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(54) Title: IMPLANT WITH CURVED BONE CONTACTING ELEMENTS

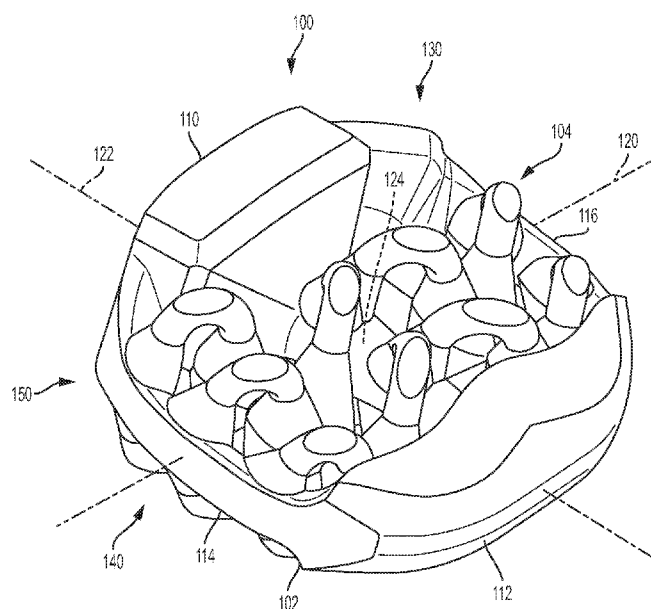


FIG. 1

(57) Abstract: An implant that includes a body and a plurality of arched bone contacting elements is disclosed. The body includes a peripheral structure and three support beams extending in a central region of the peripheral structure. Arched bone contacting elements extend between adjacent beams and between beams and the peripheral structure. The arched bone contacting elements include flared legs. The arched bone contacting elements may be arranged in V-like configurations on the superior and inferior sides.



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## **IMPLANT WITH CURVED BONE CONTACTING ELEMENTS**

### **RELATED APPLICATIONS**

**[0001]** This application is a continuation-in-part of McShane, III et al., U.S. Patent Application Publication No. 2017/0042697, published on February 16, 2017, and entitled "Implant with Arched Bone Contacting Elements," which is a continuation-in-part of Morris et al., U.S. Publication Number 2016/0324656, published on November 10, 2016, and entitled "Coiled Implants and Systems and Methods Thereof," which application claims priority to U.S. Provisional Application Number 62/154,599, filed April 29, 2015, U.S. Provisional Application Number 62/217,542, filed September 11, 2015, and U.S. Provisional Application Number 62/301,546, filed February 29, 2016. This Application also claims priority to U.S. Provisional Application Number 62/412,657, filed October 25, 2016. Each of the above-listed applications is incorporated herein by reference.

### **BACKGROUND**

**[0002]** The embodiments are generally directed to implants for supporting bone growth in a patient.

**[0003]** A variety of different implants are used in the body. Implants used in the body to stabilize an area and promote bone ingrowth provide both stability (i.e. minimal deformation under pressure over time) and space for bone ingrowth.

**[0004]** Spinal fusion, also known as spondylodesis or spondylosyndesis, is a surgical treatment method used for the treatment of various morbidities such as degenerative disc disease, spondylolisthesis (slippage of a vertebra), spinal stenosis, scoliosis, fracture, infection or tumor. The aim of the spinal fusion procedure is to reduce instability and thus pain.

**[0005]** In preparation for the spinal fusion, most of the intervertebral disc is removed. An implant, the spinal fusion cage, may be placed between the

vertebra to maintain spine alignment and disc height. The fusion, i.e. bone bridge, occurs between the endplates of the vertebrae.

**[0006]** Wedge implants may also be used in other parts of the body to fuse adjacent bones other than vertebrae, or to fuse segments of a single bone such as for an opening wedge osteotomy. For example, wedge implants may also be used for osteotomy procedures, as well as sacroiliac (S.I.) joint fusion or stabilization procedures.

## SUMMARY

**[0007]** In one aspect, an implant includes a body, a first arched bone contacting element having two ends attached to the body; and a second arched bone contacting element having two ends attached to the body.

**[0008]** In another aspect, an implant includes a body including a lateral axis. The implant also includes a first arched bone contacting element oriented at a first angle with respect to the lateral axis and a second arched bone contacting element oriented at a second angle with respect to the lateral axis. The first angle is different from the second angle.

**[0009]** In another aspect, an implant includes a body comprising a peripheral structure, a first support beam and a second support beam. The peripheral structure bounds an interior region and the first support beam and the second support beam span the interior region. The implant also includes a first arched bone contacting element extending from a portion of the peripheral structure to the first support beam and a second arched bone contacting element extending from the first support beam to the second support beam.

**[0010]** In another aspect, an implant includes a body having a leading edge portion, a trailing edge portion, and an intermediate portion extending between the leading edge portion and the trailing edge portion. The leading edge portion includes a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion. The trailing edge portion includes a monolithic structure including at least one receptacle configured to receive an insertion tool. In addition, the intermediate portion includes a plurality of elongate curved structural members.

**[0011]** In another aspect, an implant includes a body having a leading edge portion, a trailing edge portion, and an intermediate portion extending between the leading edge portion and the trailing edge portion. The leading edge portion includes a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion. The trailing edge portion

includes a monolithic structure including at least one receptacle configured to receive an insertion tool. In addition, the implant further includes at least one elongate substantially spiral member forming perimeter portions of the implant extending between the leading edge portion and the trailing edge portion.

**[0012]** In another aspect, an implant includes a body having a leading edge portion, a trailing edge portion, and an intermediate portion extending between the leading edge portion and the trailing edge portion. The leading edge portion includes a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion. The trailing edge portion includes a monolithic structure including at least one receptacle configured to receive an insertion tool. In addition, the implant includes at least one support beam extending between the leading edge portion and the trailing edge portion. Further, the implant includes at least one elongate substantially helical member extending between the leading edge portion and the trailing edge portion.

**[0013]** Other systems, methods, features and advantages of the embodiments will be, or will become, apparent to one of ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description and this summary, be within the scope of the embodiments, and be protected by the following claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** The embodiments can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the embodiments. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

**[0015]** FIG. 1 is a schematic isometric view of an embodiment of an implant;

**[0016]** FIG. 2 is a schematic isometric view of an embodiment of an implant;

**[0017]** FIG. 3 is a schematic isometric view of an embodiment of an implant;

**[0018]** FIG. 4 is a schematic superior view of a body of the implant of FIG. 1;

**[0019]** FIG. 5 is a schematic isometric view of the body of FIG. 4;

**[0020]** FIG. 6 is a schematic anterior view of an embodiment of an implant;

**[0021]** FIG. 7 is a schematic posterior view of an embodiment of an implant;

**[0022]** FIG. 8 is a schematic view of an arched bone contacting element including several schematic cross-sections, according to an embodiment;

**[0023]** FIG. 9 is a schematic view of an implant including an enlarged schematic view of the attachment region between an arched bone contacting element and a portion of a body of the implant, according to an embodiment;

**[0024]** FIG. 10 is a schematic superior view of the implant of FIG. 1;

**[0025]** FIG. 11 is a schematic superior view of another embodiment of an implant;

**[0026]** FIG. 12 is a schematic isometric view of another embodiment of an implant;

- [0027]** FIG. 13 is a schematic superior view of the implant of FIG. 12;
- [0028]** FIG. 14 is a schematic isometric view of an embodiment of an implant including a roughened surface;
- [0029]** FIG. 15 is a schematic view of a roughened surface region, according to an embodiment;
- [0030]** FIG. 16 is a schematic illustration of an osteotomy procedure involving implantation of a wedge implant;
- [0031]** FIG. 17 is a schematic leading edge perspective view of an embodiment of an implant;
- [0032]** FIG. 18 is a schematic trailing edge perspective view of the implant shown in FIG. 17;
- [0033]** FIG. 19 is a schematic lateral view of the implant shown in FIG. 17;
- [0034]** FIG. 20 is a schematic leading edge view of the implant shown in FIG. 17;
- [0035]** FIG. 21 is a schematic trailing edge view of the implant shown in FIG. 17;
- [0036]** FIG. 22 is a schematic leading edge perspective view of another embodiment of an implant;
- [0037]** FIG. 23 is a schematic illustration of another osteotomy procedure involving implantation of a wedge implant;
- [0038]** FIG. 24 is a schematic illustration of another osteotomy procedure involving implantation of a wedge implant;
- [0039]** FIG. 25 is a schematic trailing edge perspective view of another embodiment of an implant;
- [0040]** FIG. 26 is a schematic trailing edge perspective view of another embodiment of an implant;
- [0041]** FIG. 27 is a schematic illustration of a sacroiliac joint stabilization procedure involving implantation of a wedge implant;



**[0042]** FIG. 28 is a schematic leading edge perspective view of another embodiment of an implant;

**[0043]** FIG. 29 is a schematic trailing edge perspective view of the implant shown in FIG. 28;

**[0044]** FIG. 30 is a schematic leading edge perspective view of another embodiment of an implant;

**[0045]** FIG. 31 is a schematic leading edge perspective view of another embodiment of an implant;

**[0046]** FIG. 32 is a schematic leading edge perspective view of another embodiment of an implant;

**[0047]** FIG. 33 is a schematic leading edge perspective view of another embodiment of an implant; and

**[0048]** FIG. 34 is a schematic leading edge perspective view of another embodiment of an implant.

## DETAILED DESCRIPTION

**[0050]** The embodiments described herein are directed to implants including portions for insertion within recesses in bone. The portions configured for insertion within the recesses each include a body having a substrate or central portion and a multi-layer bone interfacing lattice. The layers of the bone interfacing lattice may include elongate curved structural members. Such structural members may have any of a variety of curved configurations. For example, the structural members may include portions that are helical, spiraled, coiled, sinusoidal, arched, or otherwise curved. Examples of such curved configurations are provided in the following applications.

**[0051]** In addition to the various provisions discussed below, any of the embodiments disclosed herein may make use of any of the body/support structures, frames, plates, coils or other structures disclosed in McShane III et al., U.S. Publication Number \_\_\_\_\_, published on \_\_\_\_\_, and titled "Implant with Protected Fusion Zones," and which is incorporated herein by reference in its entirety. For purposes of convenience, this application will be referred to throughout the present application as "The Protective Fusion Zones application." (Currently U.S. Patent Application No. 15/334,022, filed on October 25, 2016; Attorney Docket No. 138-1007.)

**[0052]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates or other structures disclosed in McShane III et al., U.S. Publication Number 2017/0042697, published on February 16, 2017, and titled "Implant with Arched Bone Contacting Elements," and which is incorporated herein by reference in its entirety. (Attorney Docket No. 138-1009.)

**[0053]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates or other structures disclosed in McShane III et al., U.S. Publication Number \_\_\_\_\_, published on \_\_\_\_\_, and titled "Implant with Structural Members Arranged Around a Ring," and

which is incorporated herein by reference in its entirety and referred to herein as "The Ring application." (Currently U.S. Patent Application No. 15/457,470, filed on March 13, 2017; Attorney Docket No. 138-1012.)

**[0054]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates, or other structures disclosed in Morris et al., U.S. Publication Number 2016/0324656, published on November 10, 2016, and titled "Coiled Implants and Systems and Methods of Use Thereof," and which is incorporated herein by reference in its entirety and referred to herein as "The Coiled Implant Application." (Attorney Docket No. 138-1024.)

**[0055]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates, or other structures disclosed in Nyahay et al., U.S. Publication Number \_\_\_\_\_, published on \_\_\_\_\_, and entitled "Implant with Bone Contacting Elements Having Helical and Undulating Planar Geometries," and which is incorporated herein by reference in its entirety. (Currently U.S. Patent Application No. 15/457,515, filed on March 13, 2017; Attorney Docket No. 138-1037.)

**[0056]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates, or other structures disclosed in Nyahay et al., U.S. Publication Number \_\_\_\_\_, published on \_\_\_\_\_, and entitled "Corpectomy Implant," and which is incorporated herein by reference in its entirety. (Currently U.S. Patent Application No. 15/457,550, filed on March 13, 2017; Attorney Docket No. 138-1042.)

**[0057]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates, or other structures disclosed in Bishop et al., U.S. Publication Number \_\_\_\_\_, published on \_\_\_\_\_, and entitled "Implant with Supported Helical Members," and which is incorporated herein by reference in its entirety. (Currently U.S. Patent Application No. 15/457,485, filed on March 13, 2017; Attorney Docket No. 138-1043.)

**[0058]** Also, any of the embodiments disclosed herein may make use of any of the body/support structures, elements, frames, plates, or other structures

disclosed in \_\_\_\_\_ et al., U.S. Publication Number \_\_\_\_\_, published on \_\_\_\_\_, and entitled "\_\_\_\_\_" and which is incorporated herein by reference in its entirety. (Currently U.S. Patent Application No. \_\_\_\_\_, filed on \_\_\_\_\_; Attorney Docket No. 138-1046.)

**[0059] Introduction to Implant**

**[0060]** FIGS. 1-3 illustrate isometric views of an embodiment of implant 100. Implant 100 may also be referred to as a cage or fusion device. In some embodiments, implant 100 is configured to be implanted within a portion of the human body. In some embodiments, implant 100 may be configured for implantation into the spine. In some embodiments, implant 100 may be a spinal fusion implant, or spinal fusion device, that is inserted between adjacent vertebrae to provide support and/or facilitate fusion between the vertebrae.

**[0061]** In some embodiments, implant 100 may include a body 102. Body 102 may generally provide a frame or skeleton for implant 100. In some embodiments, implant 100 may also include a plurality of arched bone contacting elements 104. Plurality of arched bone contacting elements 104 may be attached, and/or continuously formed (or "integrally formed") with, body 102.

**[0062]** As used herein, each arched bone contacting element comprises a distinctive member or element that spans a region or area of an implant. In some embodiments, these elements may overlap or intersect, similar to elements in a lattice or other 3D mesh structure. In other embodiments, the elements may not overlap or intersect. Some embodiments may use elements in which the length of the element is greater than its width and its thickness. For example, in embodiments where an element has an approximately circular cross-sectional shape, the element has a length greater than its diameter. In the embodiments seen in FIGS. 1-3, each arched bone contacting element is seen to have an approximately rounded or circular cross-sectional shape (i.e., the element has the geometry of a solid tube) along at least a portion of the element. However, in other embodiments, an element could have any other cross-sectional shape, including, but not limited to various polygonal cross-sectional shapes, as well as

any other regular and/or irregular cross-sectional shapes. In some cases, for example, the cross-sectional shape of an arched bone contacting element could vary along its length (e.g., the diameter or shape could change along its length).

**[0063]** For purposes of clarity, reference is made to various directional adjectives throughout the detailed description and in the claims. As used herein, the term “anterior” refers to a side or portion of an implant that is intended to be oriented towards the front of the human body when the implant has been placed in the body. Likewise, the term “posterior” refers to a side or portion of an implant that is intended to be oriented towards the back of the human body following implantation. In addition, the term “superior” refers to a side or portion of an implant that is intended to be oriented towards a top (e.g., the head) of the body while “inferior” refers to a side or portion of an implant that is intended to be oriented towards a bottom of the body. Reference is also made herein to “lateral” sides or portions of an implant, which are sides or portions facing along lateral directions of the body following implantation.

**[0064]** In FIGS. 1-3, implant 100 is understood to be configured with an anterior side 110 and a posterior side 112. Implant 100 may also include a first lateral side 114 and a second lateral side 116 that extend between the posterior side 112 and the anterior side 110 on opposing sides of implant 100. Furthermore, implant 100 may also include a superior side 130 and an inferior side 140.

**[0065]** Reference is also made to directions or axes that are relative to the implant itself, rather than to its intended orientation with regards to the body. For example, the term “distal” refers to a part that is located further from a center of an implant, while the term “proximal” refers to a part that is located closer to the center of the implant. As used herein, the “center of the implant” could be the center of mass and/or a central plane and/or another centrally located reference surface.

**[0066]** As used herein, the term “fixedly attached” shall refer to two components joined in a manner such that the components may not be readily separated (for example, without destroying one or both components).

**[0067]** An implant may also be associated with various axes. Referring to FIG. 1, implant 100 may be associated with a lateral axis 120 that extends along implant 100 between first lateral side 114 and second lateral side 116. Additionally, implant 100 may be associated with a posterior-anterior axis 122 that extends between posterior side 112 and anterior side 110. Moreover, implant 100 may be associated with a vertical axis 124 that extends along the thickness dimension of implant 100 and which is generally perpendicular to both lateral axis 120 and posterior-anterior axis 122.

**[0068]** An implant may also be associated with various reference planes or surfaces. As used herein, the term “median plane” refers to a vertical plane which passes from the anterior side to the posterior side of the implant, dividing the implant into right and left halves, or lateral halves. As used herein, the term “transverse plane” refers to a horizontal plane located in the center of the implant that divides the implant into superior and inferior halves. As used herein, the term “coronal plane” refers to a vertical plane located in the center of the implant that divides the implant into anterior and posterior halves. In some embodiments, the implant is symmetric about two planes, such as the transverse plane.

**[0069] Peripheral Structure**

**[0070]** In some embodiments, a body may comprise a peripheral structure and one or more support beams that extend from the peripheral structure. A peripheral structure may be comprised of any number of plates, walls or similar structures. In some embodiments the peripheral structure could comprise a ring. In other words, in some embodiments, the peripheral structure could be a peripheral ring structure. As seen in FIGS. 1-3, body 102 may be further comprised of a peripheral structure 150. Peripheral structure 150 is seen to have a ring-like geometry.

**[0071]** FIG. 4 is a schematic isometric view of body 102 shown in isolation without any arched bone contacting elements and FIG. 5 is a schematic top view of body 102 in isolation from any arched bone contacting elements. Referring to FIGS. 4-5, peripheral structure 150 may be further comprised of an anterior side 152, a posterior side 154, a first lateral side 156 and a second lateral side 158. As seen in FIGS. 1-2, in this exemplary embodiment, peripheral structure 150 is a continuous structure so that anterior side 152 is connected to first lateral side 156, first lateral side 156 is connected to posterior side 154, posterior side 154 is connected to second lateral side 158 and second lateral side 158 is connected to anterior side 152. That is, anterior side 152, first lateral side 156, posterior side 154 and second lateral side 158 together form a continuous or unbroken ring.

**[0072]** FIG. 6 is a schematic front view of implant 100 while FIG. 7 is a schematic rear view of implant 100. Referring now to FIGS. 4-7, anterior side 152 is further comprised of a first anterior portion 160 and a second anterior portion 162. First lateral side 156 extends from first anterior portion 160 of anterior side 152 to posterior side 154. Likewise, second lateral side 158 extends from second anterior portion 162 of anterior side 152 to posterior side 154.

**[0073]** First anterior portion 160 is comprised of a distal surface 164 (best seen in FIG. 6), a superior surface 166 and an inferior surface 168. First anterior portion 160 also includes a first lateral surface 170 and a second lateral surface (not shown) opposite first lateral surface 170. In addition, first anterior portion 160 includes a proximal surface 174 that is joined with a second support beam 254 as discussed below.

**[0074]** Second anterior portion 162 includes distal surface 184 (best seen in FIG. 6), a superior surface 186 and an inferior surface (not shown). Second anterior portion 162 also includes a first lateral surface 190 (see FIG. 5). In addition, second anterior portion 162 includes a proximal surface 194 that is joined with a third support beam 256 as discussed below. Moreover, second anterior portion 162 is disposed adjacent to first anterior portion 160. In some

embodiments, first anterior portion 160 and second anterior portion 162 are joined together.

**[0075]** Each of first lateral side 156 and second lateral side 158 comprise a distal surface joined with a proximal surface. In some cases, the proximal surface may be convex. For example, first lateral side 156 includes distal surface 210 and proximal surface 212, where proximal surface 212 is convex and joined directly to distal surface 210 along the superior and inferior sides of implant 100.

**[0076]** Posterior side 154 of implant 100 comprises a superior surface 200 and an inferior surface 202 (see FIG. 7). Posterior side 154 also includes a distal surface 204 and a proximal surface 206. As seen in FIG. 5, the geometry of implant 100 at posterior side 154 tapers towards first lateral side 156 and second lateral side 158.

**[0077]** In some embodiments, the vertical height or thickness of different portions of a peripheral structure could vary. In the embodiment shown in FIG. 6, which shows a front schematic view of implant 100, first anterior portion 160 is shown to have a first height 300 while second anterior portion 162 is shown to have a second height 302. Here, first height 300 is seen to be greater than second height 302. In some embodiments, this tapering in height from the centrally located first anterior portion 160 to the adjacent second anterior portion 162 helps give anterior side 152 of peripheral structure 150 a convex shape to better fit between adjacent vertebral bodies upon implantation.

**[0078]** Furthermore, as seen in FIG. 7, the height of peripheral structure 150 along posterior side 154 is indicated as third height 304. In the exemplary embodiment, third height 304 is less than first height 300. Moreover, in some cases, third height 304 may be slightly less than second height 302. In some embodiments, variations in height or vertical thickness between the posterior and anterior sides of an implant may allow for an implant with hyper-lordotic angles between the inferior and superior surfaces. In other embodiments, variations in



vertical thickness may be used to control the relative rigidity of the device in different locations.

**[0079]** In some embodiments, the thickness of peripheral structure 150 may be smaller along both of first lateral side 156 and second lateral side 158 than along either of anterior side 152 or posterior side 154. In the exemplary embodiment first lateral side 156 and second lateral side 158 have a similar fourth height 306. Here, fourth height 306 is less than first height 300, second height 302 and third height 304. By using a reduced height or vertical thickness for the lateral sides as compared to the anterior and posterior sides, it is possible to attach arched bone contacting elements to the lateral sides while maintaining a smooth vertical profile across the superior and inferior surfaces of implant 100 (see FIG. 7).

**[0080] Support Beams**

**[0081]** In some embodiments, a body may be provided with one or more support beams (or support structures) that act to reinforce a peripheral structure. In some embodiments, one or more support beams could be disposed along the interior of a peripheral structure. For example, in some embodiments, one or more support beams could extend from a first location on an inwardly (or proximally) facing surface of the support structure to a second location on the inwardly facing surface of the support structure. In other words, in some embodiments, one or more support beams may span an interior region bounded by the peripheral structure.

**[0082]** As seen in FIGS. 4-5, body 102 includes a plurality of support beams 250. These include first support beam 252, second support beam 254 and third support beam 256. In the embodiment shown in FIGS. 4-5, each of these support beams extends from a first location on inwardly facing surface 260 of peripheral structure 150 to a second location on an inwardly facing surface of peripheral structure 150. Here, it may be understood that the inwardly facing surface 260 of peripheral structure 150 is comprised of the proximal surfaces of

the various sides of peripheral structure 150 (e.g., proximal surface 174, proximal surface 194, proximal surface 212, etc.).

**[0083]** Referring to FIGS. 4-5, first support beam 252 includes a first end 270 attached to a first anterior location 271 of inwardly facing surface 260 and a second end 272 attached at a second anterior location 273 of inwardly facing surface 260. Likewise, each of second support beam 254 and third support beam 256 include opposing ends attached to different locations along inwardly facing surface 260. With this arrangement, plurality of support beams 250 are seen to span an interior region 290 (or central region) that is bounded by peripheral structure 150.

