 728. The present example is shown and described with a second bone anchor 730 associated with the spinal rod 12 and implanted at an adjacent vertebral level.

[0172] The first bone anchor 722 may be any bone anchor suitable for securing a spinal rod in place relative to a bone. By way of example, the bone anchor 722 includes a threaded shank 732 and a ring shaped head 734. Other types of anchors including tulip based pedicle screws like those described in above examples (as well as bone anchor 730 of this example) are possible. The threaded shank 732 is configured to provide purchase in bone tissue. The ring shaped head 734 includes a rod hole 736 sized and configured to allow passage of the transition rod 721 (or spinal rod 12) therethrough. One elastomer sleeve 724 is positioned on the rod 721 proximally of the head 734, and the other elastomer sleeve 724 is positioned on the rod 721 distally of the head 734. The first locking ring 726 is secured to the rod

**721** proximally of the proximal elastomer sleeve **724**. The second locking ring **728** is secured to the rod **721** distally of the distal elastomer sleeve **724**.

[0173] The first locking ring **726** shown by way of example comprises a body **738** having a rod hole **740** extending therethrough and a locking element aperture **742** that opens to the rod hole **740** and is configured to receive a locking element **744**. The locking element **744** may be any of the setscrew type locking elements described by way of example above. Other locking ring configurations are possible that may or may not need secondary locking elements.

[0174] The second locking ring **728** shown by way of example is capable of joining a pair of rods and comprises a body **746** having a rod hole **748** extending therethrough, and first and second locking element apertures **750**, **752** that open to the rod hole **748** and are configured to receive first and second locking elements **754**, **756** respectively. The locking elements **754**, **756** may be any of the setscrew type locking elements described by way of example above. In the instant example the first locking element **754** secures the second locking element **728** to the transition rod **721** and the second locking element **756** secures the second locking element **728** to the spinal rod **12**. Although described as a junction point between the transition rod **721** and the spinal rod **12**, the second locking ring **728** may be secured to only one rod and therefore may be identical to the first locking ring **726**. Other locking ring configurations are possible that may or may not need secondary locking elements.

[0175] In an initial unbiased position, the various elements are positioned such that the proximal elastomer sleeve **724** abuts the head **734** and first locking ring **726**, while the distal elastomer sleeve **724** abuts the head **734** and second locking ring **726**. When flexion occurs and the rod **721** experiences forward bending, the elastomer sleeves **724** will be compressed and as a result exert a counterforce back on the first and second locking rings **726**, **728** and head **734**. This counterforce will work to return the rod **721** toward its initial position.

[0176] FIGS. 96-98 illustrate an example of another fixation assembly that works to present a physical barrier to flexion at the proximal and/or distal instrumented vertebra. The fixation assembly **760** described herein forms part of the spinal fixation system **10** and is suitable for use with the spinal rod **12** and/or a transition rod such as one of the several examples described above. By way of example, the fixation assembly **760** includes bone anchor **762**, flexible cable rod **764**, and attachment element **766**. The present example is shown and described with a second bone anchor **768** associated with the spinal rod **12** and implanted at an adjacent vertebral level.

[0177] The bone anchor **762** may be any bone anchor suitable for securing a spinal rod in place relative to a bone. By way of example, the bone anchor **762** includes a threaded shank **770** and a ring shaped head **772**. Other types of anchors including tulip based pedicle screws like those described in above examples (as well as bone anchor **768** of this example) are possible. The threaded shank **770** is configured to provide purchase in bone tissue. The ring shaped head **772** includes a rod hole **774** sized and configured to allow passage of the cable rod **764** therethrough. The head **772** further includes a proximal abutment surface **776** oriented toward the proximal end of the cable rod **764** and configured to flushly engage the flexion stop **778** when necessary during flexion.

[0178] The cable rod **764** is a flexible cable and has a proximal terminus comprising a flexion stop **778**. By way of example, the flexion stop **778** is a rigid member attached to the end of the cable rod **764** and having a diameter (or length dimension) that is greater than the diameter of the rod hole **774** so that the flexion stop **778** is incapable of passing through the rod hole **774**. During flexion the cable rod **764** will be pulled through the rod hole **774** until the flexion stop **778** abuts the abutment surface **776**. When this abutment happens, the top vertebra (that is falling forward) will in effect be held up by the cable rod **764**, preventing further flexion from occurring.

[0179] The attachment element **766** is configured to attach the distal end of the cable rod **764** to the proximal end of the spinal rod **12**. By way of example, the attachment element **766** comprising a housing **780** having a rod channel **782** and a plurality of locking element apertures **784**, each of which is configured to receive a locking element **786**. In use, the distal end of the cable rod **764** is received within the rod channel **782** and secured with the proximal most locking element **786**. The proximal end of the spinal rod **12** is received within the rod channel **782** and secured with the distal most locking element **786**. In the present example, the locking elements **786** may be one of the several examples of setscrew type locking elements described above. Although shown and described herein as a housing and setscrew based attachment mechanism, it should be understood that the cable rod **764** and spinal rod **12** may be joined by any suitable method without departing from the scope of this disclosure.

