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(12) **United States Patent**
Ledet et al.

(10) **Patent No.:** **US 10,639,076 B2**
(45) **Date of Patent:** **May 5, 2020**

(54) **DYNAMIC FIXATION SYSTEM, METHOD OF USE, AND FIXATION SYSTEM ATTACHMENT PORTIONS**

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NY (US)

(73) Assignee: **REVIVO MEDICAL, LLC**,
Loudonville, NY (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/919,204**

(22) Filed: **Mar. 12, 2018**

(65) **Prior Publication Data**

US 2018/0199963 A1 Jul. 19, 2018

Related U.S. Application Data

(63) Continuation-in-part of application No. 15/829,027,
filed on Dec. 1, 2017, which is a continuation of
application No. 15/594,183, filed on May 12, 2017,
now Pat. No. 9,861,392, which is a continuation of
application No. 15/337,253, filed on Oct. 28, 2016,
now Pat. No. 9,788,864, which is a continuation of
application No. 14/237,733, filed as application No.

(Continued)

(51) **Int. Cl.**

A61B 17/70 (2006.01)
A61B 17/80 (2006.01)
A61F 2/44 (2006.01)
A61B 17/00 (2006.01)

(52) **U.S. Cl.**

CPC **A61B 17/7026** (2013.01); **A61B 17/701**
(2013.01); **A61B 17/7004** (2013.01); **A61B**
17/7007 (2013.01); **A61B 17/7011** (2013.01);
A61B 17/7025 (2013.01); **A61B 17/7028**
(2013.01); **A61B 17/7029** (2013.01); **A61B**
17/7059 (2013.01); **A61B 17/8085** (2013.01);
A61F 2/4455 (2013.01); **A61B 17/8023**
(2013.01); **A61B 2017/00004** (2013.01)

(58) **Field of Classification Search**

CPC A61B 17/7062; A61B 17/7067; A61B
17/7068
USPC 606/246–249, 257; 623/17.11–17.16
See application file for complete search history.

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Primary Examiner — Julianna N Harvey

Assistant Examiner — Christina NegrelliRodriguez

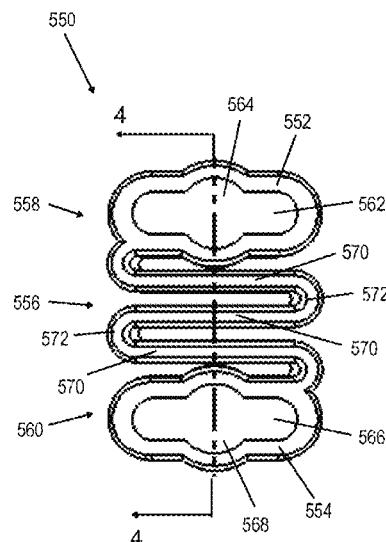
(74) *Attorney, Agent, or Firm* — Heslin Rothenberg
Farley & Mesiti P.C.; Kristian E. Ziegler

(57)

ABSTRACT

Fixation systems including a member, a first attachment portion, a second attachment portion, and an intermediate portion. The first attachment portion is attached at a superior end of the member and includes a first opening. The second attachment portion is attached at an inferior end of the member and includes a second opening. The intermediate portion connects the first and second attachment portions. The fixation systems may also include a relief in at least one of the first opening and the second opening. Surgical methods for inserting the fixation systems in a patient are also disclosed.

22 Claims, 46 Drawing Sheets



Related U.S. Application Data

PCT/US2012/049959 on Aug. 8, 2012, now Pat. No. 9,510,871.

- (60) Provisional application No. 61/574,636, filed on Aug. 8, 2011, provisional application No. 61/574,662, filed on Aug. 8, 2011, provisional application No. 61/628,662, filed on Nov. 4, 2011, provisional application No. 61/628,663, filed on Nov. 4, 2011, provisional application No. 62/469,799, filed on Mar. 10, 2017, provisional application No. 62/470,554, filed on Mar. 13, 2017.

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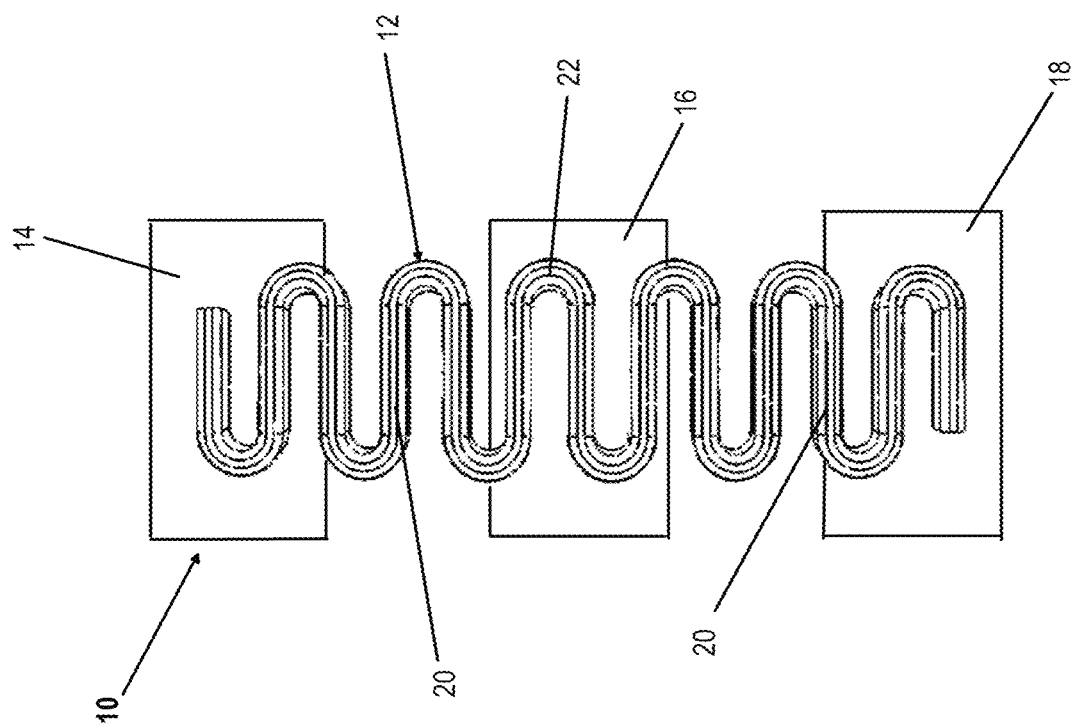