**[0084]** The plurality of support beams 250 may be characterized as being centrally located within implant 100 with respect to peripheral structure 150. As used herein, "centrally located" does not refer to a precise location that is at the geometric center or center of mass of an implant, but rather a general area or region disposed inwardly of a peripheral structure (e.g., within interior region 290). Thus, in the following description and in the claims, a support beam may be referred to as a central beam.

**[0085]** In different embodiments, the number of support beams could vary. In some embodiments, a single support beam could be used. In other embodiments, two or more support beams could be used. In the exemplary embodiment shown in FIGS. 4-5, three support beams are used.

**[0086]** In different embodiments, the orientation of one or more beams could vary. In some embodiments, two or more support beams could be oriented in parallel. In other embodiments, two or more support beams could be disposed at oblique angles to one another. In the exemplary embodiment, first support beam 252, second support beam 254 and third support beam 256 may be disposed in parallel to one another. Moreover, in the exemplary embodiment, plurality of support beams 250 may be oriented in a posterior-anterior direction (i.e., along posterior-anterior axis 122). Of course, in other embodiments, plurality of support beams 250 could be oriented in any other directions.

**[0087]** In different embodiments, the spacing, or separation, between adjacent support beams could vary. In some embodiments, the spacing between adjacent support beams could be small relative to the lateral width of an implant. For example, the spacing could range between 0% and 10% of the width of an implant. In other embodiments, the spacing between adjacent support beams could be large relative to the width of an implant. For example, the spacing could range between 10% and 95% of the width of an implant (for example, two beams located adjacent to opposing lateral sides of the implant may be spaced apart by 95% of the width of the implant). The spacing between adjacent beams (or between a beam and a portion of a peripheral structure) may be constant or may vary across an implant.

**[0088]** It may be appreciated that the relative spacing between support beams may be selected according to many factors, including the thicknesses of one or more support beams, the number of support beams used, the desired strength to weight ratio for an implant as well as other factors. Moreover, the spacing between adjacent support beams may be determined according to the dimensions of one or more arched bone contacting elements, since the arched bone contacting elements extend between adjacent support beams (or between a support beam and the peripheral structure).

**[0089]** In the embodiment shown in FIG. 4, first support beam 252 is spaced apart from first lateral side 156 by a spacing 292. First support beam 252 and second support beam 254 are spaced apart from one another by a spacing 294. Second support beam 254 and third support beam 256 are spaced apart from one another by a spacing 296. Third support beam 256 is spaced apart from second lateral side 158 by spacing 298. In the exemplary embodiment, each of spacing 292, spacing 294, spacing 296 and spacing 298 generally have a value in the range between 15% and 30% of width 199 of implant 100. Of course it may be appreciated that each spacing is an average or approximate spacing, since the spacing between adjacent components can vary, for example, along posterior-anterior axis 122.

**[0090]** In different embodiments, the geometry of one or more support beams could vary. In some embodiments, one or more support beams could have a curved geometry. In other embodiments, one or more support beams could have a substantially straight geometry. In the embodiment shown in FIGS. 4-5, each of plurality of support beams 250 has a substantially straight geometry. Moreover, the cross-sectional geometry of each support beam is substantially rounded. However, in other embodiments, one or more support beams could have any other cross-sectional shape, including but not limited to: rectangular shapes, polygonal shapes, regular shapes and/or irregular shapes. The cross-sectional shapes could also vary across a length of a support beam from, for example, a rounded cross-sectional shape (e.g., circular or elliptic) to a polygonal cross-sectional shape (e.g., rectangular).

**[0091]** In different embodiments, the thickness of one or more support beams could vary. Generally, the thickness (or diameter) of a support beam could vary in a range between 1% and 95% of the width (or length) of an implant. In the exemplary embodiment, first support beam 252, second support beam 254 and third support beam 256 have diameters in a range approximately between 2% and 15% of width 199 of implant 100, as seen in FIG. 4. More specifically, second support beam 254 has a diameter 255 that is greater than a diameter 253 of first support beam 252 and also that is greater than a diameter 257 of third support beam 256. In some cases, second support beam 254 may have the largest diameter. Because impact forces are applied at the center of implant 100 (where second support beam 254 is located) by a device coupled to implant 100 at first interior portion 160, this greater diameter for second support beam 254 may help reinforce the center of implant 100.

**[0092]** In at least some embodiments, support beams in the body of an implant may be coplanar. In FIGS. 4-5, first support beam 252, second support beam 254 and third support beam 256 are seen to reside in a similar plane of implant 100. The coplanar arrangement of support beams may help provide a

generally symmetric arrangement for implant 100 between the superior and inferior sides.

**[0093]** Generally, the geometry of one or more portions of the body of an implant could vary from one embodiment to another. For example, portions of a body can include one or more windows, slots and/or openings that may facilitate bone growth through the implant and/or may reduce weight.

**[0094] Fastening Provisions**

**[0095]** Some embodiments can include one or more fastener receiving provisions. Some embodiments can include one or more attachment openings that may engage an insertion or implantation device. In some embodiments, an implant can include one or more threaded cavities. In some embodiments, a threaded cavity can be configured to mate with a corresponding threaded tip on an implantation tool or device. In other embodiments, a threaded cavity can receive a fastener for purposes of fastening an implant to another device or component in an implantation system that uses multiple implants and/or multiple components.

**[0096]** As best seen in FIG. 6, implant 100 includes a first threaded cavity 360 disposed in first anterior portion 160. Implant 100 also includes second threaded cavity 362 disposed in second anterior portion 162. In some embodiments, first threaded cavity 360 may receive the threaded tip of an implantation tool (not shown). Such a tool could be used to drive implant 100 between adjacent vertebral bodies. Optionally, in some cases, implant 100 may also include a pair of indentations (indentation 365 and indentation 367) that may facilitate alignment between an implantation tool and implant 100. In some embodiments, second threaded cavity 362 could be used to fasten implant 100 to a separate component (not shown) of a broader implantation system. For example, some embodiments could incorporate a separate plate that may be fastened to implant 100 using a fastener secured within first threaded cavity 360 or second threaded cavity 362. Such a plate could include additional fixation members (e.g., screws) that could be used with the implant.

**[0097]     Arched Bone Contacting Elements**

**[0098]**     In some embodiments, an arched bone contacting element may include a first end portion, an intermediate portion and a second end portion. In some embodiments, the intermediate portion may have an arched geometry. In such cases, an intermediate portion having an arched geometry may be referred to as an “arched portion”. In some embodiments, the first end portion and/or the second end portion could have a flared geometry. In such cases, an end having a flared geometry may be referred to as a “flared leg” of the arched bone contacting element.

**[0099]**     FIG. 8 is a schematic view of an exemplary arched bone contacting element seen in isolation, including several enlarged schematic cross-sectional views taken at various locations of the element. Referring to FIG. 8, arched bone contacting element 400 is comprised of a first end portion, which is referred to as a first flared leg 402. Arched bone contacting element 400 is also comprised of an arched portion 404. Additionally, arched bone contacting element 400 is comprised of a second end portion, which is referred to as a second flared leg 406.

**[00100]**     In some embodiments, an arched bone contacting element can include provisions for engaging a vertebral body following implantation. In some embodiments, one or more arched bone contacting elements can include at least one distal surface region that is configured to directly contact a vertebral endplate. In some cases, a distal surface region could be a flattened surface region. In other cases, a distal surface region could be a convex surface region. In still other cases, a distal surface region could be a concave surface region. More generally, a distal surface region could have a different curvature from the adjacent surface regions of an arched portion. Moreover, the particular curvature for a distal surface region could be selected to match the local geometry of an opposing vertebral endplate.

**[00101]**     As an example, in FIG. 8, arched bone contacting element 400 is seen to include a distal surface region 490 that is located in arched portion 404. In

some embodiments, distal surface region 490 may have a convex curvature that is smaller than the curvature of adjacent regions of arched portion 404. Similarly, as best seen in FIG. 7, the remaining arched bone contacting elements of implant 100 are also configured with distal bone contacting regions having a smaller curvature than adjacent surface regions of arched portion 404 (i.e., these distal surface regions may be flatter than the remaining regions of arched portion 404, but may not be completely flat). Together, these distal bone contacting regions provide a partial smooth surface that can engage a vertebral body. Moreover, in some embodiments, the collection of flattened (or convex) bone contacting regions together form a minimal contact surface with the bone and thereby allow for an increased amount of graft material or bone growth promoting material to be placed in direct contact with the bone. Specifically, bone growth promoting material that is disposed in between arched bone contacting elements, including being disposed in the open regions along the superior and inferior surfaces, may directly contact the bone.

**[00102]** For purposes of reference, arched bone contacting element 400 may be characterized as having a curved central axis 401. As used herein, the curved central axis of an element is an axis that extends along the length of the element and is located at an approximate center of the element at each location along its length. It may be understood that the cross-sections discussed below and shown in FIG. 8 are taken along planes that are perpendicular to curved central axis 401.

**[00103]** As seen in FIG. 8, arched portion 404 has an arched geometry. Arched portion 404 is also seen to have a rounded cross-sectional shape. More specifically, in some cases, arched portion 404 has an approximately circular (or near-circular) cross-sectional shape. In some embodiments, the diameter and cross-sectional shape of arched portion 404 stays relatively constant along much of the length of arched portion 404 (i.e., along curved central axis 401). However, it may be understood that the cross-sectional shape of arched portion 404 could vary, for example, along flattened bone contacting region 490. For reference, a

cross-section of arched portion 404 taken at reference plane 471 is shown in FIG. 8. Of course, in other embodiments, arched portion 404 could have any other cross-sectional shape.

**[00104]** At each flared leg, the cross-sectional shape of arched bone contacting element 400 may vary. For example, as seen in FIG. 8, the cross-sectional shape of first flared leg 402 has a first cross-sectional shape 410 at a location adjacent arched portion 404 (taken at reference plane 472). First flared leg 402 also has a second cross-sectional shape 412 and a third cross-sectional shape 414. Here, the third cross-sectional shape 414 is taken at a location furthest from arched portion 404 (taken at reference plane 474), and second cross-sectional shape 412 is taken at an intermediate location along first flared leg 402 (taken at reference plane 473).

**[00105]** As shown in FIG. 8, the cross-sectional shape of first flared leg 402 varies from an approximately circular cross-sectional shape (i.e., first cross-sectional shape 410) to an approximately elliptic cross-sectional shape (i.e., third cross-sectional shape 414). For example, the first cross-sectional shape 410 of first flared leg 402 has a similar diameter 420 along both a first axis 430 and a second axis 432. However, the second cross-sectional shape 412 has a major diameter 422 along first axis 430 that is greater than its minor diameter 424 along second axis 432. Furthermore, the third cross-sectional shape 414 also has a major diameter 426 along first axis 430 and a minor diameter 428 along second axis 432, where major diameter 426 is greater than major diameter 422 and minor diameter 428 is greater than minor diameter 424. Thus, the cross-sectional size of first flared leg 402 increases as its shape also changes from an approximately circular shape to an approximately elliptic shape.

**[00106]** With the arrangement described above, the cross-sectional area of arched bone contacting element 400 may be a minimum in arched portion 404. Moreover, moving along curved central axis 401 from arched portion 404 to first flared leg 402, the cross-sectional area increases through first flared leg 402 until



reaching a maximum at the furthest end of first flared leg 402 (and similarly reaching a maximum at the furthest end of second flared leg 406).

**[00107]** This increase in cross-sectional area provides for a wider base for each arched bone contacting element at its attachment to the body and can thus improve the strength of the attachment between the arched bone contacting element and the body. Moreover, the variation in cross-sectional shape allows the increase in size to be primarily directed in a direction parallel with the underlying structure (e.g., a support beam or a section of the peripheral structure). For example, as seen in FIG. 9, first flared leg 402 has a longest dimension parallel with a central axis 480 of peripheral segment 482 to which first flared leg 402 is attached. Here, peripheral segment 482 is a segment of implant 499. Moreover, first flared leg 402 has a smallest dimension parallel with a widthwise axis 484 of peripheral segment 482. Thus, the surface area of the attachment between arched bone contacting element 400 and peripheral segment 482 is increased while preventing first flared leg 402 from extending beyond peripheral segment 482 in the direction of widthwise axis 484.

**[00108]** While the geometry of first flared leg 402 is discussed in detailed, it may be appreciated that second flared leg 406 may have a similar geometry to first flared leg 402. Likewise, the flared legs of the remaining arched bone contacting elements of implant 100 may also have similar geometries to first flared leg 402.

**[00109]** The particular cross-sectional geometries (circular and elliptic) illustrated for portions of an arched bone contacting element in FIG. 8 are only intended to be schematic representations of possible variations in geometry for an arched bone contacting element. In some embodiments, a flared leg could have a more irregular geometry, which while increasing in size and becoming elongated along one axis, does not have a substantially elliptic cross-sectional shape. Moreover, the cross-sectional shape could change between any two shapes at opposing ends of the flared leg. Exemplary cross-sectional shapes include, but

are not limited to: rounded (including circular and elliptic), rectangular, polygonal, regular, irregular as well as any other shapes.

**[00110]** Embodiments could include any number of arched bone contacting elements. Some embodiments may include a single arched bone contacting element. Still other embodiments could include any number of arched bone contacting elements in the range between 2 and 50. In still further embodiments, an implant could include more than 50 elements. In the exemplary embodiment shown in FIGS. 1-3, implant 100 includes 18 arched bone contacting elements, including nine elements on superior side 130 and nine elements on inferior side 140. The number of arched bone contacting elements used can vary according to factors including implant size, desired implant strength, desired volume for bone graft or other bone growth promoting materials as well as possibly other factors.

**[00111]** In different embodiments, the arrangement of arched bone contacting elements in an implant could vary. In some embodiments, arched bone contacting elements could attach to any portions of a peripheral structure, to any beams of an implant, as well as other arched bone contacting elements. In some embodiments, an arched bone contacting element could extend across the entire width of an implant. In other embodiments, an arched bone contacting element may only extend across a portion of the width of an implant.

**[00112]** In order to enhance strength in an implant, some embodiments may use arched bone contacting elements that only extend between adjacent beams or between a beam and an adjacent portion of a peripheral structure.

**[00113]** FIG. 10 is a schematic top view of implant 100. Referring to FIG. 10, plurality of arched bone contacting elements 104 includes a superior set of arched bone contacting elements 502 and an inferior set of arched bone contacting element 504 (visible in FIG. 7). Superior set 502 is further comprised of a first group of arched bone contacting elements 510 (or simply, first group 510), a second group of arched bone contacting elements 512 (or simply second group 512), a third group of arched bone contacting elements 514 (or simply third group

514) and a fourth group of arched bone contacting elements 516 (or simply fourth group 516). In the embodiment of FIG. 10, each group of arched bone contacting elements includes two or more elements that extend between the same two beams or between the same beam and the same side of peripheral structure 150.

**[00114]** As seen in FIG. 10, first group 510 includes first arched bone contacting element 521, second arched bone contacting element 522 and third arched bone contacting element 523. Each of these elements extends between first lateral side 156 of peripheral structure 150 and first support beam 252. For example, first arched bone contacting element 521 has a flared leg 531 attached to first lateral side 156 and a flared leg 532 attached to first support beam 252. Similarly, each of second arched bone contacting element 522 and third arched bone contacting element 523 have one flared leg attached to first lateral side 156 and another flared leg attached to first support beam 252.

**[00115]** Second group 512 includes fourth arched bone contacting element 524 and fifth arched bone contacting element 525. Each of these elements extends between first support beam 252 and second support beam 254. For example, fourth arched bone contacting element 524 has a flared leg 541 attached to first support beam 252 and another flared leg 542 attached to second support beam 254. Similarly, fifth arched bone contacting element 525 has a flared leg attached to first support beam 252 and another flared leg attached to second support beam 254.

**[00116]** Third group 514 includes sixth arched bone contacting element 526 and seventh arched bone contacting element 527. Each of these elements extends between second support beam 254 and third support beam 256. For example, sixth arched bone contacting element 526 has a flared leg 551 attached to second support beam 254 and another flared leg 552 attached to third support beam 256. Similarly, seventh arched bone contacting element 527 has a flared leg attached to second support beam 254 and another flared leg attached to third support beam 256.

**[00117]** Fourth group 516 includes eighth arched bone contacting element 528 and ninth arched bone contacting element 529. Each of these elements extends between third support beam 256 and second lateral side 158 of peripheral structure 150. For example, eighth arched bone contacting element 528 has a flared leg 561 attached to third support beam 256 and another flared leg 562 attached to second lateral side 158. Similarly, ninth arched bone contacting element 529 has a flared leg attached to third support beam 256 and another flared leg attached to second lateral side 158.

**[00118]** In some cases, some portions of adjacent arched bone contacting elements could be in contact or partially overlap. For example, some embodiments could have flared legs that are in contact or partially overlap. As an example, in FIG. 10, flared leg 532 is disposed adjacent to, and in partial contact with flared leg 541. It may be appreciated, though, that each arched bone contacting element attaches at its ends to portions of the body of implant 100.

**[00119]** Although the ends of two or more arched bone contacting elements may be in contact with one another, the arched portions of each element remain separated from adjacent elements. In other words, there is no intersection between the arched portions of different arched bone contacting elements. Specifically, in some embodiments, the arched portion of each arched bone contacting element may be non-intersecting or separated from one another. Also, there is no intersection of arched bone contacting elements at or near the regions where the arched bone contacting elements contact the vertebrae. Thus it may be seen that implant 100 provides a plurality of arched bone contacting elements 104 that are non-intersecting and are arranged to be in contact with an opposing vertebral surface.

**[00120]** Some embodiments may include provisions that allow a structure to be self-supporting during manufacturing, for example, when the structure is manufactured using a 3D printing process. In some embodiments, the arrangement of arched bone contacting elements may be selected to facilitate self-support during manufacturing (e.g., during a 3D printing process). In some

embodiments, the arched bone contacting elements can be arranged in angled orientations relative to the body or an axis of the body. In some embodiments, the arched bone contacting elements may be arranged into a herringbone-like pattern that is further comprised of individual V-like configurations of elements. Such a configuration may enable the implant to be printed with self-supporting structures.

**[00121]** One or more arched bone contacting elements may be angled with respect to one or more axes of an implant. Referring to FIG. 10, for example, second arched bone contacting element 522 is oriented at an oblique angle with respect to lateral axis 120 (and also with respect to posterior-anterior axis 122). Additionally, fourth arched bone contacting element 524 is oriented at an oblique angle with respect to lateral axis 120 (and also with respect to posterior-anterior axis 122). Moreover, second bone contacting element 522 and fourth bone contacting element 524 are oriented at different angles from lateral axis 122. As shown in FIG. 10, the remaining arched bone contacting elements may also be oriented at an oblique angle with respect to lateral axis 120 of implant 100. Thus it may be seen that the arched bone contacting elements are not arranged in parallel on implant 100.

**[00122]** In some embodiments, at least two arched bone contacting elements may be arranged in a V-like configuration, or pattern, on a body of an implant. For example, second arched bone contacting element 522 and fourth arched bone contacting element 524 are arranged in a first V-like configuration 600. Additionally, sixth arched bone contacting element 526 and eighth arched bone contacting element 528 are arranged in a second V-like configuration 602. Also, third arched bone contacting element 523 and fifth arched bone contacting element 525 are arranged in a third V-like configuration 604. Finally, seventh arched bone contacting element 527 and ninth arched bone contacting element 529 are arranged in a fourth V-like configuration 606. Although the present embodiment includes four V-like configurations on the superior side (i.e., superior set of arched bone contacting elements 502), as well as another four V-like

configurations on the inferior side, other embodiments could include any other number of V-like configurations on the superior side or the inferior side.

**[00123]** In different embodiments, the positioning and orientation of V-like configurations could vary. In some embodiments, all of the V-like configurations may be oriented in a similar direction. In other embodiments, two or more V-like configurations could be oriented in different directions. Moreover, in some cases, two or more V-like configurations could be arranged in rows and/or columns.

**[00124]** In the embodiment shown in FIG. 10, each V-like configuration has a common orientation corresponding to the posterior-anterior axis 122. Specifically, each configuration is arranged such that the tip of the V points along posterior-anterior axis 122 and in the direction towards posterior side 154. Moreover, first V-like configuration 600 and second V-like configuration 602 are disposed adjacent to one another in a first row such that they have different positions along lateral axis 120. Likewise, third V-like configuration 604 and fourth V-like configuration 606 are disposed adjacent to one another in a second row. Furthermore, first V-like configuration 600 and third V-like configuration 604 are disposed adjacent to one another in a first column such that they have different positions along posterior-anterior axis 122. Likewise, second V-like configuration 602 and fourth V-like configuration 606 are disposed adjacent one another in a second column. As seen in FIG. 10, when considered together, the four V-like configurations form a larger herringbone pattern 620 on body 102.

**[00125]** Each V-like configuration may be centered around a single support beam. For example, first V-like configuration 600 and second V-like configuration may be centered around first support beam 252. Also, third V-like configuration and fourth V-like configuration may be centered around third support beam 256.

**[00126]** Each V-like configuration may extend from a lateral side of body 102 to a central support beam (e.g., second support beam 254). For example, first V-like configuration 600 extends from first lateral side 156 to second support beam

254. And second V-like configuration 602 extends from second support beam 254 to second lateral side 158.

**[00127]** In some cases, orienting arched bone contacting elements into a herringbone pattern may facilitate easier insertion of the implant. In particular, by angling the arched bone contacting elements away from the lateral direction, the elements may present a smaller surface area along the implantation direction (i.e., the posterior direction), which could potentially ease insertion effort.

**[00128]** The arrangement of arched bone contacting elements may also be designed to achieve a desired total open volume. As used herein a total volume is the combined volume of any openings between arched bone contacting elements, any openings in the body, or between arched bone contacting elements and the body. This open configuration may facilitate bone growth in and through the implant. A portion or all of the open spaces is optionally filled with a bone graft or bone growth promoting material prior to or after insertion of the implant to facilitate bone growth.

**[00129]** The total volume of the open spaces (also referred to simply as the open space volume) within any particular implant is dependent on the overall dimension of the implant as well as the size and dimension of individual components within the implant including arched bone contacting elements. The open space volume may range from about 20% to 80% of the volume of the implant. In some embodiments, implant 100 may have an open space volume that is between 25% and 80% of the implant's total volume. In still further embodiments, implant 100 may have an open space volume that is between 50% and 70% of the total implant volume.

**[00130]** In some embodiments, an implant can be configured with one or more symmetries. In some cases, an implant may have a mirrored symmetry about one or more reference planes. In other cases, an implant may have a translational symmetry about one or more reference planes. In still other cases, an implant could have both a mirror symmetry and a translational symmetry.

**[00131]** Referring to FIGS. 1 and 2, implant 100 may include at least one mirror symmetry. For purposes of reference, implant 100 may be split into a superior half and an inferior half. Here, the “superior half” of implant 100 includes the portions of body 102 and plurality of arched bone contacting elements 104 disposed above the transverse plane. Likewise, the “inferior half” of implant 100 includes the portions of body 102 and plurality of arched bone contacting elements 104 disposed below the transverse.