[0180] Several of the examples described herein involve tethers attached to the bone anchor or to a bone hook that then act as artificial ligaments to secure the rod to the bone. In some instances it may not be necessary to attach the tethers to implanted hardware other than the rod. In these instances it is contemplated that the tether may be wrapped around the bone structure without having a terminus that is attached to implanted hardware.

[0181] While specific embodiments have been shown by way of example in the drawings and described herein in detail, it will be appreciated that the invention is susceptible to various modifications and alternative forms (beyond combining features disclosed herein). The description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

What is claimed is:

1. A rod attachment for securing a spinal rod to a bone structure, the rod attachment comprising:
  - a first side, a second side, and a lumen extending longitudinally along a first axis through the first side and the second side of the rod attachment, the lumen dimensioned to receive the spinal rod and wherein the first lumen is configured to allow the spinal rod to enter from the first side and exit the lumen from the second side;
  - a third side of the rod attachment including at least one aperture, wherein the at least one aperture intersects the lumen along a second axis about perpendicular to the first axis; and

- a fourth side of the rod attachment including a tether connector, wherein the tether connector is configured to receive a tether parallel to and offset from the second axis.
2. The rod attachment of claim 1, wherein the lumen has an enclosed perimeter.
3. The rod attachment of claim 1, wherein the rod attachment further comprises: a housing section that contains the lumen, the at least one aperture, and the tether connector.
4. The rod attachment of claim 1, wherein the tether connector comprises:
- a post member extending outwardly from the fourth side; and
  - a second lumen extending through the post member.
5. The rod attachment of claim 4, wherein the lumen does not intersect the second lumen.
6. The rod attachment of claim 1, wherein the rod attachment further comprises:
- at least one locking element in the at least one aperture.
7. The rod attachment of claim 6, wherein the at least one aperture comprises an aperture screw thread, wherein the at least one locking element comprises a locking screw thread, and wherein the aperture screw thread and the locking screw thread are complementary.
8. The rod attachment of claim 7, wherein the aperture screw thread is configured to engage with the locking screw thread as the at least one locking element is advanced via rotation in the at least one aperture.
9. A rod attachment for securing a spinal rod to a bone structure, the rod attachment comprising:
- a first side, an second side and a first lumen extending longitudinally through the first side of the rod attachment and the second side of the rod attachment, wherein the first lumen is dimensioned to receive the spinal rod and configured to allow the spinal rod to enter from the first side and exit the first lumen from the second side;
  - a third side having a first aperture and a second aperture, wherein the first aperture and the second aperture each intersect the first lumen; and
  - a fourth side including a tether connector, wherein the tether connector comprises a post member extending outwardly from the fourth side, wherein the post member comprises a second lumen dimensioned to receive a tether.
10. The rod attachment of claim 9, wherein the rod attachment further comprises: a housing section that contains the first lumen, the first aperture, the second aperture, and the tether connector.
11. The rod attachment of claim 9, wherein the first lumen does not intersect the second lumen.
12. The rod attachment of claim 9, wherein the rod attachment further comprises:
- a first locking element in the first aperture; and
  - a second locking element in the second aperture.
13. The rod attachment of claim 12, wherein the first and second apertures comprise aperture screw threads, wherein the first and second locking elements comprise locking screw threads, and wherein the aperture screw threads and the locking screw threads are complementary.
14. A bone anchor for securing a spinal rod to a bone structure, the bone anchor comprising:
- a threaded shank; and
  - a housing comprising:
    - a base coupled to the threaded shank;
    - a pair of upstanding arms spaced apart forming a channel dimensioned to fit a portion of the spinal rod; and
    - a tether connector on a given arm of the pair of upstanding arms.
15. The bone anchor of claim 14, wherein the housing is coupled to the threaded shank in a multi-axial configuration in which the housing can rotate and pivot relative to the threaded shank.
16. The bone anchor of claim 14, wherein the tether connector comprises:
- a post member extending outwardly from the given arm; and
  - a lumen extending through the post member.
17. The bone anchor of claim 16, wherein the channel does not intersect the lumen.
18. The bone anchor of claim 14, wherein the bone anchor further comprises:
- a locking element that is attachable to the housing between the pair of upstanding arms.
19. The bone anchor of claim 18, wherein the locking element comprises an upper portion that mates with the pair of upstanding arms and a lower portion that engages with a given portion of the spinal rod.
20. The bone anchor of claim 18, wherein each arm of the pair of upstanding arms comprises a locking engagement feature configured to engage with a housing engagement feature of the locking element as the locking element is advanced via rotation between the pair of upstanding arms.

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