FIG. 1

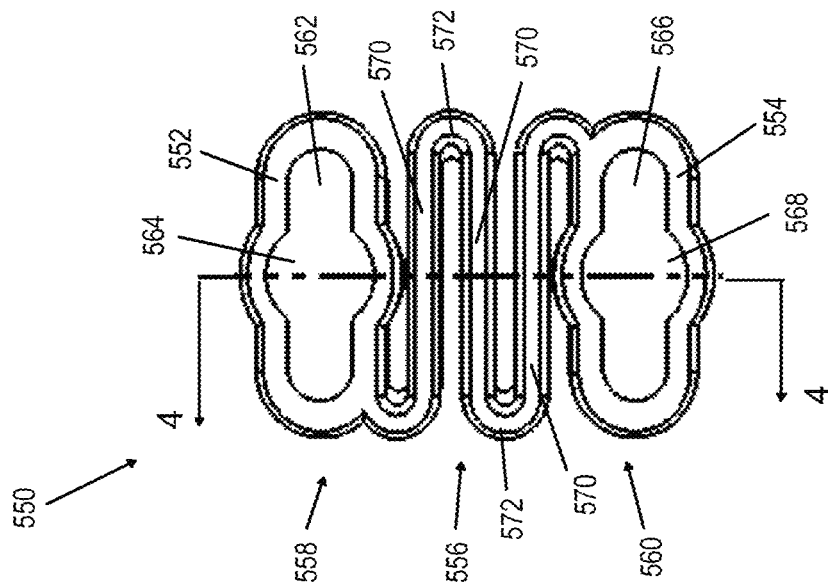


FIG. 2

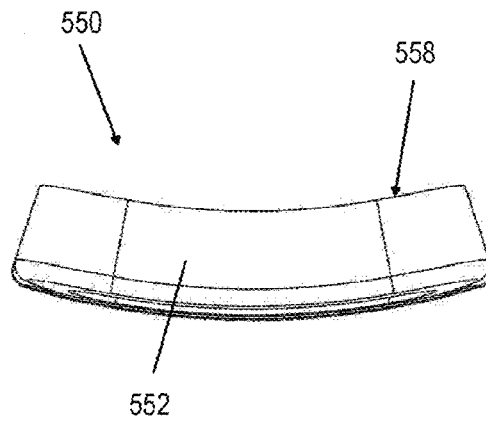


FIG. 3

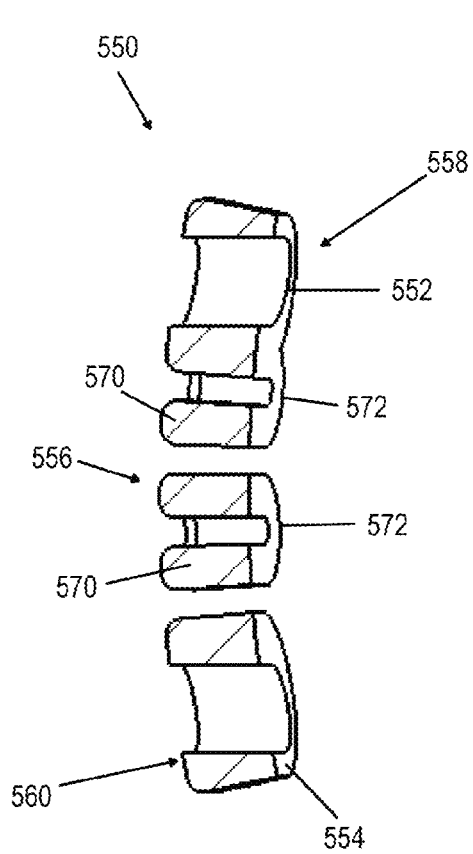


FIG. 4

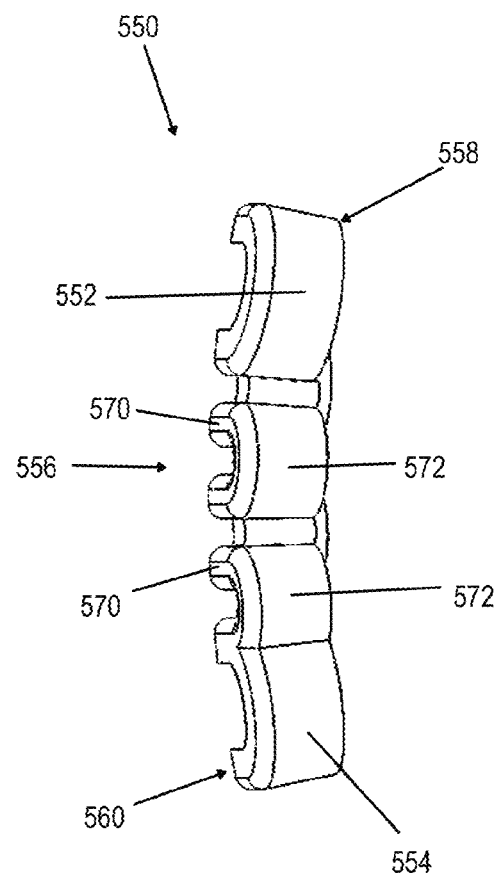


FIG. 5

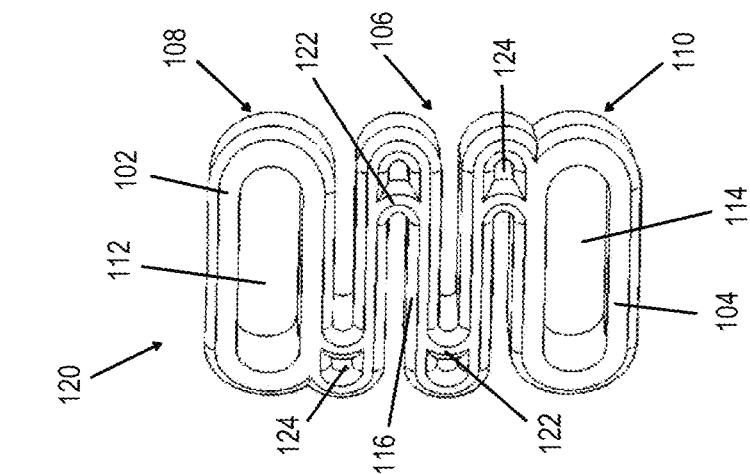


FIG. 6

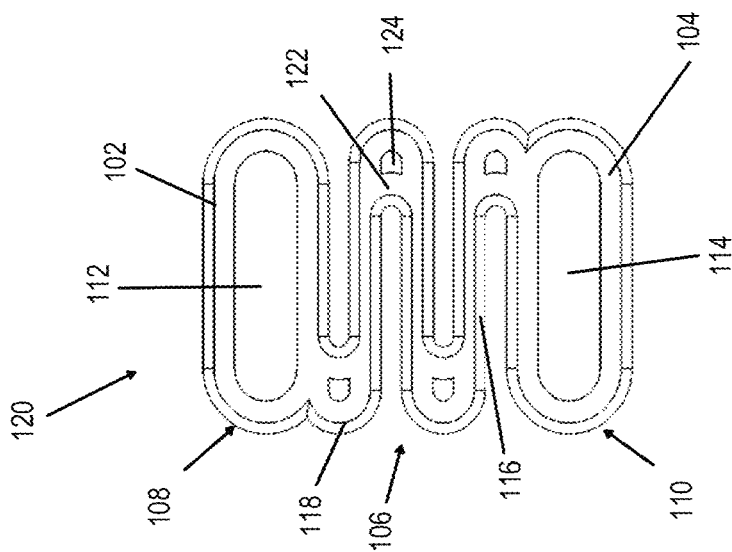


FIG. 7

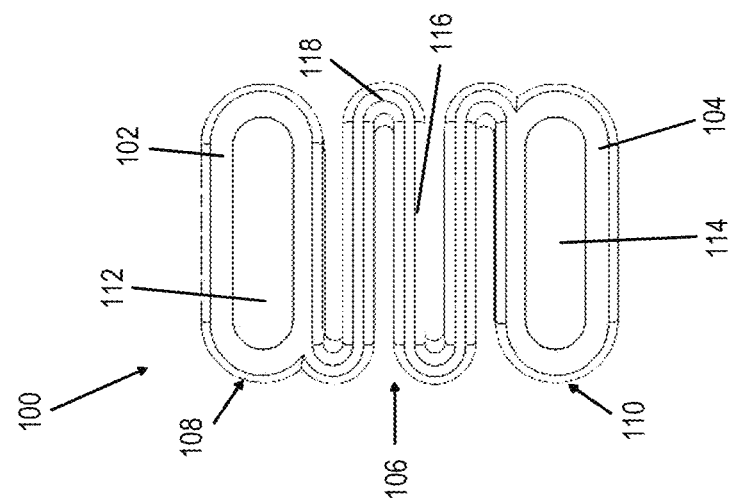


FIG. 8

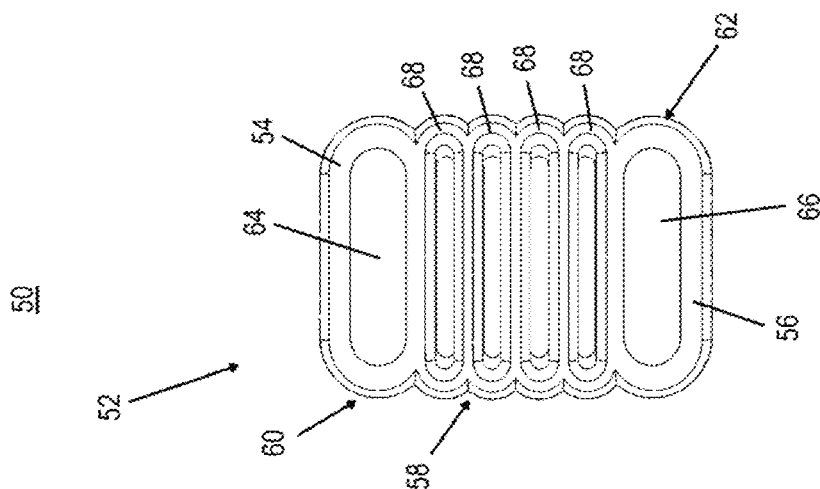


FIG. 11

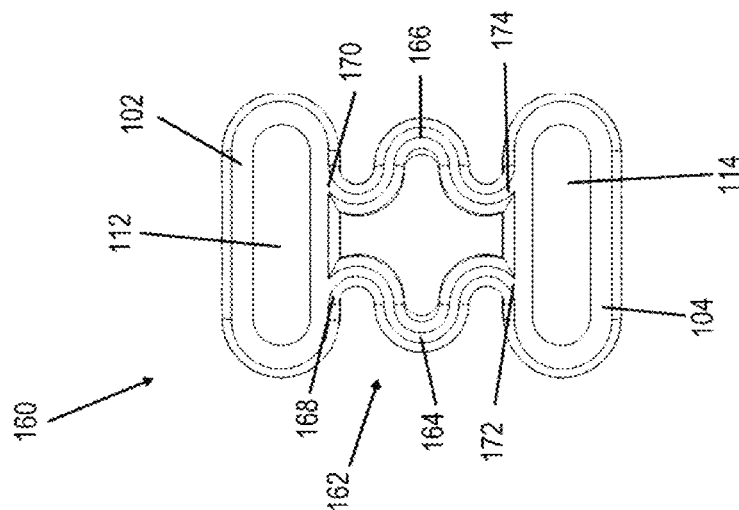


FIG. 10

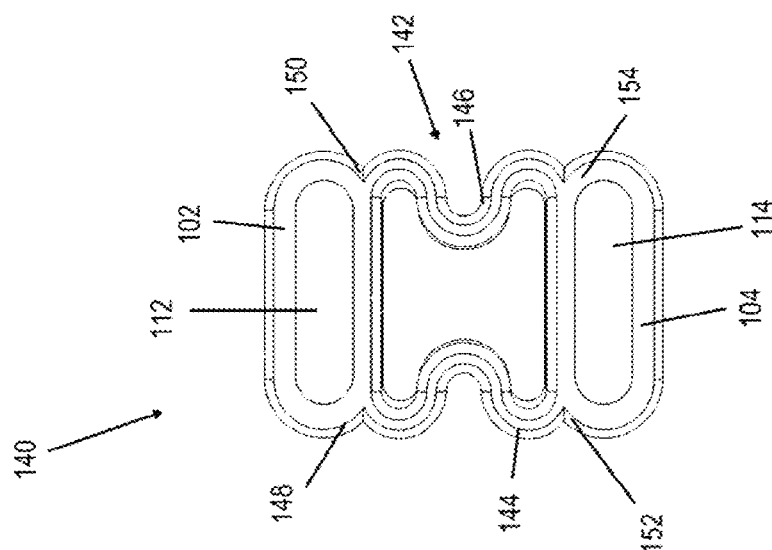


FIG. 9

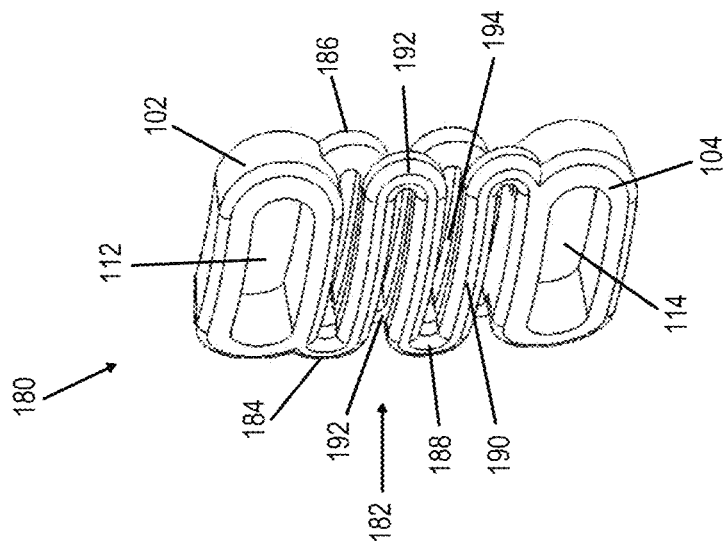


FIG. 13

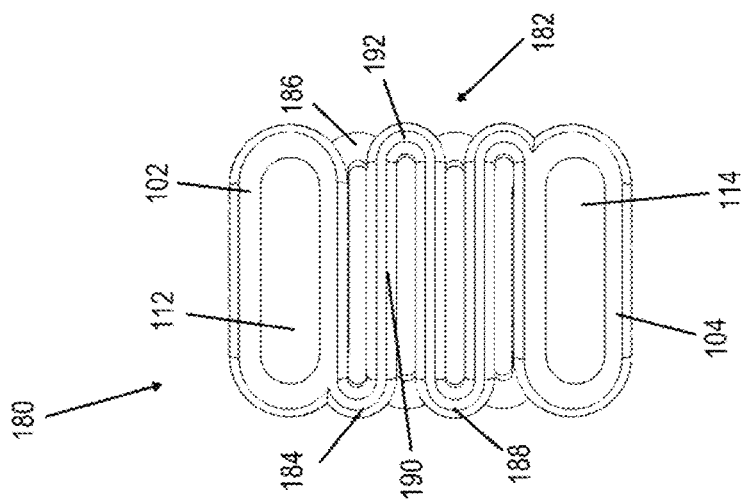


FIG. 12

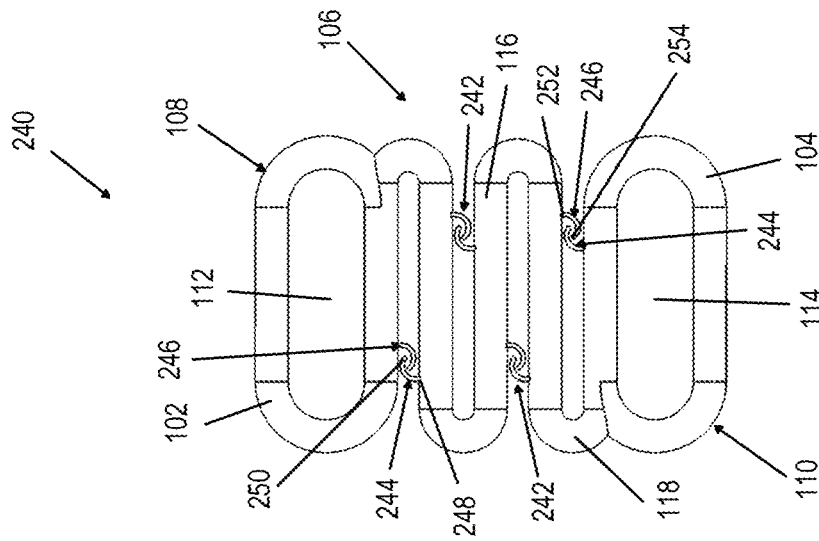


FIG. 16

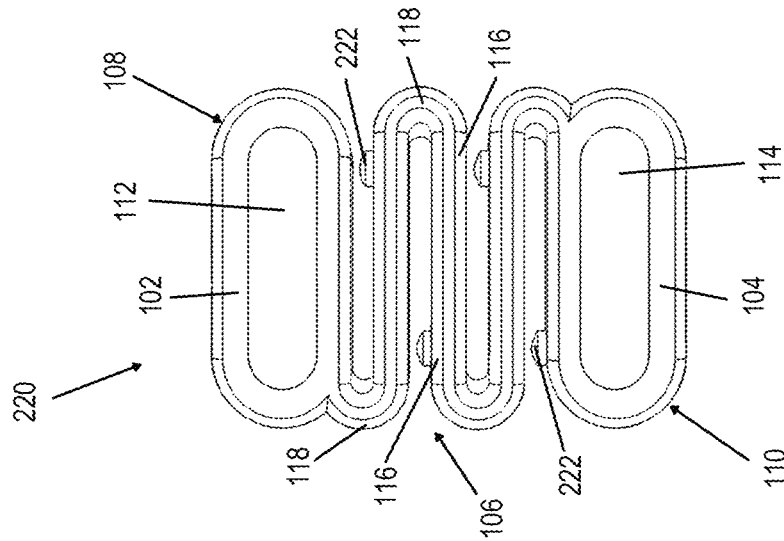


FIG. 15

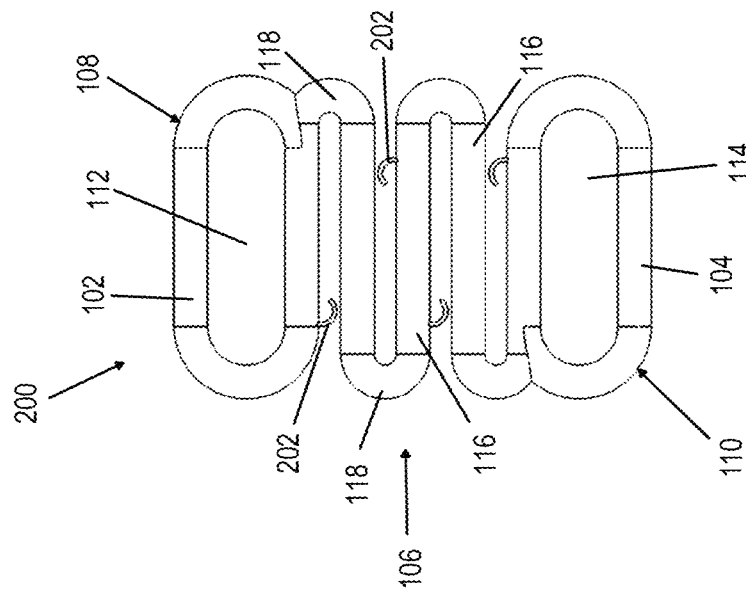


FIG. 14

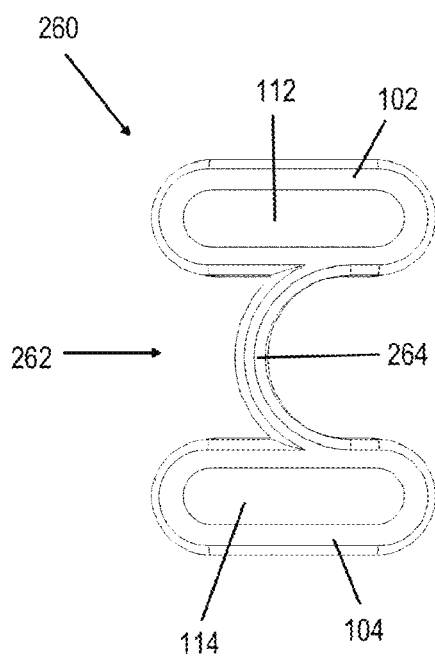


FIG. 17

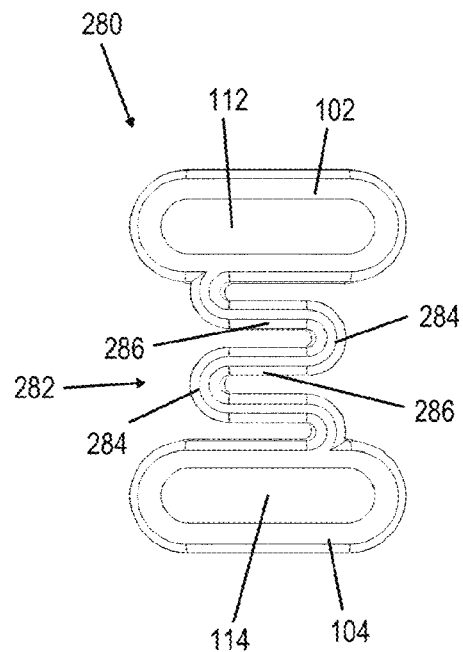


FIG. 18

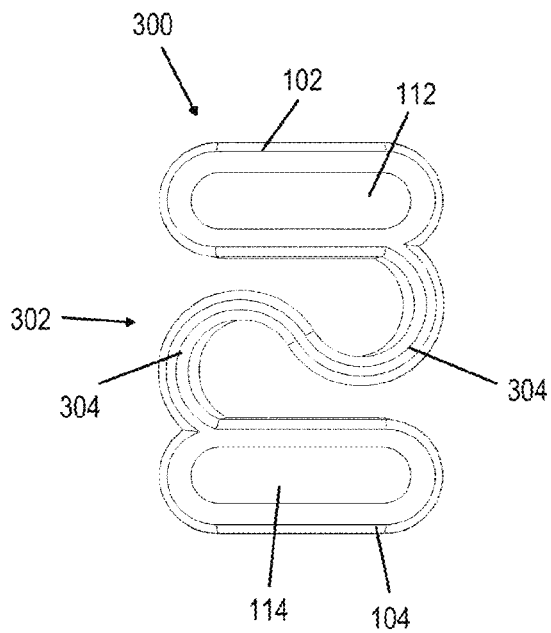


FIG. 19

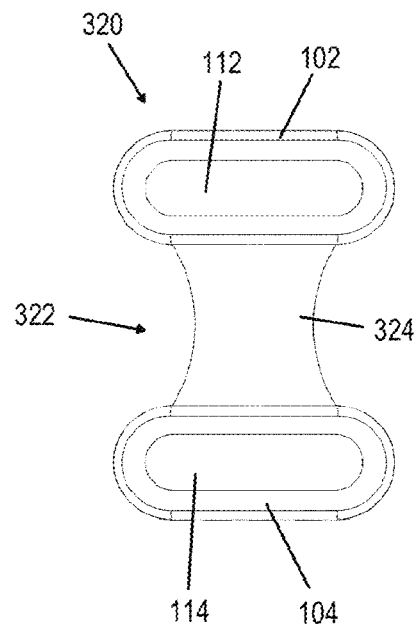


FIG. 20

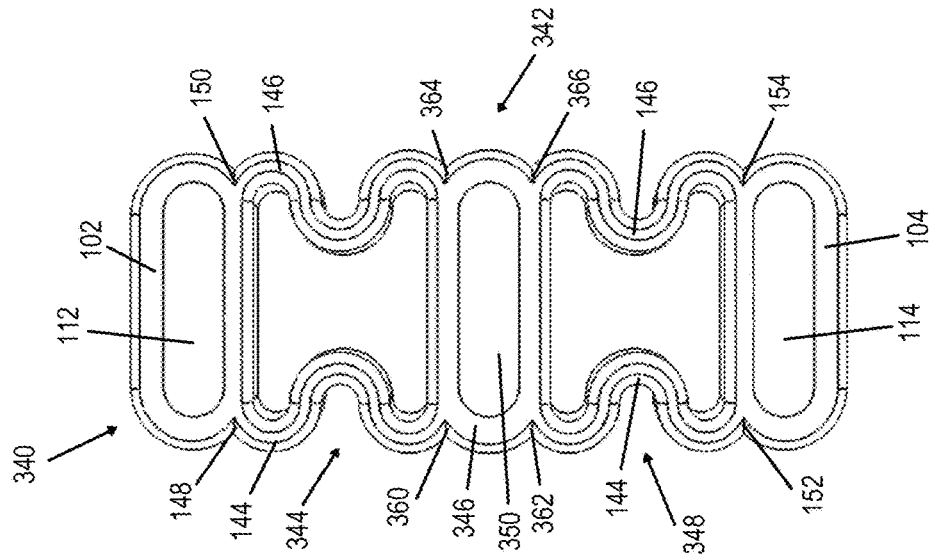


FIG. 23

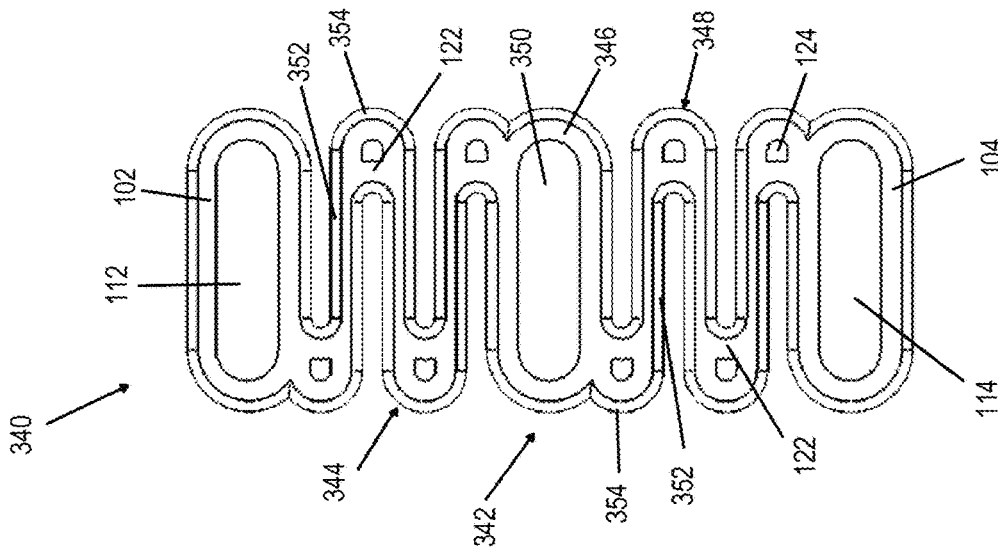


FIG. 22

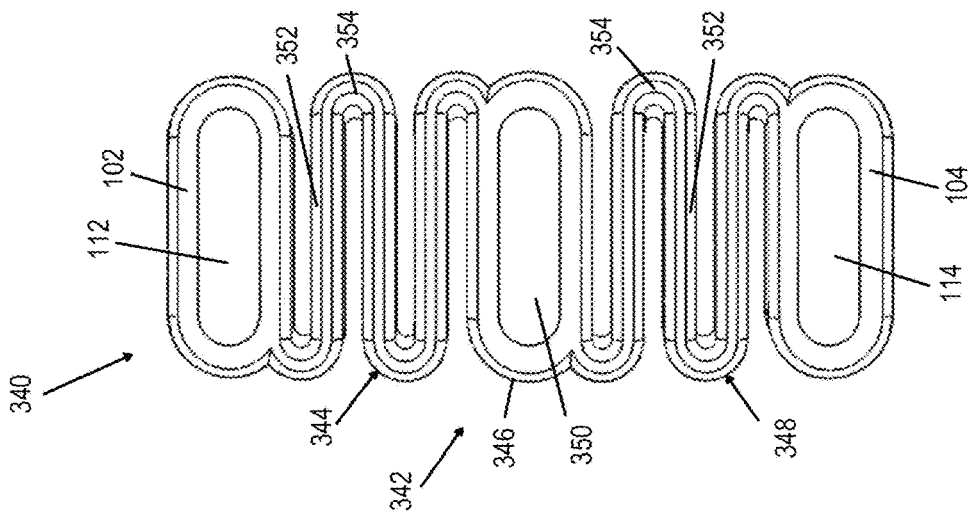


FIG. 21

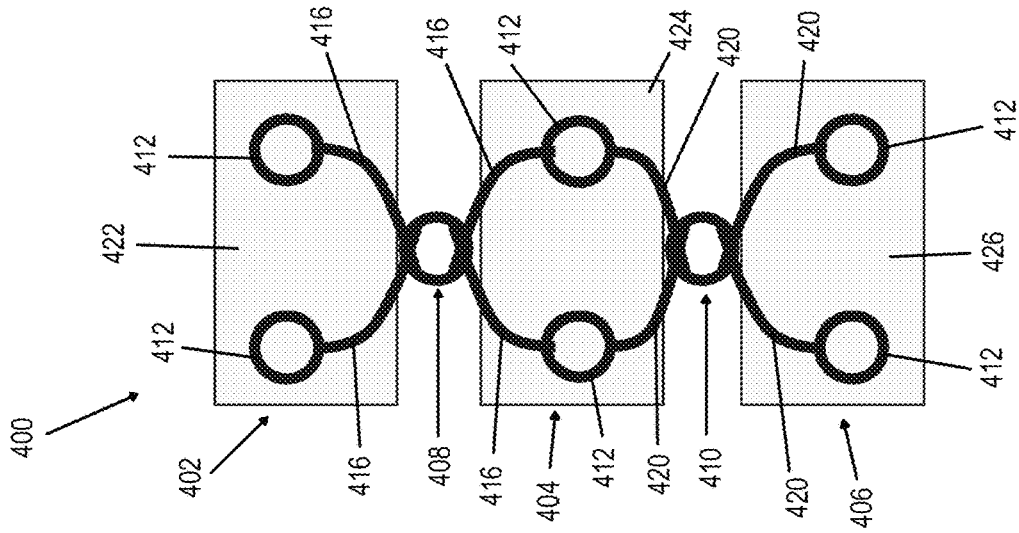


FIG. 26

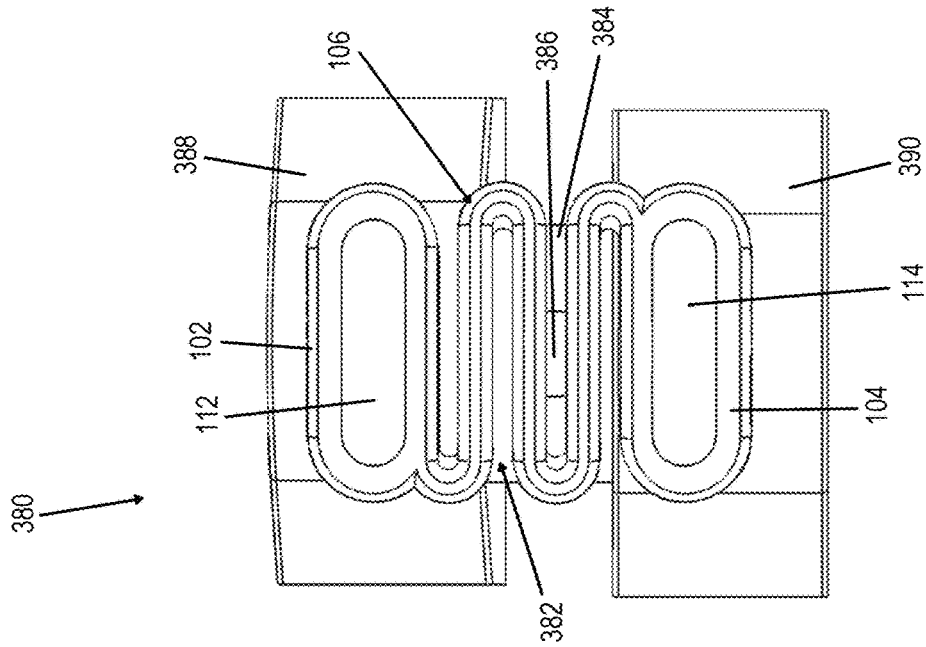


FIG. 25