**[00132]** With respect to the transverse plane (which coincides generally with body 102 in this embodiment), it may be seen that the superior half of implant 100 mirrors the inferior half of implant 100. This includes not only the geometry of the body but also the shape, size and orientations of each arched bone contacting element. It may be appreciated that this mirror symmetry may only be approximate in some embodiments. The symmetric configuration of implant 100, for example the mirror symmetry between the superior and inferior halves of implant 100, may help to balance loads in the vertical direction, or the direction along the length of the spine.

**[00133] Additional Embodiments**

**[00134]** In different embodiments, the dimensions of an implant can vary. Exemplary dimensions that could be varied include length, width and thickness. Moreover, in some cases, the diameter of one or more arched bone contacting elements could vary from one embodiment to another.

**[00135]** FIG. 11 is a schematic view of another embodiment of an implant 700. Implant 700 may be similar in many ways to implant 100 discussed above and shown in FIGS. 1-10. In some embodiments, implant 700 may have a greater width and length (and thus a larger overall footprint) than implant 100. In order to accommodate the larger size, implant 700 may include an additional arched bone contacting element 702 on superior side 710, as well as a corresponding element on an inferior side (not shown).

**[00136]** As seen in FIG. 11, arched bone contacting element 702 extends from support beam 720 to lateral side 722 of implant 700. With this additional



arched bone contacting element, group of arched bone contacting elements 730 on lateral side 724 is seen to have the same number of elements (i.e., three) as group of arched bone contacting elements 732 on lateral side 722. This configuration of arched bone contacting elements is thus seen to have a mirror symmetry about a central axis 740 of implant 700.

**[00137]** FIGS. 12-13 illustrate a schematic view of another embodiment of an implant 800. Implant 800 may be similar in many ways to implant 100 and implant 700 discussed above and shown in FIGS. 1-11. In some embodiments, implant 800 may have a greater width and length (and thus a larger overall footprint) than implant 700.

**[00138]** Some embodiments can include one or more arched bone contacting elements that are attached at both ends to a single support beam. Some embodiments can include one or more arched bone contacting elements that are attached to a single segment of a peripheral structure.

**[00139]** Referring to FIGS. 12-13, implant 800 is comprised of a plurality of arched bone contacting elements 804 attached to a body 802. Body 802 is further comprised of a peripheral structure 806, a first support beam 810, a second support beam 812 and a third support beam 814.

**[00140]** Referring now to FIG. 13, plurality of arched bone contacting elements 804 is further comprised of a first group of arched bone contacting elements 820 (or first group 820), a second group of arched bone contacting elements 822 (or second group 822), a third group of arched bone contacting elements 824 (or third group 824), a fourth group of arched bone contacting elements 826 (or fourth group 826), a fifth group of arched bone contacting elements 828 (or fifth group 828), a sixth group of arched bone contacting elements 830 (or sixth group 830), a seventh group of arched bone contacting elements 832 (or seventh group 832) and an eighth group of arched bone contacting elements 834 (or eighth group 834).

**[00141]** Second group 822 includes arched bone contacting elements extending from first lateral side 811 of peripheral structure 806 to first support

beam 810. Fourth group 826 includes arched bone contacting elements extending from first support beam 810 to second support beam 812. Fifth group 828 includes arched bone contacting elements extending from second support beam 812 to third support beam 814. Seventh group 832 includes arched bone contacting elements extending from third support beam 814 to second lateral side 813 of peripheral structure 806. Moreover, the arched bone contacting elements in second group 822, fourth group 826, fifth group 828 and seventh group 832 are generally arranged into V-like configurations organized into a herringbone-like pattern, similar to the arrangement of arched bone contacting elements of implant 100.

**[00142]** As implant 800 has an increased footprint compared to implant 100 and implant 700, additional arched bone contacting elements may be included to provide a larger (partial) contact surface on the superior and inferior sides of implant 800. In the embodiment shown in FIGS. 12-13, some of these additional arched bone contacting elements are added along the lateral sides of body 802 as well as first support beam 810, second support beam 812 and third support beam 814.

**[00143]** First group 820 includes an arched bone contacting element 901 and an arched bone contacting element 902, which are both connected at each end to first lateral side 811 of peripheral structure 806. Specifically, for example, arched bone contacting element 901 includes a first flared leg 911 attached to first lateral side 811 and a second flared leg 912 attached to first lateral side 811.

**[00144]** Additionally, third group 824 includes three arched bone contacting elements, each of which are attached at both ends to first support beam 810. For example, arched bone contacting element 903 includes first flared leg 921 attached to first support beam 810 and a second flared leg 922 attached to first support beam 810. Likewise, sixth group 830 includes three arched bone contacting elements. Each of these elements includes two flared legs that are both attached at third support beam 814. Additionally, eighth group 834 includes

two arched bone contacting elements. Each of these elements includes two flared legs that are both attached at second lateral side 813 of peripheral structure 806.

**[00145] Surface Texturing**

**[00146]** Embodiments can include provisions for texturing one or more surfaces of an implant. Such texturing can increase or otherwise promote bone growth and/or fusion to surfaces of the implant. In some embodiments, arched bone contacting elements and/or sections of a body may be textured.

**[00147]** In some embodiments, the surface structure of one or more regions of an implant may be roughened or provided with irregularities. Generally, this roughened structure may be accomplished through the use of acid etching, bead or grit blasting, sputter coating with titanium, sintering beads of titanium or cobalt chrome onto the implant surface, as well as other methods. In some embodiments, the roughness can be created by 3D printing a raised pattern on the surface of one or more regions of an implant. In some embodiments, the resulting roughened surface may have pores of varying sizes. In some embodiments, pore sizes could range between approximately 0.2 mm and 0.8 mm. In one embodiment, pore sizes could be approximately 0.5 mm. Of course in other embodiments, surface roughness comprising pore sizes less than 0.2 mm and/or greater than 0.8 mm are possible.

**[00148]** An embodiment using textured surfaces is shown in an isometric view of an alternative embodiment and implant 900 seen in FIG. 14. As seen in FIG. 14, implant 900 includes a smooth peripheral surface 902. The remaining surfaces of implant 900, however, have been roughened. These include the visible portions of superior surface 904, which is further comprised of superior surfaces of peripheral structure 950 and the surfaces of plurality of arched bone contacting elements 952. For purposes of illustration, the roughened surfaces are indicated schematically using stippling. These roughened or porous surfaces may help improve bone growth along surfaces of the implant. As a particular example, arched bone contacting element 960 is seen to have a roughened surface region 962 (also seen in the enlarged schematic view of FIG. 15) that extends through

the entire element including distal surface region 964 which is intended to directly contact an adjacent vertebra.

**[00149]** It may be appreciated that any of the embodiments illustrated in the Figures can include one or more roughened surfaces. For example, in some embodiments implant 100, implant 700 or implant 900 could include one or more roughened surfaces. Moreover, the roughened surfaces could be selectively applied to some portions of an implant but not others.

**[00150] Bone Growth Promoting Material**

**[00151]** In some embodiments, bone growth can be facilitated by applying a bone growth promoting material in or around portions of an implant. As used herein, a “bone growth promoting material” (or BGPM) is any material that helps bone growth. Bone growth promoting materials may include provisions that are freeze dried onto a surface or adhered to the metal through the use of linker molecules or a binder. Examples of bone growth promoting materials are any materials including bone morphogenetic proteins (BMPs), such as BMP-1, BMP-2, BMP-4, BMP-6, and BMP-7. These are hormones that convert stem cells into bone forming cells. Further examples include recombinant human BMPs (rhBMPs), such as rhBMP-2, rhBMP-4, and rhBMP-7. Still further examples include platelet derived growth factor (PDGF), fibroblast growth factor (FGF), collagen, BMP mimetic peptides, as well as RGD peptides. Generally, combinations of these chemicals may also be used. These chemicals can be applied using a sponge, matrix or gel.

**[00152]** Some bone growth promoting materials may also be applied to an implantable prosthesis through the use of a plasma spray or electrochemical techniques. Examples of these materials include, but are not limited to, hydroxyapatite, beta tri-calcium phosphate, calcium sulfate, calcium carbonate, as well as other chemicals.

**[00153]** A bone growth promoting material can include, or may be used in combination with a bone graft or a bone graft substitute. A variety of materials may serve as bone grafts or bone graft substitutes, including autografts (harvested

from the iliac crest of the patient's body), allografts, demineralized bone matrix, and various synthetic materials.

**[00154]** Some embodiments may use autograft. Autograft provides the spinal fusion with calcium collagen scaffolding for the new bone to grow on (osteoconduction). Additionally, autograft contains bone-growing cells, mesenchymal stem cells and osteoblast that regenerate bone. Lastly, autograft contains bone-growing proteins, including bone morphogenic proteins (BMPs), to foster new bone growth in the patient.

**[00155]** Bone graft substitutes may comprise synthetic materials including calcium phosphates or hydroxyapatites, stem cell containing products which combine stem cells with one of the other classes of bone graft substitutes, and growth factor containing matrices such as INFUSE® (rhBMP-2-containing bone graft) from Medtronic, Inc.

**[00156]** It should be understood that the provisions listed here are not meant to be an exhaustive list of possible bone growth promoting materials, bone grafts or bone graft substitutes.

**[00157]** In some embodiments, BGPM may be applied to one or more outer surfaces of an implant. In other embodiments, BGPM may be applied to internal volumes within an implant. In still other embodiments, BGPM may be applied to both external surfaces and internally within an implant.

**[00158] Osteotomy Implants**

**[00159]** In some embodiments, the implant may be configured for implantation as part of an opening osteotomy procedure. In such embodiments, the implant may be substantially wedge-shaped. To facilitate implantation, the leading edge (i.e., the narrow end) of the wedge may have a substantially smooth surface. In addition, in order to receive an elongate insertion tool, the trailing edge (i.e., the thicker end) of the wedge may have a monolithic structure. The monolithic structure may include a receptacle configured to receive an insertion tool, for example, via a threaded connection.

**[00160]** FIG. 16 is a schematic illustration of an osteotomy procedure involving the implantation of a wedge implant. As shown in FIG. 16, an implant 1600 may be substantially wedge-shaped. As part of an opening osteotomy procedure, a bone, such as tibia 1605, may be cut on one side, and pried open to create a recess 1610 in the bone. Implant 1600 may be inserted into recess 1610 to fill in the gap and, thereby, effectively lengthen one side of the bone. That is, the bone may have a first side 1615 and a second side 1620. Recess 1610 may be created in first side 1615, and thus, insertion of wedge-shaped implant 1600 effectively lengthens first side 1615 of tibia 1605. This lengthening of one side of a bone can correct malformations, whether congenital or due to trauma or disease. For example, the lengthening of a lateral or medial side of the tibia can correct for conditions such as bowlegs or knock-knees. Such procedures can also be used to treat osteoarthritis on one side of the knee, by shifting a person's weight to the healthy side of the knee.

**[00161]** FIG. 17 is a schematic leading edge perspective view of implant 1600. As shown in FIG. 17, implant 1600 may include a body 1625. Body 1625 may have a leading edge portion 1635, a trailing edge portion 1640, and an intermediate portion 1645 extending between leading edge portion 1635 and trailing edge portion 1640.

**[00162]** Implant 1600 may be used in osteotomy procedures in a number of anatomical locations. Accordingly, the directional references are provided with respect to a plurality of axes. In particular, implant 1600 may have a length extending from leading edge portion 1635 to trailing edge portion 1640 along a longitudinal axis 1650, as shown in FIG. 17. As also shown in FIG. 17, implant 1600 may have a width extending along a lateral axis 1655 perpendicular to longitudinal axis 1650. Further, implant 1600 may have a thickness in a third dimension along a third axis 1660 perpendicular to longitudinal axis 1650 and lateral axis 1655.

**[00163]** In some embodiments, the leading edge of the implant may include provisions to facilitate insertion of the implant between opposing sides of a

bone recess. For example, the leading edge may be provided with a bullnose feature. That is, the leading edge may include a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion.

**[00164]** As shown in FIG. 17, leading edge portion 1635 may have a leading edge surface 1665 that is substantially smooth across a substantial majority of leading edge portion 1635. In some embodiments, the substantially smooth leading edge surface 1665 may extend the entire thickness of leading edge portion 1635 in the direction of third axis 1660, as shown in FIG. 17. As further shown in FIG. 17, leading edge surface 1665 may be substantially rounded in the direction of third axis 1660. (See also FIG. 19.) As also shown in FIG. 17, in some embodiments, leading edge surface 1665 may be rounded in the direction of lateral axis 1655. (See also FIG. 18.)

**[00165]** The implant may include provisions for receiving an insertion tool. For example, some embodiments can include a monolithic structure in the trailing edge of the implant. The monolithic structure can include one or more receptacles configured to engage an insertion or implantation tool. In some embodiments, such receptacles may include female threads configured to engage insertion or implantation tools.

**[00166]** FIG. 18 is a schematic trailing edge perspective view of the implant 1600. As shown in FIG. 18, trailing edge 1640 may include a monolithic structure 1670. Monolithic structure 1670 may including a receptacle 1675 configured to receive an insertion tool (see, e.g., FIG. 24 for an exemplary insertion tool). In some embodiments, receptacle 1675 may include female threading 1676 configured to receive male threading on an insertion tool.

**[00167]** The implant may include provisions to promote bone ingrowth. For example, in some embodiments, the implant may include a plurality of elongate curved structural members. Spaces may be defined between the elongate curved structural members to permit bone ingrowth in between and around the elongate curved structural members. In some embodiments, the

elongate curved structural members may have any of a variety of curved configurations. For example, the structural members may include portions that are helical, spiraled, coiled, sinusoidal, arched, or otherwise curved.

**[00168]** As shown in FIG. 18, in some embodiments, implant 1600 may include one or more elongate curved structural members 1680. As shown in FIG. 18, elongate curved structural members 1680 may be substantially spiral members, such as a first spiral member 1685 and a second spiral member 1690. The two spiral members may be substantially concentric about third axis 1660. For example, as shown in FIG. 18, first spiral member 1685 may be an outer spiral forming perimeter portions of implant 1600 extending between leading edge portion 1635 and trailing edge portion 1640. Second spiral member 1690 may be an inner spiral. As shown in FIG. 18, first spiral member 1685 and second spiral member 1690 may have substantially the same gauge (e.g., wire diameter). In other embodiments, first spiral member 1685 and second spiral member 1690 may be formed with different gauges.

**[00169]** Elongate curved structural members 1680 may provide longitudinal compressive strength to implant 1600. That is, since implant 1600 is inserted in the direction of longitudinal axis 1650 by pushing it toward leading edge portion 1635 with an insertion tool from trailing edge portion 1640, implant 1600 may be subjected to significant longitudinal compressive forces. Accordingly, elongate curved structural members 1680 may be configured to withstand such compressive forces and to maintain an amount of rigidity that enables insertion of leading edge portion 1635 without buckling or undue compression of intermediate portion 1645. Accordingly, the gauge, material, and geometrical shape of elongate curved structural members 1680 may be selected to provide the longitudinal compressive strength desired for the intended implantation location.

**[00170]** First spiral member 1685 may have a substantially tapered thickness in the direction of third axis 1660, providing implant 1600 with its substantially wedge-shaped configuration. As shown in FIG. 18, second spiral member 1690 may have a substantially constant thickness in the direction of third



axis 1660. Due to one spiral member having a tapered thickness and the other spiral member having a constant thicknesses, in at least one area of the implant, the two spirals will have different thicknesses. For example, one end of the implant may be provided with a difference in thickness of the two spirals. As shown in FIG. 18, in the leading edge end of implant 1600, first spiral member 1685 and second spiral member 1690 may have substantially the same thickness, whereas, in the trailing edge end of implant 1600, first spiral member 1685 and second spiral member 1690 have different thicknesses, with first spiral member 1685 having a larger thickness than second spiral member 1690. In the configuration of FIG. 18, with an inner spiral member having a smaller thickness than the outer spiral member, a hollowed central region 1691 of implant 1600 may be provided, which may facilitate use of bone graft material.

**[00171]** FIG. 19 is a schematic lateral view of the implant 1600. As shown in FIG. 19, the body of implant 1600 may be substantially wedge-shaped. That is, the thickness of implant 1600 may be tapered. For example, as shown in FIG. 19, implant 1600 may have a first thickness 1695 proximate leading edge portion 1635, and a second thickness 1700 at trailing edge portion 1640, wherein second thickness 1700 is greater than first thickness 1695.

**[00172]** In addition, it will be noted that, as shown in FIG. 19, first thickness 1695 of implant 1600 is completely formed by the substantially smooth leading edge surface 1665 of leading edge portion 1635. In addition, the previously discussed rounded profile of leading edge surface 1665 is also clearly shown in FIG. 19. Both of these features may facilitate insertion of implant 1600 into a recess in bone.

**[00173]** FIG. 20 is a schematic leading edge view of implant 1600. Previously discussed hollow central region 1691 is shown from a different perspective in FIG. 20.

**[00174]** FIG. 21 is a schematic trailing edge view of implant 1600. FIG. 21 illustrates the relative proportions of trailing edge portion 1640. For example, in some embodiments, trailing edge portion 1640 may have a thickness 1705 that

extends a substantial majority of second thickness 1700 of elongate curved structural members 1680 in the trailing edge end of implant 1600.

**[00175]** In addition to having a wedge configuration due to varying thickness in third axis 1665, the perimeter portions of implant 1600 may define a substantially teardrop shape. The substantially teardrop shape may be suitable for implantation in certain bone locations. For example, the substantially teardrop shape may be suitable for implantation in a tibial osteotomy due to the curved nature of the outer surface of the tibia at the location the osteotomy is typically performed. In other embodiments, implants having different shapes may be used. For example, implants having substantially square or rectangular shapes may be used, particularly where the surface of the bone in which the implant is to be inserted has a less rounded surface.

**[00176]** FIG. 22 is a schematic leading edge perspective view of another embodiment of an implant. FIG. 22 shows an implant 2200. Implant 2200 may have a substantially square shape. As shown in FIG. 22, implant 2200 may include a body 2225. Body 2225 may have a leading edge portion 2235, a trailing edge portion 2240, and an intermediate portion 2245 extending between leading edge portion 2235 and trailing edge portion 2240.

**[00177]** Implant 2200 may be used in osteotomy procedures in a number of anatomical locations. Accordingly, the directional references are provided with respect to a plurality of axes. In particular, implant 2200 may have a length extending from leading edge portion 2235 to trailing edge portion 2240 along a longitudinal axis 2250, as shown in FIG. 22. As also shown in FIG. 22, implant 2200 may have a width extending along a lateral axis 2255 perpendicular to longitudinal axis 2250. Further, implant 2200 may have a thickness in a third dimension along a third axis 2260 perpendicular to longitudinal axis 2250 and lateral axis 2255.

**[00178]** In some embodiments, the leading edge of the implant may include provisions to facilitate insertion of the implant between opposing sides of a bone recess. For example, the leading edge may be provided with a bullnose

feature. That is, the leading edge may include a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion.

**[00179]** As shown in FIG. 22, leading edge portion 2235 may have a leading edge surface 2265 that is substantially smooth across a substantial majority of leading edge portion 2235. In some embodiments, the substantially smooth leading edge surface 2265 may extend the entire thickness of leading edge portion 2235 in the direction of third axis 2260, as shown in FIG. 22. As further shown in FIG. 22, leading edge surface 2265 may be substantially rounded in the direction of third axis 2260.

**[00180]** The implant may include provisions for receiving an insertion tool. For example, some embodiments can include a monolithic structure in the trailing edge of the implant. The monolithic structure can include one or more receptacles configured to engage an insertion or implantation tool. In some embodiments, such receptacles may include female threads configured to engage insertion or implantation tools.

**[00181]** FIG. 23 is a schematic illustration of another osteotomy procedure. In FIG. 23, the implantation of implant 2200 is depicted. As shown in FIG. 23, implant 2200 may be implanted as part of an opening osteotomy procedure performed on a cuneiform bone in the foot, such as medial cuneiform 2220. As also shown in FIG. 23, implant 2200 may have a substantially wedge-shaped configuration in which the trailing edge end has a greater thickness than the leading edge end of implant 2200. Accordingly, implant 2200 may be inserted into a recess 2210 in medial cuneiform 2220.

**[00182]** FIG. 23 includes a schematic trailing edge perspective view of implant 2200. As shown in FIG. 23, trailing edge 2240 may include a monolithic structure 2270. Monolithic structure 2270 may include a receptacle 2275 configured to receive an insertion tool (see, e.g., FIG. 24 for an exemplary insertion tool). In some embodiments, receptacle 2275 may include female threading 2276 configured to receive male threading on an insertion tool. Also, in

some embodiments, implant 2200 may include one or more inserter features similar to indentations 365 and 367 shown in FIG. 6.

**[00183]** The implant may include provisions to promote bone ingrowth. For example, in some embodiments, the implant may include a plurality of elongate curved structural members. Spaces may be defined between the elongate curved structural members to permit bone ingrowth in between and around the elongate curved structural members. In some embodiments, the elongate curved structural members may have any of a variety of curved configurations. For example, the structural members may include portions that are helical, spiraled, coiled, sinusoidal, arched, or otherwise curved.

**[00184]** As shown in FIG. 23, instead of a single large spiral member providing the entire thickness of the implant, implant 2200 may have a plurality of elongate curved structural members 2280 stacked in the direction of third axis 2260. Elongate curved structural members 2280 may include a plurality of spiral members. One or more of the spiral members may form perimeter portions of implant 2200, as shown in FIG. 23. Also, one or more of the spiral members may extend between leading edge portion 2235 and trailing edge portion 2240. Accordingly, such spiral members may provide implant 2200 with longitudinal compressive strength to maintain structural integrity during insertion into an osteotomy recess.

**[00185]** FIG. 24 is a schematic illustration of another osteotomy procedure involving the implantation of implant 2200. As shown FIG. 24, an osteotomy procedure may be performed on other bones a foot 2400, such as a calcaneus 2405. Such an osteotomy procedure may create a recess 2410 in calcaneus 2405. Implant 2200 may be configured (and sized) for insertion into recess 2410.

**[00186]** FIG. 24 also shows an insertion tool 2415, configured to engage receptacle 2275 of implant 2200. For example, insertion tool 2415 may include male threads 2420 configured to engage the female threads in receptacle 2275.

**[00187]** FIG. 25 is a schematic trailing edge perspective view of another embodiment of a wedge type implant. As shown in FIG. 25, an implant 2500 may have substantially the same structure as implant 2200. For example, implant 2500 may include a body 2525. Body 2525 may have a leading edge portion 2535, a trailing edge portion 2540, and an intermediate portion 2545 extending between leading edge portion 2535 and trailing edge portion 2540. Body 2525 may also include a plurality of elongate curved structural members 2580.

**[00188]** As shown in FIG. 25, implant 2500 may also include a first structural support beam 2286 extending between leading edge portion 2535 and trailing edge portion 2540. Along with elongate curved support members 2580, first structural support beam 2586 may provide longitudinal compressive strength to implant 2500. In some embodiments, implant 2500 may include more than one structural support beam. For example, implant 2500 may include a second structural support beam 2587. As shown in FIG. 25, first structural support beam 2586 and second structural support beam 2587 may be disposed on opposing lateral sides of implant 2500. In some embodiments, the structural support beams may be disposed within one or more of elongate support members 2580. For example, as shown in FIG. 25, first structural support member 2586 may be disposed within a first spiral member 2585 extending between leading edge portion 2535 and trailing edge portion 2540.

**[00189]** FIG. 26 is a schematic trailing edge perspective view of another embodiment of a wedge type implant. As shown in FIG. 26, an implant 2600 may have substantially the same structure as implant 2200. For example, implant 2600 may include a body 2625. Body 2625 may have a leading edge portion 2635, a trailing edge portion 2640, and an intermediate portion 2645 extending between leading edge portion 2635 and trailing edge portion 2640. Body 2625 may also include a plurality of elongate curved structural members 2680.

**[00190]** As shown in FIG. 26, implant 2600 may also include a structural support beam 2686 extending between leading edge portion 2635 and trailing edge portion 2640. Along with elongate curved support members 2680, first

structural support beam 2686 may provide longitudinal compressive strength to implant 2500.

**[00191] Sacroiliac Joint Implants**

**[00192]** Wedge type implants may be used in other surgical procedures. For example, wedge type implants may be used in sacroiliac joint stabilization procedures. Such implants may be inserted between the sacrum and ilium in order to immobilize or fuse the joint between these two bones. Such implants may have provisions to facilitate insertion. For example, such implants may have a substantially wedge-shaped configuration, and may include a bullnose leading edge and a monolithic trailing edge portion configured to engage an insertion tool. In addition, such implants may have provisions to promote bone ingrowth. For example, such implants may include a plurality of elongate curved structural members arranged to define spaces between the structural members. This open structure may promote bone ingrowth between and around the elongate curved structural members.

**[00193]** FIG. 27 is a schematic illustration of a sacroiliac joint stabilization procedure involving the implantation of a wedge implant. As shown in FIG. 27, an implant 2700 may be substantially wedge-shaped. As part of a sacroiliac joint stabilization procedure, the sacroiliac joint 2704 between the sacrum 2705 and the ilium 2710 may be stabilized by inserting implant 2700 between these two bones.

**[00194]** As shown in FIG. 27, an insertion tool 2715 may be used to deliver implant 2700 into sacroiliac joint 2704. Insertion tool 2715 may be configured to engage a trailing edge portion of implant 2700 and may be utilized to drive into and orient implant 2700 with respect to sacroiliac joint 2704. In some embodiments, insertion tool 2715 may engage with implant 2700 via a threaded connection.

**[00195]** FIG. 28 is a schematic leading edge perspective view of implant 2700. As shown in FIG. 27, implant 2700 may include a body 2725. Body 2725 may have a leading edge portion 2735, a trailing edge portion 2740, and an

intermediate portion 2745 extending between leading edge portion 2735 and trailing edge portion 2740.

**[00196]** Although, implant 2700 is illustrated as implantable for sacroiliac stabilization procedures, such an implant with the same or similar configuration may be used in a variety of medical procedures, such as osteotomy procedures, bone fusion procedures, etc. Accordingly, the directional references are provided with respect to a plurality of axes. In particular, implant 2700 may have a length extending from leading edge portion 2735 to trailing edge portion 2740 along a longitudinal axis 2750, as shown in FIG. 28. As also shown in FIG. 28, implant 2700 may have a width extending along a lateral axis 2755 perpendicular to longitudinal axis 2750. Further, implant 2700 may have a thickness in a third dimension along a third axis 2760 perpendicular to longitudinal axis 2750 and lateral axis 2755.

**[00197]** In some embodiments, the leading edge of the implant may include provisions to facilitate insertion of the implant between opposing bones of the sacroiliac joint. For example, the leading edge may be provided with a bullnose feature. That is, the leading edge may include a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion.

**[00198]** As shown in FIG. 28, leading edge portion 2735 may have a leading edge surface 2765 that is substantially smooth across a substantial majority of a width of leading edge portion 2735. As shown in FIG. 28, in some embodiments, leading edge surface 2765 may be rounded in the direction of lateral axis 2755.

**[00199]** Leading edge portion 2735 may have a substantially tapered thickness in the direction of third axis 2760, providing implant 2700 with its substantially wedge-shaped configuration. That is, leading edge portion 2735 may have a first thickness 2795 and trailing edge portion 2740 may have a second thickness 2800. As shown in FIG. 28, second thickness 2800 may be greater than first thickness 2795.

**[00200]** The implant may include provisions to promote bone ingrowth. For example, in some embodiments, the implant may include a plurality of elongate curved structural members. Spaces may be defined between the elongate curved structural members to permit bone ingrowth in between and around the elongate curved structural members. In some embodiments, the elongate curved structural members may have any of a variety of curved configurations. For example, the structural members may include portions that are helical, spiraled, coiled, sinusoidal, arched, or otherwise curved.

**[00201]** As shown in FIG. 28, in some embodiments, implant 2700 may include one or more elongate curved structural members 2780. As shown in FIG. 28, elongate curved structural members 2780 may include at least one elongate curved structural member 2785 extending longitudinally from leading edge portion 2735 to trailing edge portion 2740 of implant 2700. As further shown in FIG. 28, in some embodiments, elongate curved structural member 2785 may have a substantially sinusoidal configuration. Accordingly, elongate curved structural member 2785 may curve back and forth in the direction of third axis 2760. The sinusoidal configuration may provide open spaces on opposing sides of the structural member to facilitate bone ingrowth, receive bone graft material, or both. As shown in FIG. 28, in some embodiments, implant 2700 may include a plurality of sinusoidal structural members having opposing curvatures. That is, where a first structural member curves in a first direction, the adjacent structural member may curve in the opposite direction.

**[00202]** Elongate curved structural members 2780 may provide longitudinal compressive strength to implant 2700. That is, since implant 2700 is inserted in the direction of longitudinal axis 2750 by pushing it toward leading edge portion 2735 with an insertion tool from trailing edge portion 2740, implant 2700 may be subjected to significant longitudinal compressive forces. Accordingly, elongate curved structural members 2780 may be configured to withstand such compressive forces and to maintain an amount of rigidity that enables insertion of leading edge portion 2735 without buckling or undue compression of intermediate



portion 2745. Accordingly, the gauge, material, and geometrical shape of elongate curved structural members 2780 may be selected to provide the longitudinal compressive strength desired for the intended implantation location.

**[00203]** The implant may include provisions for receiving an insertion tool. For example, some embodiments can include a monolithic structure in the trailing edge of the implant. The monolithic structure can include one or more receptacles configured to engage an insertion or implantation tool. In some embodiments, such receptacles may include female threads configured to engage insertion or implantation tools.

**[00204]** FIG. 29 is a schematic trailing edge perspective view of implant 2700. As shown in FIG. 29, trailing edge 2740 may include a monolithic structure 2770. Monolithic structure 2770 may including a receptacle 2775 configured to receive an insertion tool (see, e.g., FIG. 27 for an exemplary insertion tool). In some embodiments, receptacle 2775 may include female threading 2776 configured to receive male threading on an insertion tool.

**[00205]** The implant can be formed with elongate curved structural members having a variety of configurations. FIGS. 30-34 illustrate several embodiments that implement substantially the same leading edge portion and trailing edge portion as implant 2700, but which include differing elongate curved structural members.

**[00206]** FIG. 30 is a schematic leading edge perspective view of another embodiment of an implant. FIG. 30 illustrates an implant 3000 having a body 3025. Body 3025 may have a leading edge portion 3035, a trailing edge portion 3040, and an intermediate portion 3045 extending between leading edge portion 3035 and trailing edge portion 3040. Implant 3000 may also include a plurality of elongate curved structural members 3080.

**[00207]** One or more of elongate curved structural members 3080 may have a sinusoidal configuration. For example, a first sinusoidal structural member 3085 and a second sinusoidal member 3090 may extend between leading edge portion 3035 and trailing edge portion 3040. As shown in FIG. 30, first sinusoidal

structural member 3085 and second sinusoidal member 3090 may curve back and forth in a lateral direction. First sinusoidal structural member 3085 and second sinusoidal member 3090 may also provide longitudinal compressive strength to implant 3000. In addition, in some embodiments, a portion of one or more of elongate curved structural members 3080 may have a substantially helical configuration.

**[00208]** FIG. 31 is a schematic leading edge perspective view of another embodiment of an implant. FIG. 31 illustrates an implant 3100 having a body 3125. Body 3125 may have a leading edge portion 3135, a trailing edge portion 3140, and an intermediate portion 3145 extending between leading edge portion 3135 and trailing edge portion 3140. Implant 3100 may also include a plurality of elongate curved structural members 3180.

**[00209]** As shown in FIG. 31, in some embodiments, plurality of elongate curved structural members 3180 may include one or more substantially helical members longitudinally from leading edge portion 3135 to trailing edge portion 3140. For example, implant 3100 may include a first substantially helical member 3185, a second substantially helical member 3190, and a third substantially helical member 3195 extending between leading edge portion 3135 and trailing edge portion 3140.

**[00210]** In some embodiments, implant 3100 may include one or more structural support beams. For example, as also shown in FIG. 31, implant 3100 may include a first structural support beam 3196 and a second structural support beam 3197. First structural support beam 3196 and second structural support beam 3197 may provide implant 3100 with longitudinal compressive strength. In addition, first structural support beam 3196 and second structural support beam 3197 may also provide a framework upon which one or more of the substantially helical members may be disposed.

**[00211]** FIG. 32 is a schematic leading edge perspective view of another embodiment of an implant. FIG. 32 illustrates an implant 3200 having a body 3225. Body 3225 may have a leading edge portion 3235, a trailing edge portion

3240, and an intermediate portion 3245 extending between leading edge portion 3235 and trailing edge portion 3240. Implant 3200 may also include a plurality of elongate curved structural members 3280.

**[00212]** As shown in FIG. 32, implant 3200 may include a first structural support beam 3296 and a second structural support beam 3297. First structural support beam 3296 and second structural support beam 3297 may provide implant 3200 with longitudinal compressive strength. In addition, first structural support beam 3296 and second structural support beam 3297 may also provide a framework upon which one or more of the elongate curved structural members may be disposed.

**[00213]** As shown in FIG. 32, in some embodiments, implant 3200 may include a central wall portion 3260 disposed between leading edge portion 3235 and trailing edge portion 3240 of implant 3200. Central wall portion 3260 may span between first structural support beam 3296 and second structural support beam 3297, thus forming a framework. Thus, central wall portion 3260 may provide structural strength to implant 3200 both by adding a structural member to form a framework, and by shortening the length of the elongate curved structural members. Further, elongate curved structural members 3280 may be substantially symmetrically arranged on opposing sides of central wall portion 3260, as shown in FIG. 32. This may ensure that the strength of implant 3200 is consistent along a substantial majority of the longitudinal length of implant 3200.

**[00214]** FIG. 33 is a schematic leading edge perspective view of another embodiment of an implant. FIG. 33 illustrates an implant 3300 having a body 3325. Body 3325 may have a leading edge portion 3335, a trailing edge portion 3340, and an intermediate portion 3345 extending between leading edge portion 3335 and trailing edge portion 3340. Implant 3300 may also include a plurality of elongate curved structural members 3380.

**[00215]** As shown in FIG. 33, implant 3300 may include a plurality of structural support beams extending between leading edge portion 3335 and trailing edge portion 3340. For example, implant 3300 may include a first

structural support beam 3396 and a second structural support beam 3397. Implant 3300 may also include a third structural support beam 3398 and a fourth structural support beam 3399 extending. Since first structural support beam 3396, second structural support beam 3397, third structural support beam 3398, and fourth structural support beam 3399 extend between leading edge portion 3335 and trailing edge portion 3340, these structural support beams may provide implant 3300 with longitudinal compressive strength. In addition, these structural support beams may also provide a framework upon which one or more of the elongate curved structural members may be disposed.

**[00216]** As shown in FIG. 33, elongate curved structural members 3380 and the structural support beams may be configured in a rib-cage structure, defining an interior volume of space. The interior volume of space may be configured to receive bone graft material and facilitate the ingrowth of bone around the support members of implant 3300.

**[00217]** FIG. 34 is a schematic leading edge perspective view of another embodiment of an implant. FIG. 34 illustrates an implant 3400 having a body 3425. Body 3425 may have a leading edge portion 3435, a trailing edge portion 3440, and an intermediate portion 3445 extending between leading edge portion 3435 and trailing edge portion 3440. Implant 3400 may also include a plurality of elongate curved structural members 3480.

**[00218]** As shown in FIG. 34, implant 3400 may include a plurality of structural support beams extending between leading edge portion 3435 and trailing edge portion 3440. For example, implant 3400 may include a first structural support beam 3496, a second structural support beam 3497, and a third structural support beam 3498. Since first structural support beam 3496, second structural support beam 3497, and third structural support beam 3498 extend between leading edge portion 3435 and trailing edge portion 3440, these structural support beams may provide implant 3400 with longitudinal compressive strength. In addition, these structural support beams may also provide a framework upon which one or more of the elongate curved structural members may be disposed.

**[00219]** As shown in FIG. 34, elongate curved structural members 3480 and the structural support beams may be configured in a rib-cage structure, defining an interior volume of space. The interior volume of space may be configured to receive bone graft material and facilitate the ingrowth of bone around the support members of implant 3400.

**[00220] Manufacturing and Materials**

**[00221]** The various components of an implant may be fabricated from biocompatible materials suitable for implantation in a human body, including but not limited to, metals (e.g. titanium or other metals), synthetic polymers, ceramics, and/or their combinations, depending on the particular application and/or preference of a medical practitioner.

**[00222]** Generally, the implant can be formed from any suitable biocompatible, non-degradable material with sufficient strength. Typical materials include, but are not limited to, titanium, biocompatible titanium alloys (e.g.  $\gamma$ Titanium Aluminides, Ti6-Al4-V ELI (ASTM F 136), or Ti6-Al4-V (ASTM F 1108 and ASTM F 1472)) and inert, biocompatible polymers, such as polyether ether ketone (PEEK) (e.g. PEEK-OPTIMA®, Invibio Inc). Optionally, the implant contains a radiopaque marker to facilitate visualization during imaging.

**[00223]** In different embodiments, processes for making an implant can vary. In some embodiments, the entire implant may be manufactured and assembled via injection-molding, cast or injection molding, insert-molding, co-extrusion, pultrusion, transfer molding, overmolding, compression molding, 3-Dimensional (3-D) printing, dip-coating, spray-coating, powder-coating, porous-coating, milling from a solid stock material and their combinations. Moreover, the embodiments can make use of any of the features, parts, assemblies, processes and/or methods disclosed in the "Coiled Implants Application".

**[00224] Other Embodiments**

**[00225]** Implants according to the present disclosure may include a variety of features disclosed in the list of items below.

**[00226]** i.) An implant is disclosed comprising: a body having a leading edge portion, a trailing edge portion, and an intermediate portion extending between the leading edge portion and the trailing edge portion; wherein the leading edge portion includes a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion; wherein the trailing edge portion includes a monolithic structure including at least one receptacle configured to receive an insertion tool; and wherein the intermediate portion includes a plurality of elongate curved structural members.

**[00227]** ii.) The plurality of elongate curved structural members can include one or more spiral members.

**[00228]** iii.) The plurality of elongate curved structural members can include one or more substantially helical members.

**[00229]** iv.) The receptacle can include female threading configured to receive male threading on an insertion tool.

**[00230]** v.) The body may be substantially wedge-shaped.

**[00231]** vi.) The implant may be configured for implantation in an opening wedge osteotomy procedure.

**[00232]** vii.) The implant may be configured for implantation in a sacroiliac joint.

**[00233]** viii.) The elongate curved structural members can include at least one elongate curved structural member extending longitudinally from the leading edge portion to the trailing edge portion of the implant and having a substantially sinusoidal configuration.

**[00234]** ix.) The elongate curved structural members can include a plurality of substantially helical members extending longitudinally from the leading edge portion to the trailing edge portion of the implant.

**[00235]** x.) The implant can include a central wall portion disposed between the leading edge portion and the trailing edge portion of the implant; wherein the plurality of elongate curved structural members are substantially symmetrically arranged on opposing sides of the central wall portion.

**[00236]** xi.) The implant can include at least one support beam extending between the leading edge portion and the trailing edge portion.

**[00237]** xii.) An implant is disclosed comprising: a body having a leading edge portion, a trailing edge portion, and an intermediate portion extending between the leading edge portion and the trailing edge portion; wherein the leading edge portion includes a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion; wherein the trailing edge portion includes a monolithic structure including at least one receptacle configured to receive an insertion tool; and further including at least one elongate substantially spiral member forming perimeter portions of the implant extending between the leading edge portion and the trailing edge portion.

**[00238]** xiii.) The body may be substantially wedge-shaped.

**[00239]** xiv.) The implant can be configured for implantation in an opening wedge osteotomy procedure.

**[00240]** xv.) The implant can include at least one support beam extending between the leading edge portion and the trailing edge portion.

**[00241]** xvi.) The receptacle can include female threading configured to receive male threading on an insertion tool.

**[00242]** xvii.) An implant is disclosed comprising: a body having a leading edge portion, a trailing edge portion, and an intermediate portion extending between the leading edge portion and the trailing edge portion; wherein the leading edge portion includes a substantially smooth surface forming a substantial majority of a leading edge surface of the leading edge portion; wherein the trailing edge portion includes a monolithic structure including at least one receptacle configured to receive an insertion tool; and at least one support beam extending between the leading edge portion and the trailing edge portion; and at least one

elongate substantially helical member extending between the leading edge portion and the trailing edge portion.

**[00243]** xviii.) The implant can be configured for implantation in a sacroiliac joint.

**[00244]** xix.) The implant can include at least one support beam extending between the leading edge portion and the trailing edge portion.

**[00245]** xx.) The receptacle can include female threading configured to receive male threading on an insertion tool.

**[00246]** Furthermore, every aspect, component, feature and/or item (in particular items i.) to xx.) or others) listed above and/or below in connection with the present invention can be considered a separate embodiment of the present invention, as defined by the claims or the description. In some cases, two or more aspects, components, features and/or items (in particular items i.) to xx.) or others) may be combined to form an embodiment of the present invention, as defined by the claims or the description.

**[00247]** While various embodiments have been described, the description is intended to be exemplary, rather than limiting and it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of the embodiments. Although many possible combinations of features are shown in the accompanying figures and discussed in this detailed description, many other combinations of the disclosed features are possible. Any feature of any embodiment may be used in combination with or substituted for any other feature or element in any other embodiment unless specifically restricted. Therefore, it will be understood that any of the features shown and/or discussed in the present disclosure may be implemented together in any suitable combination. Accordingly, the embodiments are not to be restricted except in light of the attached claims and their equivalents. Also, various modifications and changes may be made within the scope of the attached claims.



**WHAT IS CLAIMED IS:**

1. An implant, comprising:  
a body;  
a first arched bone contacting element having two ends attached to the body; and  
a second arched bone contacting element having two ends attached to the body.
2. The implant according to claim 1, wherein the first arched bone contacting element includes an arched portion and at least one flared leg.
3. The implant according to claim 2, wherein the first arched bone contacting element includes a curved central axis, wherein a cross-sectional area of the first arched bone contacting element varies along the curved central axis; and wherein the cross-sectional area is a minimum at the arched portion.
4. The implant according to claim 2, wherein the at least one flared leg includes a first portion attached to the body and a second portion proximate the arched portion; and wherein the first portion has a first cross-sectional shape and wherein the second portion has a second cross-sectional shape that is different than the first portion.
5. The implant according to claim 4, wherein the first cross-sectional shape is approximately circular and wherein the second cross-sectional shape is approximately elliptic.

6. The implant according to claim 4, wherein the first portion of the at least one flared leg of the first arched bone contacting element is attached to a segment of the body extending along a first axis of the implant; and wherein a longest dimension of the first portion is approximately aligned with the first axis.
7. The implant according to claim 1, wherein the first arched bone contacting element includes a distal surface region and wherein the distal surface region has a different curvature than an adjacent surface region of the arched portion.
8. The implant according to claim 1, wherein the first arched bone contacting element includes a roughened surface region.
9. The implant according to claim 1, wherein each arched bone contacting element is configured to direct bone growth from a superior or inferior surface of the implant towards an internal region of the implant.
10. An implant, comprising:
  - a body including a lateral axis;
  - a first arched bone contacting element oriented at a first angle with respect to the lateral axis and a second arched bone contacting element oriented at a second angle with respect to the lateral axis; and
  - wherein the first angle is different from the second angle.
11. The implant according to claim 10, wherein the first arched bone contacting element and the second arched bone contacting element are arranged in a first V-like configuration on the body.

12. The implant according to claim 10, wherein:  
the body has a posterior side and an anterior side;  
the body has a first axis extending from the posterior side to the anterior side and wherein the first axis is perpendicular to the lateral axis that extends between a first lateral side and a second lateral side of the body;  
a third arched bone contacting element and a fourth arched bone contacting element arranged in a second V-like configuration on the body.  
wherein the first V-like configuration and the second V-like configuration have different positions along the lateral axis.
13. The implant according to claim 12, wherein:  
the body includes a peripheral structure bounding an interior region, and wherein the body includes a support beam extending through the interior region;  
wherein the first V-like configuration extends between the first lateral side of the implant to the support beam and wherein the second V-like configuration extends between the support beam and the second lateral side of the implant.
14. The implant according to claim 10, wherein the implant includes a plurality of pairs of arched bone contacting elements, each of the pairs from the plurality of pairs being arranged in a plurality of V-like configurations.
15. The implant according to claim 14, wherein:  
the body includes a peripheral structure bounding an interior region, and wherein the body includes a first support beam, a second support beam and a third support beam extending through the interior region;  
wherein two V-like configurations of the plurality of V-like configurations are centered around the first support beam, wherein two V-like configurations of the plurality of V-like configurations are centered around the third support beam, and wherein all of the V-like configurations of the plurality of V-like configurations are in contact with the second support beam.

16. An implant, comprising:  
a body comprising a peripheral structure, a first support beam and a second support beam;  
wherein the peripheral structure bounds an interior region and wherein the first support beam and the second support beam span the interior region;  
a first arched bone contacting element extending from a portion of the peripheral structure to the first support beam; and  
a second arched bone contacting element extending from the first support beam to the second support beam.
17. The implant according to claim 16, wherein the first support beam is a straight beam and wherein the second support beam is a straight beam.
18. The implant according to claim 16, wherein the implant includes a third arched bone contacting element, and wherein the third arched bone contacting element includes a first end and a second end, and wherein the first end and the second end are attached to the first support beam.
19. The implant according to claim 16, wherein the implant includes a third arched bone contacting element, and wherein the third arched bone contacting element includes a first end and a second end, and wherein the first end and the second end are attached to a lateral side of the peripheral structure.
20. The implant according to claim 16, wherein the implant includes a third support beam spanning the interior region and wherein the first support beam, the second support beam and the third support beam are approximately coplanar.

21. The implant according to claim 16, wherein the first arched bone contacting element includes a convex bone contacting region.
22. The implant according to claim 16, wherein the first arched bone contacting element and the second arched bone contacting element are arranged in a V-like configuration on the body.
23. The implant according to claim 16, wherein the peripheral structure includes at least one attachment opening for engaging an insertion device.