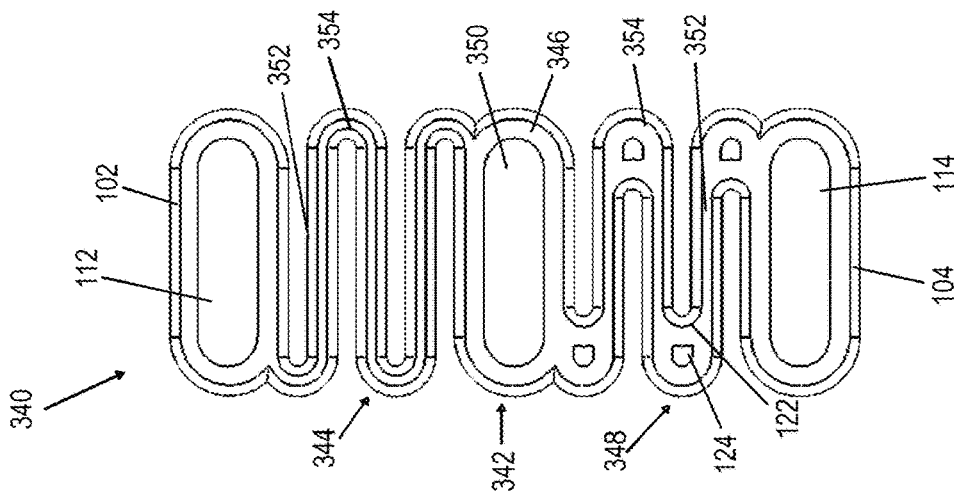


FIG. 24

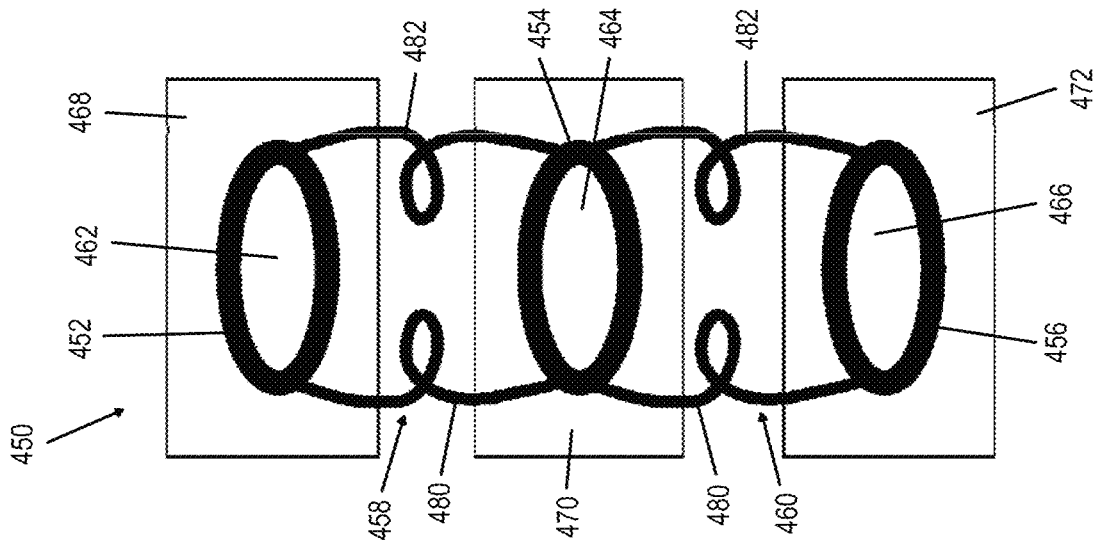


FIG. 27

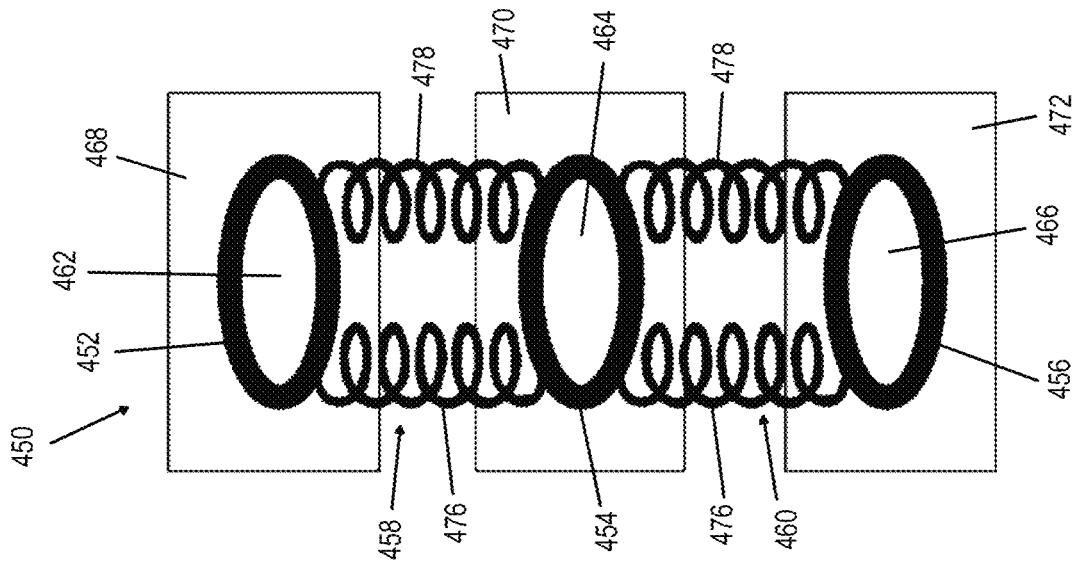


FIG. 28

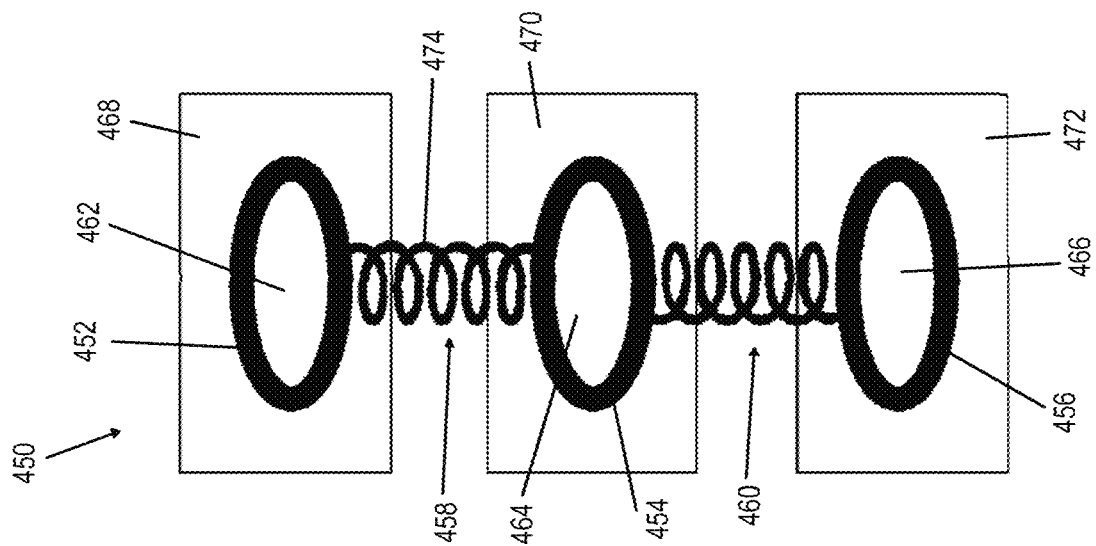


FIG. 29

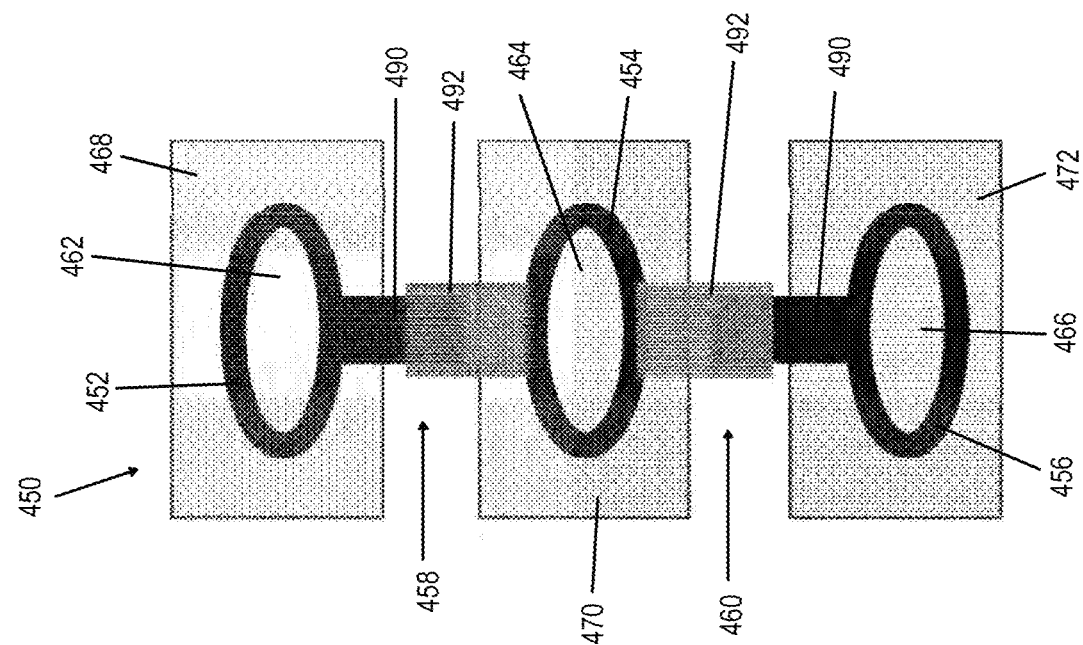


FIG. 30

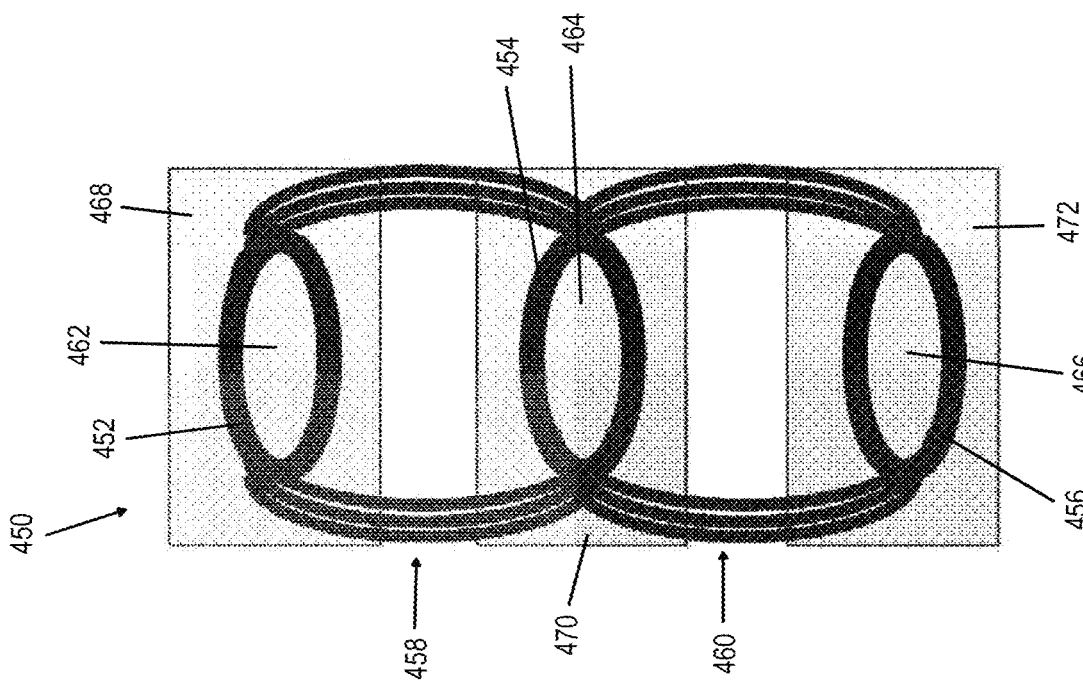


FIG. 31

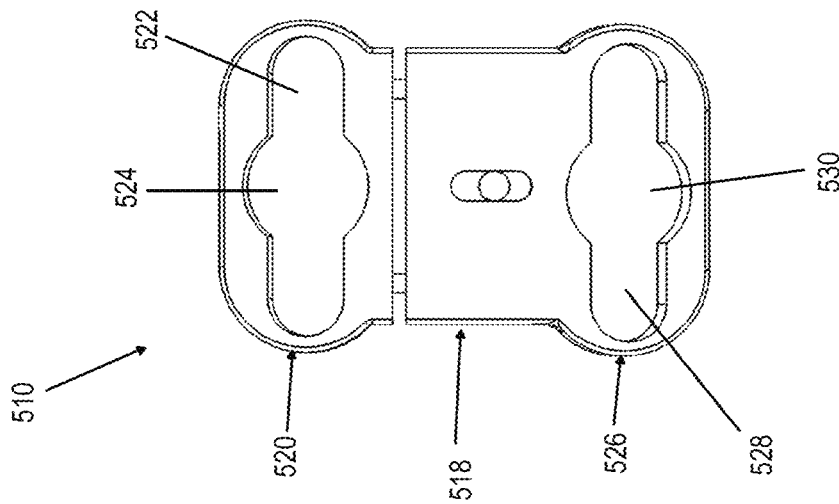


FIG. 33

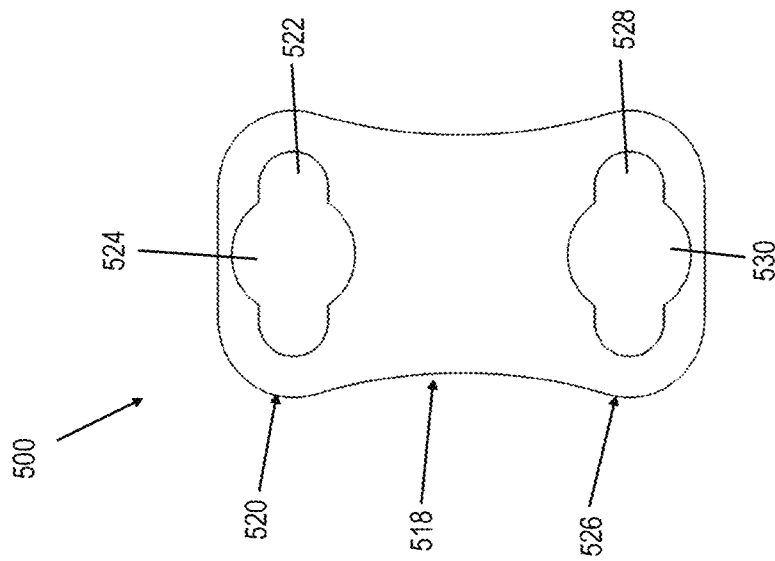


FIG. 32

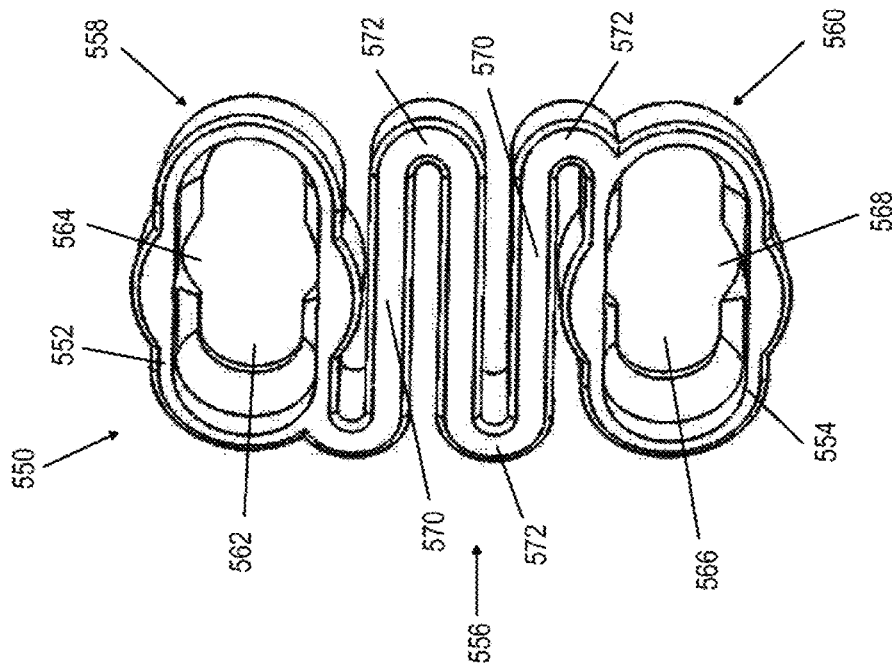


FIG. 35

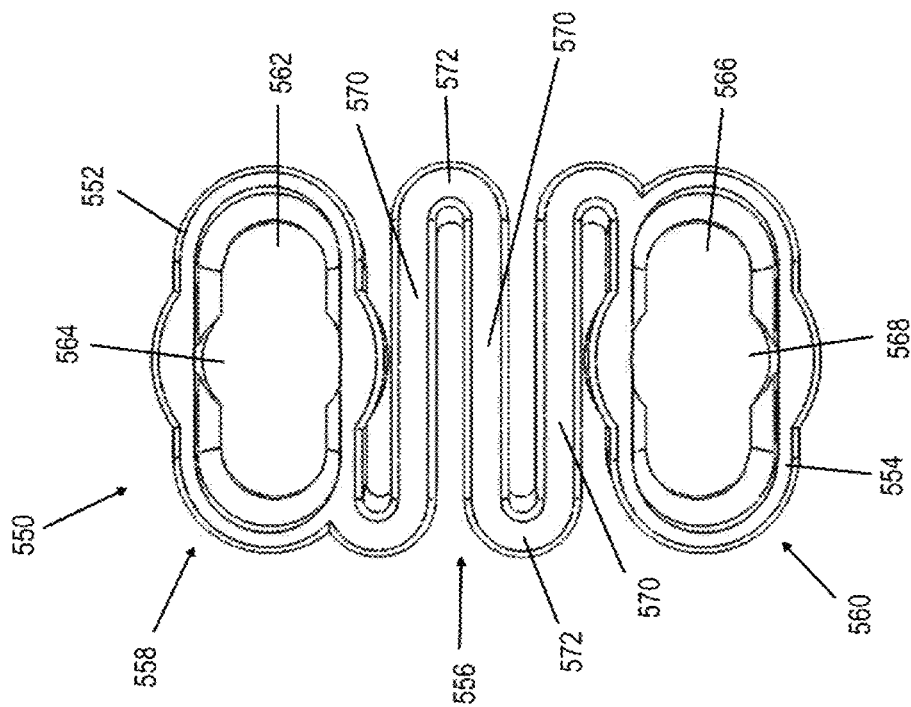


FIG. 34

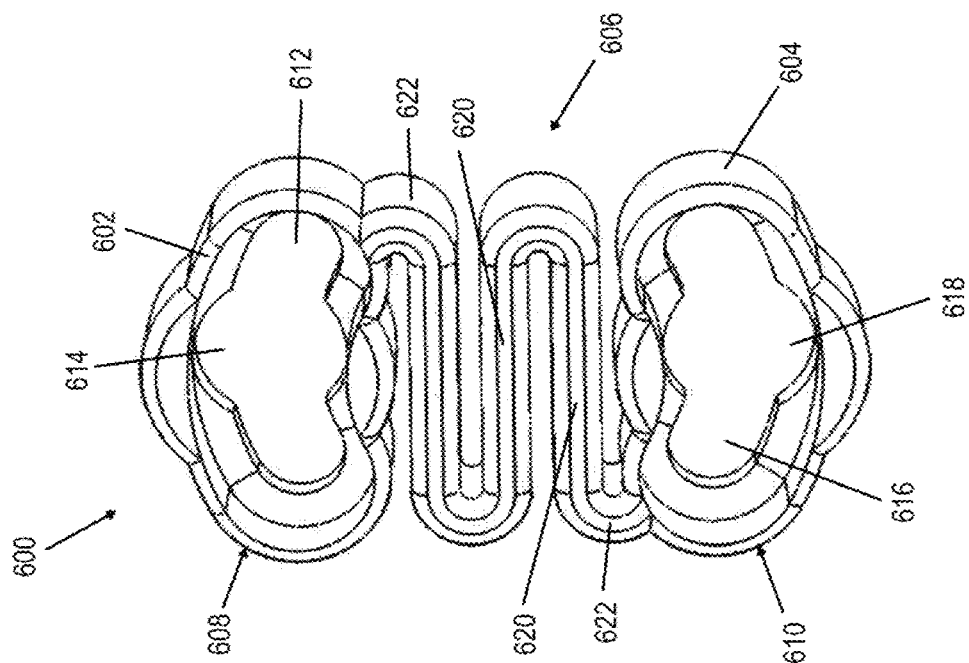


FIG. 36

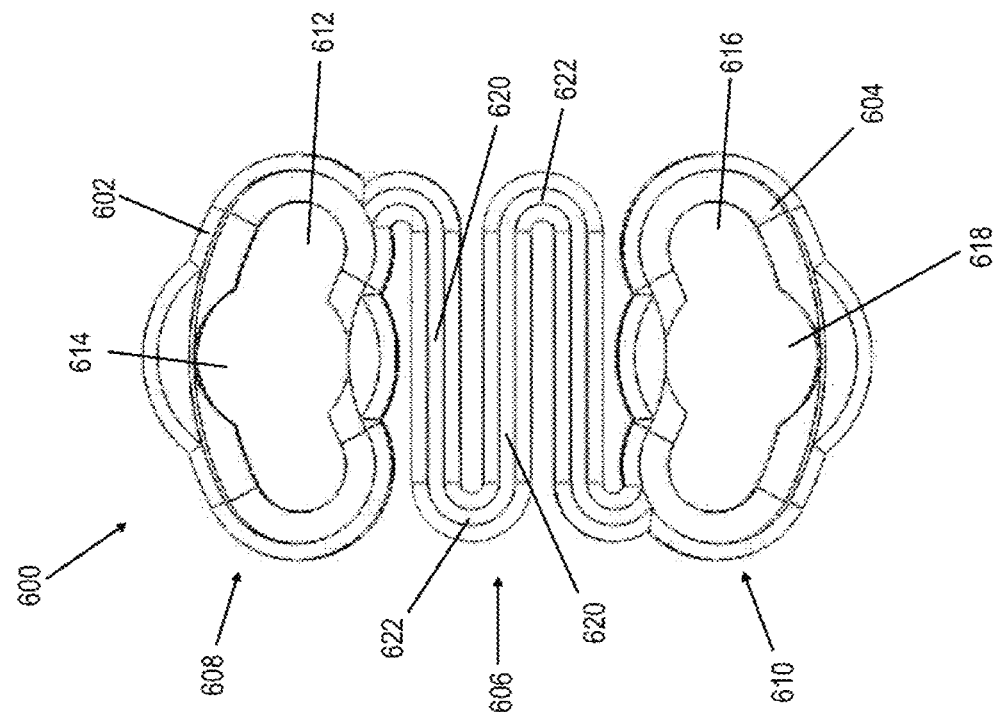


FIG. 37

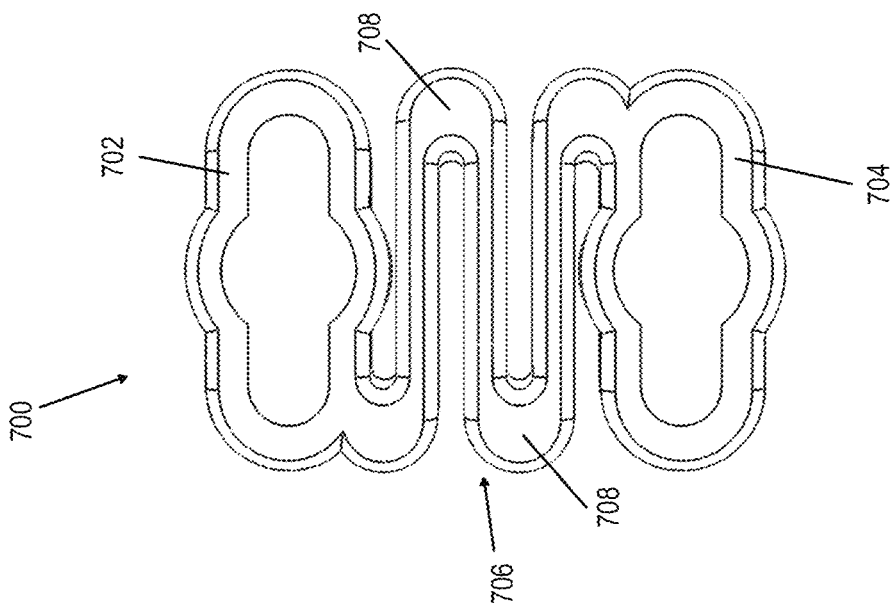


FIG. 40

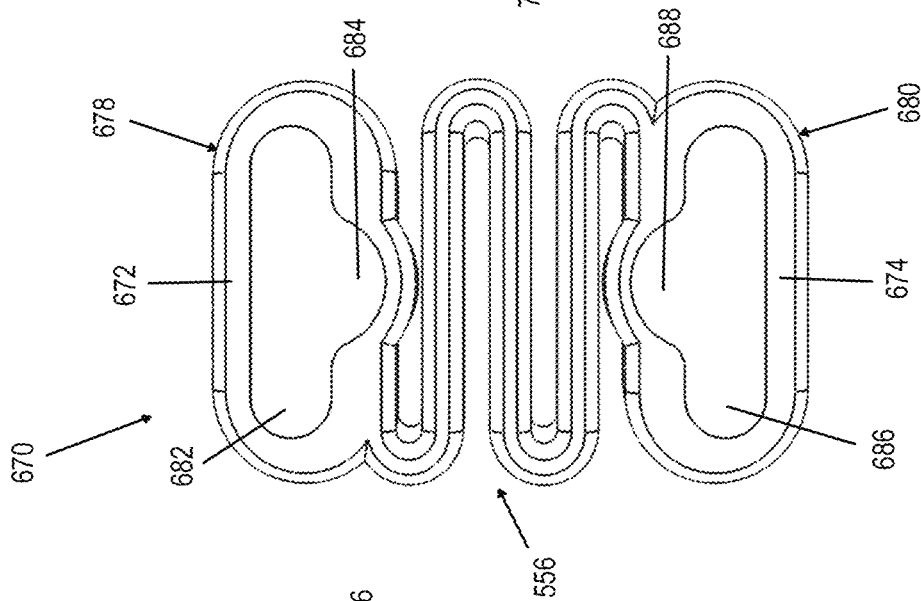


FIG. 39

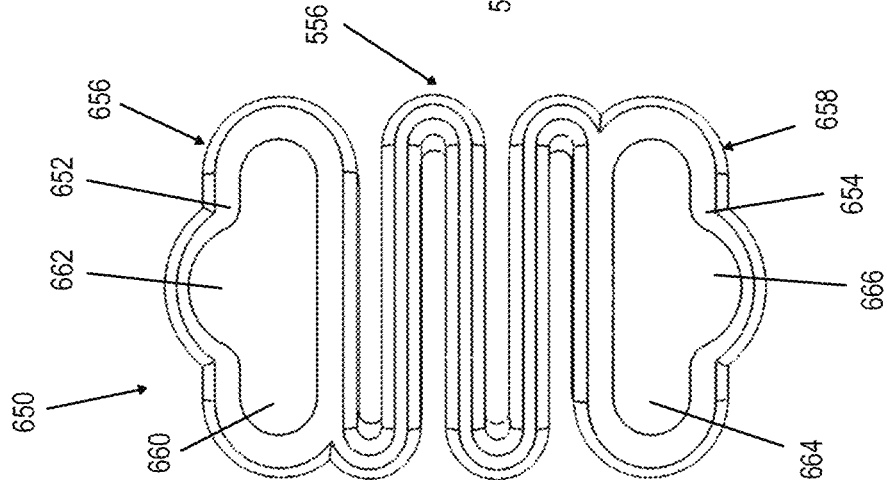


FIG. 38

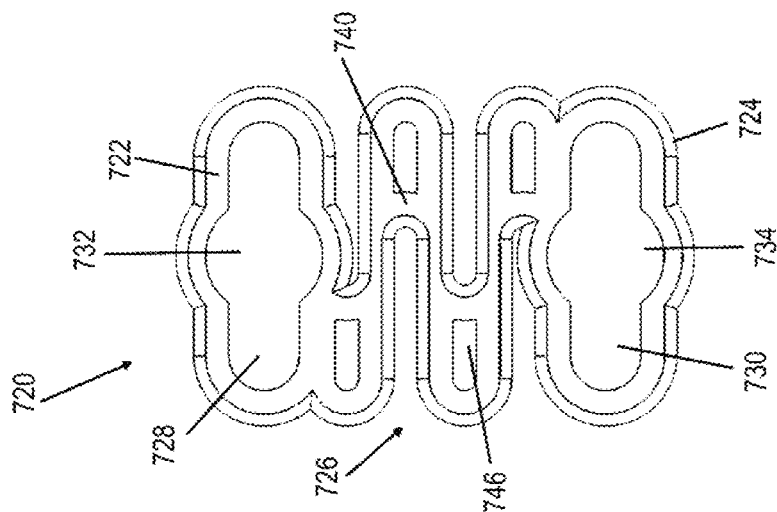


FIG. 43

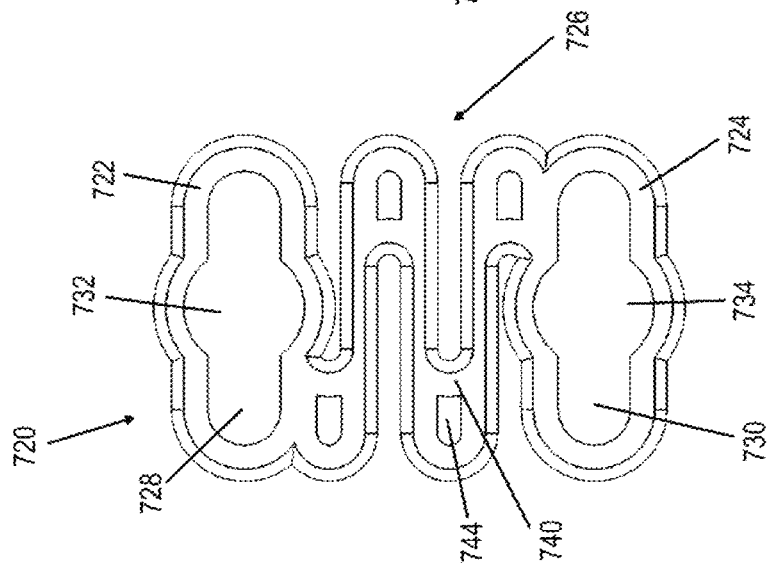


FIG. 42

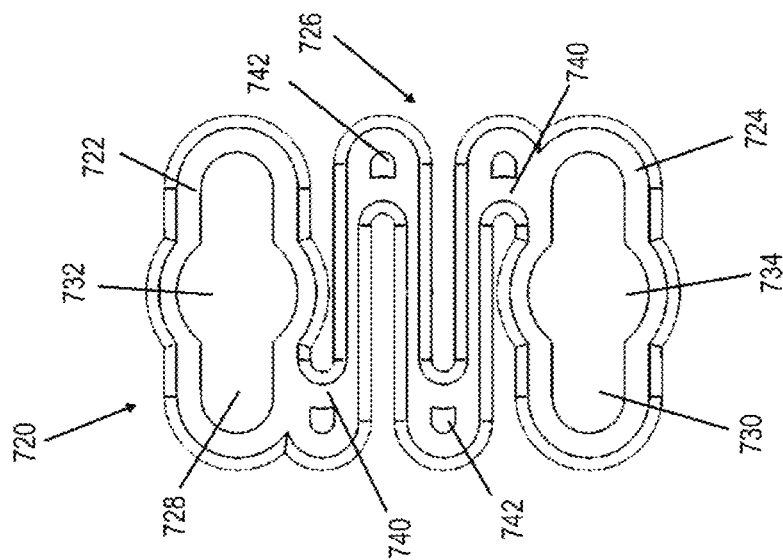


FIG. 41

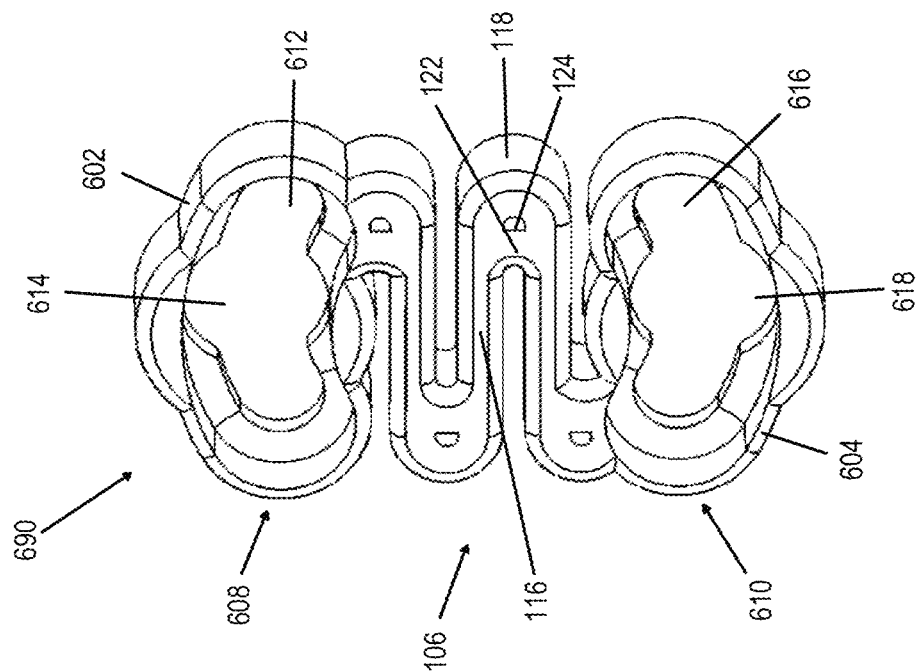


FIG. 44

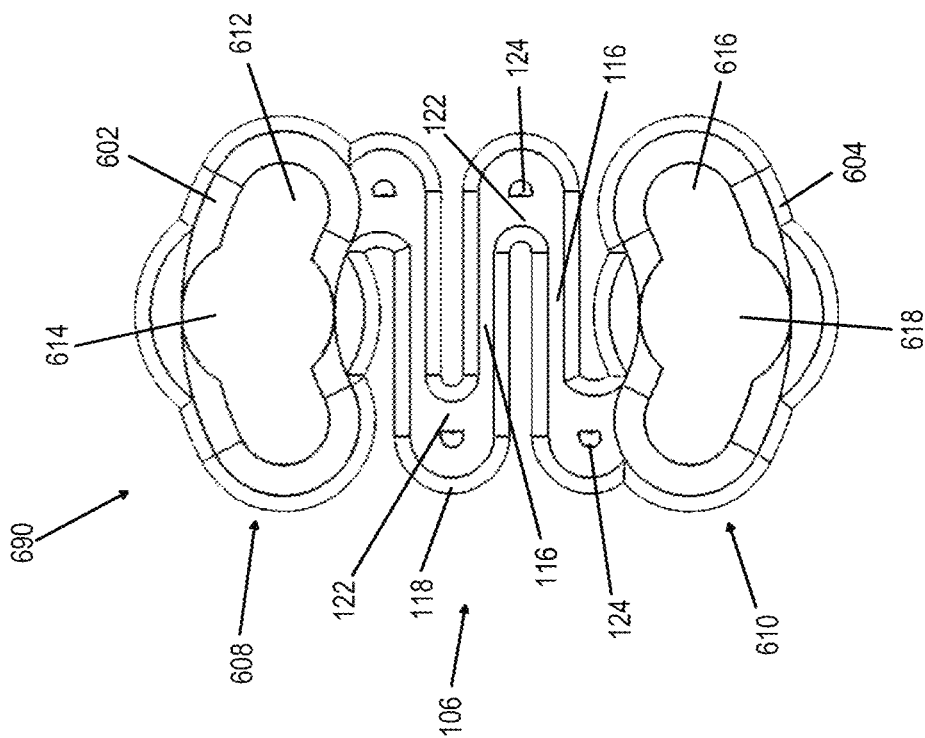


FIG. 45

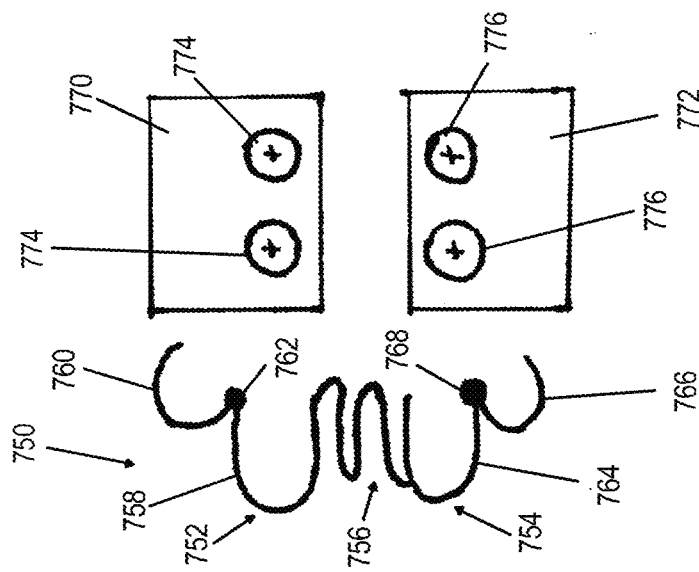


FIG. 46

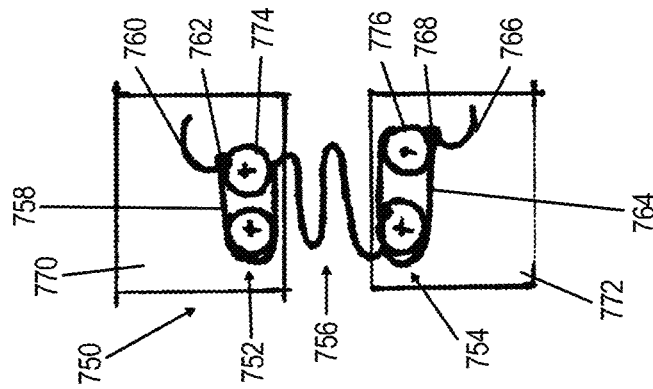


FIG. 47

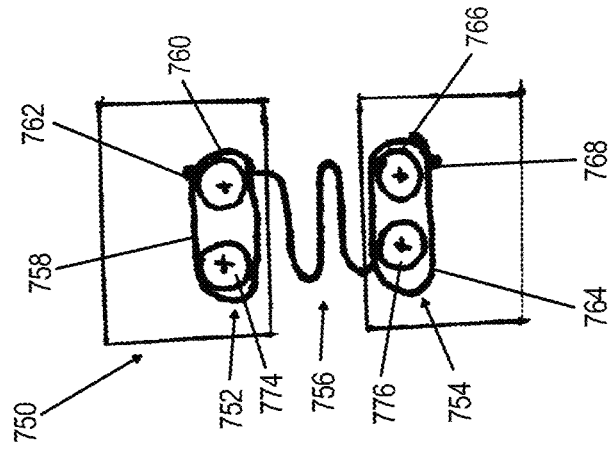
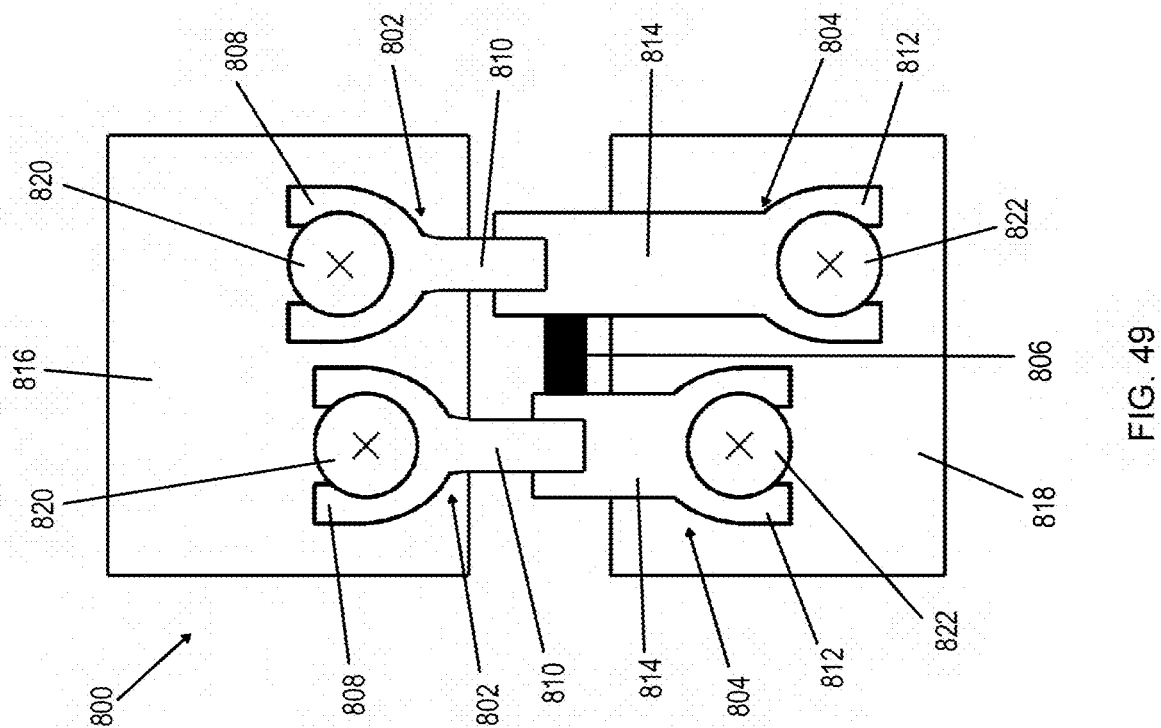
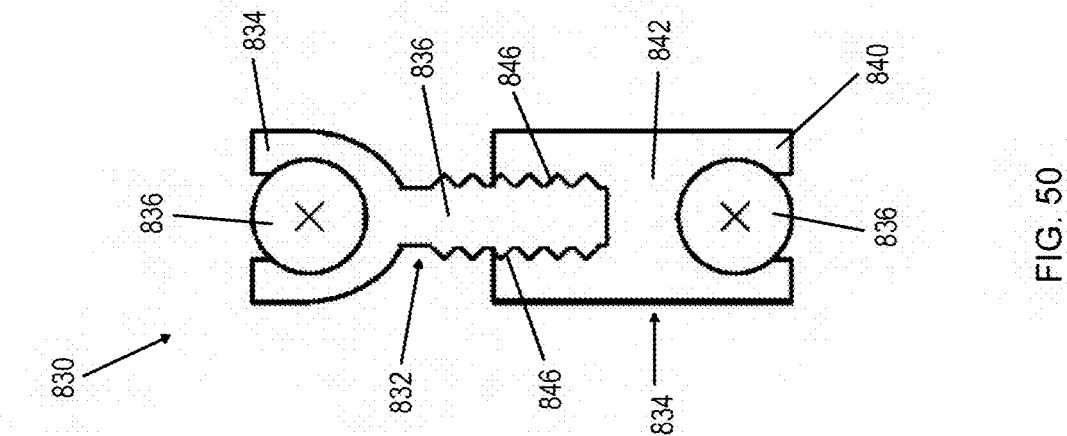


FIG. 48



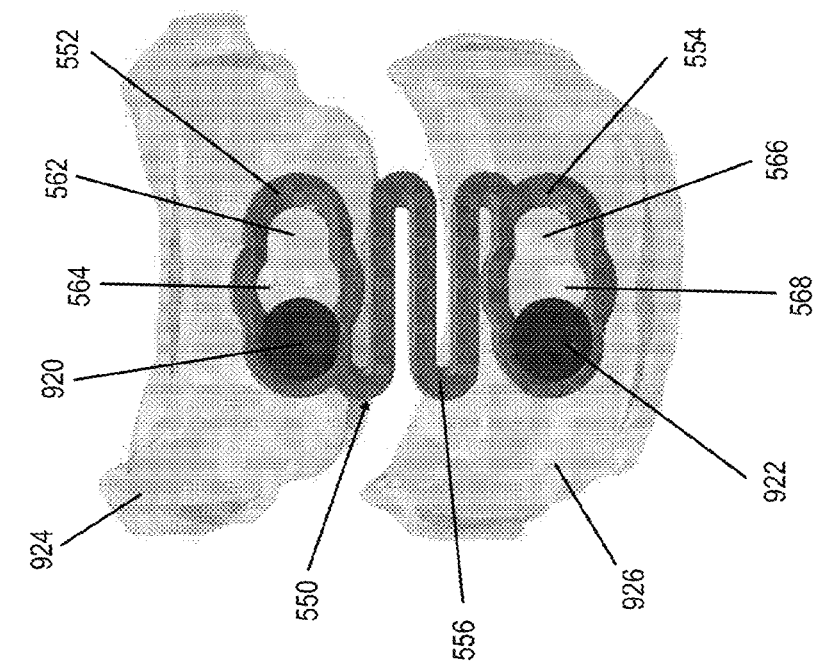


FIG. 52

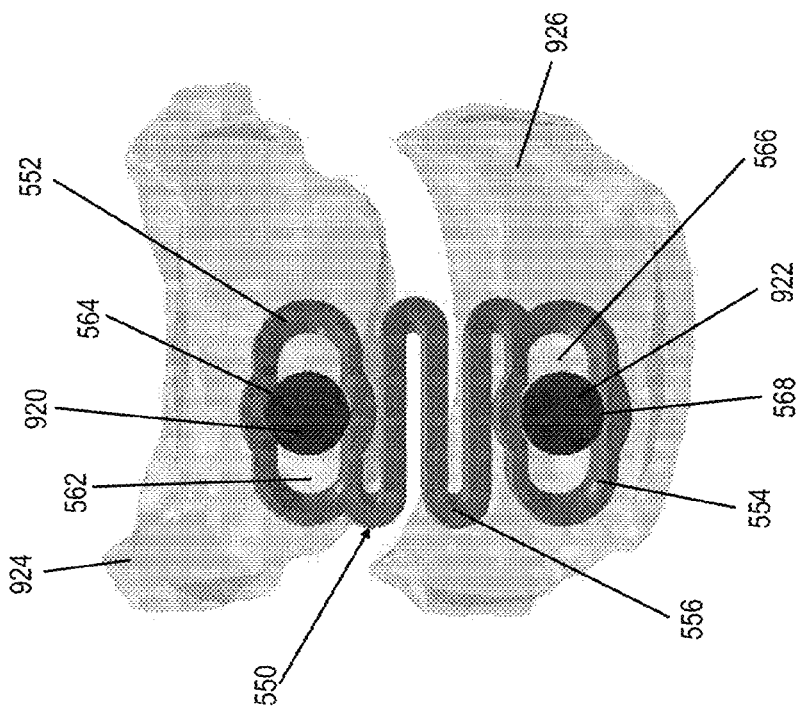


FIG. 51

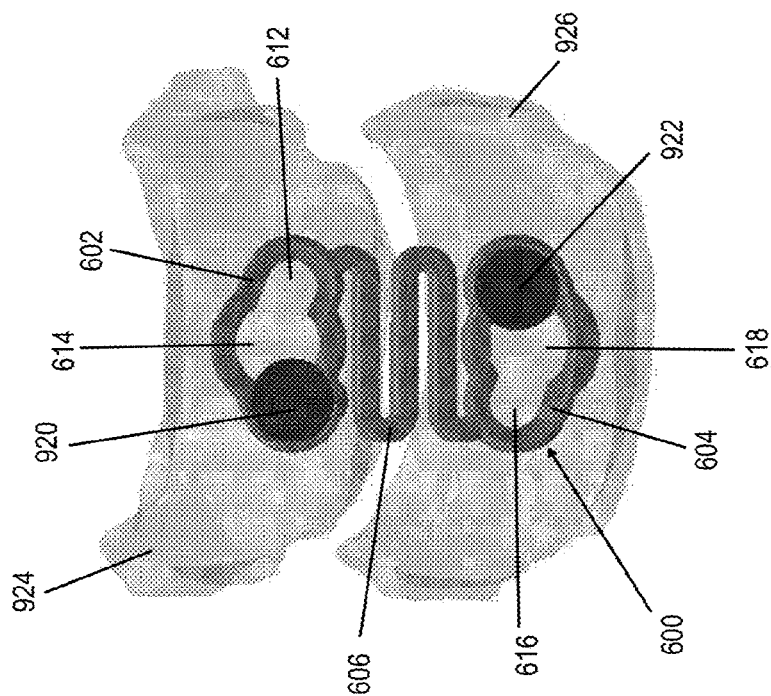


FIG. 54

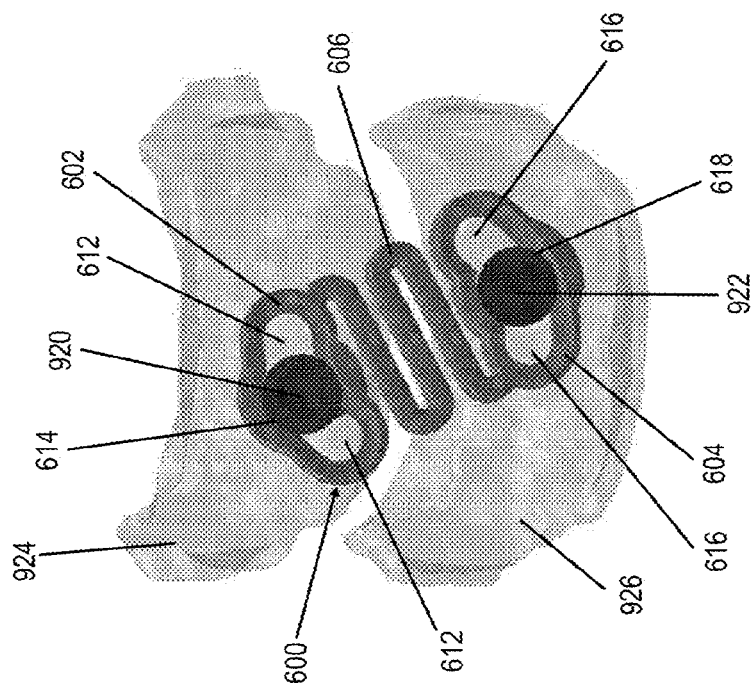


FIG. 53

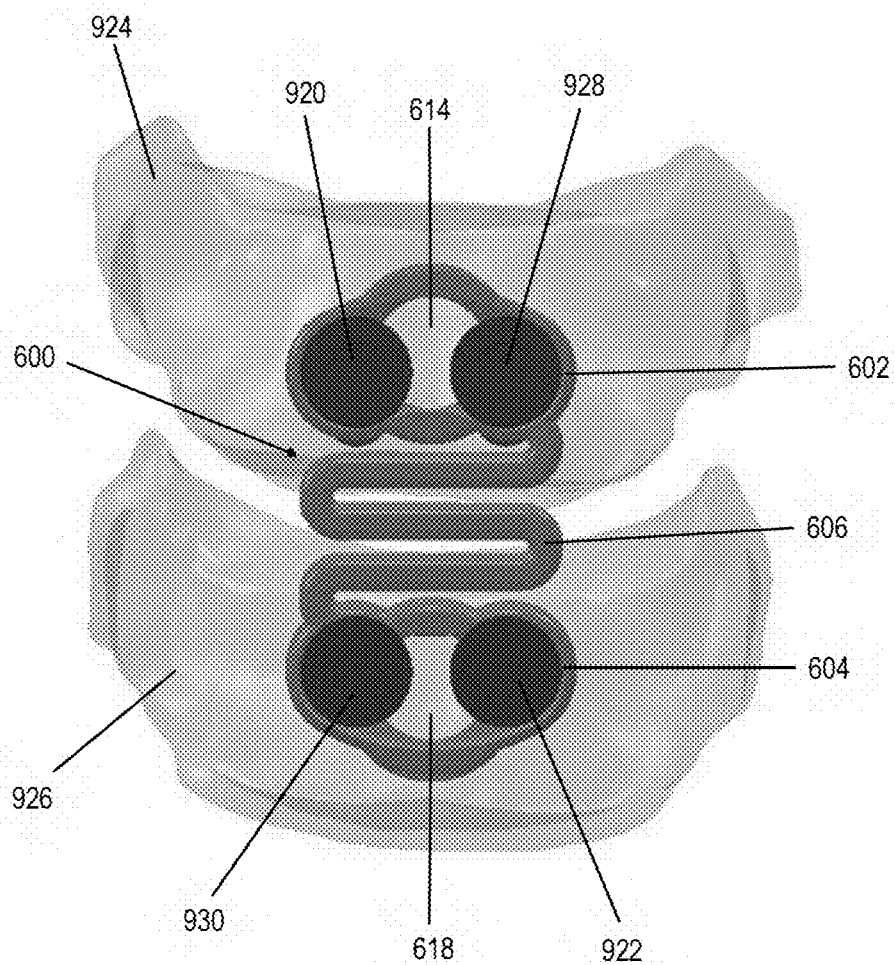


FIG. 55

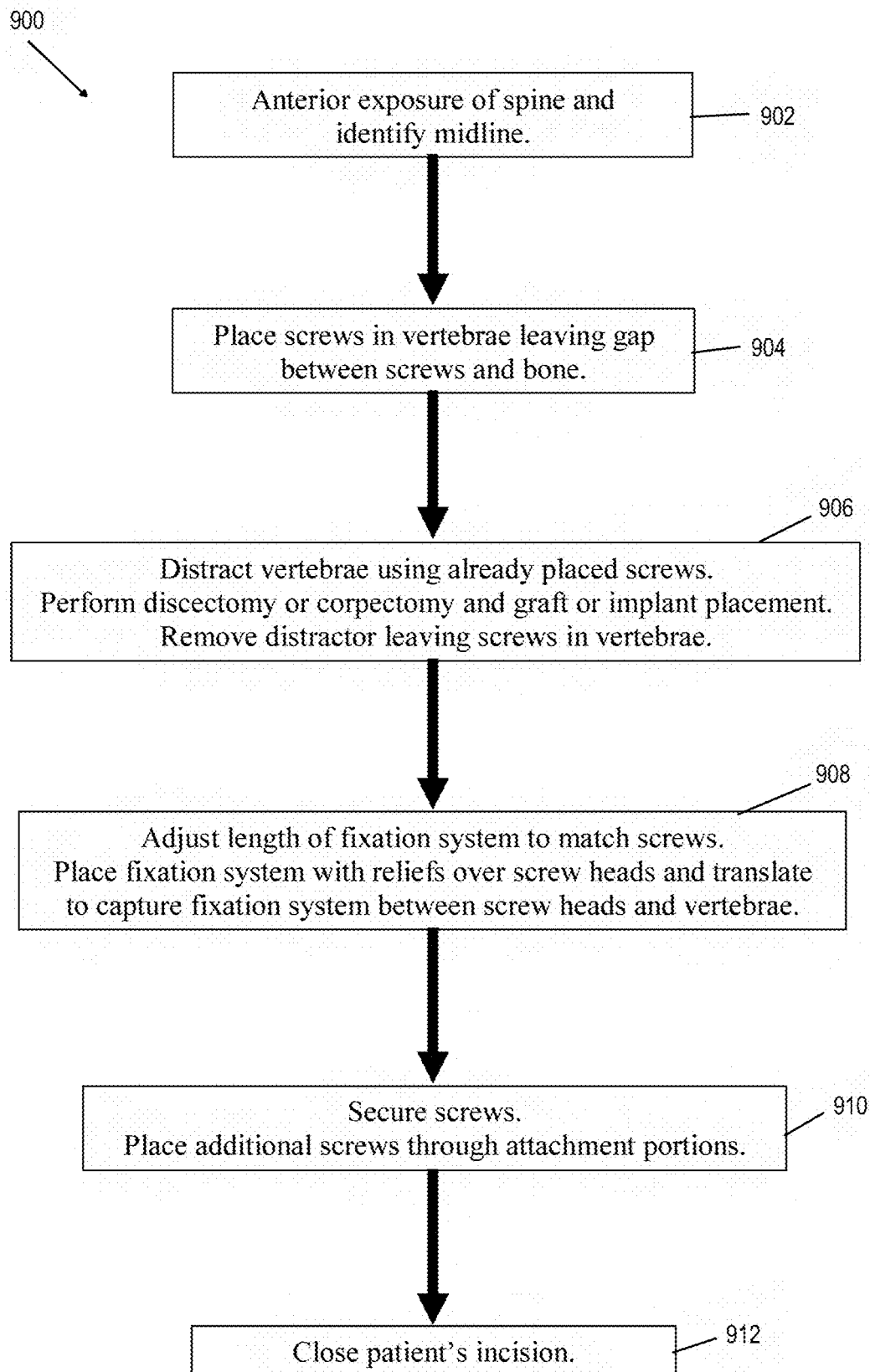


FIG. 56

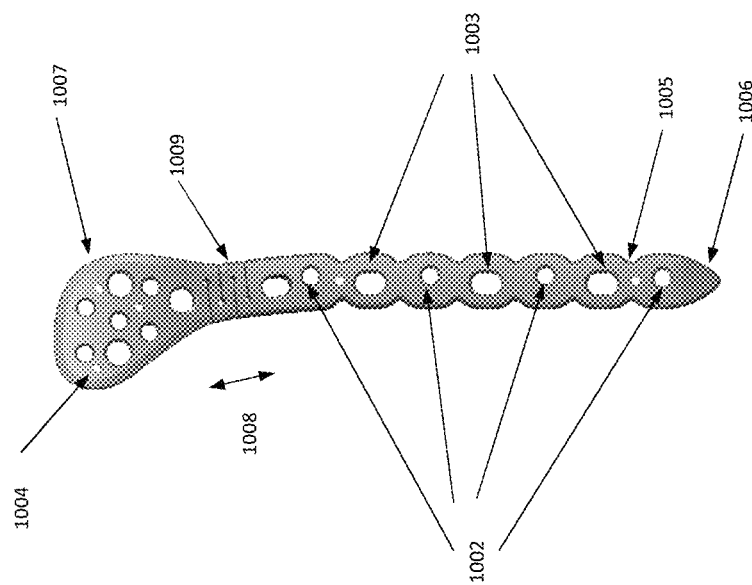


FIG. 57

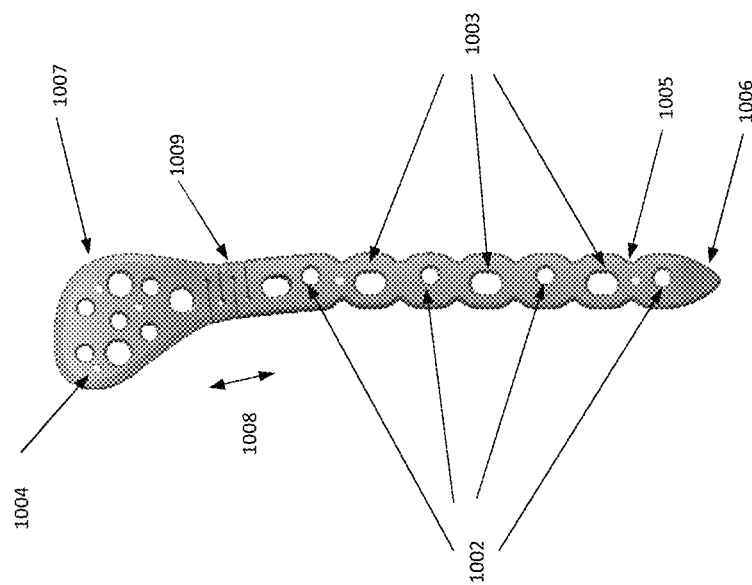


FIG. 58

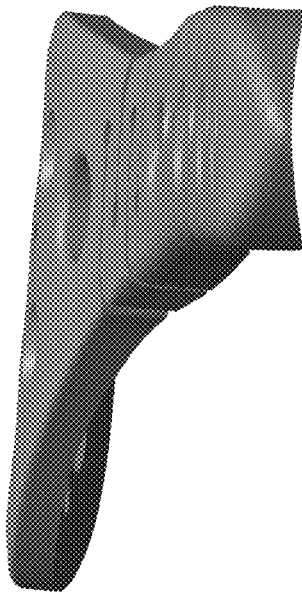


FIG. 60



FIG. 59

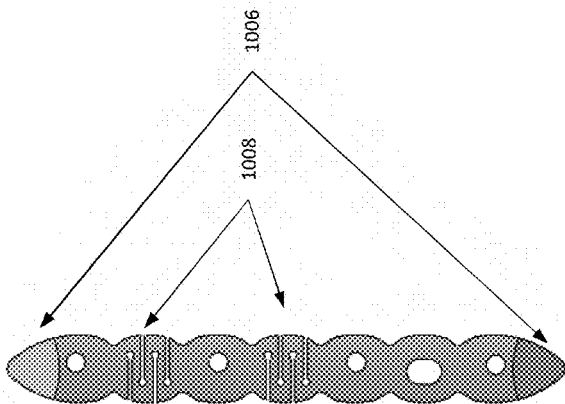


FIG. 61b

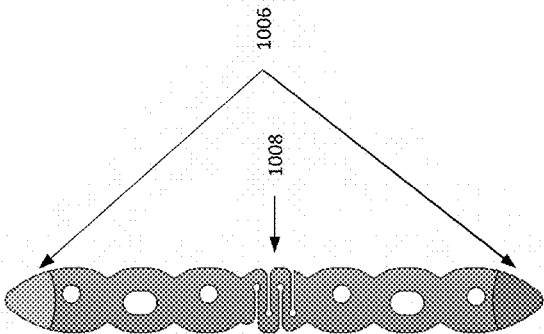


FIG. 61a

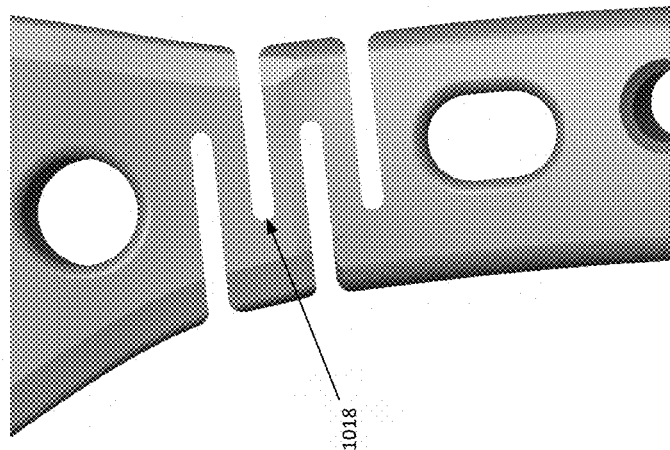


FIG. 63

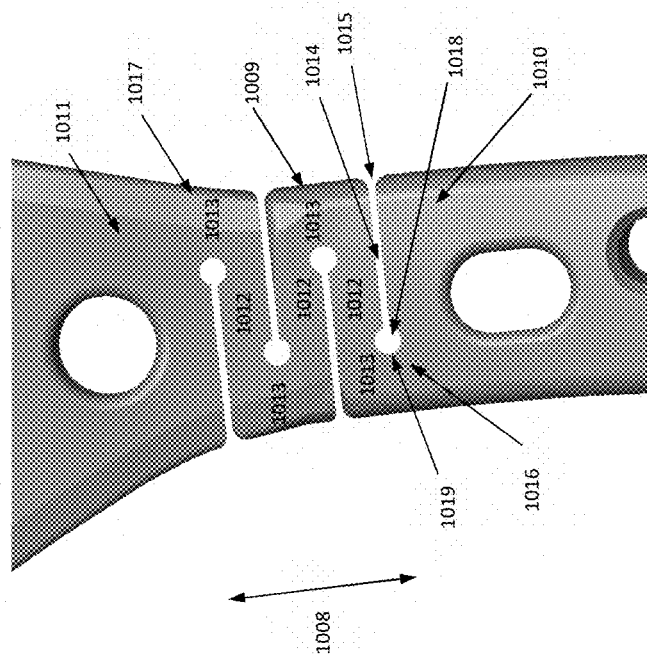


FIG. 62

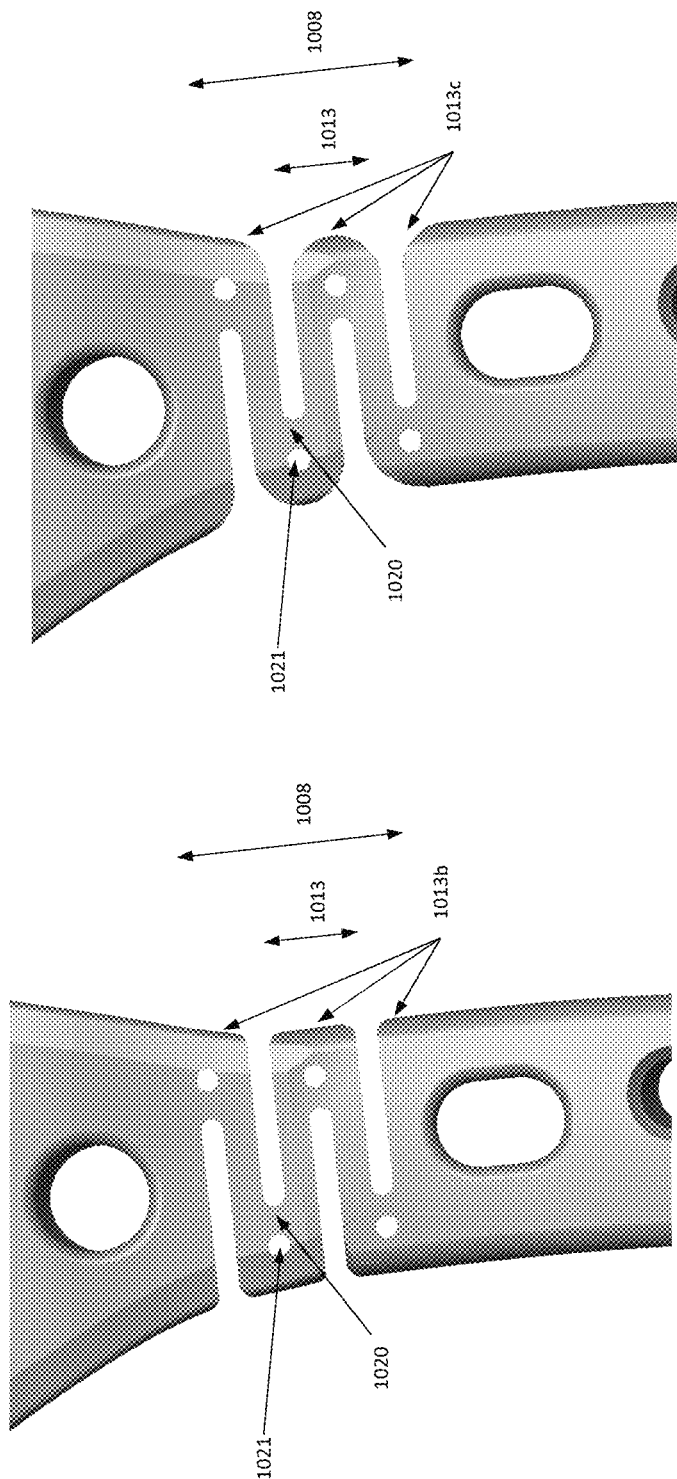


FIG. 64b

FIG. 64a

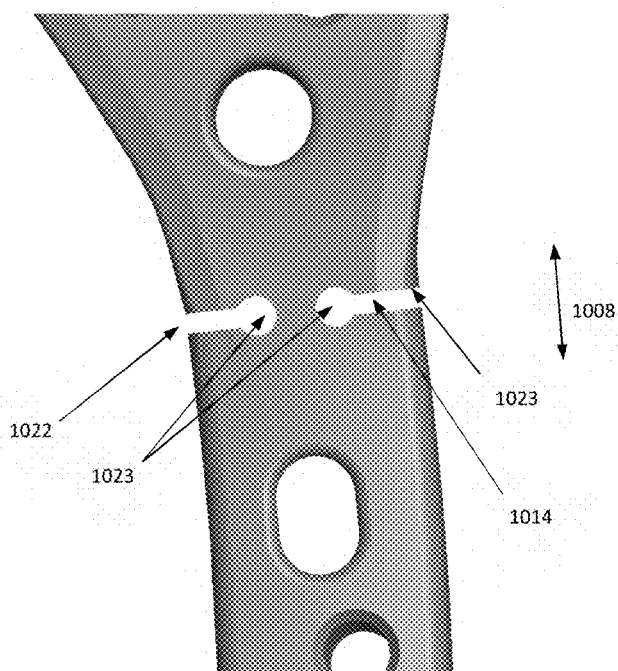


FIG. 65

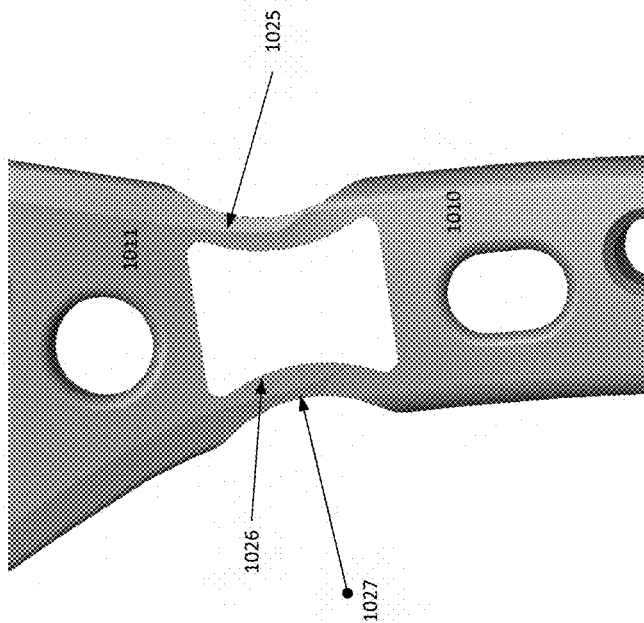


FIG. 67

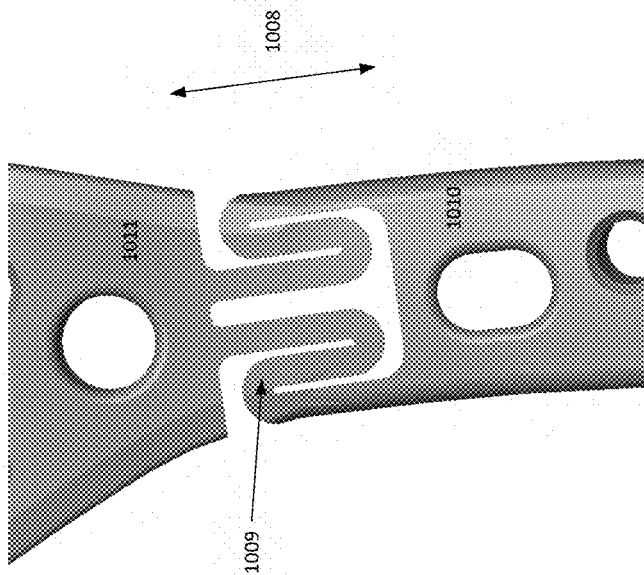


FIG. 66

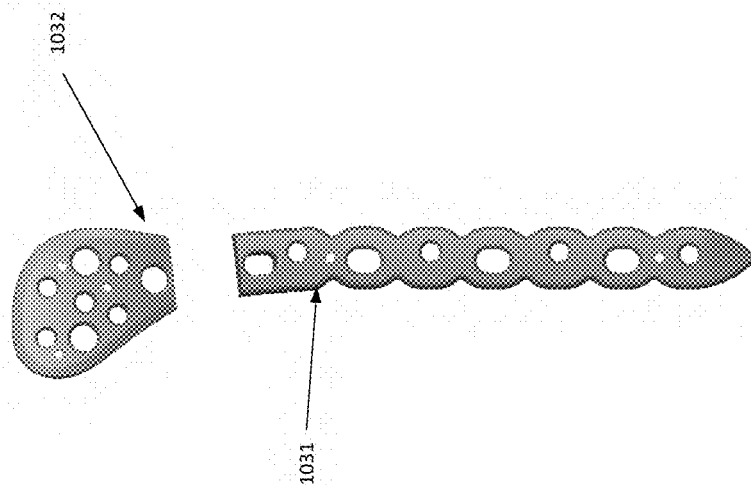


FIG. 69

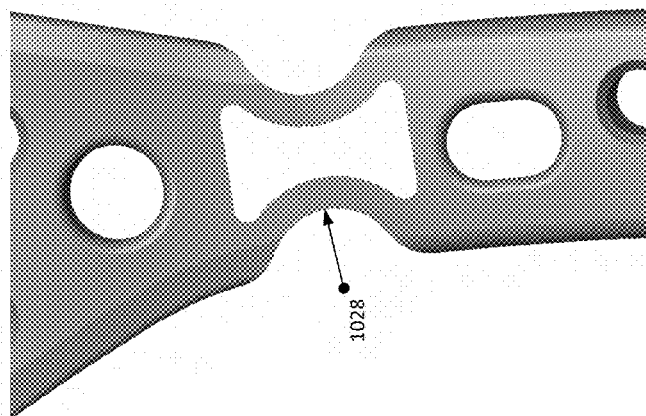


FIG. 68

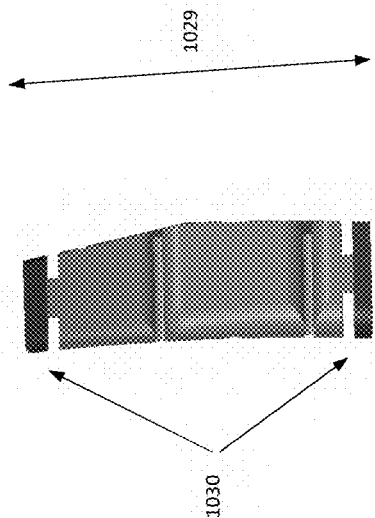


FIG. 70

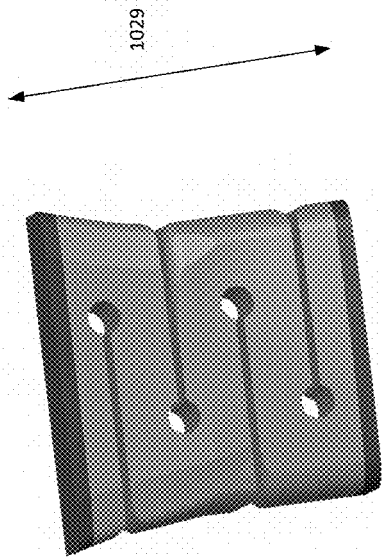


FIG. 71

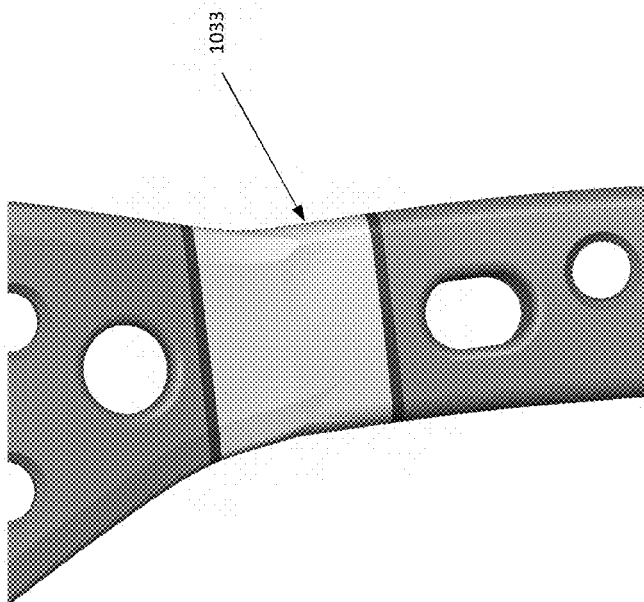


FIG. 73

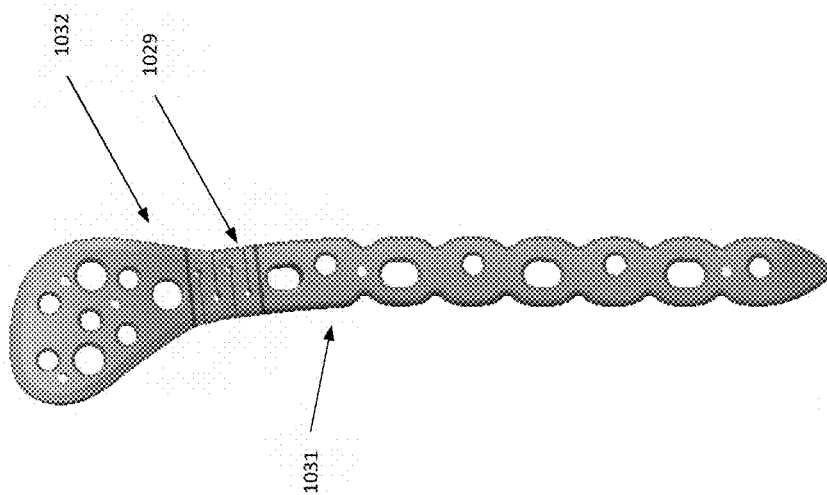


FIG. 72

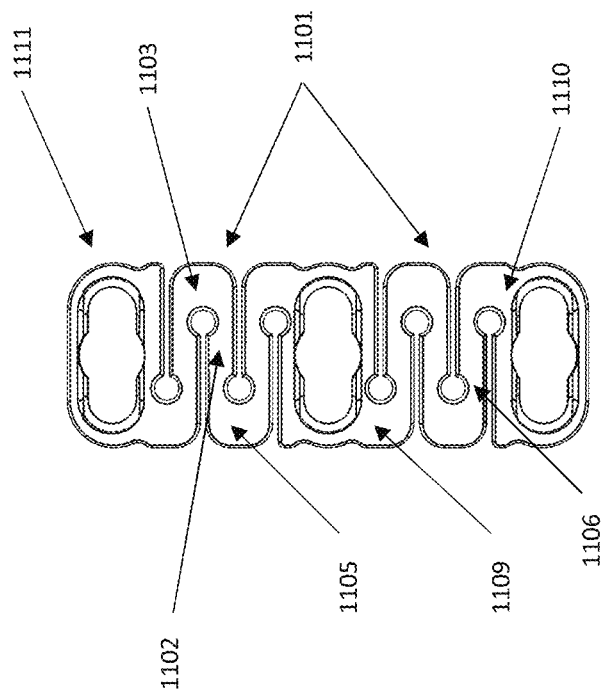


FIG. 75

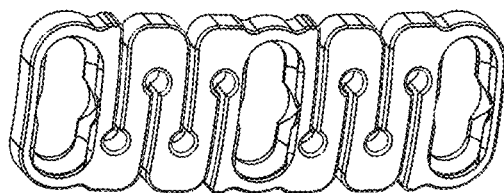


FIG. 74

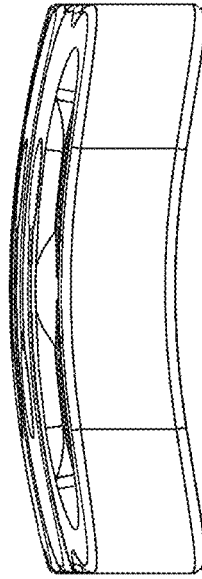


FIG. 77

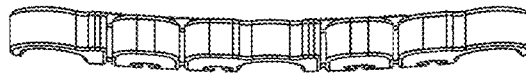


FIG. 76

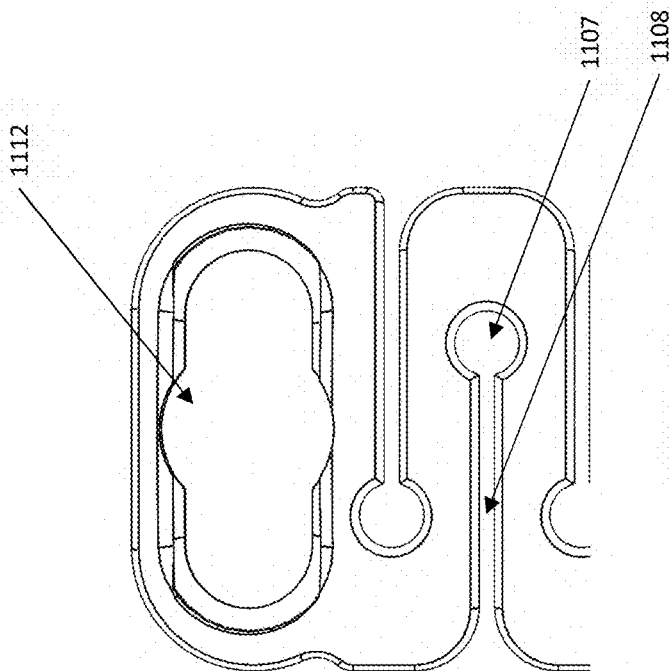


FIG. 79

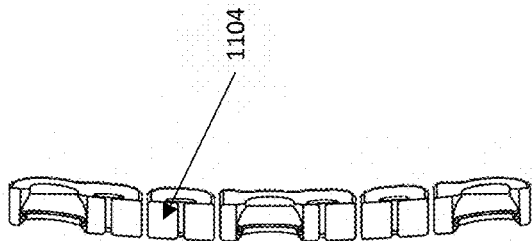


FIG. 78

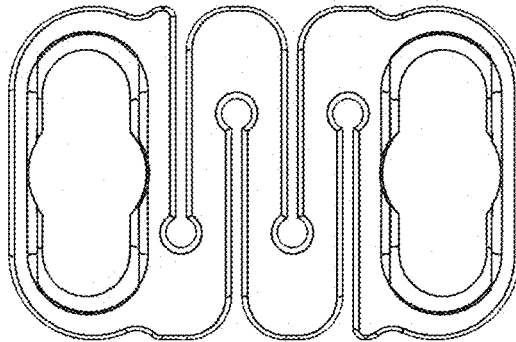


FIG. 81

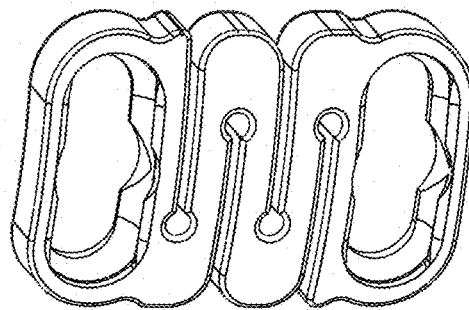


FIG. 80

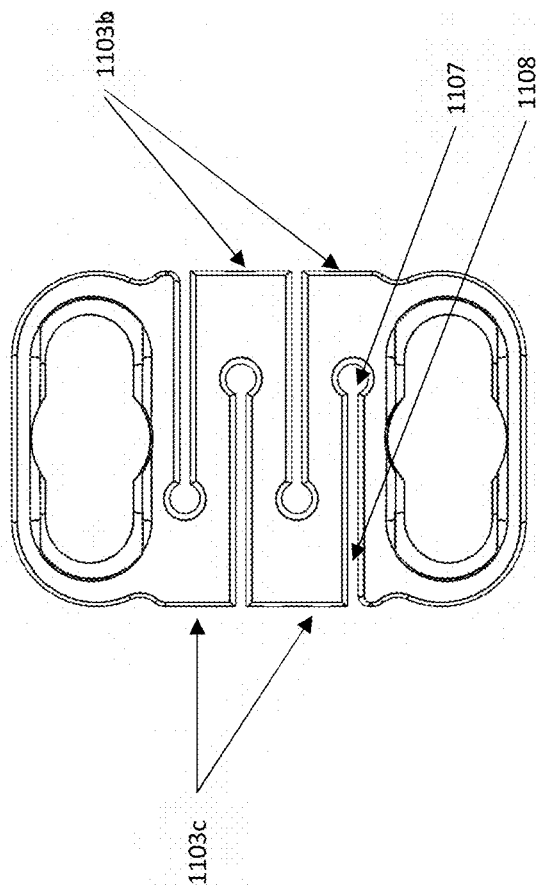


FIG. 82b



FIG. 82a

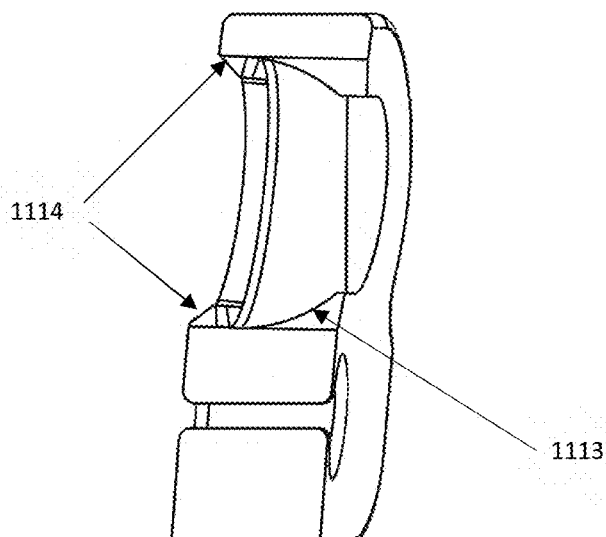


FIG. 83

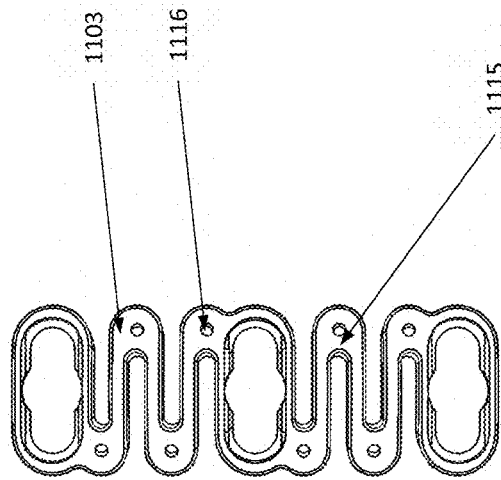


FIG. 85

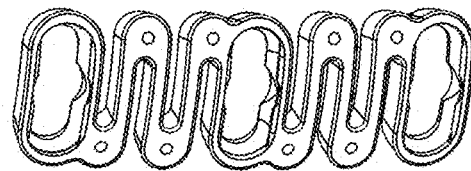


FIG. 84

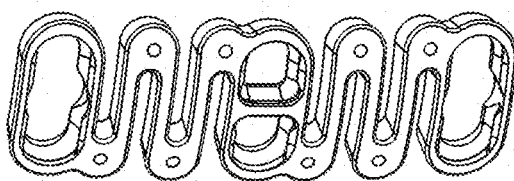


FIG. 87



FIG. 86

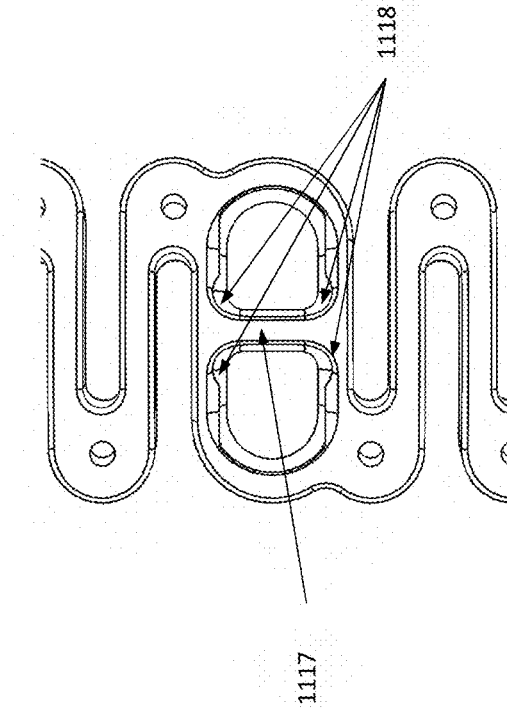


FIG. 89

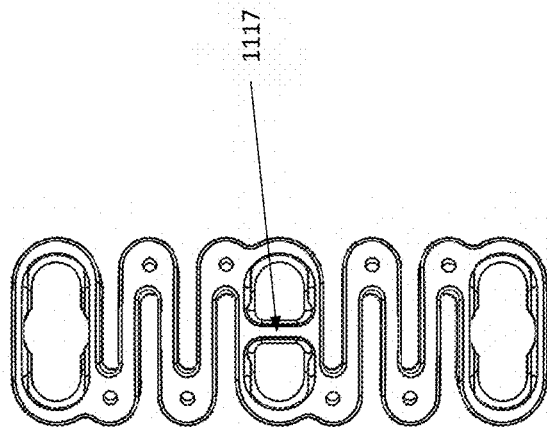


FIG. 88

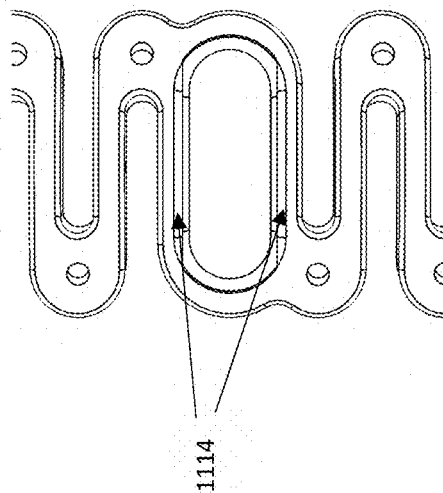


FIG. 91

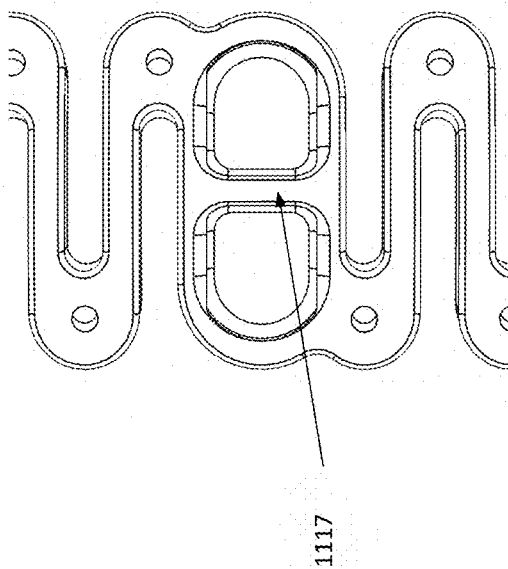


FIG. 90

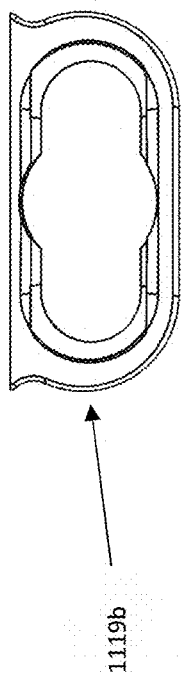
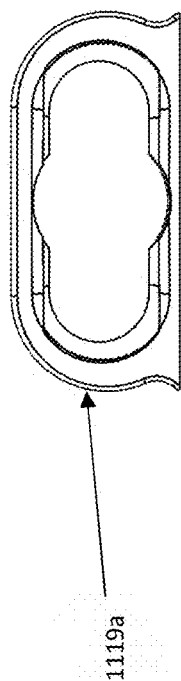


FIG. 92

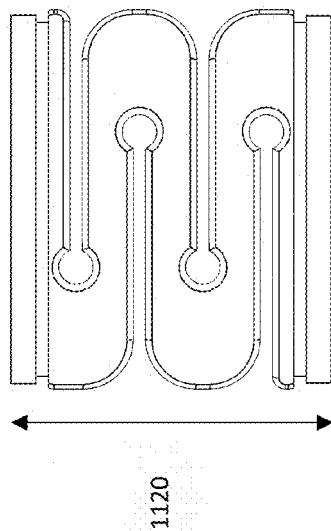


FIG. 93

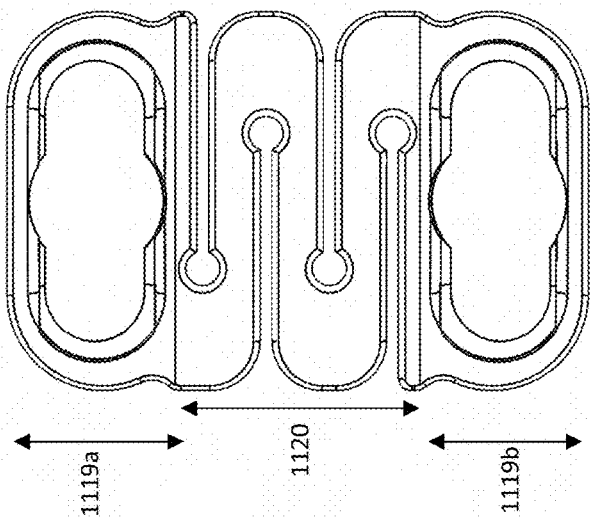


FIG. 95

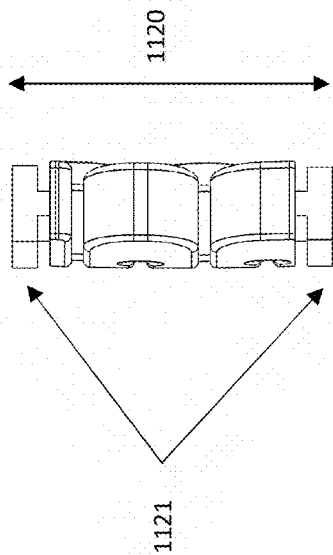


FIG. 94

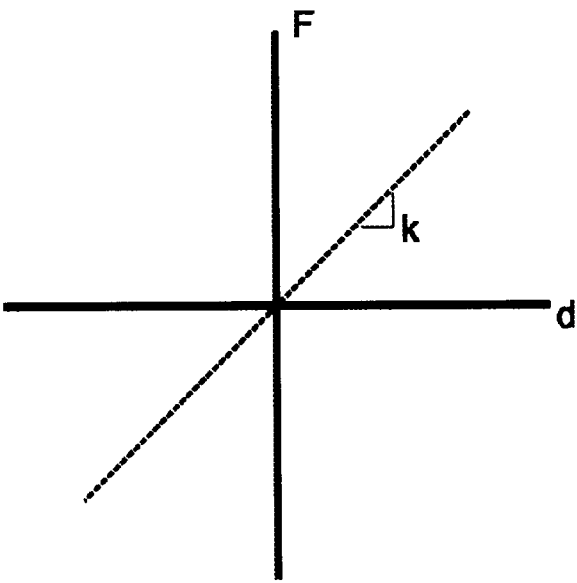


FIG. 96

DYNAMIC FIXATION SYSTEM, METHOD OF USE, AND FIXATION SYSTEM ATTACHMENT PORTIONS

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. application Ser. No. 15/829,027 filed Dec. 1, 2017, which is a continuation of U.S. application Ser. No. 15/594,183 filed May 12, 2017, which is a continuation of U.S. application Ser. No. 15/337,253 filed Oct. 28, 2016, which issued as U.S. Pat. No. 9,788,864 on Oct. 17, 2017, which is a continuation of U.S. application Ser. No. 14/237,733 filed May 16, 2014, which issued as U.S. Pat. No. 9,510,871 on Dec. 6, 2016 and which is a national stage filing under section 371 of International application Ser. No. PCT/US2012/049959 filed on Aug. 8, 2012 and published in English on Feb. 14, 2013 as WO 2013/022944 A1 and claims priority benefit under 35 U.S.C. § 119(e) of U.S. provisional patent application Nos. 61/574,662 and 61/574,636 filed Aug. 8, 2011 and U.S. provisional patent application Nos. 61/628,662 and 61/628,663 filed Nov. 4, 2011, which are incorporated herein by reference in their entireties. This application also claims priority to U.S. provisional patent application No. 62/469,799 filed Mar. 10, 2017 and U.S. provisional patent application No. 62/470,554 filed Mar. 13, 2017, which are incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

The present disclosure relates generally to a spinal fixation device and, in particular, to a dynamic spinal fixation system and method of use for stabilizing one or more levels of the cervical spine or lumbar spine as well as to a spinal fixation system including attachment portions with reliefs. When non-surgical treatments of spinal injuries, diseases, and trauma fail, anterior spinal surgery is often performed to access the cervical or lumbar vertebrae or intervertebral discs. The anterior spinal surgery that is performed may be an anterior cervical discectomy and fusion ("ACDF"). During an ACDF procedure a bone graft or interbody implant is often used to replace the removed disc and a spinal fixation plate is then attached to adjacent vertebrae to stabilize the spine and foster arthrodesis. Current procedures employ placement of the plate first and the screws to fix that plate to vertebrae second. Most commonly, spinal fixation plates are affixed to the vertebrae using bone screws.

The currently available spinal fixation plates or devices limit visualization of the vertebrae during placement. In addition, currently available spinal fixation devices are difficult to place along the midline. The currently available spinal fixation devices also create an inability to align intervening segments for fixation. Finally, the currently available spinal fixations devices make it difficult to pull the vertebrae up into a more lordotic position when significant kyphosis exists.

Accordingly, the present invention contemplates new and improved spinal fixation systems which overcome the above-referenced problems and others.

Bone fractures are a common occurrence. In many cases, conservative treatment, such as closed reduction and casting, will result in successful stabilization of the injured bone or bones for healing. In other cases, such as more unstable fractures or fractures in bones with limited blood supply, the fracture may require surgical treatment. One common sur-

gical treatment is open reduction internal fixation (ORIF). A wide array of implants can be used during ORIF, including but not limited to: plates, screws, pins, staples, wires, hooks, or combinations thereof. In the case of plates, bone screws are placed through holes or slots in the plate and are used to affix adjacent bone segments, thus stabilizing the fracture while healing takes place. Similar techniques are used for fusing two adjacent bones when stabilization across a joint is required.

Optimal loading and optimal stabilization have not been achieved with existing implants. Implants which are too compliant can result in excessive motion which can result in a delayed union or non-union of the fracture. Implants which are too rigid can result in stress-shielding, bony resorption, and delayed or non-union of the fracture which often results in plate or screw failure. The ideal mechanical environment is achieved through load-sharing. In the case of a fracture, loads transmitted through the bone are shared between the fracture and the plate. Without the plate, all of the applied loads are transmitted through the fracture. With an extremely rigid plate, none of the applied loads are transmitted through the fracture. In this way, the stiffness of the plate largely dictates the biomechanics experienced by the fracture. Ideally, the plate affords a balance between overloading (and excess motion) and underloading (and stress-shielding).