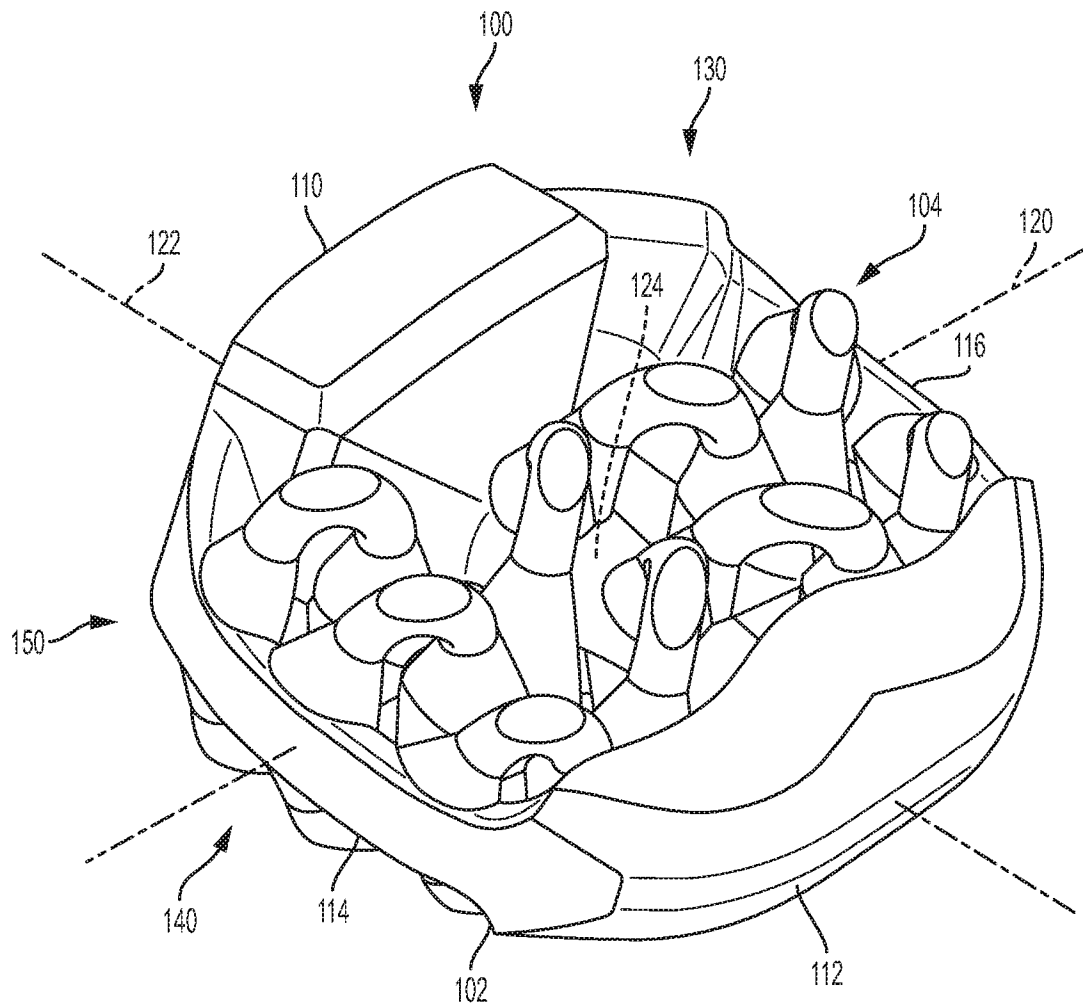
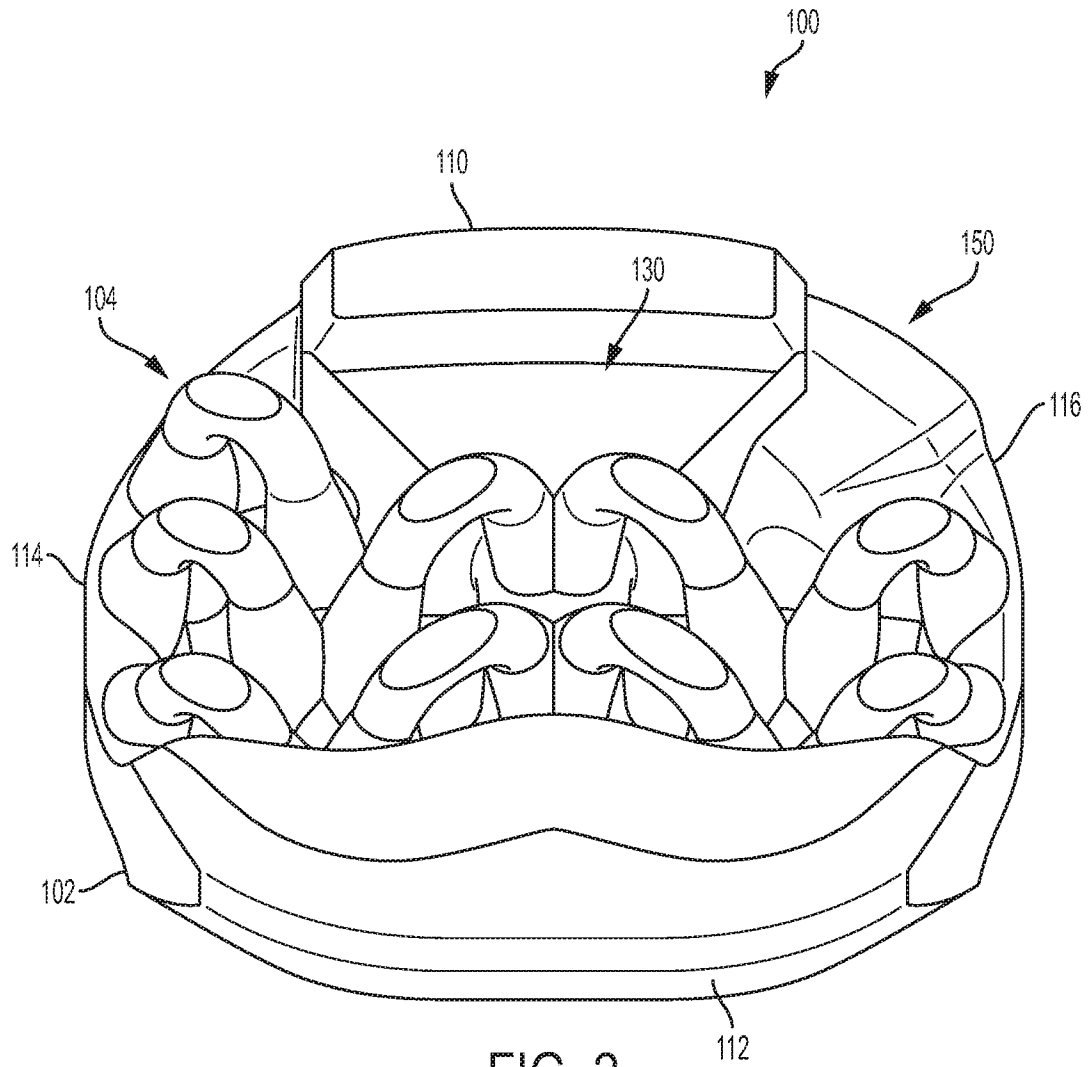
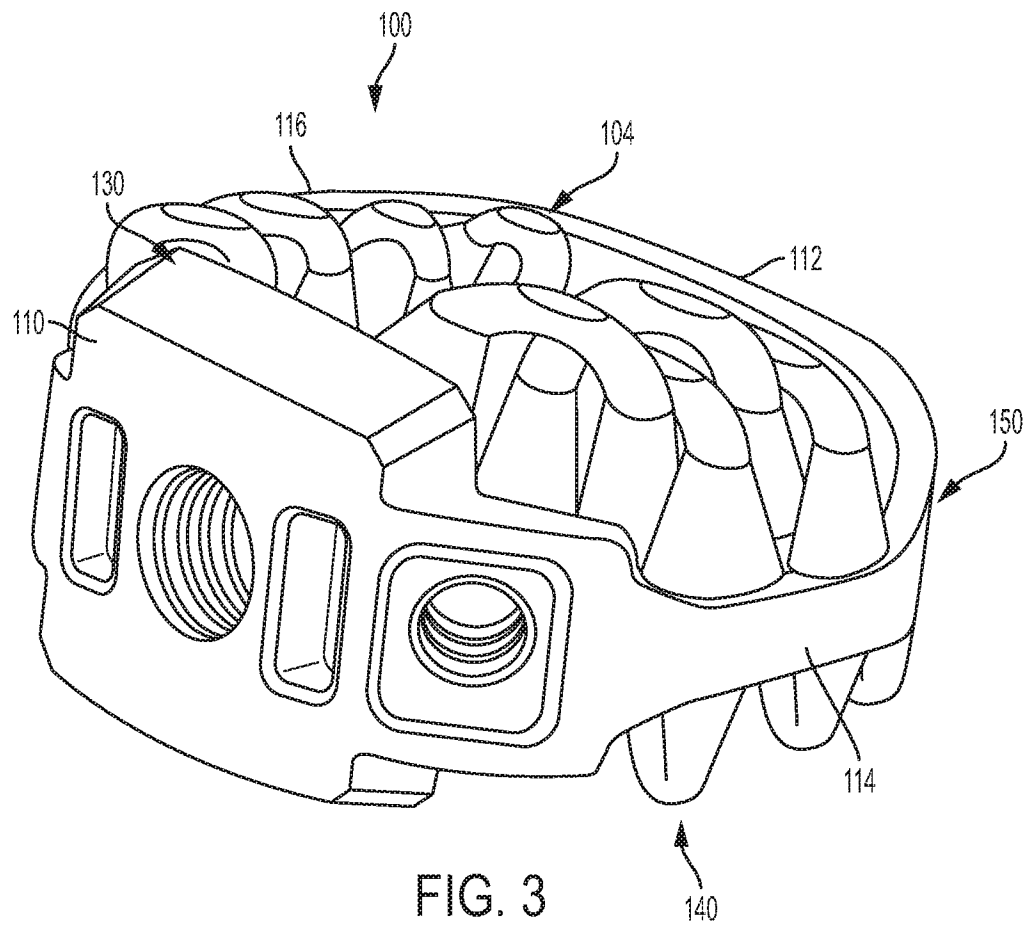


FIG. 1







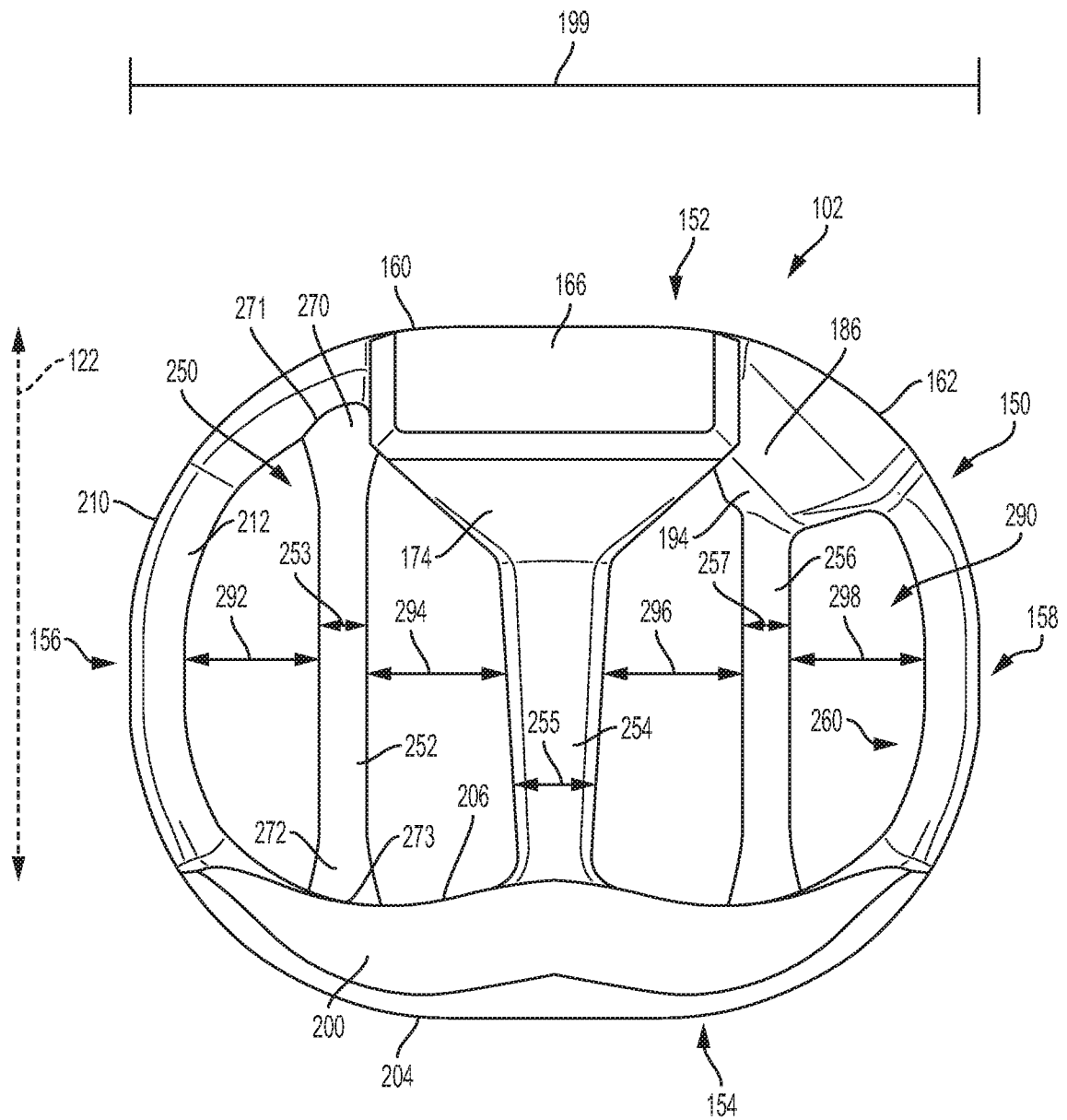


FIG. 4

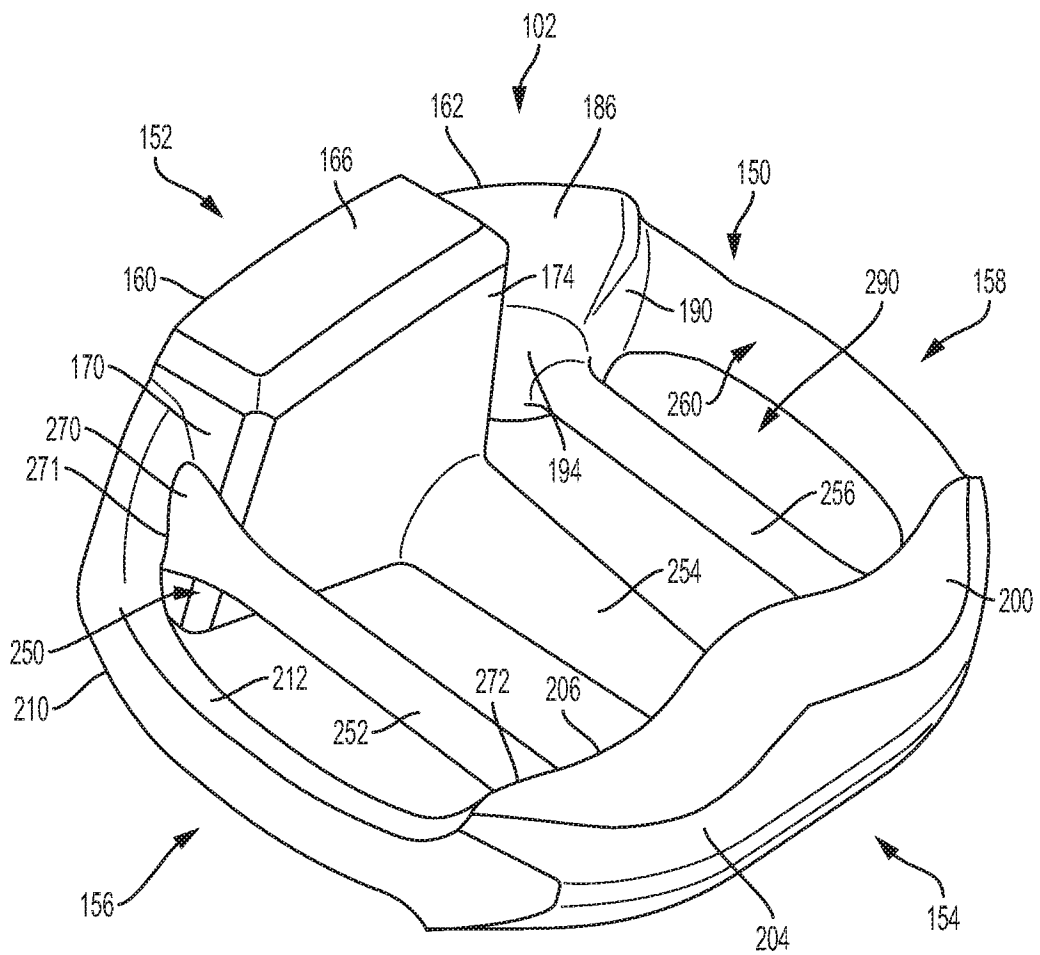


FIG. 5

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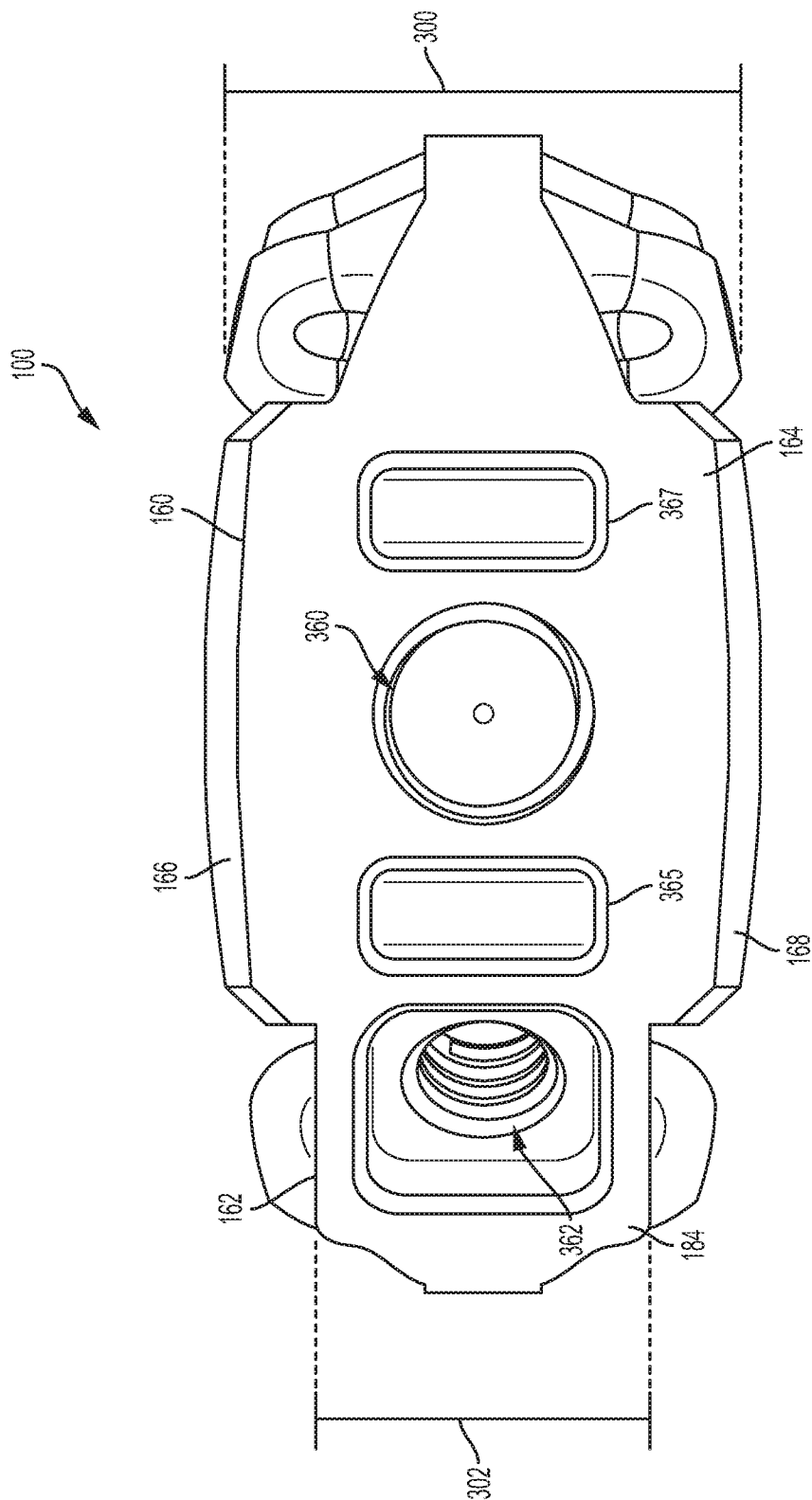
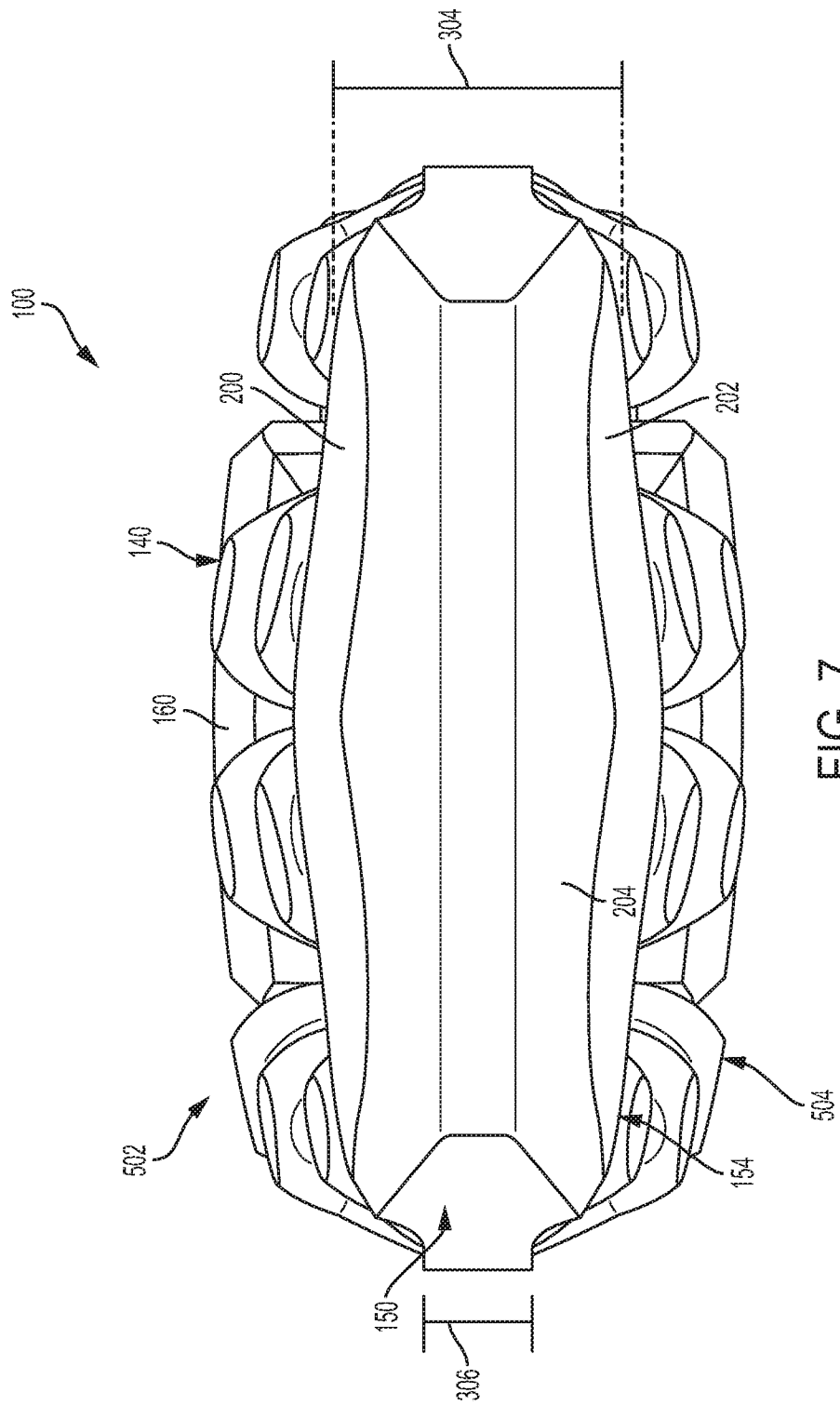