Seminal research in fracture fixation biomechanics has demonstrated that rigid fixation (<2% strain) leads to primary bone formation. Osteoclasts traverse the fracture and osteoblasts form new bone across the fracture site in the wake of the cutting cone. Less rigid fixation which results in 2%-10% strain leads to secondary bone formation. In this case, a callus forms to further stabilize the fracture and fibrochondrocytes mineralize by endochondral ossification forming woven bone. Eventually the fracture site is remodeled to form lamellar bone. When the fixation is so compliant that it allows >10% strain, most fractures go on to form a fibrous non-union. Some designs of fracture fixation plates, intramedullary rods, and external fixation systems are based on these guiding biomechanical principles.

Traditional reconstruction (recon) plates are static and minimize interfragmentary motion by lagging the bone fragments to the rigid plate via screw fixation. The goal is to fix the bone fragments in a neutral position so that healing can occur. An alternative for facilitating compression of the fracture site is dynamic compression plating (DCP) systems. DCP systems utilize tapered screw holes or slots, which facilitate compression of the fracture fragments across the fracture site as bone screws are tightened to the bone.

Locking plates have gained popularity in recent years. They are used to stabilize fractures in lower density bone commonly found near the ends of long bones (in the metaphyses) or in patients with reduced bone density due to metabolic disease (osteoporosis). Although these plates provide improved fixation in lower density bone, the screw-plate interface is rigid (locked) and thus there is limited load-sharing across the fracture site. The amount of load-sharing is thus dependent on the stiffness of the plate.

Cervical and lumbar spinal pathology is common in all industrialized nations. For patients who fail conservative therapy, spinal surgery is an option. The gold standard for cervical radiculopathy is anterior cervical decompression and fusion (ACDF). A common treatment for lumbar radiculopathy is anterior lumbar interbody fusion (ALIF). The implants, general steps, and goals for each procedure are similar. Commonly, the cervical spine is exposed from an anterior approach and a single level or multiple levels of the spine are exposed. A discectomy and decompression are

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performed using standard techniques. A bone graft or interbody implant is often placed to fill the vacated disc space and to assist in maintaining disc height. A spinal fixation plate is then used to stabilize the spine and to foster arthrodesis. Spinal fixation plates span a single intervertebral disc and are affixed to two adjacent vertebrae for a single level procedure. When multiple discs are involved in the pathology, a corpectomy is often performed in addition to discectomies at each offending level. In the case of two level fixation with a corpectomy, the spinal fixation plate spans two intervertebral discs and affixes to the adjacent vertebrae. In the case of two level fixation without a corpectomy, the spinal fixation plate spans two intervertebral disc and affixes to both the adjacent and intervening vertebrae. Most commonly, spinal fixation plates are affixed to the vertebrae using bone screws.

One skilled in the art recognizes that midline placement of the plate is critical to the success of the ACDF. However, existing techniques and plates are generally limited in that they do not allow the user (surgeon) to visualize the vertebrae during placement.

One skilled in the art further recognizes that dynamic fixation of the spine with a dynamic fixation plate is advantageous for load sharing and fostering interbody fusion. Interbody motion in flexion/extension is particularly advantageous, while anterior/posterior shear motion is disadvantageous.

During surgery and placement of the fixation plate, it is often necessary to adjust the lordotic curve of the spine to a more anatomic shape. Using standard techniques, the fixation plate is often used to "pull" the vertebrae into shape by lagging the vertebrae to the plate using bone screws.

An elastic element is one that deforms when loaded and returns to its original shape (or near original shape) when unloaded. An elastic element will deform when loaded in tension or compression (or bending or torsion). In one special case, elastic deformation may be linearly proportional to load as shown in FIG. 96. In this special case, force (F) causes a deformation (d) that is linearly proportional to the force by a constant (k) and is governed by $F=kd$. Those skilled in the art will recognize that the relationship between force and deformation does not have to be linear, but could also be non-linear.

SUMMARY OF THE INVENTION

The present invention is directed toward devices and methods for use in stabilizing one or more levels of the cervical spine or lumbar spine.

In one aspect of the present invention provided herein, is a dynamic spinal fixation system. The dynamic spinal fixation system includes a member with a superior end and an inferior end. The member includes a first attachment portion with a first opening at the superior end and a second attachment portion with a second opening at the inferior end. An intermediate portion connects the first attachment portion and the second attachment portion.

In another embodiment of the present invention provided herein, is a dynamic spinal fixation system. The dynamic spinal fixation system includes a member with a top end and a bottom end. The member includes a first attachment portion with a first opening at the top end and a second attachment portion with a second opening at the bottom end. An intermediate portion connects the first attachment portion and the second attachment portion. At least one of the first and second openings includes a relief.

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In a further aspect of the present invention provided herein, is a surgical method for fusing a spine. The method includes obtaining a dynamic spinal fixation system. The dynamic spinal fixation system includes a member with a superior end and an inferior end. The member includes a first attachment portion at the inferior end which includes a first opening with a first relief and a second attachment portion which includes a second opening with a second relief. An intermediate portion connects the first attachment portion and the second attachment portion. A first bone fastener is inserted into a first vertebra of a patient and a second bone fastener is inserted into a second vertebra of the patient. The first vertebra is superior the second vertebra. The first relief is then aligned with the first fastener and the second relief is aligned with the second fastener. The member is moved into alignment with the first vertebra and the second vertebra for fixation by sliding the member to engage the first fastener in the first opening and second fastener in the second opening. The first fastener is tightened to the first vertebra and the second fastener is tightened to the second vertebra to secure the dynamic spinal fixation system to at least the first vertebra and the second vertebra of a patient's spine. The method is advantageous because it provides a surgeon with the ability to place the bone fasteners into the spine prior to placement of the dynamic spinal fixation system which assists in placing the system in the midline of the spine while also allowing for ideal fastener placement with respect to the vertebrae.