FIG. 6

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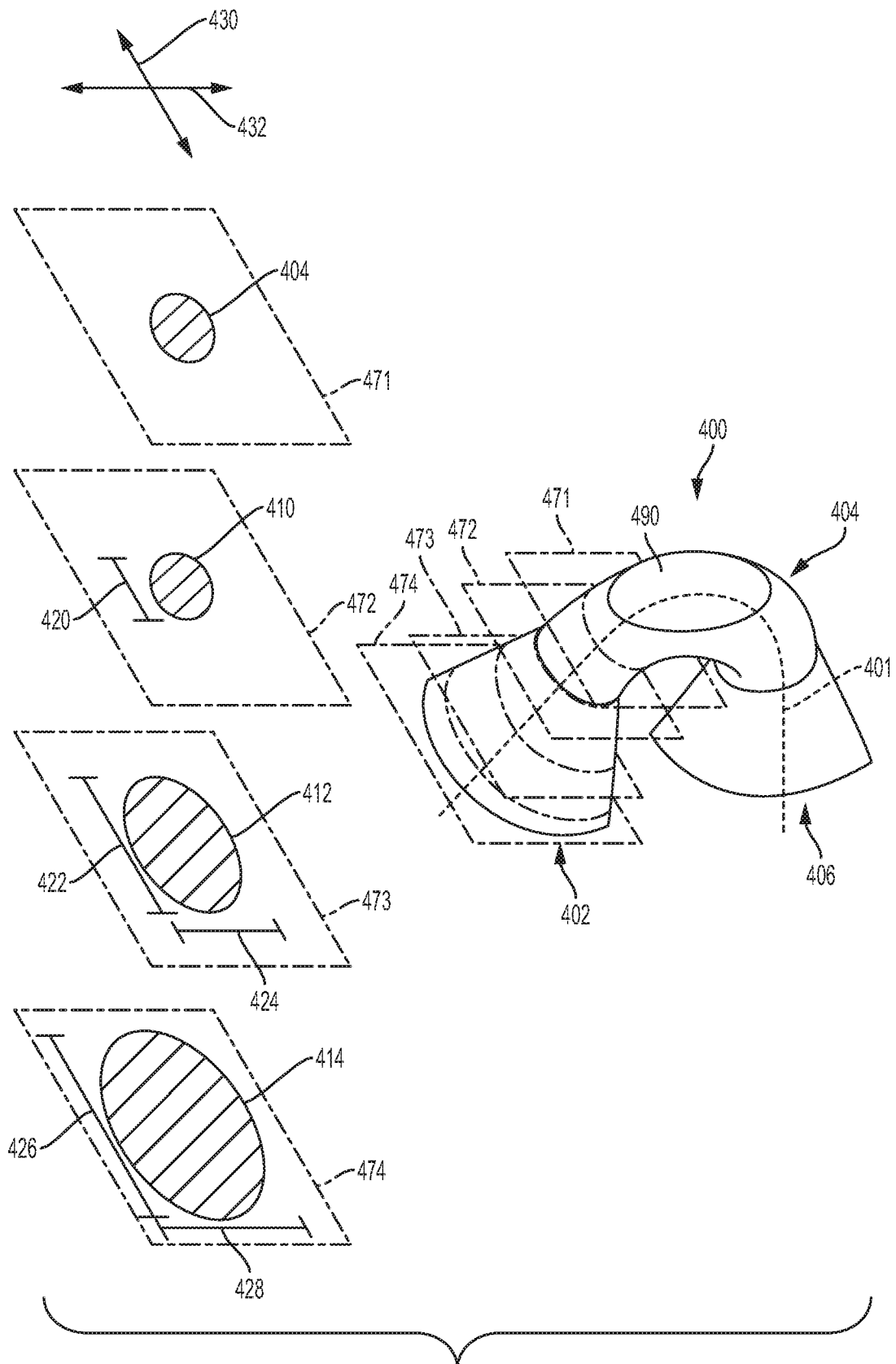


FIG. 8

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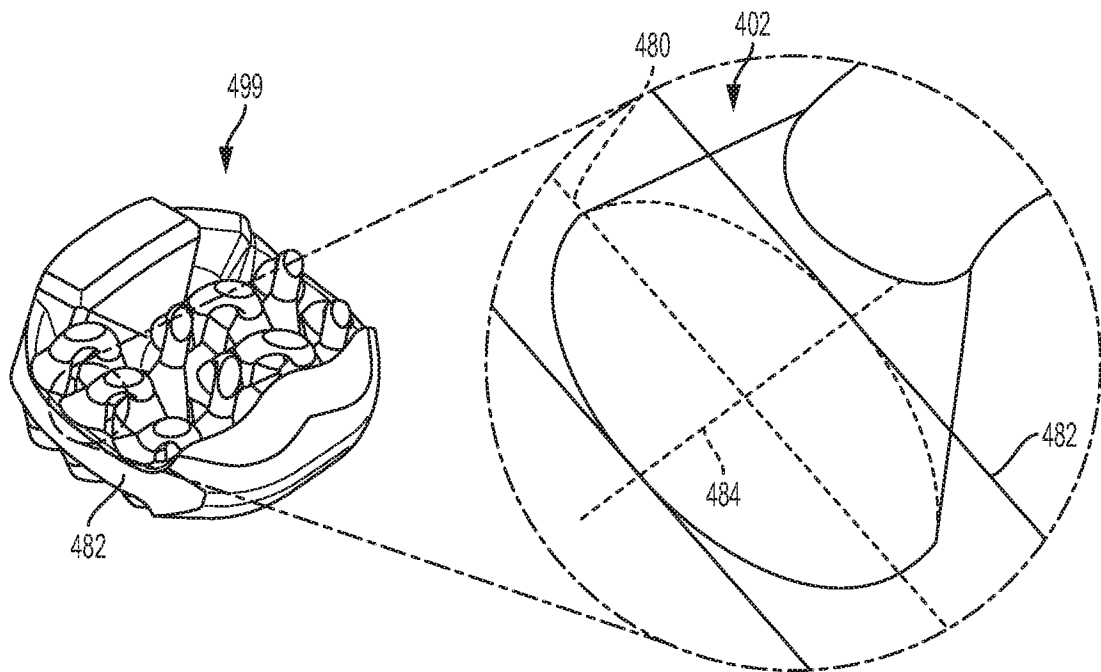


FIG. 9

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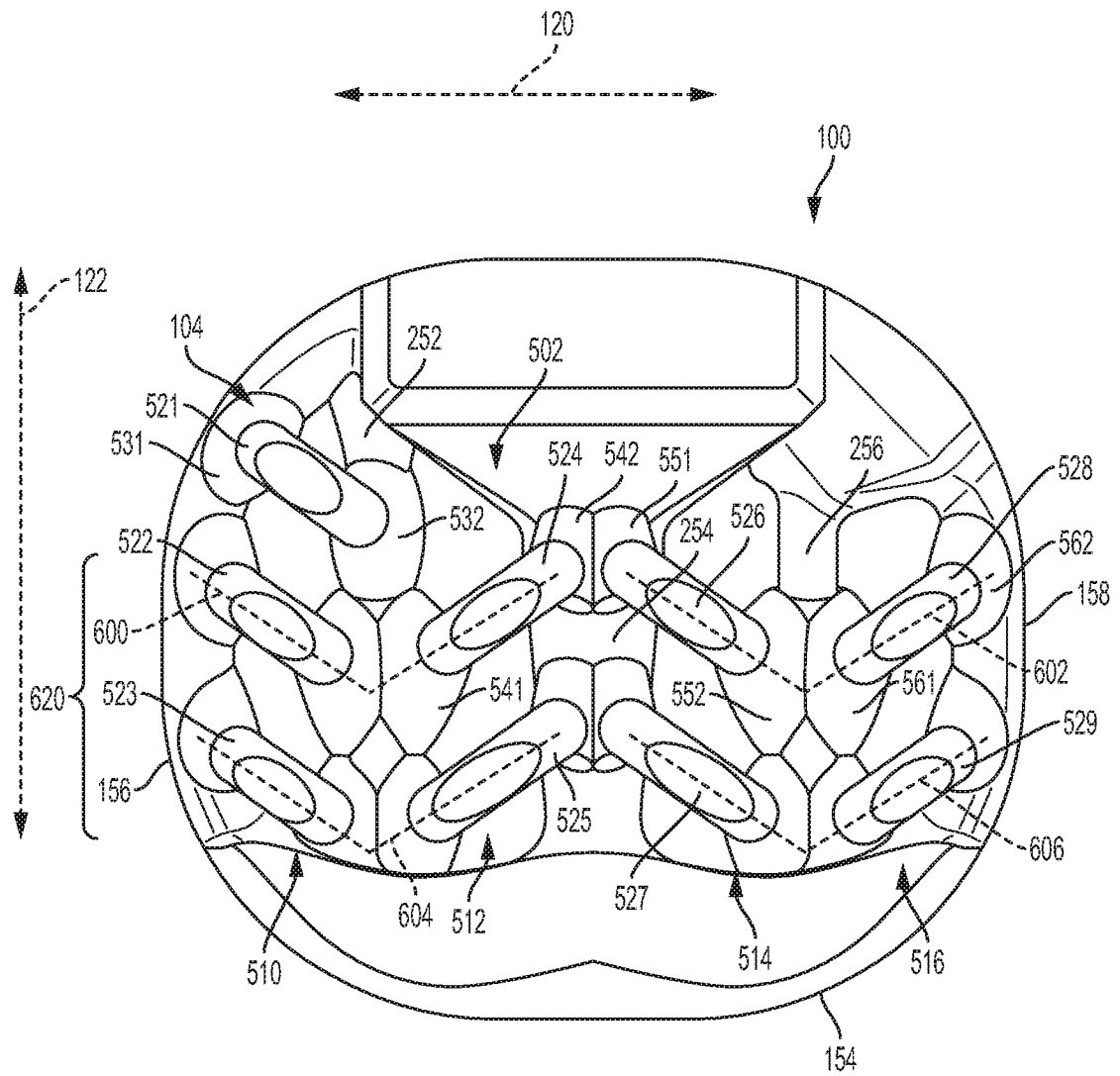


FIG. 10

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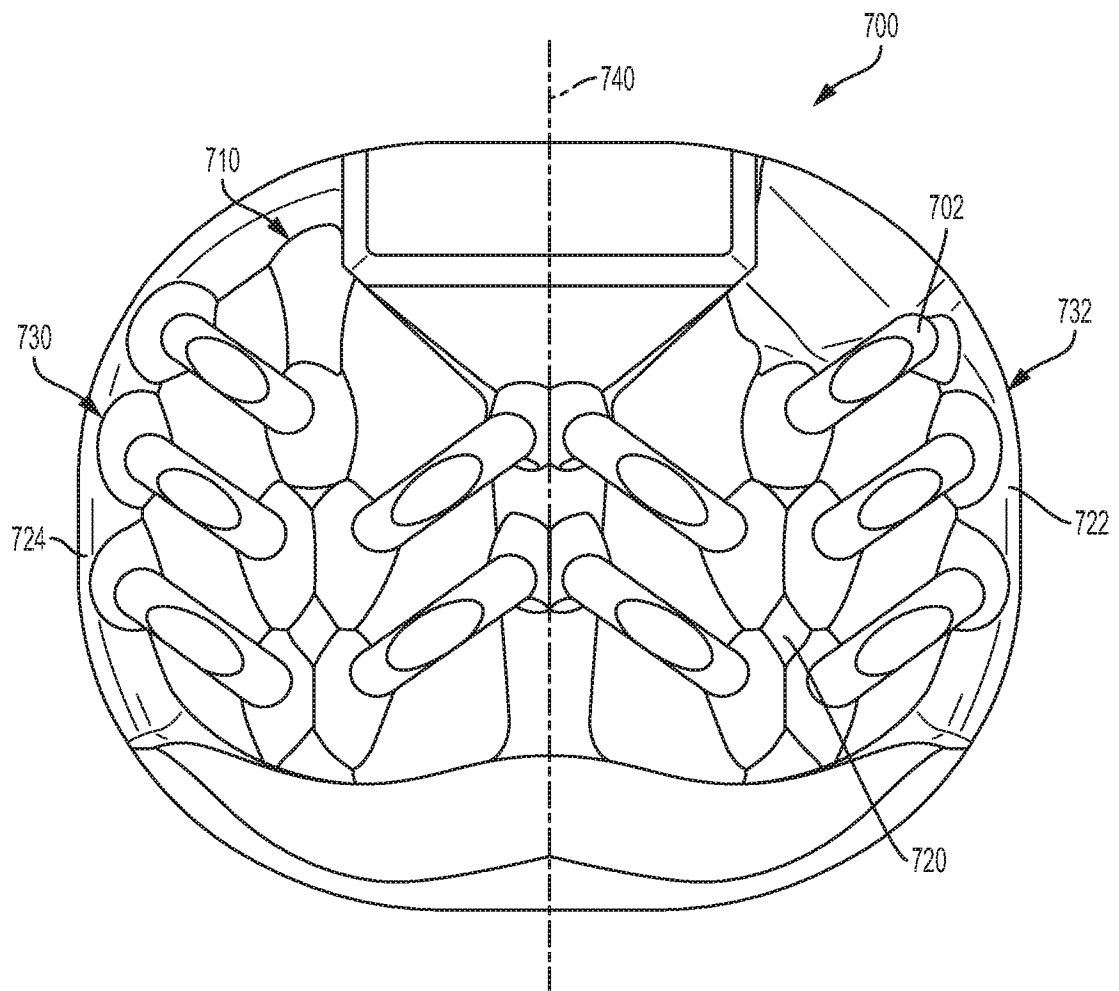


FIG. 11



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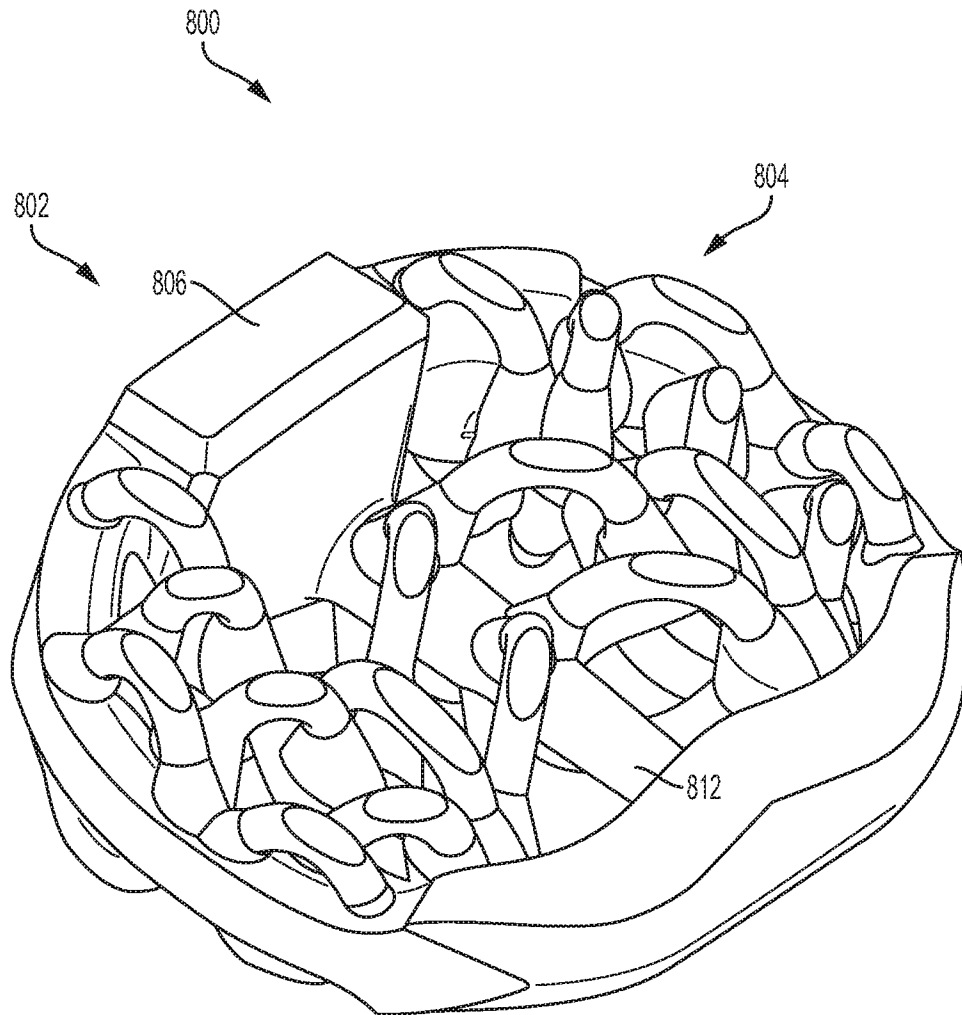


FIG. 12

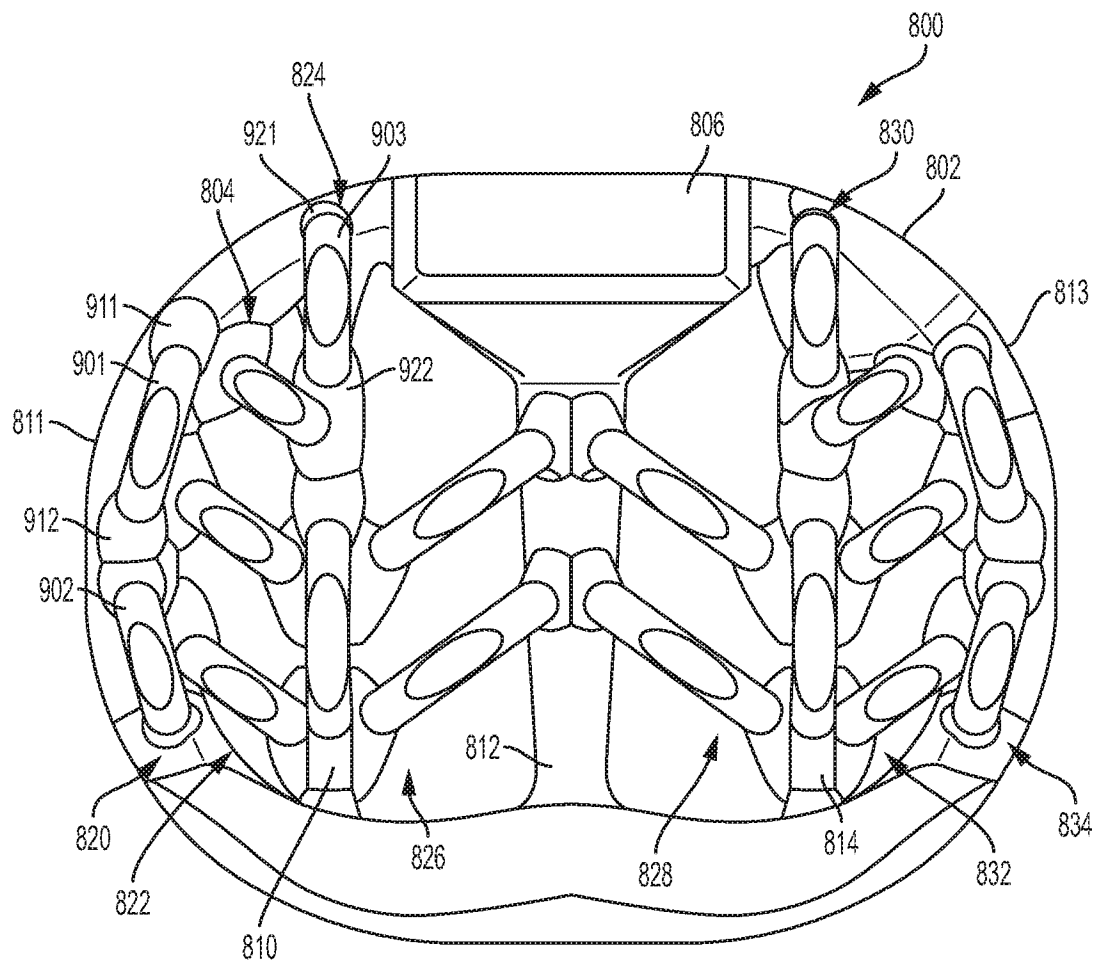


FIG. 13

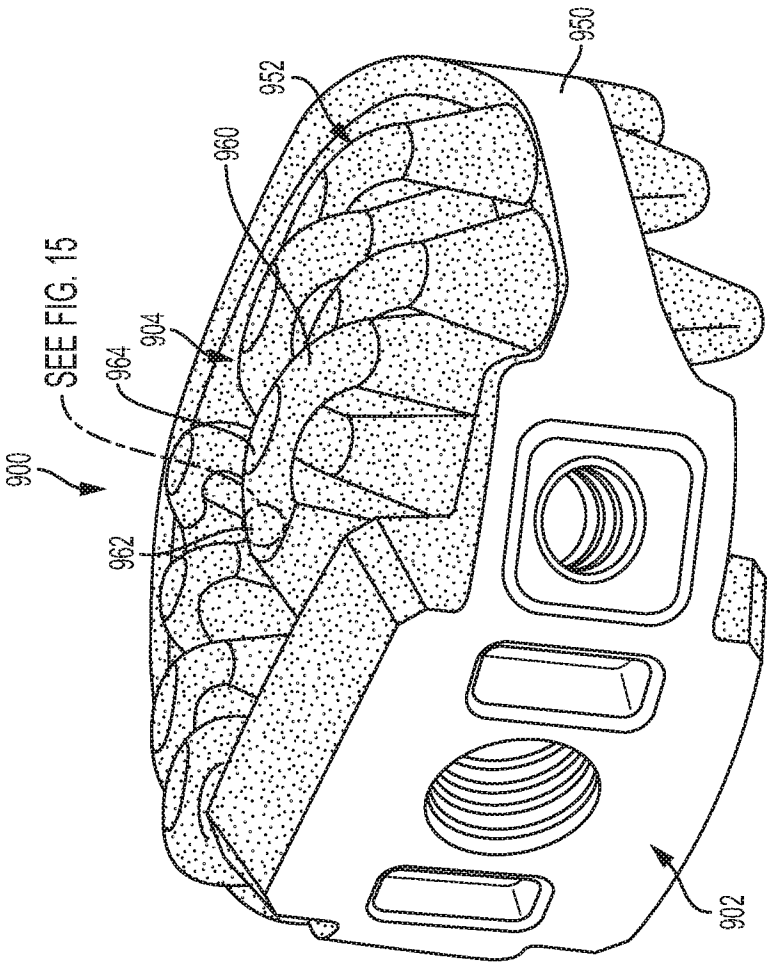


FIG. 14

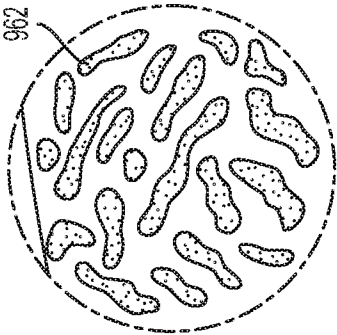


FIG. 15

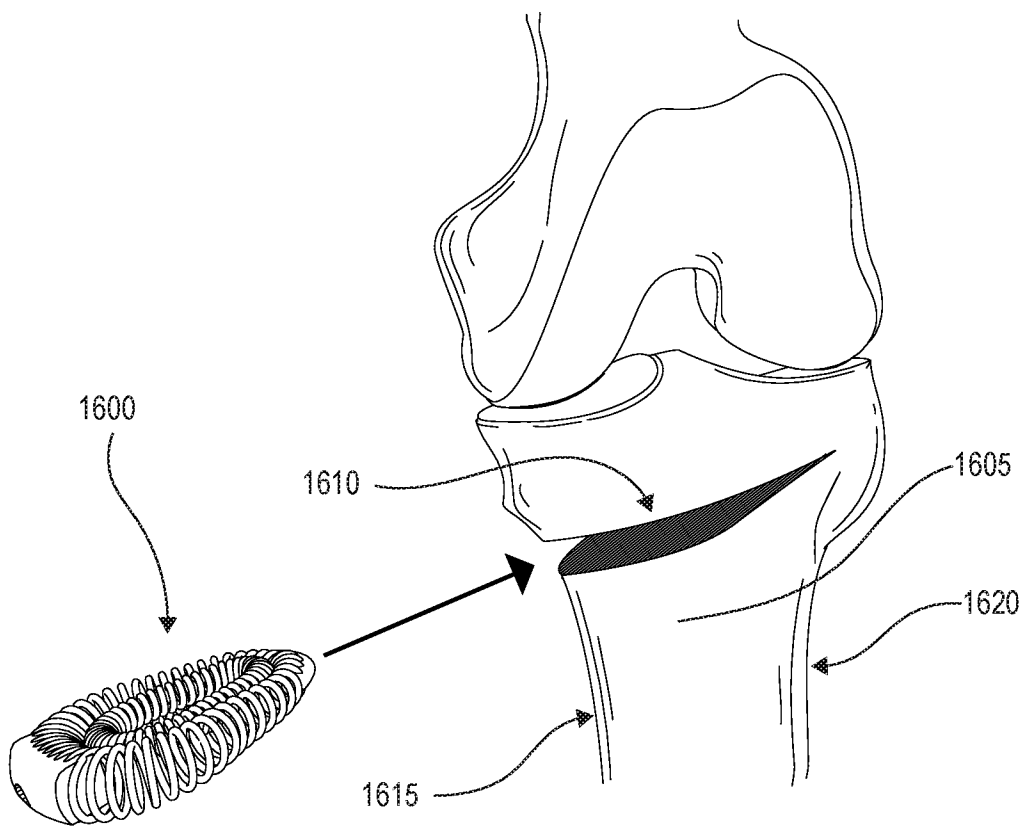


FIG. 16

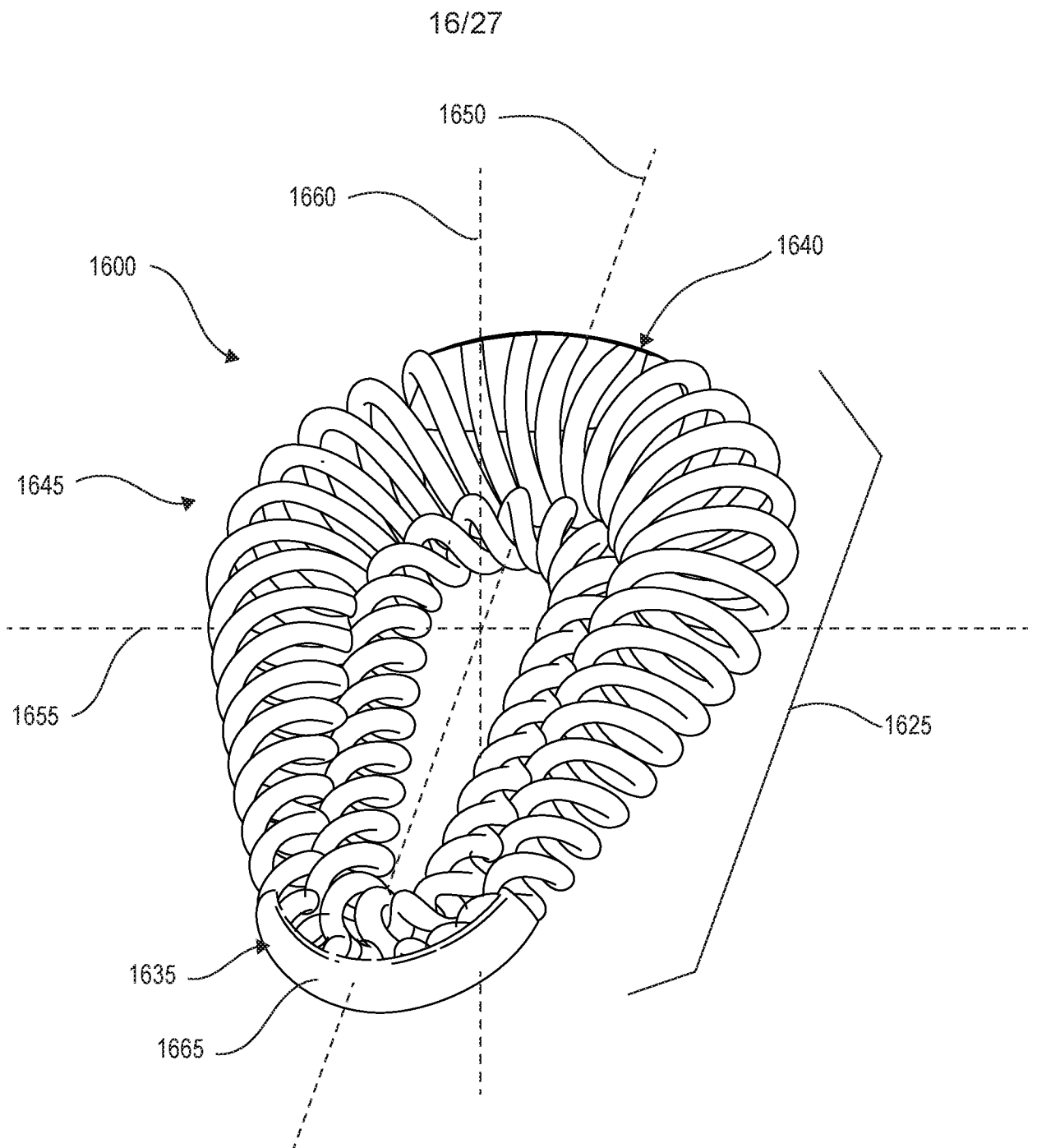


FIG. 17

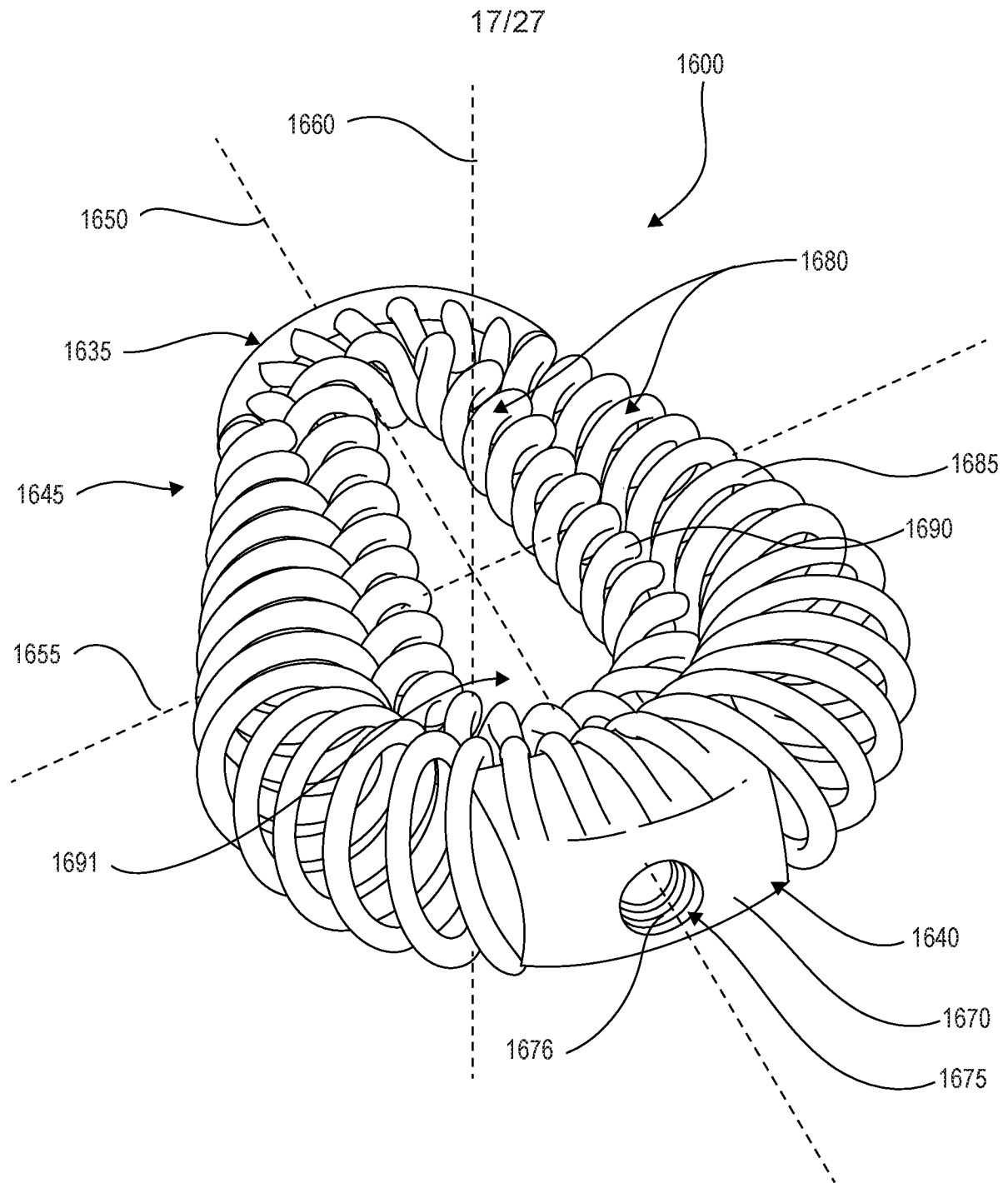
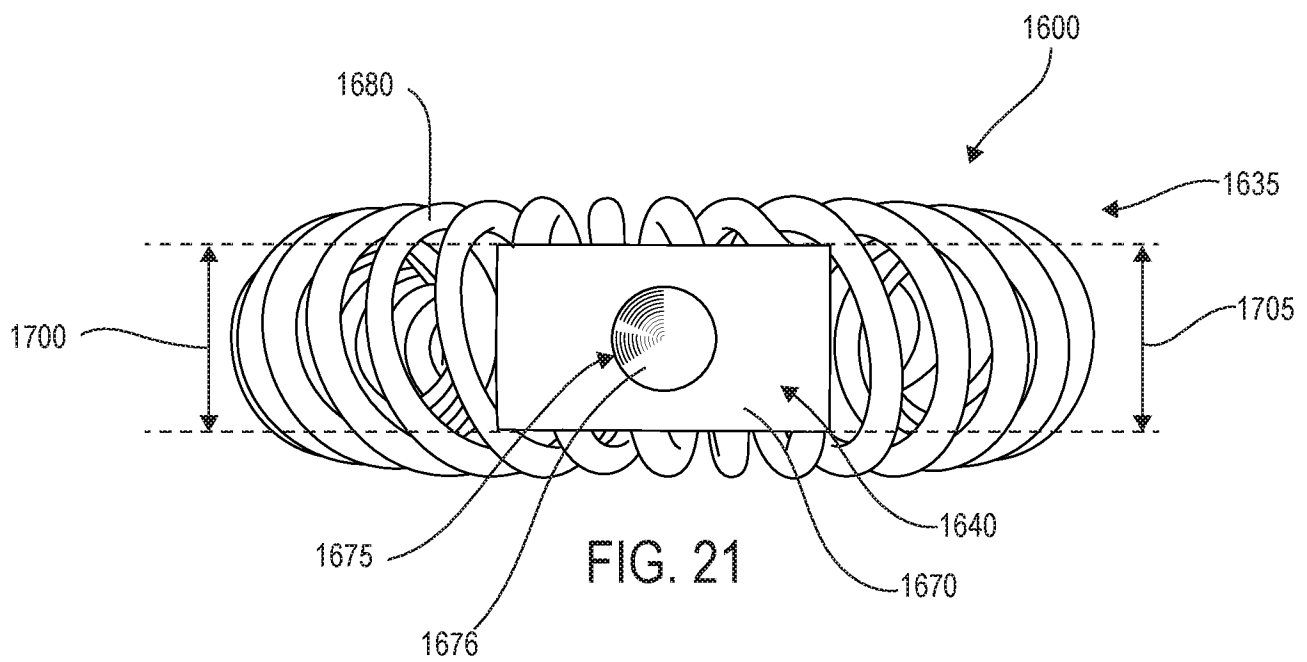
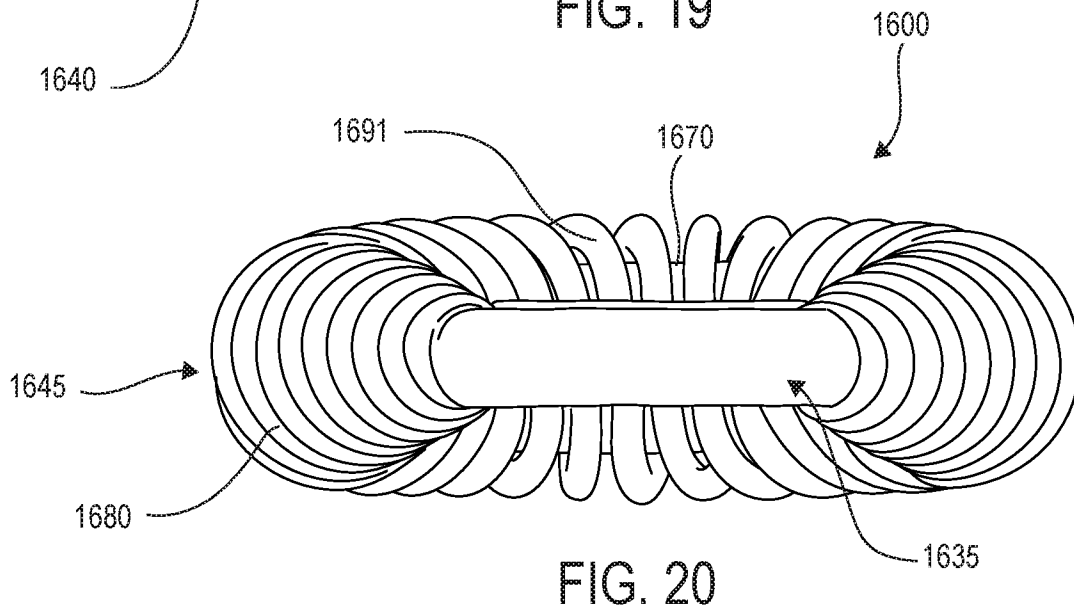
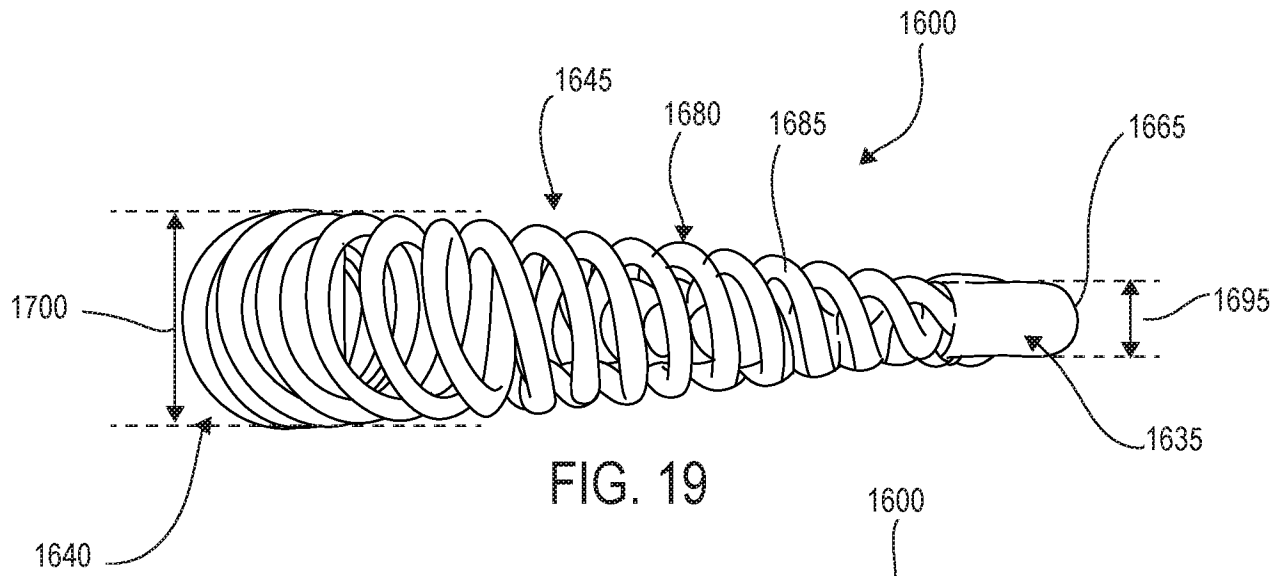


FIG. 18

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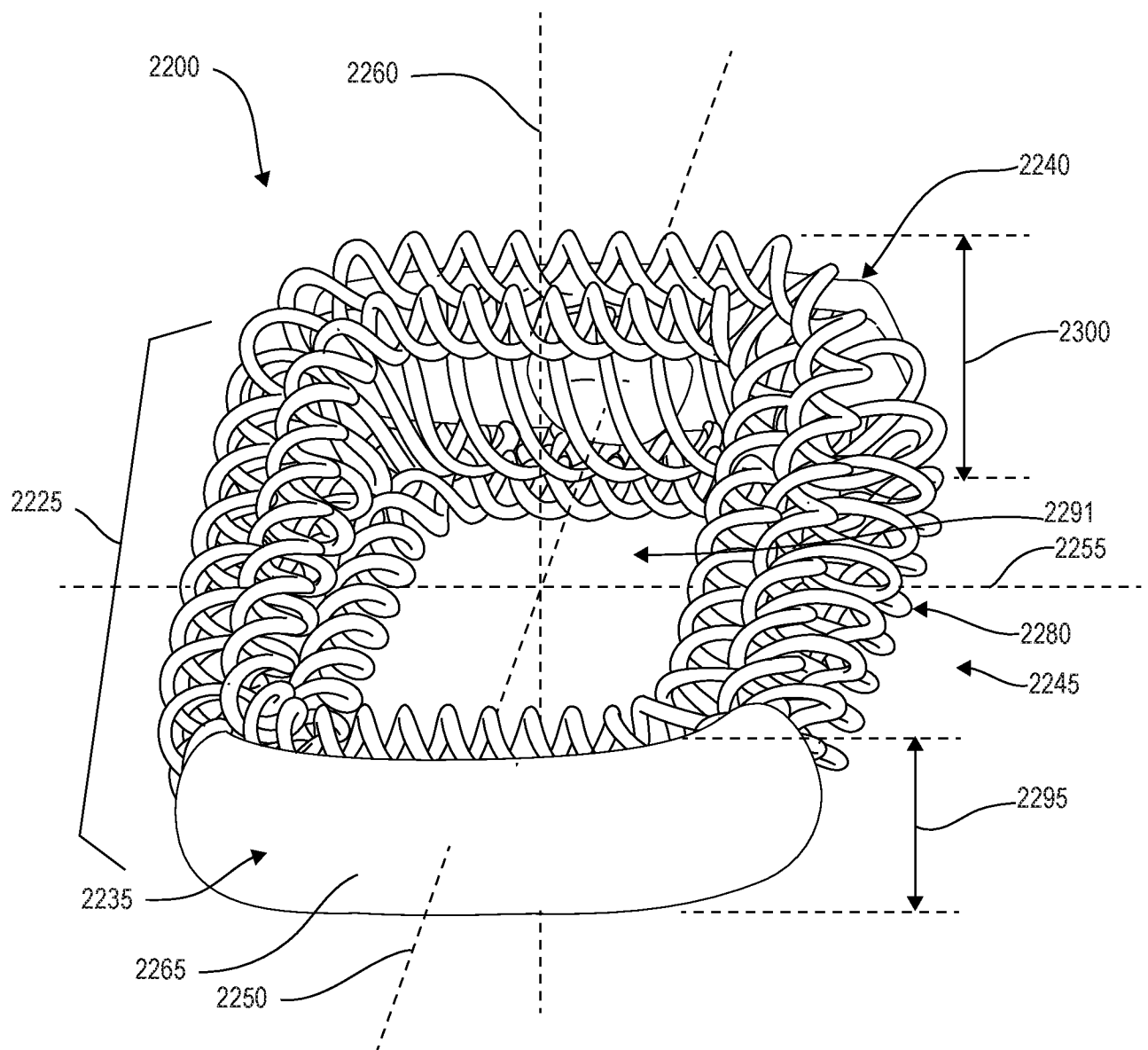