A method and apparatus for stabilizing adjacent bone segments using an elastically deformable implant are described. One embodiment includes at least one elastically deformable component whose shape facilitates screw fixation to bony fragments and controlled deformation in axial compression, while maintaining a high level of rigidity when subjected to bending, torsion, and transverse shear. The implant includes more rigid regions for affixing the implant to the bone and less rigid elastic regions for fostering controlled elastic deformation. The implant further includes elastic compliance for pre-compression or pre-distraction of the fracture site.

A method and apparatus for stabilizing one or more levels of the cervical spine or lumbar spine using a dynamic implant are described. One embodiment includes at least one elastic component whose shape facilitates screw fixation to bony vertebral bodies and controlled deformation in axial compression, lateral bending, and flexion/extension while maintaining a high level of rigidity in the anterior/posterior direction. The implant includes more rigid platform sections for affixing the implant to the vertebrae and less rigid elastic sections between the platforms for fostering controlled elastic deformation. The implant further includes elastic compliance for pre-compression or pre-distraction of one or more motion segments of the spine. The implant includes substantially open geometry for enhanced visualization of the surgical site and also includes an anti-backout mechanism for preventing the fixation screws from separating from the implant.

These and other objects, features and advantages of this invention will become apparent from the following detailed description of the various aspects of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and together with the detailed

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description herein, serve to explain the principles of the invention. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIG. 1 shows a front view of one embodiment of a two level dynamic spinal fixation system, in accordance with an aspect of the present invention;

FIG. 2 shows a front view of one embodiment of a one level dynamic spinal fixation system including reliefs, in accordance with an aspect of the present invention;

FIG. 3 shows a top view of the dynamic spinal fixation system of FIG. 2, in accordance with an aspect of the present invention;

FIG. 4 is a cross-sectional perspective view of the dynamic spinal fixation system shown in FIG. 2 as viewed along section line 4-4 in FIG. 2, in accordance with an aspect of the present invention;

FIG. 5 is a side perspective view of the dynamic spinal fixation system shown in FIG. 4, in accordance with an aspect of the present invention;

FIG. 6 is another embodiment of a one level dynamic spinal fixation system from a front view, in accordance with an aspect of the present invention;

FIG. 7 shows a front view of yet another embodiment of a one level dynamic spinal fixation system, in accordance with an aspect of the present invention;

FIG. 8 is a perspective view of the dynamic spinal fixation system embodiment of FIG. 7, in accordance with an aspect of the present invention;

FIG. 9 is an additional embodiment of a one level dynamic spinal fixation system from a front view, in accordance with an aspect of the present invention;

FIG. 10 shows a further embodiment of a one level dynamic spinal fixation system from a front view, in accordance with an aspect of the present invention;

FIG. 11 shows a front view of yet another embodiment of a one level dynamic spinal fixation system, in accordance with an aspect of the present invention;

FIG. 12 is another embodiment of a one level dynamic spinal fixation system shown from a front view, in accordance with an aspect of the present invention;

FIG. 13 is a perspective view of the dynamic spinal fixation system embodiment of FIG. 12, in accordance with an aspect of the present invention;

FIG. 14 shows another embodiment of a one level dynamic spinal fixation system with a hard stop from a front view, in accordance with an aspect of the present invention;

FIG. 15 is a front view of a further embodiment of a one level dynamic spinal fixation system with an alternative hard stop, in accordance with an aspect of the present invention;

FIG. 16 is a front view of yet another embodiment of a one level dynamic spinal fixation system with a further alternative hard stop, in accordance with an aspect of the present invention;

FIG. 17 shows a front view of an additional embodiment of a one level dynamic spinal fixation system, in accordance with an aspect of the present invention;

FIG. 18 shows another embodiment of a one level dynamic spinal fixation system from a front view, in accordance with an aspect of the present invention;

FIG. 19 shows a front view of still another embodiment of a one level dynamic spinal fixation system, in accordance with an aspect of the present invention;

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FIG. 20 shows a further embodiment of a one level dynamic spinal fixation system from a front view, in accordance with an aspect of the present invention;

FIG. 21 is a front view of a two level embodiment of the dynamic spinal fixation system of FIG. 8, in accordance with an aspect of the present invention;

FIG. 22 is a front view of a two level embodiment of the dynamic spinal fixation system of FIG. 9, in accordance with an aspect of the present invention;

FIG. 23 is a front view of a two level embodiment of the dynamic spinal fixation system of FIG. 10, in accordance with an aspect of the present invention;

FIG. 24 is a front view of a two level dynamic spinal fixation system embodiment that combines the dynamic fixation systems of FIG. 8 and FIG. 9, in accordance with an aspect of the present invention;

FIG. 25 is a front view of the one level dynamic spinal fixation system embodiment of FIG. 8 integrated with an interbody cage, in accordance with an aspect of the present invention;

FIG. 26 is a front view of another embodiment of a two level dynamic spinal fixation system, in accordance with an aspect of the present invention;

FIG. 27 is another embodiment of a two level dynamic spinal fixation system with at least one coil spring-like member shown from a front view, in accordance with an aspect of the present invention;

FIG. 28 is a front view of yet another embodiment of a two level dynamic spinal fixation system with at least two parallel coil spring-like members, in accordance with an aspect of the present invention;

FIG. 29 is a further embodiment of a two level dynamic spinal fixation system with at least two parallel torsional spring members shown from a front view, in accordance with an aspect of the present invention;

FIG. 30 is a front view of another embodiment of a two level dynamic spinal fixation system with at least two elastic members, in accordance with an aspect of the present invention;

FIG. 31 is a further embodiment of a two level dynamic spinal fixation system with piston members shown from a front view, in accordance with an aspect of the present invention;

FIG. 32 is a front view of a static spinal fixation system embodiment with attachment portions including openings with reliefs, in accordance with an aspect of the present invention;

FIG. 33 is a front view of another embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs; in accordance with an aspect of the present invention;

FIG. 34 is a front view of a further embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs, in accordance with an aspect of the present invention;

FIG. 35 is a perspective view of the dynamic spinal fixation system embodiment of FIG. 34, in accordance with an aspect of the present invention;

FIG. 36 is a front view of yet another embodiment of a dynamic spinal fixation system with curved attachment portions including openings with reliefs, in accordance with an aspect of the present invention;

FIG. 37 is a perspective view of the dynamic spinal fixation system embodiment of FIG. 36, in accordance with an aspect of the present invention;

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FIG. 38 is a front view of another dynamic spinal fixation system embodiment with attachment portions including openings with off center reliefs, in accordance with an aspect of the present invention;

FIG. 39 is a front view of a further embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs, in accordance with an aspect of the present invention;

FIG. 40 is yet another embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs shown from a front view, in accordance with an aspect of the present invention;

FIG. 41 is a front view of an additional embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs, in accordance with an aspect of the present invention;

FIG. 42 is another embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs from a front view, in accordance with an aspect of the present invention;

FIG. 43 is a front view of still a further embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs, in accordance with an aspect of the present invention;

FIG. 44 is a front view of the embodiment dynamic spinal fixation system of FIG. 41 wherein the openings are curved, in accordance with an aspect of the present invention;

FIG. 45 is a perspective view of the dynamic spinal fixation system embodiment of FIG. 44, in accordance with an aspect of the present invention;

FIG. 46 is an exploded view of another embodiment of a dynamic spinal fixation system with attachment portions including openings with reliefs and two vertebrae with four fasteners secured to the vertebrae, in accordance with an aspect of the present invention;

FIG. 47 is a front view of the embodiment of FIG. 46 wherein the dynamic spinal fixation system with attachment portions including openings with reliefs is inserted over the fasteners and the arms are in an open position, in accordance with an aspect of the present invention;

FIG. 48 is a front view of the dynamic spinal fixation system of FIGS. 46 and 47 secured to the two vertebrae with closed arms, in accordance with an aspect of the present invention;

FIG. 49 is a front view of another embodiment dynamic spinal fixation system with curved attachment portions secured to two vertebrae, in accordance with an aspect of the present invention;

FIG. 50 is a front view of yet another embodiment of a dynamic spinal fixation system with curved attachment portions secured to two vertebrae, in accordance with an aspect of the present invention;

FIG. 51 is a front view of the dynamic spinal fixation system of FIGS. 34 and 35 with the reliefs of the fixation system mating with two aligned fasteners secured to two vertebrae, in accordance with an aspect of the present invention;

FIG. 52 is a front view of the dynamic spinal fixation system of FIG. 51 after sliding the fixation system along the openings to secure the fasteners, in accordance with an aspect of the present invention;

FIG. 53 is a front view of the dynamic spinal fixation system of FIGS. 36 and 37 with the reliefs of the fixation system mating with two offset fasteners secured to two vertebrae, in accordance with an aspect of the present invention;

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FIG. 54 is a front view of the dynamic spinal fixation system of FIG. 53 after rotation of the fixation system, in accordance with an aspect of the present invention;

FIG. 55 is a front view of the dynamic spinal fixation system embodiment of FIGS. 53 and 54 secured to two vertebrae with four fasteners, in accordance with an aspect of the present invention;

FIG. 56 depicts one embodiment of a surgical method for implanting a dynamic spinal fixation system into a patient's body, in accordance with an aspect of the present invention;

FIG. 57 shows a perspective view of one embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 58 shows a front view of the dynamic fracture fixation system embodiment of FIG. 57, in accordance with an aspect of the invention;

FIG. 59 shows a side view of the dynamic fracture fixation system embodiment of FIG. 57, in accordance with an aspect of the invention;

FIG. 60 shows a bottom view of the dynamic fracture fixation system embodiment of FIG. 57, in accordance with an aspect of the invention;

FIG. 61a shows a front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 61b shows a front view of another embodiment of the dynamic fracture fixation system that includes more than one elastic region, in accordance with an aspect of the invention;

FIG. 62 shows a detailed front view of the dynamic fracture fixation system embodiment of FIG. 57, in accordance with an aspect of the invention;

FIG. 63 shows a detailed front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 64a shows a detailed front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 64b shows a detailed view of yet another embodiment of the dynamic fracture fixation system that contains curved lateral edges, in accordance with an aspect of the invention;

FIG. 65 shows a detailed front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 66 shows a detailed front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 67 shows a detailed front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 68 shows a detailed view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 69 shows a front view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 70 shows a front view of another embodiment used in conjunction with the embodiment in FIG. 69, in accordance with an aspect of the invention;

FIG. 71 shows a side view of the embodiment shown in FIG. 70 used in conjunction with the embodiment in FIG. 69, in accordance with an aspect of the invention;

FIG. 72 shows a front view of the embodiment of the dynamic fracture fixation system including the assembled components in FIGS. 69-71, in accordance with an aspect of the invention;

FIG. 73 shows a detailed view of another embodiment of the dynamic fracture fixation system, in accordance with an aspect of the invention;

FIG. 74 a perspective view of one embodiment of the spinal fixation system, in accordance with an aspect of the invention;

FIG. 75 shows a front view of the embodiment shown in FIG. 74, in accordance with an aspect of the invention;

FIG. 76 shows a side view of the embodiment shown in FIG. 74, in accordance with an aspect of the invention;

FIG. 77 shows a top view of the embodiment shown in FIG. 74, in accordance with an aspect of the invention;

FIG. 78 shows a detailed section view of the embodiment shown in FIG. 74, in accordance with an aspect of the invention;

FIG. 79 shows a detailed front view of the embodiment shown in FIG. 74, in accordance with an aspect of the invention;

FIG. 80 shows a perspective view of another embodiment of the spinal fixation system, in accordance with an aspect of the invention;

FIG. 81 shows a front view of the embodiment shown in FIG. 80, in accordance with an aspect of the invention;

FIG. 82a shows a side view of the embodiment shown in FIG. 80, in accordance with an aspect of the invention;

FIG. 82b shows a front view of yet another embodiment, depicting substantially planar lateral sides, in accordance with an aspect of the invention;

FIG. 83 shows a detailed side view of the embodiment shown in FIG. 80, in accordance with an aspect of the invention;

FIG. 84 shows a perspective view of another embodiment shown of the spinal fixation system, in accordance with an aspect of the invention;

FIG. 85 shows a front view of the embodiment shown in FIG. 84, in accordance with an aspect of the invention;

FIG. 86 shows a side view of the embodiment shown in FIG. 84, in accordance with an aspect of the invention;

FIG. 87 shows a perspective view of another embodiment of the spinal fixation system, including a vertical support in one of the slots, in accordance with an aspect of the invention;

FIG. 88 shows a front view of the embodiment shown in FIG. 87, in accordance with an aspect of the invention;

FIG. 89 shows a detailed front view of the embodiment shown in FIG. 87, in accordance with an aspect of the invention;

FIG. 90 shows a detailed front view of another embodiment of the spinal fixation system, in accordance with an aspect of the invention;

FIG. 91 shows a detailed front view of yet another embodiment of the spinal fixation system, in accordance with an aspect of the invention;

FIG. 92 shows a front view of another embodiment of the spinal fixation system, includes modular slots, in accordance with an aspect of the invention;

FIG. 93 shows a front view of another embodiment of the spinal fixation system, includes a modular elastic member and used in conjunction with the embodiment shown in FIG. 92, in accordance with an aspect of the invention;

FIG. 94 shows a side view of the embodiment of the spinal fixation system shown in FIG. 93, includes a modular elastic member and used in conjunction with the embodiment shown in FIG. 92, in accordance with an aspect of the invention; and

FIG. 95 shows a front view of the embodiment of the spinal fixation system shown in FIGS. 92-94, comprised of

assembled slots and a modular elastic member, in accordance with an aspect of the invention.

FIG. 96 illustrates elastic deformation being linearly proportional to load.

DETAILED DESCRIPTION FOR CARRYING OUT THE INVENTION

In this application, the words proximal, distal, anterior, posterior, medial and lateral are defined by their standard usage for indicating a particular part or portion of a bone or prosthesis coupled thereto, or directional terms of reference, according to the relative disposition of the natural bone. For example, "proximal" means the portion of a bone or prosthesis nearest the torso, while "distal" indicates the portion of the bone or prosthesis farthest from the torso. As an example of directional usage of the terms, "anterior" refers to a direction towards the front side of the body, "posterior" refers to a direction towards the back side of the body, "medial" refers to a direction towards the midline of the body and "lateral" refers to a direction towards the sides or away from the midline of the body.

Referring to the drawings, wherein like reference numerals are used to indicate like or analogous components throughout the several views and referring now to FIG. 1 which depicts a dynamic spinal fixation plate or system 10. The dynamic spinal fixation system 10 includes a single member 12. The single member 12 is aligned with a first vertebra 14 at a superior end, a second vertebra 16 at a mid-point, and a third vertebra 18 at an inferior end. The system 10 may be secured to the vertebrae 14, 16, 18 using bone fasteners, not shown.

The single member 12 may be comprised of a single elastic component with a plurality of straight and curved portions. The single member 12 may be a wire, rod, tube, or other curvilinear spring-like element and may be made of a metallic, polymer, ceramic, or composite material. The single member 12 or elastic component may include a plurality of straight portions 20 and a plurality of curved portions 22 to facilitate fixation of a bone fastener, such as a screw, nail, staple, wire, pin, and the like, to the vertebrae 14, 16, 18. The plurality of straight portions 20 may preferably range from one to fifteen per level and the plurality of curved portions 22 may preferably range from one to sixteen per level. More preferably the plurality of straight portions 20 may range from one to six per level and the plurality of curved portions 22 may range from one to seven per level. In the depicted embodiment, the single member 12 includes thirteen straight portions 20 and twelve curved portions 22. The bone fasteners may be placed through the single member 12 to engage the vertebrae, specifically the bone fasteners may be placed through any two horizontal sections of the single member 12. In alternative embodiments, the single member 12 may include attachment portions at the positions where the single member 12 is secured to the vertebrae and the attachment portions may have closed geometries of the types described in greater detail below.

In addition, the shape of the single member 12 may also facilitate controlled deformation in axial compression and in flexion/extension while maintaining a high level of rigidity in lateral bending and in the anterior/posterior direction. The single member 12 of the dynamic spinal fixation system 10 may be comprised of at least one spring-like elastically deformable element. The spring-like element may be curvilinear in shape and allow for elastic deformation when loaded. The deformation of the spring-like element is pri-

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marily in the axial direction allowing for controlled or limited flexion and extension. Further, the single member 12 may be shaped to match the curvature of the spine in the sagittal and transverse planes. Alternative shapes that are advantageous to promote stability or arthrodesis of the spine are also contemplated.

The single member 12 may have a cross-section that is circular, elliptical, square, rectangular, or another uniform or non-uniform geometric shape. In addition, the single member 12 may have a uniform geometry along the sagittal and/or transverse planes. Alternatively, the single member 12 may have a non-uniform geometry along the sagittal and/or transverse planes, whereby the single member 12 changes in thickness becoming either thicker or thinner along the sagittal and/or transverse planes. For example, the single member 12 may be thicker near the lateral aspects of the dynamic spinal fixation system 10 and may be thinner near the midline of the dynamic spinal fixation system 10. A system 10 with thicker lateral aspects and thinner near the midline gives the single member 12 a larger cross-section dimension at the lateral sides of the system 10 and a smaller cross-section dimension near the midline of the system 10. The single member 12 may also be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes.

The system 10 provides for a high proportion of open area between plurality of straight and curved portions of the single member 12 allowing for easy visualization through the single member 12. The system 10 also provides elastic compliance allowing the single member 12 to be pre-compressed or pre-distraction prior to attachment to the vertebrae 14, 16, 18. By pre-compressing the single member 12, the system 10 can facilitate pre-distraction of one or more motion segments of the spine when attached to the vertebrae 14, 16, 18. Alternatively, by pre-distraction the single member 12, the system 10 can facilitate pre-compression of one or more motion segments of the spine when attached to the vertebrae 14, 16, 18.

Referring now to FIGS. 2-5, an alternative embodiment of a dynamic spinal fixation system or plate 550 is shown. The system 550 includes a superior end 558 and an inferior end 560. A first attachment portion 552 is at the superior end 558 of the system 550 and a second attachment portion 554 is at the inferior end 560 of the system 550. An intermediate portion 556 connects the first attachment portion 552 and the second attachment portion 554. The first attachment portion 552 and second attachment portion 554 or platform sections may have a generally closed geometry such as a circle, ellipse, square, rectangle, or other closed geometry to facilitate placement of bone fasteners, such as bone screws, nails, staples, wires, pins, and the like. The first attachment portion 552 includes a first opening or slot 562 which is oriented in a transverse direction and further includes a relief 564 or a larger aperture creating a "key hole" slot. Likewise, second attachment portion 554 includes a second opening or slot 566 which is oriented in a transverse direction and further includes a relief 568 or larger aperture creating a "key hole" slot. The reliefs 564, 568 are centered in the first and second openings 562, 566, respectively. In alternative embodiments, the openings 562, 566 could also include additional reliefs allowing for additional bone fasteners to be inserted into the vertebrae before placement of the system 550 onto a patient's spine. In other alternative embodiments, the openings 562, 566 could also be oriented vertically or in any

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other direction. Multiple openings or tracks 562, 566 in each attachment portion 552, 554 may also be included in alternative embodiments.

The reliefs 564, 568 allow the first attachment portion 552 and second attachment portion 554 to be placed over the bone fastener heads, such as screw heads, that are already fixed to a vertebral body. The bone fasteners could also be pins, wires, nails, or any other method for fixing system 550 to a bone. The first and second openings 562, 566 are smaller than the geometry of the head of the bone fastener and the reliefs 564, 568. Thus, the geometry of the first and second openings 562, 566, respectively, allows the first and second attachment portions 552, 554 to be captured between the bone fastener heads and the underlying vertebra when the system 550 is slid into position between the head of the bone fasteners and the vertebra. Once the system 550 is in a desired position the surgeon may insert additional bone fasteners to secure the system 550 to the patient's spine.

The intermediate portion 556 may be comprised of an elastic mechanism that includes a plurality of straight portions 570 and a plurality of curved portions 572. The straight portions 570 and the curved portions 572 of the elastic mechanism provide open areas to allow for easy spine visualization through the system 550. The elastic mechanism of the intermediate portion 556 may be curvilinear in shape and allow for elastic deformation in any direction when loaded. The deformation of the elastic mechanism or spring-like element is primarily in the axial direction allowing for flexion and extension. The system 550 is designed to be flexible in the superior/inferior direction and more rigid in lateral bending and torsion. Further, the system 550 may be shaped to match the curvature of the spine in the sagittal and transverse planes. As best seen in FIG. 3, the system 550 is curved in the transverse plane to correspond to the shape of the vertebrae. A cross-sectional view of system 550 taken along line 4-4 is shown in FIG. 4 and a side view of the system 550 from FIG. 4 is shown in FIG. 5. The system 550 may also be curved in the sagittal plane to correspond to the shape of the spine. The intermediate portion 556 may be made of a non-uniform geometric shape and have a uniform or non-uniform cross-sectional geometry.

Referring now to FIG. 6, another embodiment dynamic spinal fixation system or plate 100 is shown. The system 100 includes a first attachment portion 102, a second attachment portion 104, and an intermediate portion 106 connecting the first attachment portion 102 and the second attachment portion 104. The first attachment portion or platform 102 is at a superior end 108 of the system 100 and the second attachment portion or platform 104 is at an inferior end 110. The first attachment portion 102 and second attachment portion 104 may be rigid sections for affixing the system 100 to the vertebrae. The intermediate portion 106 may be comprised of an elastic mechanism that has a less rigid elastic member with spring-like section for fostering controlled deformation.

The first attachment portion 102 includes a first opening 112 and the second attachment portion 104 includes a second opening 114. The openings 112 and 114 may be used to secure the system 100 to at least two adjacent vertebrae using bone fasteners. The uniform openings 112 and 114 allow for bone fastener placement anywhere along the openings 112 and 114. Alternatively, the first and second attachment portions 102 and 104 may include solid sections with at least one aperture through the attachment portions 102 and 104 to allow for placement of bone fasteners through the attachment portions 102 and 104 at pre-designated locations.

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The intermediate portion 106 may be comprised of an elastic mechanism that includes a plurality of straight portions 116 and a plurality of curved portions 118. The straight portions 116 and the curved portions 118 of the elastic mechanism provide open areas to allow for easy spine visualization through the system 100. The elastic mechanism of the intermediate portion 106 may be curvilinear in shape and allow for elastic deformation in any direction when loaded. The deformation of the elastic mechanism or spring-like element is primarily in the axial direction allowing for flexion and extension. The system 100 is designed to be flexible in the superior/inferior direction and more rigid in lateral bending and torsion. Further, the system 100 may be shaped to match the curvature of the spine in the sagittal and transverse planes.

As seen in FIGS. 7 and 8, the dynamic spinal fixation system or plate 120 includes a first attachment portion 102, a second attachment portion 104, an intermediate portion 106, and at least one support strut 122. The first attachment portion 102 and second attachment portion 104 are of the type described above with reference to FIG. 6. The support struts 122 may be lateral to the midline to enhance the rigidity of the elastic mechanism, in particular in bending and torsion, while still allowing the system 120 to deform elastically. In alternative embodiments the support struts 122 may be along the midline of the system 120. The support struts 122 provide at least one additional support between the straight portions 116 of the intermediate portion 106 and may be generally parallel to the curved portions 118. In alternative embodiments, the struts 122 may have a radius of curvature smaller than the radius of curvature of the curved portions 118. The support struts 122 also create an opening 124 between the curved portions 118 and the support struts 122. In the depicted embodiment there are four support struts 122. Additional support struts may also be added generally in parallel with the support struts 122 to provide additional rigidity to the intermediate portion 106.

Another dynamic spinal fixation system 140 or plate is shown in FIG. 9. The system 140 includes first attachment portion 102, second attachment portion 104, and intermediate portion 142. The first attachment portion 102 and second attachment portion 104 are of the type described above with reference to FIGS. 6-8. The intermediate portion 142 may include two or more separate portions. In the depicted embodiment of system 140 the intermediate portion 142 includes a first intermediate side 144 parallel to a second intermediate side 146. The first intermediate side 144 is a mirror image of the second intermediate side 146. The intermediate portion 142 connects the first attachment portion 102 and the second attachment portion 104. The first intermediate side 144 mates with the inferior side of the first attachment portion 102 on a first lateral end 148 and with the superior side of the second attachment portion 104 on a first lateral end 152. The second intermediate side 146 mates with the inferior side of the first attachment portion 102 on a second lateral end 150 and with the superior side of the second attachment portion 104 on a second lateral end 154. The intermediate portion 142 is less rigid than the first and second attachment portions 102, 104 to allow for controlled elastic deformation. The spring-like elastic first intermediate side 144 and second intermediate side 146 enhance the rigidity of the two or more sides 144, 146, in particular in bending and torsion, while still allowing the system to deform elastically.

Referring now to FIG. 10, a dynamic spinal fixation system 160 is shown. The dynamic spinal fixation system 160 includes first attachment portion 102, second attachment

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portion 104, and intermediate portion 162. The first attachment portion 102 and second attachment portion 104 are of the type described above with reference to FIG. 8. The intermediate portion 162 may include two or more separate sides. In the depicted embodiment of system 160, the intermediate portion 162 includes a first intermediate side 164 parallel to a second intermediate side 166. The first intermediate side 164 is a mirror image of the second intermediate side 166. The intermediate portion 162 connects the first attachment side 102 and the second attachment side 104. The first intermediate side 164 mates with an inferior side of the first attachment side 102 at a first medial position 168 and with the superior side of the second attachment portion 104 at a first medial position 172. The second intermediate side 166 mates with the inferior side of the first attachment portion 102 at a second medial position 170 and with the superior side of the second attachment portion 104 at a second medial position 174. The intermediate portion 162 is less rigid than the first and second attachment portions 102, 104 to allow for controlled elastic deformation. The system 160 allows for elastic motion primarily in the axial (flexion/extension) direction while the amount of motion in lateral bending and torsion is dictated by the configuration of the spring-like elements.

Referring now to FIG. 11, an alternative embodiment of a dynamic spinal fixation system or plate 50 is shown. The system 50 includes a member 52 with a superior end 60 and an inferior end 62. A first attachment portion 54 is at the superior end 60 of the member 52 and a second attachment portion 56 is at the inferior end 62 of the member 52. An intermediate portion 58 connects the first attachment portion 54 and the second attachment portion 56. The first attachment portion 54 and second attachment portion 56 or platform sections may have a generally closed geometry such as a circle, ellipse, square, rectangle, or other closed geometry to facilitate placement of bone fasteners, such as bone screws, nails, staples, wires, pins, and the like. The first attachment portion 54 includes a first opening 64 and the second attachment portion 56 includes a second opening 66. The openings 64 and 66 may be used to secure the system 50 to at least two adjacent vertebrae using bone fasteners. The openings 64 and 66 allow for bone fastener placement anywhere along the openings 64 and 66 because there are no pre-designated locations for the bone fasteners. Alternatively, the first and second attachment portions 54 and 56 may include solid sections with at least one aperture through the attachment portions 54 and 56 to allow for placement of bone fasteners through the attachment portions 54 and 56 at pre-designated locations. The intermediate portion 58 includes at least one closed member 68. The closed member 68 may be elastic. In the depicted embodiment there are four closed members 68. In the preferred embodiments the closed members 68 may range from one to ten. The closed elastic members 68 may have an elliptical, circular, rectangular, square, or any other closed shape. The closed elastic members 68 may also be made of a non-uniform geometric shape and have a uniform or non-uniform cross-sectional geometry. The member 52 may be curved in the transverse plane to correspond to the shape of the vertebrae. The member 52 may also be curved in the sagittal plane to correspond to the shape of the spine.

Another dynamic spinal fixation system 180 is depicted in FIGS. 12 and 13. The dynamic spinal fixation system 180 includes first attachment portion 102, second attachment portion 104, and an intermediate portion 182. The intermediate portion 182 includes a first intermediate side 184 and a second intermediate side 186. The first attachment portion

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102, second attachment portion 104, and the first intermediate side 184 are of the type described above with reference to FIG. 6. The second intermediate side 186 is a mirror image of the first intermediate side 184. The first intermediate side 184 includes a first plurality of curved portions 188 and a first plurality of straight portions 190. The second intermediate side 186 includes a second plurality of curved portions 192 and a second plurality of straight portions 194. The first intermediate side 184 is connected to the first attachment portion 102 and the second attachment portion 104 on the anterior aspect and the second intermediate side 186 is connected to the first attachment portion 102 and the second attachment portion 104 on the posterior aspect. The first intermediate side 184 overlaps with the second intermediate side 186. The first plurality of straight portions 190 and the second plurality of straight portions 194 are aligned while the first plurality of curved portions 188 and the second plurality of curved portions 192 are opposite each other. In alternative embodiments, the plurality of curved portions could be aligned and the plurality of straight portions could be offset. The intermediate portion 182 enhances rigidity by adding a second intermediate side 186 to the first intermediate side 184. However, even with the enhanced rigidity of the intermediate portion 182, the system 180 is able to deform elastically. Additional intermediate portions could also be added to further enhance rigidity of the system 180 while still allowing the system 180 to deform elastically. The first intermediate side 184 and the second intermediate side 186 may have uniform or non-uniform cross-sectional geometry.

Referring now to FIG. 14, another embodiment dynamic spinal fixation system 200 is shown. The system 200 is of the type described above with reference to FIG. 6 including a first attachment portion 102, a second attachment portion 104, and an intermediate portion 106. The system 200 further includes at least one hard stop 202 attached to the intermediate portion 106. In the depicted embodiment there are four hard stops 202 and the hard stops 202 comprise arced members positioned between two adjacent straight portions 116. The hard stops 202 may also be placed between two adjacent curved portions 118. The hard stops 202 limit the amount of deformation of the intermediate portion 106 when the system 200 is in compression. When the system 200 experiences compressive loading or bending, the intermediate member 106 deforms until the hard stops 202 are engaged on the adjacent straight portions 116. When the hard stops 202 contact the straight portions 116 deformation is limited.

Depicted in FIG. 15, is another dynamic spinal fixation system 220 including first attachment portion 102, second attachment portion 104, and intermediate portion 106 as described above with reference to FIG. 6, and further comprising at least one alternative hard stop 222. The hard stop 222 is attached to the intermediate portion 106 and has a generally domed shape. In the depicted embodiment, there are four hard stops 222 located between two adjacent straight portions 116. Although not shown, it is also contemplated that the hard stops 222 may be placed between two curved portions 118. The hard stops 222 also limit the amount of deformation in the intermediate portion 106 during compression of the system 220. During compression of the system 220, the intermediate portion 106 is squeezed together until at least one straight portion 116 makes contact with an adjacent hard stop 222.

FIG. 16 illustrates another embodiment dynamic spinal fixation system 240 including first attachment portion 102, second attachment portion 104, and intermediate portion

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106 as described above with reference to FIG. 6, and further comprising at least one alternative hard stop 242. The hard stops 242 are redundant hard stops. In the depicted embodiment, there are four hard stops 242. The hard stop 242 includes a first member 244 and a second member 246. The first member 244 is arced from a first end 248 to a second end 250. The second member 246 is also arced from a first end 252 to a second end 254. The first end 248 of the first member 244 and the first end 252 of the second member 246 are attached to adjacent straight portions 116. While the second end 250 of the first member 244 and the second end 254 of the second member 246 are arced towards each other in order for second end 250 to overlap with second end 254.

Under compressive loading, tensile loading, or bending the intermediate portion 106 deforms until the hard stops 242 are engaged on the mating features, which include the first member 244, the second member 246, and the second ends 250, 254 of the first member 244 and second member 246, respectively. The amount of deformation of the intermediate portion 106 is limited in compression when the first members 244 and second members 246 of the hard stops 242 contact an adjacent straight portion 116. In addition the amount of deformation of the intermediate portion 106 is also limited in tension when the second end 250 of the first member 244 and the second end 254 of the second member 246 engage each other.

The intermediate members 58, 106, 142, 162, 182, and 556, of FIGS. 2-16 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes.

Referring now to FIG. 17, yet another embodiment dynamic spinal fixation system 260 is shown. The system 260 including first attachment portion 102 and second attachment portion 104 as described above with reference to FIG. 6, and further includes an intermediate portion 262. The intermediate portion 262 connects the first attachment portion 102 and the second attachment portion 104 and includes at least one curve 264. In the depicted embodiment the at least one curve 264 arcs in a generally medial direction relative to the system 260.

Another embodiment dynamic spinal fixation system 280 is illustrated in FIG. 18. The system 280 including first attachment portion 102 and second attachment portion 104 as described above with reference to FIG. 6, and further includes an intermediate portion 282. The intermediate portion 282 connects the first attachment portion 102 and the second attachment portion 104. The intermediate portion 282 is a more complex portion and includes multiple curved sections 284 and multiple straight sections 286. In the depicted embodiment the intermediate portion 282 is narrower in width than the first and second attachment portions 102, 104 and is located in a generally medial position.

Depicted in FIG. 19 is still another embodiment dynamic spinal fixation system 300. The system 300 including first attachment portion 102 and second attachment portion 104 as described above with reference to FIG. 6, and further includes an intermediate portion 302. The intermediate portion 302 connects the first attachment portion 102 and the second attachment portion 104. The intermediate portion 302 includes at least one wide curve 304 per level. In the depicted embodiment the intermediate portion 302 includes two wide curves 304.

Referring now to FIG. 20 another dynamic spinal fixation system 320 is shown. The system 320 includes first attachment portion 102 and second attachment portion 104 as described above with reference to FIG. 6, and further

includes an intermediate portion 322. The intermediate portion 322 connects the first attachment portion 102 and the second attachment portion 104. The intermediate portion 322 includes a solid or closed elastic member or element 324. The solid member 324 may be of any shape that deforms elastically when loaded.

The intermediate portions 262, 282, 302, and 322 of FIGS. 17-20 may be made of a metal, polymer, ceramic, or composite material. Further the intermediate portions 262, 282, 302, and 322 of FIGS. 17-20, may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes.

The dynamic spinal fixation systems of FIGS. 2-20 each illustrate a one level system. Each of the systems of FIGS. 2-20 can be modified to include additional attachment portions and either additional or elongated intermediate portions for engaging more than two adjacent vertebrae. For example and as seen in FIGS. 21-24, the dynamic spinal fixation system 340 is a two level system for the spine. The system 340 includes a first attachment portion 102 and a second attachment portion 104 as described above with reference to FIG. 8, and further includes an intermediate portion 342. The intermediate portion 342 includes a first intermediate member 344, a third attachment portion 346, and a second intermediate member 348. The first intermediate member 344 and second intermediate member 348 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes. The third attachment portion 346 may be rigid for affixing the system 340 to a vertebra. The third attachment portion 346 includes a third opening 350 which may be used to secure the system 340 to a vertebra using at least one bone fastener. The third opening 350 is uniform and therefore allows for placement of bone fasteners at any point along the third opening 350. The first, second, and third openings 112, 114, and 350, respectively, may include a ridge or lip for the bone fasteners to mate with when inserted into the patient's vertebrae to maintain a low profile of the first, second, and third attachment portions 102, 104, and 346, respectively. The low profile will prevent the bone fasteners from protruding above the first, second, and third attachment portions 102, 104, and 346, respectively, and agitating the patient's tissue. Alternatively, the attachment portions 102, 104, and 346 may include solid sections with at least one aperture through the platform to allow for placement of bone fasteners through the attachment portions 102, 104, and 346 at pre-designated locations.

Referring now to FIG. 21, the first intermediate member 344 and the second intermediate member 348 are of the type illustrated in FIG. 6 and described with reference to intermediate portion 106. The first intermediate member 344 and the second intermediate member 348 may each be comprised of a single elastic component including a plurality of straight portions 352 and a plurality of curved portions 354. The straight portions 352 and the curved portions 354 provide open areas that allow for easy visualization through the system 340 to a patient's spine. The first intermediate member 344 and the second intermediate member 348 may be curvilinear in shape and allow for elastic deformation in any direction when loaded. Further, the system 340 may be shaped to match the curvature of the spine in the sagittal and transverse planes.

Referring now to FIG. 22, the dynamic spinal fixation system 340 includes an alternative first intermediate member 344 and second intermediate member 348 of the types

illustrated in FIG. 7 and described above with reference to intermediate portion 106 including at least one support strut 122. The first intermediate member 344 and the second intermediate member 348 may each be comprised of a single elastic component including a plurality of straight portions 352 and a plurality of curved portions 354. The support struts 122 may be lateral to the midline of the system 340 enhance the rigidity of the first intermediate member 344 and the second intermediate member 348, in particular in bending and torsion, while still allowing elastic deformation. The support struts 122 provide at least one additional rod between the straight portions 352 of the first intermediate member 344 and the second intermediate member 348 and are generally parallel to the curved portions 354. Alternatively, the struts 122 may have a radius of curvature smaller than the radius of curvature of the curved portions 118. The support struts 122 also create an opening 124 between the curved portions 354 and the support struts 122. In the depicted embodiment there are four support struts 122 for each of the first intermediate member 344 and the second intermediate member 348.

Referring now to FIG. 23, the dynamic spinal fixation system 340 includes yet another alternative first intermediate member 344 and the second intermediate member 348. The first intermediate member 344 and second intermediate member 348 are of the type illustrated in FIG. 9 and described with reference to intermediate portion 142. The first intermediate member 344 and second intermediate member 348 each include a first portion 144 parallel to a second portion 146. The first portion 144 is a mirror image of the second portion 146. The first intermediate member 344 connects the first attachment portion 102 and the third attachment portion 346. The first portion 144 mates with the inferior side of the first attachment portion 102 on a first lateral end 148 and with the superior side of the third attachment portion 346 on a first lateral end 360. The second portion 146 mates with the inferior side of the first attachment portion 102 on a second lateral end 150 and with the superior side of the third attachment portion 346 on a second lateral end 362. The second intermediate member 348 connects the third attachment portion 346 and the second attachment portion 104. The first portion 144 mates with the inferior side of the third attachment portion 346 on a first lateral end 364 and with the superior side of the second attachment portion 104 on a first lateral end 152. The second portion 146 mates with the inferior side of the third attachment portion 346 on a second lateral end 366 and with the superior side of the second attachment portion 104 on a second lateral end 154.

The intermediate portions 344 and 348 are less rigid than the first, second, and third attachment portions 102, 104, 346, respectively, to allow for controlled elastic deformation. The spring-like elastic first portions 144 and second portions 146 enhance the rigidity of the two or more intermediate portions 344 and 348, in particular in bending and torsion, while still allowing the intermediate portion to deform elastically.

Referring now to FIG. 24, the dynamic spinal fixation system 340 includes a first intermediate member 344 that is different than the second intermediate member 348. In the depicted embodiment the first intermediate member 344 is of the type illustrated in FIG. 6 and described with reference to intermediate portion 106 and the second intermediate member 348 is of the type illustrated in FIG. 7 and described with reference to intermediate portion 106 and including at least one support strut 122. The hybrid two level construct of intermediate portion 342 includes a first intermediate

member **344** that is a more elastic member and a second intermediate member **348** that is a more rigid member. Alternative multi-level dynamic spinal fixation systems may include various combinations of the intermediate portions of FIGS. 2-20. Each of the intermediate portions of FIGS. 2-20 may have different medial and lateral stiffness. For example, the medial stiffness may be higher than the lateral stiffness alternatively the medial stiffness may be lower than the lateral stiffness. These hybrid multi-level systems may be used to augment the stiffness of spinal levels adjacent to a single (central) level anterior cervical discectomy and fusion ("ACDF").

Although only single and double level dynamic spinal fixation systems have been shown and described, additional levels may be added to the systems as needed to stabilize a patient spine, creating systems with three levels or more. In addition, the multi-level systems may include more than three alternating attachment portions and intermediate portions for longer ACDFs.

Illustrated in FIG. 25 is another embodiment dynamic spinal fixation system **380** of the type described above with reference to FIG. 6 and further including an interbody fusion cage device **382**. The system **380** includes a first attachment portion **102**, a second attachment portion **104**, and an intermediate portion **106** of the type described above with reference to FIG. 6. The device **382** includes a hollow member **384** with a cavity **386**. A bone graft may be inserted into the cavity **386** to allow for fusion to occur between two adjacent vertebrae. The interbody fusion cage device **382** is integrated into the dynamic spinal fixation system **380**. The device **382** and system **380** may be pre-assembled prior to surgery or may be assembled during surgery. During surgery, the device **382** is placed into the disc space of the spine. Then the system **380** is aligned with a first vertebra **388** and a second vertebra **390** and may be affixed to the vertebrae using bone fasteners as described above with reference to FIG. 6. The dynamic spinal fixation systems of FIGS. 2-25 may be comprised of a metallic material, or alternatively of an elastic, hyperelastic, or deformable polymer, ceramic, or composite material.

An alternative dynamic spinal fixation system **400** is depicted in FIG. 26. The system **400** includes a first attachment portion **402**, a second attachment portion **404**, a third attachment portion **406**, a first intermediate portion **408**, and a second intermediate portion **410**. The first intermediate portion **408** connects the first attachment portion **402** and the second attachment portion **404**. The second intermediate portion **410** connects the second attachment portion **404** and the third attachment portion **406**. The first attachment portion **402**, second attachment portion **404**, and third attachment portion **406** each include two bone fastener openings **412** for using to secure the system **400** to a patient's vertebrae. The first intermediate portion **408** includes a first elastic element **414**, which may be a continuous curved torsional spring-like element, and four arms **416** connecting the first elastic element **414** and the fastener openings **412** of the first and second attachment portions **402** and **404**, respectively. The second intermediate portion **410** includes a second elastic element **418**, which may also be a continuous curved torsional spring-like element, and four arms **420** connecting the second elastic element **418** and the fastener openings **412** of the second and third attachment portions **404** and **406**, respectively. The first intermediate portion **408** and second intermediate portion **410** may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes.

The system **400** may be attached to a patient's spine by securing fastener openings **412** of the first attachment portion **402** to a first vertebra **422**, fastener openings **412** of the second attachment portion **404** to a second vertebra **424**, and fastener openings **412** of the third attachment portion **406** to a third vertebra **426**. When loaded the system **400** deforms elastically by rotation around the torsion spring elements or the first intermediate portion **408** and second intermediate portion **410**. The system **400** can be pre-compressed or pre-extended prior to attachment to a patient's first, second, and third vertebrae **422**, **424**, and **426**, respectively, to facilitate distraction or compression, respectively.

Referring now to FIGS. 27-31, another embodiment dynamic spinal fixation system **450** is illustrated. The system **450** includes a first attachment portion **452**, a second attachment portion **454**, a third attachment portion **456**, a first intermediate portion **458**, and a second intermediate portion **460**. The first attachment portion **452**, second attachment portion **454**, and third attachment portion **456** are more rigid for affixing the system **450** to a patient's vertebrae. The first attachment portion **452**, second attachment portion **454**, and third attachment portion **456** include a first opening **462**, a second opening **464**, and a third opening **466**, respectively. The first opening **462** may be used to secure the system **100** to a first vertebra **468** using bone fasteners. The second opening **464** may be used to secure the system **100** to a first vertebra **470** using bone fasteners. The third opening **466** may be used to secure the system **100** to a first vertebra **472** using bone fasteners.

The first intermediate portion **458** and a second intermediate portion **460**, or spring-like elastic sections, are less rigid than the attachment portions **452**, **454**, **456** for fostering controlled elastic deformation. The first intermediate portion **458** connects the first attachment portion **452** and second attachment portion **454**. The second intermediate portion **460** connects the second attachment portion **454** and third attachment portion **456**. As best seen in FIG. 27, the first intermediate portion **458** and second intermediate portion **460** may each include a single elastic element **474** with a plurality of coils. Alternatively and as depicted in FIG. 28, the first intermediate portion **458** and second intermediate portion **460** may each include a first elastic element **476** with a plurality of coils and a second elastic element **478** with a plurality of coils. The first elastic element **476** is parallel with the second elastic element **478** and both are comprised of elastic, metallic, spring-like components with uniform or non-uniform cross-sectional geometry. Additional parallel elastic elements could also be added to the intermediate portions **458**, **460**. The system **450** illustrated in FIG. 28 may also be monolithic and comprised of only a single component.

FIG. 29 depicts another embodiment of first intermediate portion **458** and second intermediate portion **460**, wherein the first and second intermediate portions **458** and **460** respectively, each include a first elastic element **480** with a single coil and a second elastic element **482** with a single coil. The first elastic element **480** is parallel to the second elastic element **482**. The first element **480** and second element **482** may be elastic torsional spring-like elements. Additional parallel elastic elements may be added in parallel to first and second elastic elements **480**, **482**.

Illustrated in FIG. 30 is another embodiment of first intermediate portion **458** and second intermediate portion **460**. The first intermediate portion **458** includes a first elastic element **484** parallel to a second elastic element **486**. The first element **484** and second element **486** are elastic leaf spring-like elements.

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Referring now to FIG. 31, yet another embodiment of first intermediate portion 458 and second intermediate portion 460 is shown. The first intermediate portion 458 and second intermediate portion 460 include at least one piston element 490 in series with an elastic element 492. The elastic element 492 being in series with the piston element 490 offers resistance to deformation. When the system 450 deforms under a load it is guided by the piston element 490 which is rigid in all directions other than vertical. The system 450 may also be compressed or extended prior to being secured to a patient's spine to allow for pre-distraction or pre-loading of the patient's spine.

The system 450 in FIGS. 27-31 can be pre-compressed or pre-extended prior to attachment to a patient's first, second, and third vertebrae 468, 470, and 472, respectively, to facilitate distraction or compression, respectively. In addition, each configuration of the intermediate portions of system 450 allows for elastic motion primarily in the axial (flexion/extension) direction while the amount of motion in lateral bending and torsion is dictated by the configuration of the intermediate portions of the systems 450. Further, additional elastic elements may be added in parallel to the intermediate portions of the systems 450 in FIGS. 28-30 to enhance the rigidity of the system 450, in particular in bending and torsion, while still allowing the system 450 to deform elastically. The intermediate portions 458, 460 of FIGS. 27-31 can have different geometries including but not limited to simple and slightly curved or complex and multiply curved, with narrow curves or wide curves, with one, two or more curves per level. The intermediate portions 458, 460 can also be solid or closed geometries that are elastically deformable such as metals, polymers, or composites. The first intermediate portion 458 and second intermediate portion 460 of FIGS. 27-31 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes.

In addition, as each of the dynamic spinal fixation systems of FIGS. 26-31 have been described with reference to three sections for engaging three adjacent vertebrae and two intermediate deformable portions or compliant sections for a two-level anterior cervical discectomy and fusion ("ACDF"), it should be understood that each of the systems in FIGS. 26-31 can be modified for a single-level ACDF. A single-level ACDF would only include two sections for engaging two adjacent vertebrae and one intermediate portion or elastic section. Similarly, it should also be understood that each of the systems in FIGS. 26-31 can be modified to include more than three alternating attachment sections and intermediate sections for longer ACDF's, which may be more than two-levels.

FIGS. 32-36 show spinal fixation systems that allow the bone fasteners, for example, screws, to be secured to the vertebrae before the systems are placed onto the spine. The systems generally contain at least two attachment portions or rigid platform-like sections which are used to secure the systems to a patient's vertebrae. The attachment portions are generally more rigid than the rest of the system to facilitate bone fastener fixation to the bony vertebral bodies by allowing bone fasteners, such as screws, nails, staples, wires, pins, and the like, to pass through the systems at the attachment portion or portions.

FIGS. 32 and 33 illustrate a monolithic implant 500 and a multi-component implant 510, respectively. The implant 500 is a static spinal fixation implant and the implant 510 is a dynamic implant. The implants 500, 510 each include a first attachment portion 520 including an opening 522 with

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a relief 524, a second attachment portion 526 including an opening 528 with a relief 530, and an intermediate portion 518. The first and second attachment portions 520, 526 allow for a surgeon to insert the bone fasteners into the vertebrae first, thereby, providing a complete view of the patient's spine. Then the surgeon may insert the implants 500, 510 by placing them over the bone fasteners at the reliefs 524, 530 and sliding the bone fasteners into position within the openings 522, 528. Once the bone fasteners are in place along the openings 522, 528, additional bone fasteners may be inserted to secure the implants 500, 510 to the vertebrae. The intermediate portions 518 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes. Referring now to FIG. 33, the multi-component implant 510 allows for some adjustment in length of the intermediate portion 518 along the long axis of the implant 510.

Referring now to FIGS. 34 and 35, another dynamic spinal fixation system or plate 550 embodiment is shown. The system 550 includes a first attachment portion 552, a second attachment portion 554, and an intermediate portion 556 that connects the first attachment portion 552 and second attachment portion 554. The intermediate portion 556 may be of the type described above with reference to FIG. 2 and include an elastic mechanism composed of a plurality of straight portions 570 and a plurality of curved portions 572. The first attachment portion 552 is at a superior end 558 of the system 550 and the second attachment portion 554 is at an inferior end 560. The first attachment portion 552 includes a first opening or slot 562 which is oriented in a transverse direction and further includes a relief 564 or a larger aperture creating a "key hole" slot. Likewise, second attachment portion 554 includes a second opening or slot 566 which is oriented in a transverse direction and further includes a relief 568 or larger aperture creating a "key hole" slot. The reliefs 564, 568 are centered in the first and second openings 562, 566, respectively. In alternative embodiments, the openings 562, 566 could also include additional reliefs allowing for additional bone fasteners to be inserted into the vertebrae before placement of the system 550 onto a patient's spine. In other alternative embodiments, the openings 562, 566 could also be oriented vertically or in any other direction. Multiple openings or tracks 562, 566 in each attachment portion 552, 554 may also be included in alternative embodiments.

The reliefs 564, 568 allow the first attachment portion 552 and second attachment portion 554 to be placed over the bone fastener heads, such as screw heads, that are already fixed to a vertebral body. The bone fasteners could also be pins, wires, nails, or any other method for fixing system 550 to a bone. The first and second openings 562, 566 are smaller than the geometry of the head of the bone fastener and the reliefs 564, 568. Thus, the geometry of the first and second openings 562, 566, respectively, allows the first and second attachment portions 552, 554 to be captured between the bone fastener heads and the underlying vertebra when the system 550 is slid into position between the head of the bone fasteners and the vertebra. Once the system 550 is in a desired position the surgeon may insert additional bone fasteners to secure the system 550 to the patient's spine.

An alternative embodiment dynamic spinal fixation system 600 is depicted in FIGS. 36 and 37. The system 600 includes a first attachment portion 602, a second attachment portion 604, and an intermediate portion 606 that connects the first attachment portion 602 and second attachment portion 604. The intermediate portion 606 may be of the type

described above with reference to FIG. 2 and include a single elastic mechanism that includes a plurality of straight portions 620 and a plurality of curved portions 622. The first attachment portion 602 is at a superior end 608 of the system 600 and the second attachment portion 604 is at an inferior end 610. The first attachment portion 602 includes a first opening or slot 612 which is curved and further includes a relief or a single larger aperture 614. Likewise, second attachment portion 604 includes a second opening or slot 616 which is curved and further includes a relief or single larger aperture 618. The openings 612, 616 could also include additional reliefs allowing for additional bone fasteners to be inserted into the vertebrae before placement of the system 600 onto a patient's spine. The openings 612, 616 of system 600 are concave slots that may be used to compress the intermediate portion 606 as the system 600 is slid transversely under the already-placed one or more screws or fasteners. Alternatively, the concave slots of openings 612, 616 may be used to distract the intermediate portion 606 or to maintain the same distance between the vertebrae based on the position the fasteners are inserted into the vertebrae. The slots 624 could also be convex allowing the motion segment to be distracted. The system 600 may be inserted onto the spine as described above with reference to FIGS. 34 and 35, however rather than sliding the system into position, the surgeon would rotate the system 600 into position between the head of the bone fasteners and the vertebra.

The dynamic spinal fixation systems of FIGS. 38-39 depict embodiments similar to those described above with reference to FIGS. 34-35, but wherein the systems include alternative relief positions. The reliefs may be located superiorly or inferiorly to the openings of the attachment portions to facilitate compression or distraction of the dynamic spinal fixation systems.

Referring now to FIG. 38, the dynamic spinal fixation system 650 includes first attachment portion 652, second attachment portion 654, and intermediate portion 556 which connects first attachment portion 652 and second attachment portion 654. The first attachment portion 652 is at a superior end 656 of the system 650 and the second attachment portion 654 is at an inferior end 658. The first attachment portion 652 includes a first opening 660 which is oriented in a transverse direction and further includes a relief 662 positioned superior to a midline of the first opening 660. The second attachment portion 654 includes a second opening 664 which is oriented in a transverse direction and further includes a relief 666 positioned inferior to a midline of the second opening 664. The relief 660 is connected to the first opening 660 and the relief 666 is connected to the second opening 664.

Referring now to FIG. 39, the dynamic spinal fixation system 670 includes first attachment portion 672, second attachment portion 674, and intermediate portion 676 which connects first attachment portion 672 and second attachment portion 674. The first attachment portion 672 is at a superior end 678 of the system 670 and the second attachment portion 674 is at an inferior end 680. The first attachment portion 672 includes a first opening 682 which is oriented in a transverse direction and further includes a relief 684 positioned inferior to a midline of the first opening 682. The second attachment portion 674 includes a second opening 686 which is oriented in a transverse direction and further includes a relief 688 positioned superior to a midline of the second opening 686. The relief 684 is connected to the first opening 682 and the relief 688 is connected to the second opening 686.

In the embodiments depicted in FIGS. 34-45, at least one of the attachment portions contains at least one relief allowing a bone fastener head to pass through the dynamic spinal fixation systems. Alternatively, more than one attachment portion may have a relief allowing a bone fastener to pass through the dynamic spinal fixation systems. Further, all the attachment portions could have reliefs allowing bone fasteners to pass through the dynamic spinal fixation systems. The intermediate portions of FIGS. 34-45 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes. Although the systems illustrated in FIGS. 34-45 only show one level systems, multiple level systems are also contemplated and these multiple level systems include at least one attachment portion with a relief. In addition, the length of each system shown in FIGS. 34-45 may be adjustable to accommodate the spacing between the already-placed bone fasteners. The systems may also be compressed or extended to allow the already-placed bone fasteners to pass through the reliefs in the attachment portions.

Referring now to FIG. 40, a dynamic spinal fixation system 700 is shown. The system 700 includes a first attachment portion 702, second attachment portion 704, and intermediate portion 706 which connects first attachment portion 702 and second attachment portion 704. The first attachment portion 702 and second attachment portion 704 are of the type described above with reference to first attachment portion 702 and second attachment portion 704 of FIGS. 34-35. The intermediate portion 706 or spring-like elastic section has a non-uniform cross-sectional geometry which facilitates the desired stiffnesses in different bending directions. For example, the thickened lateral cross-sectional geometry 708 selectively increases torsional stiffness without significantly increasing flexion/extension stiffness.

As best seen in FIGS. 41-43, another dynamic spinal fixation system 720 is shown. The system 720 includes a first attachment portion 722, second attachment portion 724, and intermediate portion 726 which connects first attachment portion 722 and second attachment portion 724. The first attachment portion 722 includes a first opening 728 that is oriented in a transverse direction and further includes a relief 732. The second attachment portion 724 includes a second opening 730 that is oriented in a transverse direction and further includes a relief 734. The reliefs 732, 734 are centered in the first and second openings 728, 730, respectively. The intermediate portion 726 includes at least one elastic mechanism with a plurality of straight portions 736 and a plurality of curved portions 738 and at least one support strut 740. The support struts 740 may be lateral to the midline and at different distances from the midline based on the desired rigidity of the intermediate portion 726. The support struts 740 are generally parallel to the curved portions 738 and are located between the straight portions 736. In the depicted embodiment there are four support struts 740.

Referring now to FIG. 41, an opening 742 is created between the curved portions 738 and the support struts 740. In FIG. 42, an opening 744 is created between the curved portions 738 and the support struts 740. The opening 744 is larger than the opening 742 because the support struts 740 are closer to the midline in FIG. 42 than in FIG. 41. Referring now to FIG. 43, an opening 746 is created between the curved portions 738 and the support struts 740. Opening 746 is larger than openings 742 and 744 because the support struts 740 are closer to the midline in FIG. 43 than in either FIG. 41 or 42. The support struts 740 may provide various

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levels of rigidity by reinforcing the intermediate portion 726. The amount of rigidity which intermediate portion 726 has will be based on the distance the support strut 740 is from the midline or the size of the openings 742, 744, and 746. For example, the system 720 of FIG. 43 will be more rigid than the system of FIG. 42 and both will be more rigid than the system of FIG. 41 because strut 740 in FIG. 43 is closest to the midline creating the largest opening 746 and strut 740 in FIG. 41 is farthest from the midline creating the smallest opening 742. The rigidity may be enhanced as the support struts 740 are moved closer to the midline, in particular in bending and torsion, while still allowing the system 720 to deform elastically.

FIGS. 44 and 45 illustrate another embodiment of a dynamic spinal fixation system 690. The system 690 includes a first attachment portion 602, a second attachment portion 604, and an intermediate portion 106. The first attachment portion 602 and second attachment portion 604 are of the type described above with reference to FIGS. 36 and 37. The intermediate portion 106 is of the type described above with reference to FIG. 7 wherein the intermediate portion 106 includes at least one support strut 122.

Referring now to FIGS. 46-48, another embodiment of a dynamic spinal fixation system 750 is shown with a method of inserting the system 750 onto two vertebrae. The system 750 includes a first open attachment portion or platform section 752, a second open attachment portion or platform section 754, and an intermediate portion 756. The intermediate portion 756 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes. The first open attachment portion 752 and second open attachment portion 754 are open on at least one side. The first open attachment portion 752 includes a base 758, an arm 760, and a hinge mechanism 762 which connects the arm 760 to the base 758 and allows for the arm 760 to open and close. The second open attachment portion 754 includes a base 764, an arm 766, and a hinge mechanism 768 which connects the arm 766 to the base 764 and allows for the arm 766 to open and close. The system 750 may be secured to a first vertebra 770 and a second vertebra 772 by first inserting bone fasteners 774 into the first vertebra 770 and inserting bone fasteners 776 into the second vertebra 772. The bone fasteners 774, 776 are screws in the depicted embodiment, but may also be nails, staples, wires, pins, and the like. Next the arms 760 and 766 are placed in an open position and base 758 is aligned with fasteners 774 and base 764 is aligned with fasteners 776. The system 750 may then be slid laterally between the already inserted bone fasteners 774 and 776 and the first and second vertebrae 770 and 772, respectively. The arms 760 and 766 may then be lowered to close the first attachment portion 752 and the second attachment portion 754 using the hinge mechanisms 762, 768 or similar mechanism. When the arms 760 and 766 have been lowered, the bone fasteners 774 and 776 are captured within the first open attachment portion 752 and second open attachment portion 754, respectively. Bone fasteners 774 and 776 may then be tightened to secure the system 750 to the first and second vertebrae 770 and 772, respectively.

Another dynamic spinal fixation system 800 is shown in FIG. 49. The system 800 includes two first attachment portions 802, two second attachment portions 804, and at least one brace 806. The first attachment portions 802 include first attachment sections 808 and first strut portions 810. The second attachment portions 804 include second attachment sections 812 and second strut portions 814. The first strut portions 810 of the two first attachment portions

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802 are connected vertically to the second strut portions 814 of the two second attachment portions 804. The strut portions 810 and 814 include a mechanism that has an adjustable length. The attachment portions 802 and 804 have a generally u-shaped geometry that are open on the outside allowing the attachment portions 802 and 804 to be slid between bone fastener heads and the vertebrae. The attachment portions 802 are slid in a superior direction between vertebra 816 and fastener heads 820 to capture the system 800. The attachment portions 804 are slid in an inferior direction between vertebra 818 and fastener heads 822 to capture the system 800. Once attachment portions 802 and 804 are slid into place, although not shown, a hinged enclosure, like the arms 760 and 766 of FIGS. 46-48, may capture the bone fastener heads 820 and 822.

Illustrated in FIG. 50 is another dynamic spinal fixation system 830. The system 830 includes a first attachment portion 832, a second attachment portion 834, and two bone fasteners 836. The first attachment portion 832 includes a first attachment section 834 and a first strut portion 836. The second attachment portion 838 includes a second attachment section 840 and a second strut portion 842. The attachment portions 832 and 834 have a generally U-shaped geometry that is open on the outside allowing the attachment portions 832 and 834 to be slid between bone fastener heads 844 and the vertebrae. The attachment portion 832 is slid in a superior direction and the attachment portion 834 is slid in an inferior direction between the vertebrae and bone fastener heads 844 to capture system 830. The strut portions 840 and 842 include a mechanism that has an adjustable length and the first strut portion 836 includes a plurality of teeth 846 to facilitate engagement of an adjustable mechanism. The systems 750, 800, and 830 of FIGS. 46-50 may be reinforced with an absorbable biomaterial that is resorbed over time and as the biomaterial is absorbed, the stiffness of the dynamic spinal fixation systems changes.

Referring now to FIGS. 51-55, a surgical method for implanting a dynamic spinal fixation system is depicted and will now be described. The method utilizes some of the devices, features, aspects, components and the like described above, and therefore reference will be made to the above described embodiments, such as the illustrated embodiments presented in the figures and discussed above. However, such references are made for exemplary purposes only and are not intended to limit the surgical method beyond the specifically recited steps. Further, the surgical method may be discussed under the umbrella of particular vertebrae, but such an application is not intended to be limiting and the method described herein may be used or conducted with vertebrae not specifically discussed herein without departing from the spirit and scope of the surgical method.

Assuming the patient has a spinal injury, disease, or trauma, an anterior spinal surgery, such as an anterior cervical discectomy and fusion ("ACDF"), may be performed to correct the damaged spine using the systems 550 or 600. The methods disclosed each include placing the bone fasteners first and the systems 550 or 600 second. The fasteners may also be used to distract or compress the spine prior to placement of the systems 550 or 600 over the fasteners.

As depicted in FIG. 56, the method 900 consists of the following steps. First, in order to correct a damaged spine an anterior or lateral portion of the spine is exposed by a surgeon, the vertebral level is determined, and the midline position is identified 902. The bone fasteners, screws in the depicted embodiments, are then applied at the superior

vertebra and the inferior most vertebrae leaving a gap between the screws and the vertebrae **904**. A discectomy or corpectomy is then performed by inserting a distractor into the screws for distraction and once decompression is complete a graft, implant, or interbody spacer is placed into the disc space and then the distraction apparatus is removed **906**. Next a system of a desired length is chosen to correspond to the distance between the screws and if compression or distraction is desired, a smaller or larger system is selected. Alternatively, the length of the system may be adjusted by compressing or distracting the system prior to placing the reliefs over the screw heads and translating the system to capture the attachment portions between the screw heads and vertebrae **908**. The screws are then tightened to secure the attachment portions between the screw heads and vertebrae with additional screws being inserted through the openings **910** if necessary. Finally, the patient's incision is closed **912**.

When a dynamic spinal fixation system is chosen for step **908** the inter-screw distance must first be determined. Then a surgeon must decide whether it is desirable to apply compression or extension to the graft. If the surgeon wishes to apply compression to the graft then a shorter system **550** or **600** is utilized or the system **550** or **600** may be stretched or expanded prior to placing it over the screws. Alternatively, if the surgeon wants to apply distraction to the graft then a longer system **550** or **600** is utilized or the system **550** or **600** may be compressed prior to placing it over the screws.

As illustrated in FIGS. **51-52**, in step **904**, a first fastener **920** may be applied to the superior vertebra **924** approximately 2 to 3 millimeters ("mm") off the midline to the right or left side. A second fastener **922** is then applied to the inferior most vertebrae **926** just off the midline, approximately 2 to 3 mm, and on the same side as the first fastener **920**. The first vertebra may be adjacent the second vertebra. Alternatively, the first vertebra may be separated from the second vertebra, for example, the first vertebra may be the C4 and the second vertebra may be the C6 in a two level procedure. In the depicted embodiment, the first and second fasteners **920**, **922** are applied to the left side of the midline of the vertebrae **924**, **926**. The reliefs **564**, **568** of dynamic spinal fixation system **550** are aligned with the already placed fasteners **920**, **922**. The system **550** is then slid in line with the midline of the spine and the fasteners **920**, **922** move into the left lateral sides of the openings **562**, **566**, respectively. After the system **550** is positioned, additional fasteners may be applied on the right lateral sides of the openings **562**, **566**. The fasteners may then be locked to the system **550** by a locking mechanism, such as an expansion screw or an interference type plate or screw. The first and second fasteners **920**, **922** may also be applied to the right side of the midline of the vertebrae **924**, **926** and then the fasteners **920**, **922** would be slid to the right lateral sides of the openings **562**, **566**, respectively.

As illustrated in FIGS. **53-55**, in step **904**, a first fastener **920** may be applied to the superior vertebra **924** approximately 2 to 3 mm off the midline to the right or left side. A second fastener **922** is then applied to the inferior most vertebrae **926** just off the midline, approximately 2 to 3 mm, and on the side opposite the first fastener **920**. The first vertebra may be adjacent the second vertebra. Alternatively, the first vertebra may be separated from the second vertebra, for example, the first vertebra may be the C4 and the second vertebra may be the C6 in a two level procedure. In the depicted embodiment the first fastener **920** is applied to the left side of the midline of the vertebra **924** and the second

fastener **922** is applied to the right side of the midline of the vertebra **926**. Alternatively, the first fastener **920** may be applied to the right side of the midline of the vertebra **924** and the second fastener **922** may be applied to the left side of the midline of the vertebra **926**. In still another alternative embodiment, the first and second fasteners **920** and **922** may be aligned parallel in the vertebrae **924** and **926**, respectively.

Once the fasteners **920**, **922** are inserted into the vertebrae **924**, **926**, a dynamic spinal fixation system **600** is aligned at an angle with the first fastener **920** and the second fastener **922** so that the previously placed fasteners **920** and **922** are accommodated at the reliefs **614** and **618** in the first attachment portion **602** and the second attachment portion **604**, respectively. The openings **612** and **616** are curved and concave with respect to the center of the system **600**. The curved and concave openings **612** and **616** allow the system **600** to be rotated once the system **600** is placed over at least one of the already placed fasteners **920** and/or **922**. The system **600** is then rotated in line with the midline of the spine and the fasteners **920** and **922** move into the openings **612** and **616**, as best illustrated in FIG. **52**. As the system **600** is rotated the radius of curvature of the openings **612** and **616** allows for compression or distraction of the intermediate portion **606** when the system **600** is rotated under the fasteners **920** and **922**.

In an alternative embodiment, the first and second fasteners **920**, **922** may be applied to the vertebrae **924**, **926** parallel to each other. The system **600** is aligned parallel with the fasteners **920**, **922** and the reliefs **614** and **618** are aligned with the fasteners **920**, **922**. Then system **600** is slid into position moving the fasteners **920**, **922** into the openings **612**, **616**.

Once the system **600** is rotated to the desired position along the spine, the first attachment portion **602** and second attachment portion **604** are captured between the heads of the fasteners **920** and **922** and the superior vertebra **924** and inferior vertebrae **926**. A third fastener **928** may optionally be inserted into the opening **612** and a fourth fastener **930** may also optionally be inserted into the opening **616** to further secure the system **600** to the first and second vertebrae **924** and **926**, respectively. In alternative embodiments, the openings **612** and **616** may also be convex with respect to the center of the system **600** and thereby allow for compression of the intermediate portion **606** when the system **600** is slid laterally under at least one fastener. Although the method has been described with inserting the fasteners in a given sequence, it is understood by one skilled in the art that the fasteners may be inserted into the spine in any sequence and that the dynamic spinal fixation systems may be slide or rotated in either direction.

While the above detailed description of the invention is in the context of the cervical spine, it is understood by one skilled in the art that the same design is scalable for use in the lumbar spine for anterior lumbar interbody fusion ("ALIF") or dynamic stabilization of the cervical and lumbar spine. Further while the preferred and alternative embodiments are comprised of a metallic material, it is understood that the same design is achievable through use of an elastic, hyperelastic, or deformable polymer, ceramic, or composite.

FIGS. **57-60** depict an embodiment of the invention. As shown, the fracture plate **1001** is slender with a substantially longitudinal length (L) and a general thickness (T) and width (W). Along the length of the longitudinal axis are a series of holes **1002** and/or slots **1003**, which accommodate bone fixation screws or pins. The apertures may be threaded to

accommodate locking screws, through-holes to accommodate lag screws, or slots to facilitate dynamic compression of the fracture site. One side of the apertures may be filleted, chamfered, countersunk, or counterbored to accommodate the head of bone screw. The apertures may all have the same geometry or may have different geometry. Some apertures **1004** may be significantly smaller than others to accommodate a plate-holding mechanism to be used during surgical insertion or they may be used to accommodate a k-wire or pin to aid in surgical insertion.

Along the length of the plate, there may be one or more fillets or scallops **1005** to allow pre-bending of the plate. One end of the fracture plate may be tapered into the shape of a bullet **1006** to allow for the plate to bluntly pass through soft tissue during surgical insertion. As shown, the other end of the plate is shaped and contoured specifically for affixation to the distal femur depicted by a larger width **1007**. While most of the illustrations contained herein show fracture plates for the distal femur, it is also contemplated that these features may be used in any fracture plate for any bone and any region of any bone and any fracture, such as the exemplary illustration depicted in FIGS. **61a** and **61b**. The plate may include, for example, a “cobra-head,” or alternatively may contain multiple bullet tips **1006**, such as the plate depicted in FIG. **61a**. The plate may also, for example, contain multiple elastic regions. FIG. **61b** depicts an exemplary fracture plate containing two elastic regions **1008**. Other embodiments may contain more than two elastic regions.

In the distal femoral plate, the distal end contains multiple holes, not positioned strictly along the longitudinal axis of the plate, and allows for the plate to mate with complex anatomic features. The distal femur plate shown would mate with the lateral condyles of the distal femur. The plate may be straight or it may also be curved around multiple axes to better mate with the geometry of the particular bone to which it would be attached. The curvature of the exemplary distal femur plate shown is best depicted in FIGS. **58-60**.

The embodiment also depicts an elastically deformable region **1008**, which allows a small amount of elastic deformation when a load is applied to plate. As the load is applied to the plate, the elastic region deforms, and thus will load share with the fracture, leading to more effective healing. The elastic regions depicted in FIGS. **57-64b** include a “serpentine” shape **1009** that attaches a proximal portion of the plate **1010** to a distal portion of the plate **1011**. As shown, the serpentine shape includes multiple horizontal “rungs” **1012** that are oriented substantially perpendicular to the longitudinal axis of the plate. Each rung is attached at alternating left and right sides by a curved portion **1013** that is substantially along the longitudinal axis of the plate. The spacing between the rungs, termed rung spacing **1014**, may extend entirely through the thickness of the plate and may also extend through one of the lateral sides of the plate, termed the origination of the rung spacing **1015**. At least one rung spacing originates at the edge of the plate **1016** and at least one rung spacing originates at the opposite edge of the plate **1017**. Each terminates within the plate, termed the termination of the rung spacing **1018**. The termination of the rung spacing may have a radius. In FIG. **62**, this radius **1019** is greater than half of the height of the rung spacing **1014**. As shown, there are two rung spacing originations at the right side of the plate and two rung spacing originations at the left side of the plate. The rung spacing terminations may be located along the longitudinal axis or it may be located lateral to the longitudinal axis.

FIG. **63** shows an alternative embodiment including rung spacing terminations **1018** that have a radius that is equal to the height of the rung spacing. FIGS. **64a** and **64b** show an alternative embodiment including the elastic mechanism that includes a second strut **1020**. The second strut is obtained by placing a hole **1021** through the curved portion **1013** of the elastically deformable regions **1008**. The size and location of the hole relative to the struts dictates the mechanical properties of the elastically deformable section of the plate. FIG. **64a** shows an embodiment with the elastic member having substantially planar sides **1013b** on the lateral side of the curved portion **1013** of the fracture plate. FIG. **64b** shows an embodiment with the elastic member having substantially curved sides **1013c** on the lateral side of the curved portion **1013** of the fracture plate.

FIG. **65** depicts another embodiment of the elastically deformable region **1008**, which includes slots extending from the left **1022** and right **1023** sides of the plate, each terminating with a radius **1024** that is equal to or greater than half of the height of the slots **1014**. As shown, there is one slot extending from one edge and one slot extending from the opposite edge; however, there may be more than one slot extending from each edge. The slots are symmetric about the longitudinal axis of the plate; however, it is also contemplated that the slots may be asymmetric about the axis.

Another embodiment of the elastically deformable region **1008** is depicted in FIG. **66**. As shown, the serpentine shape **1009**, is oriented ninety degrees from the serpentine shape depicted in FIG. **57-65**, such that there are two connections between the proximal **1010** and distal portions **1011** of the plate.

FIG. **67** shows an alternative embodiment of the elastically deformable region **1008**. In this figure, two curvilinear members **1025**, **1026** are attached to the proximal **1010** and distal **1011** portions of the plate. These curvilinear members may have relatively large radii of curvature **1027**, as depicted in FIG. **67**, or relatively small radii or curvature **1028** as depicted in FIG. **68**. The shape of the curvilinear members facilitates elastic deformation of the plate in the region of the members to promote load-sharing with the fracture site and enhanced bone healing.

FIGS. **69-72** show an alternative embodiment where the elastically deformable section of the plate is modular **1029** and connects the proximal and distal portions of the plate through an engagement mechanism such as sliding dovetail **1030** connection or square slot or tapered slot. The proximal **1031** and distal **1032** portions of the plate are static while the elastically deformable section allows elastic deformation under physiologic loading. At the time of surgery, the surgeon can choose the middle section of the plate and select from an array of stiffnesses ranging from static to highly elastically deformable. The middle section is then inserted between the proximal and distal ends of the plate and the plate is affixed to the bone using bone screws or pins as is typical of ORIF. Using this embodiment, the surgeon can select the stiffness of the plate for each individual patient. The elastic section of the plate can take any of the embodiments depicted in FIGS. **57-72** or could also be comprised of an elastically deformable solid material such as a polymer, elastomer, or composite **1033**, as depicted in FIG. **73**.

In FIGS. **57-61a** and **62-73**, the fracture plate is depicted to have a single elastically deformable region; however, it is understood that each plate may contain more than one elastically deformable regions.

While the preferred and alternative embodiments described herein include a metallic material, such as titanium or stainless steel alloy, it is understood that the same

design is achievable through use of an elastic, hyperelastic, or deformable polymer, elastomer, ceramic, or composite.

FIGS. 74-77 show a dynamic spinal fixation plate including at least one elastic, component whose shape facilitates screw fixation to bony vertebral bodies and also facilitates controlled deformation in axial compression, lateral bending, and flexion/extension while maintaining a high level of rigidity in the anterior/posterior direction. The dynamic spinal fixation plate includes a spring-like element that is shaped to match the curvature of the spine in the sagittal (FIG. 76) and axial (FIG. 77) planes or may be in any other shape which is advantageous to promote stability or arthrodesis of the spine. The spring-like element allows elastic deformation primarily in the axial (flexion-extension) direction.

The spring-like element is largely serpentine in shape 1101 and consists of horizontal members 1102 that are connected at the lateral aspect 1103 to each other.

The spring-like element includes a cross-section that may be circular, elliptical, square, rectangular, or other uniform or non-uniform geometric shape. In an embodiment, the cross-section is primarily rectangular with radii at the corners 1104 (FIG. 78). The spring-like element may be of uniform geometry along its length or may become thicker, thinner, or may change shape along its length. For example, the spring-like element may be thicker (have larger cross-sectional dimensions) near the lateral aspect 1105 of the plate and may be thinner (have smaller cross-sectional dimensions) near the central aspect of the plate 1102. In one embodiment, the height of the cross-section is larger along the central aspects 1102 than at least one portion of the lateral aspects 1106. In another embodiment, the internal radius of the curved portion 1107 is equal to or greater than half of the distance between horizontal portions 1108, as depicted in FIG. 79.

In the preferred embodiment, the elastic region attaches to each slot on opposite sides of midline. For example, the elastic region attaches to the left side of the superior slot 1109 and to the right side of the inferior slot 1110. This is critical to the function of the plate in that it will result in symmetric deformation when an external load is placed on the plate. As such, the implant is asymmetric in sagittal, coronal, and transverse planes.

The elastic component is comprised of a high proportion of "open area," due to the comparatively larger radii 1107 at the curved portion, allowing easy visualization through the plate. The plate further includes elastic compliance and can be pre-compressed or pre-distorted, then attached to the vertebrae to facilitate pre-distraction or pre-compression of one or more motion segments of the spine, respectively.

An embodiment of the implant includes more rigid platform sections 1111 for affixing the implant to the vertebrae. The platform sections generally have a closed geometry such as a circle, ellipse, square, rectangle, or other geometry which facilitates placement of bone screws through it. In the example shown in FIG. 75, there are three "slots," one each located in proximity to the superior and inferior regions and one located centrally, and each oriented primarily transverse to the coronal plane. Each slot accommodates two bone screws. For single level plates, there is only the superior and inferior slot on the plate, as shown in FIGS. 80-82b. As the number of fixation levels increases incrementally, the number of slots will also incrementally increase up to a total of six slots (not shown). In another embodiment, each platform section may contain one or more circular apertures, which each accommodate a single bone screw.

In some embodiments, the slots also contain a central "relief" 1112, which has a diameter that is greater than the diameter of the head of the bone fixation screw. This allows the screws to be inserted into the vertebral body before the plate is inserted into the surgical site. The plate can then be placed over the screw head and then translated into its final position.

FIGS. 74-95 depict embodiments that contain an elastic region that includes lateral sides that are curvilinear. In another embodiment, as depicted in FIG. 82b, the curved portion 1103 include substantially planar portions 1103b and 1103c on the lateral sides of the plate. One embodiment may include portions that are entirely curved, entirely straight, or a combination thereof.

As shown in the detailed section view in FIG. 83, the slots contain a hemispherical portion 1113 that mates with a hemispherical screw head. Each slot also contains an anti-backout feature 1114. Along the superior and inferior margins of each slot, there is a "lip." Each lip is angled/shaped such that the screw passes by it more easily upon insertion than it does upon removal. Insertion of the screws into the slots, allow the lip to partially flex out of the way during screw insertion and may partially plastically deform. The plate is monolithic. Importantly, the lip prevents the screw from backing-out of the slots and allows for variable angles of insertion of the screws. In addition, the screws remain "rotationally dynamic" once inserted.

In an alternative embodiment, as shown in FIGS. 84-86, the curved portion of the elastic region consist of a second strut 1115, which connects the two horizontal portions. The strut is formed by placing a hole 1116 through the curved portion 1103 of the elastic region.

In another embodiment, shown in FIGS. 87-89, at least one of the slots contain at least one additional support member 1117. In the embodiment shown, the center slot contains a support member that is substantially vertical and connects the superior portion of the slot with the inferior portion of the slot. Although this embodiment depicts the central slot with the support member, it is understood that any slot may contain the member. In this embodiment, there are reliefs 1118 at the junction of the support member and its attachment point on the slot. This relief may reduce stresses at the junction during mechanical loading.

In another embodiment, shown in FIG. 90, the central slot contains an additional support member 1117, but does not contain stress reliefs at the junction of the member and the slot.

In yet another embodiment, shown in FIG. 91, the central slot does not contain an additional support member. It also does not contain the central relief 1112 as depicted in FIGS. 74-88. In this embodiment, the slot extends between lateral sides of the plate and the anti-back-out lip 1114 extends substantially along the superior and inferior aspects of the slot.

In another embodiment, the spinal fixation system contains multiple components that can be assembled during the manufacturing process or intraoperatively. FIGS. 92-95 depict an embodiment where the slots 1119a and 1119b and the elastic member 1120 are separate components. The elastic component connects the proximal and distal portions of the plate through an engagement mechanism such as sliding dovetail 1121 connection or square slot or tapered slot. The proximal 1119a and distal 1119b portions of the plate are static while the elastically deformable section allows elastic deformation under physiologic loading. At the time of surgery, the surgeon can choose the elastic section of the plate and select from an array of stiffnesses ranging from

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static to highly elastically deformable. The middle section is then inserted between the superior and inferior ends of the plate and the plate is affixed to the bone using bone screws or pins as is typical of ORIF. Using this embodiment, the surgeon can select the stiffness of the plate for each individual patient. The elastic section of the plate can take the form of any of the embodiments depicted in FIGS. 74-91 or could also include an elastically deformable solid material such as a polymer, elastomer, or composite.

While the above detailed description of the invention is in the context of the cervical spine, it is understood that the same design is scalable for use in the lumbar spine for anterior interbody lumbar fusion (ALIF) or dynamic stabilization of the lumbar spine.

While the preferred and alternative embodiments include a metallic material, it is understood that the same design is achievable through use of an elastic, hyperelastic, or deformable polymer, ceramic, or composite.

The invention has been described with reference to the preferred embodiments. It will be understood that the architectural and operational embodiments described herein are exemplary of a plurality of possible arrangements to provide the same general features, characteristics, and general system operation. Modifications and alterations will occur to others upon a reading and understanding of the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations.

What is claimed is:

1. An implant, comprising:

a first attachment portion at a first end of the implant including a first opening;

a second attachment portion at a second end of the implant including a second opening; and

an intermediate portion connected to and extending between the first and the second attachment portions along a longitudinal axis of the implant, the intermediate portion configured to elastically compress under compressive loads in a longitudinal direction extending along the longitudinal axis and elastically elongate under tensile loads in the longitudinal direction, wherein the intermediate portion extends along only a single serpentine path in the longitudinal direction and a lateral direction that extends perpendicular to the longitudinal direction, the intermediate portion comprising:

at least two laterally-oriented portions that extend across the longitudinal axis; and

a plurality of connecting portions that extend at least in the longitudinal direction that define a maximum lateral width of the intermediate portion, a pair of the connecting portions being disposed on lateral ends of each of the laterally-oriented portions on opposing lateral sides of the longitudinal axis and extending in opposing directions at least along the longitudinal direction,

wherein the connecting portions space adjacent laterally-oriented portions along the longitudinal direction, space a first laterally-oriented portion from the first attachment portion along the longitudinal direction, and space a second laterally-oriented portion from the second attachment portion along the longitudinal direction, and

wherein adjacent laterally-oriented portions and a respective connecting portion extending therebetween form a laterally-oriented opening therebetween that extends across the longitudinal axis from a respective lateral

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side of the intermediate portion and is open at the respective lateral side of the intermediate portion, adjacent laterally-oriented openings extending from opposing lateral sides of the intermediate portion.

2. The implant of claim 1, wherein at least one of:

the first opening comprises a first relief; and

the second opening comprises a second relief.

3. The implant of claim 2, further comprising a first bone screw with a shaft portion and a head portion and a second bone screw with a shaft portion and a head portion, wherein the first opening defines the first relief which is configured such that the head portion of the first bone screw can pass through the first opening when aligned with the first relief, and wherein the second opening defines the second relief which is configured such that the head portion of the second bone screw can pass through the second opening when aligned with the second relief.

4. The implant of claim 1, wherein the first opening is configured to receive at least a portion of a first bone fastener therethrough, and the second opening is configured to receive at least a portion of a second bone fastener there-through.

5. The implant of claim 1, wherein the first opening comprises:

a first length measured along the longitudinal direction; and

a first width measured along the lateral direction, wherein the first width is larger than the first length.

6. The implant of claim 5, wherein the second opening comprises:

a second length measured along the longitudinal direction; and

a second width measured along the lateral direction, wherein the second width is larger than the second length.

7. The fixation system of claim 1, wherein at least one of the laterally-oriented portions is centered on the longitudinal axis.

8. The fixation system of claim 1, wherein the laterally-oriented portions are aligned with each other along the lateral direction.

9. The fixation system of claim 1, wherein each of the laterally-oriented portions define opposing exposed laterally extending side surfaces that define a width of the laterally-oriented portions along the longitudinal direction.

10. The fixation system of claim 9, wherein the opposing exposed laterally extending side surfaces extend linearly and across the longitudinal axis.

11. The fixation system of claim 1, wherein the entirety of each connecting portion is positioned on a respective lateral side of the longitudinal axis.

12. The fixation system of claim 1, wherein the connecting portions comprise concave inner side surfaces that define lateral ends of the laterally-oriented openings.

13. The fixation system of claim 12, wherein the concave inner side surface of each connecting portion is defined by a radius with a center that is positioned on the same lateral side of the longitudinal axis as the respective connecting portion.

14. The fixation system of claim 1, wherein the connecting portions comprise outer side surfaces that define outer lateral ends of the connecting portions, at least one of the outer side surfaces being curved.

15. The fixation system of claim 1, wherein the connecting portions comprise outer side surfaces that define outer lateral ends of the connecting portions, at least one of the outer side surfaces being linear or rectilinear.

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16. The fixation system of claim 15, wherein the connecting portions comprise arcuately concave inner side surfaces that oppose the outer side surfaces thereof, the inner side surfaces defining lateral ends of the laterally-oriented openings.

17. The fixation system of claim 1, wherein the first attachment portion, the second attachment portion and the intermediate portion define top and bottom surfaces that define the top and the bottom extent of the implant, and wherein the top and bottom of the implant are curved along the lateral direction.

18. The fixation system of claim 1, wherein the first attachment portion, the second attachment portion and the intermediate portion define top and bottom surfaces that define the top and the bottom extent of the implant, and wherein the top and bottom of the implant are curved along the longitudinal direction.

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19. The fixation system of claim 1, comprising at least four laterally-oriented portions and at least five of the connecting portions that form at least three laterally-oriented openings.

20. The fixation system of claim 1, wherein the first attachment portion, the second attachment portion and the intermediate portion are integral.

21. The fixation system of claim 1, wherein at least one of the connecting portions comprises a laterally-exterior portion and a laterally-interior strut portion that is spaced from the laterally exterior portion along the lateral direction toward the longitudinal axis.

22. The fixation system of claim 1, wherein each of the connecting portions comprises a laterally-exterior portion and a laterally-interior strut portion that is spaced from the laterally exterior portion along the lateral direction toward the longitudinal axis.

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