FIG. 22



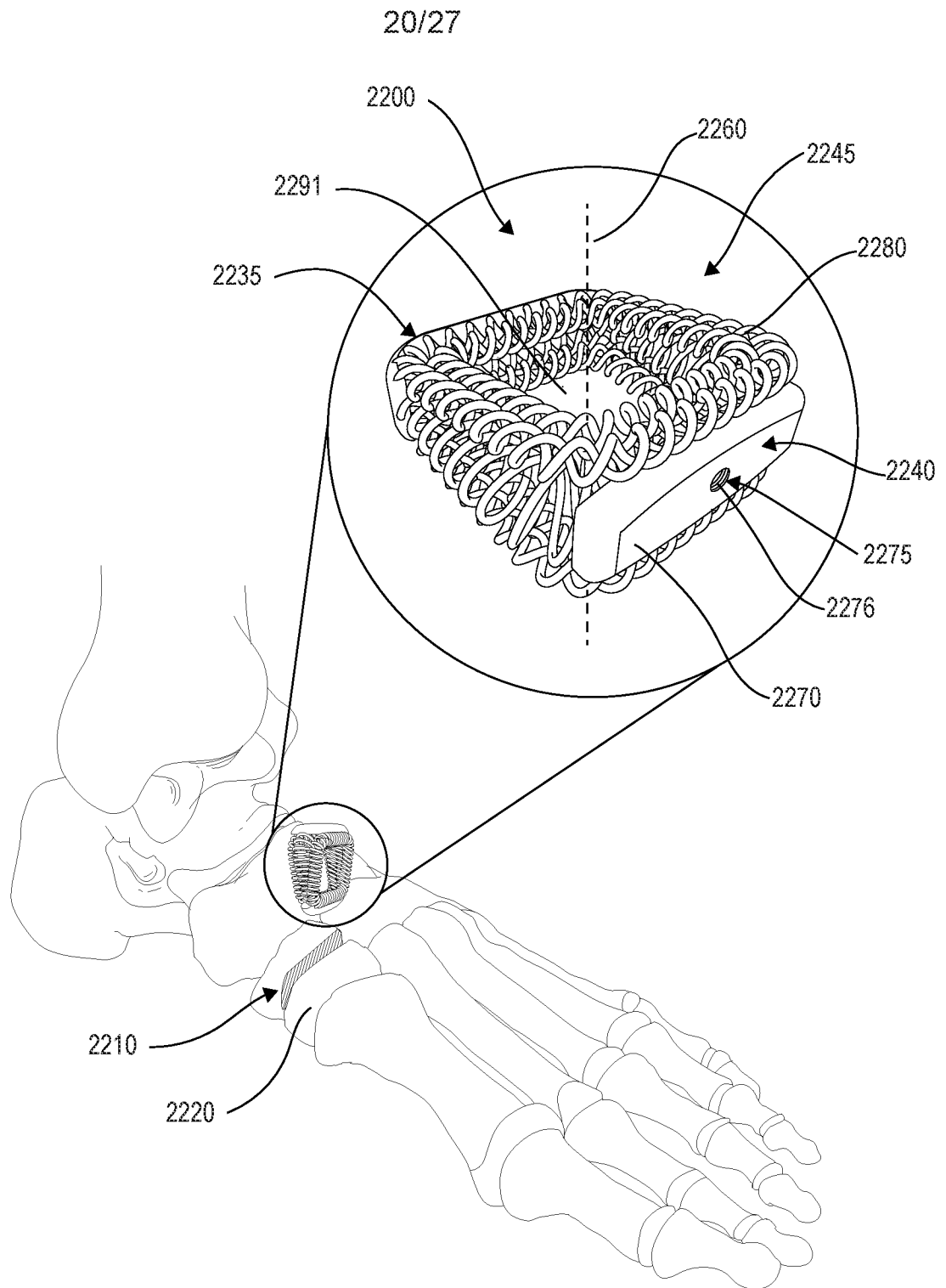


FIG. 23

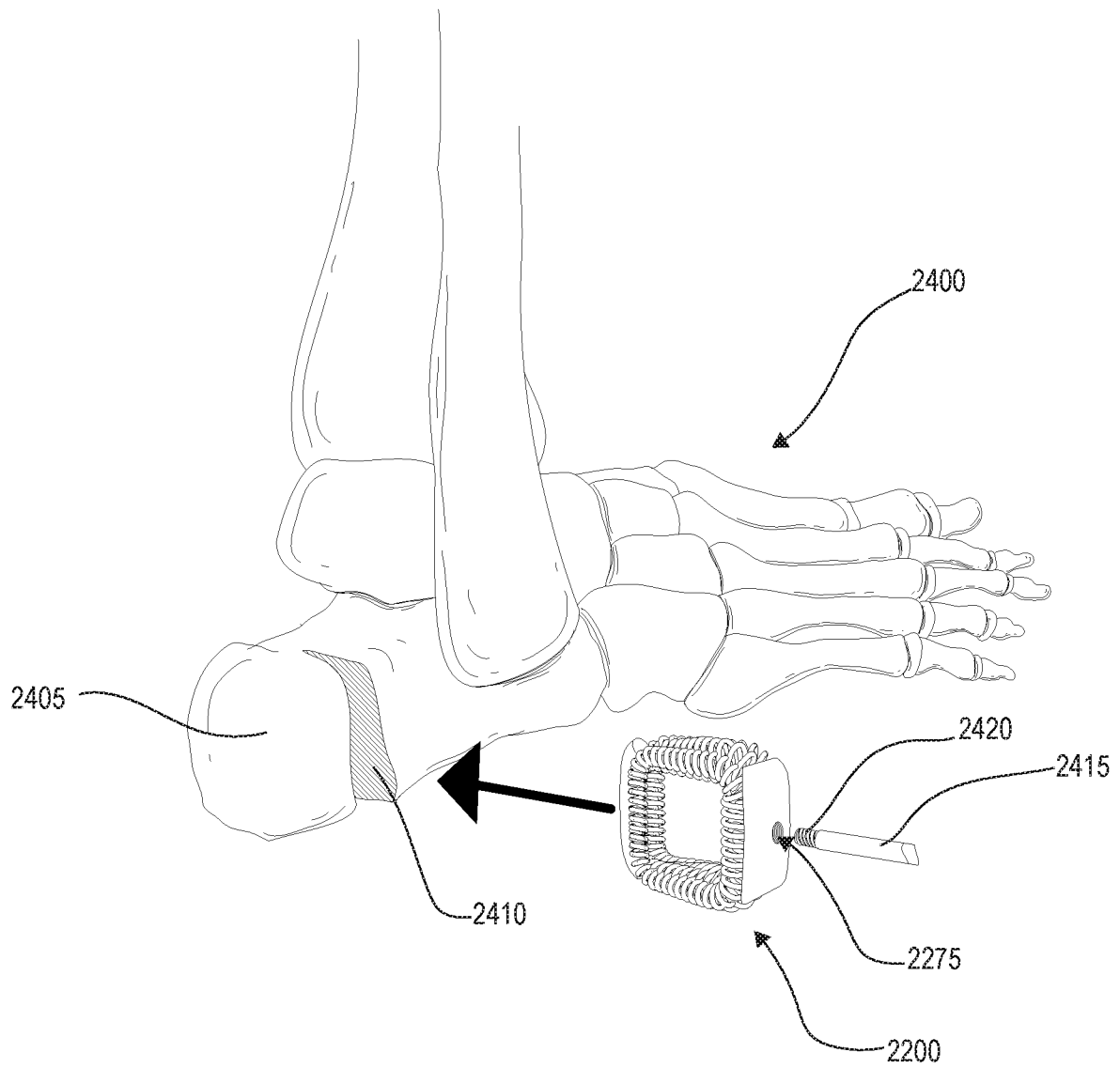


FIG. 24

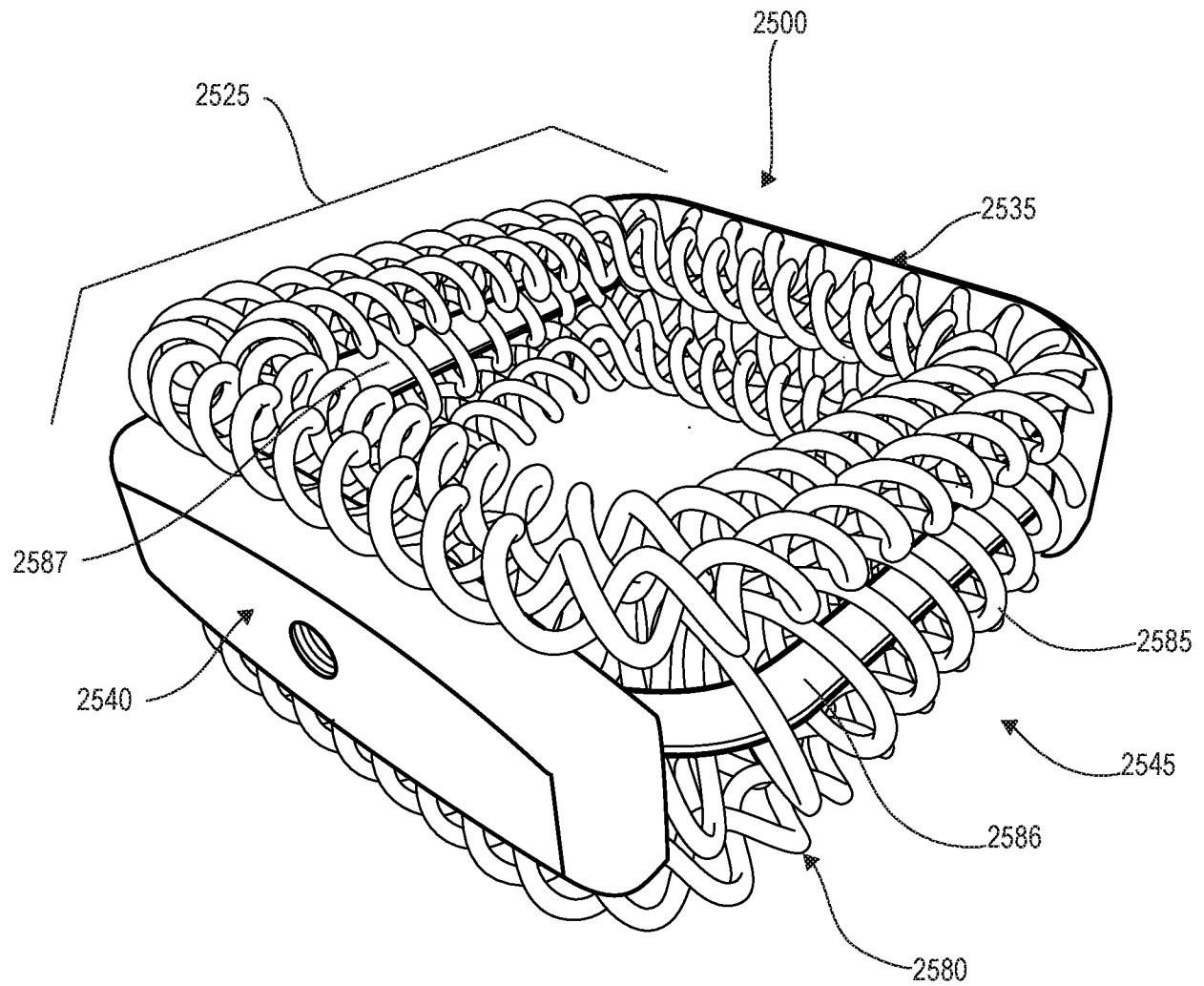


FIG. 25

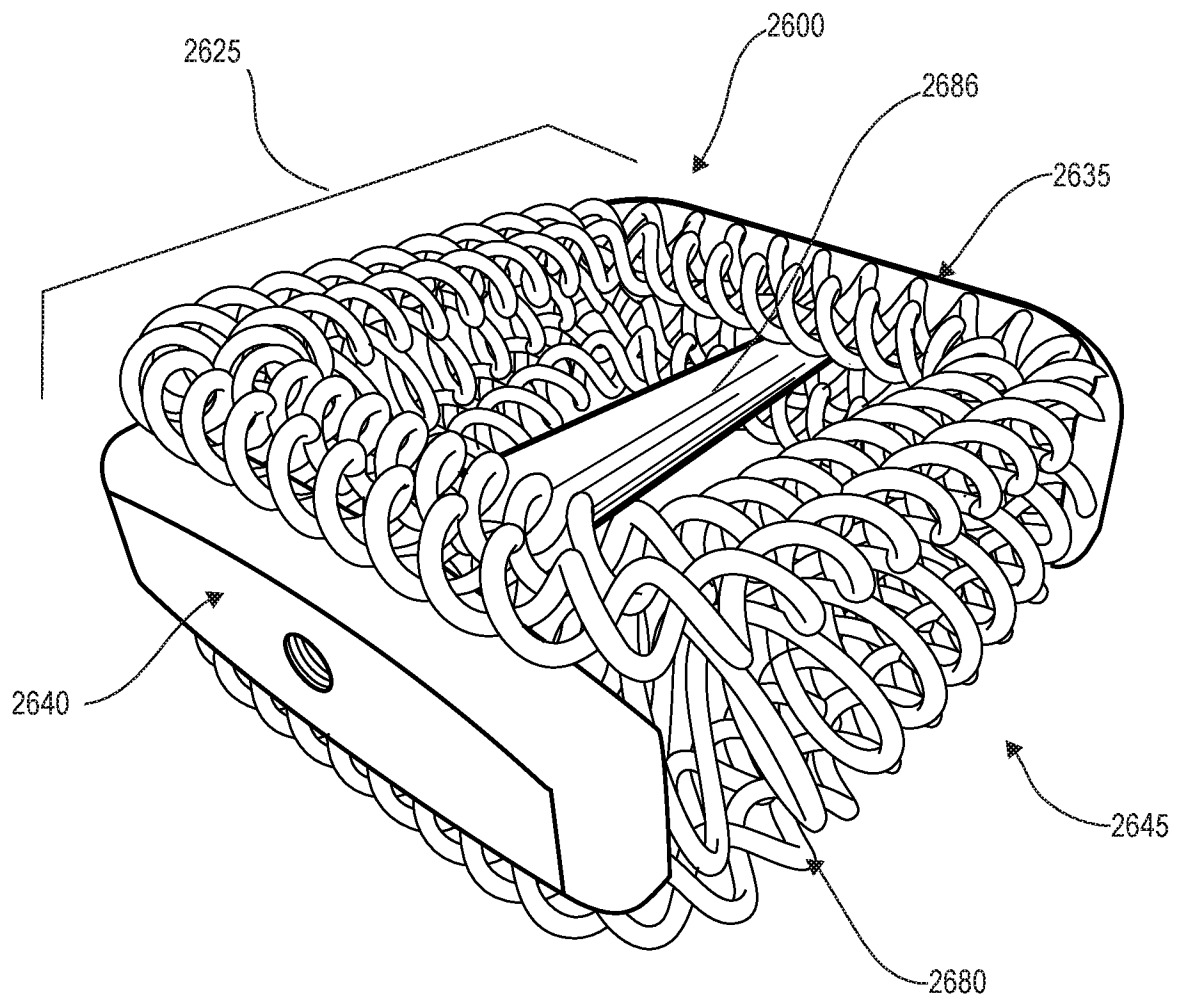


FIG. 26

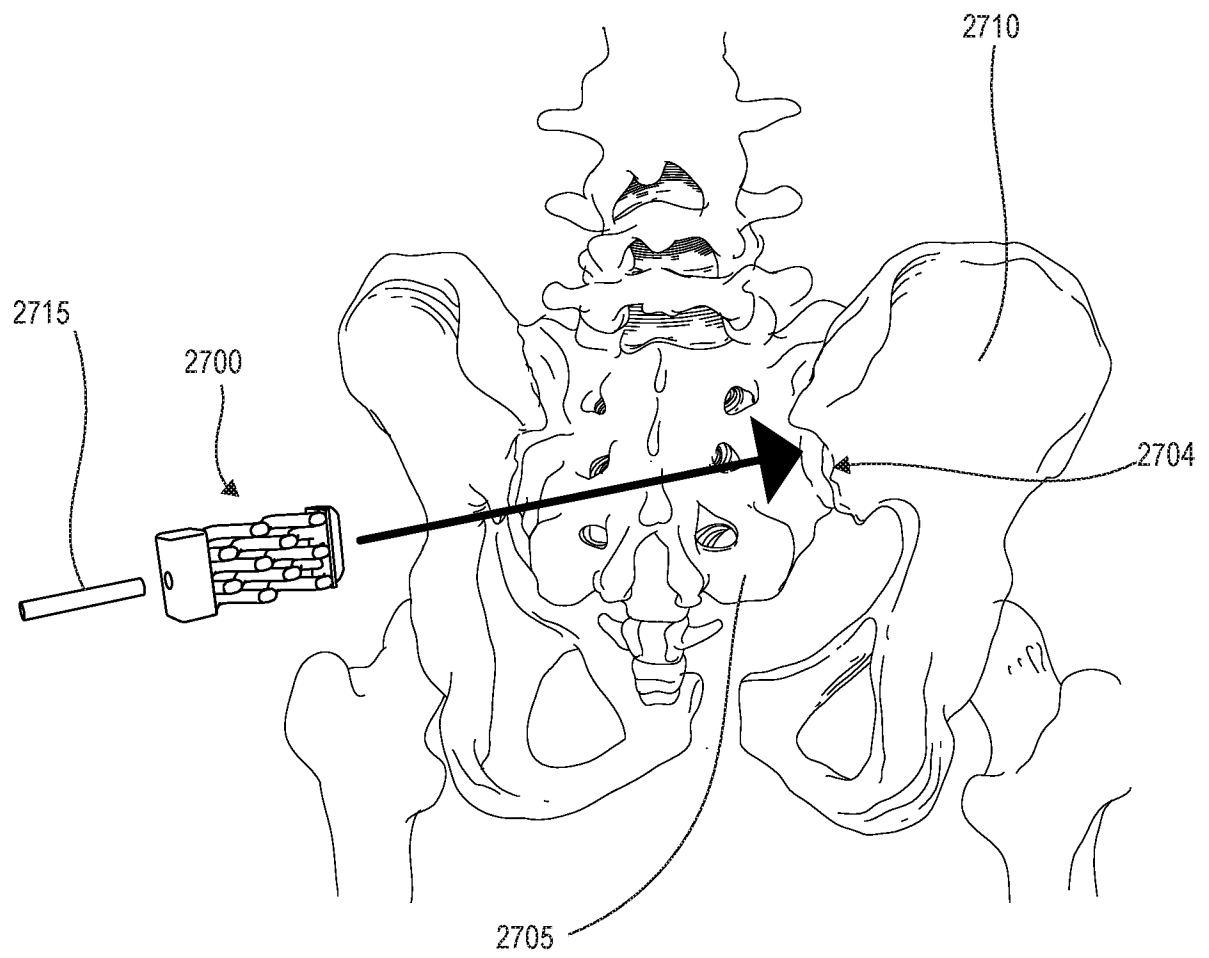


FIG. 27

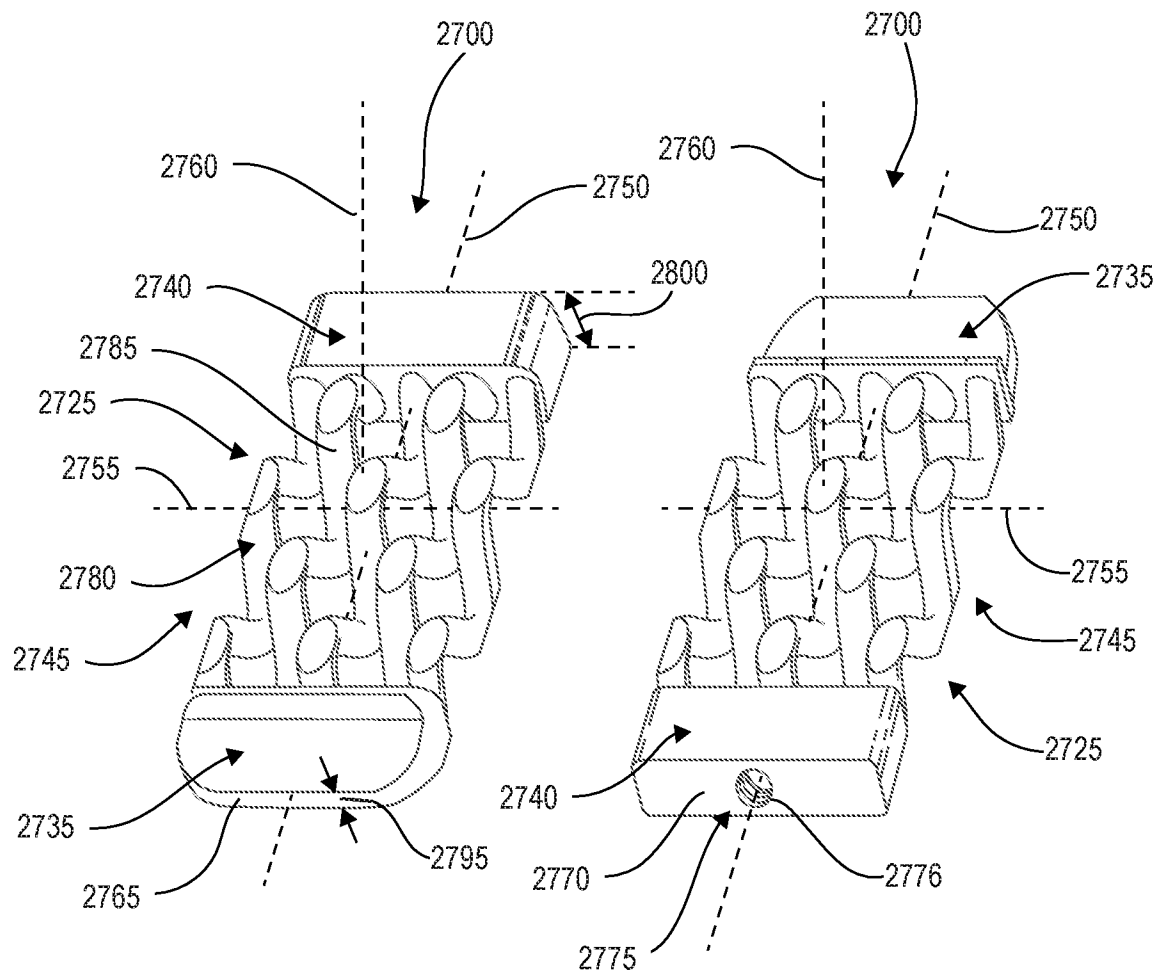


FIG. 28

FIG. 29

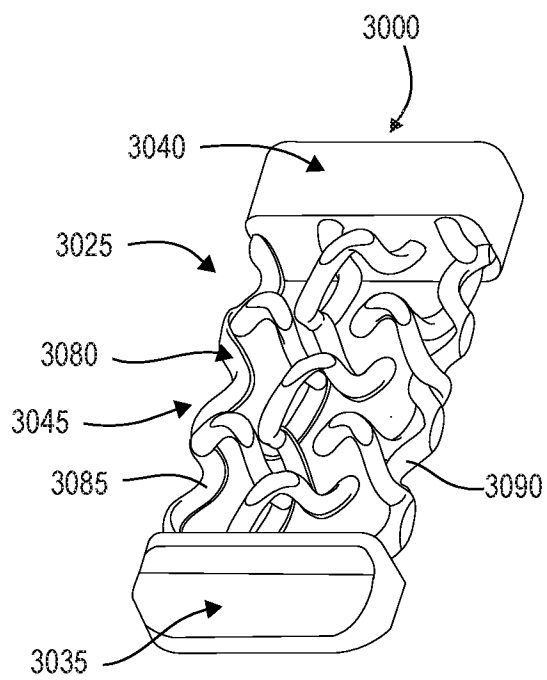


FIG. 30

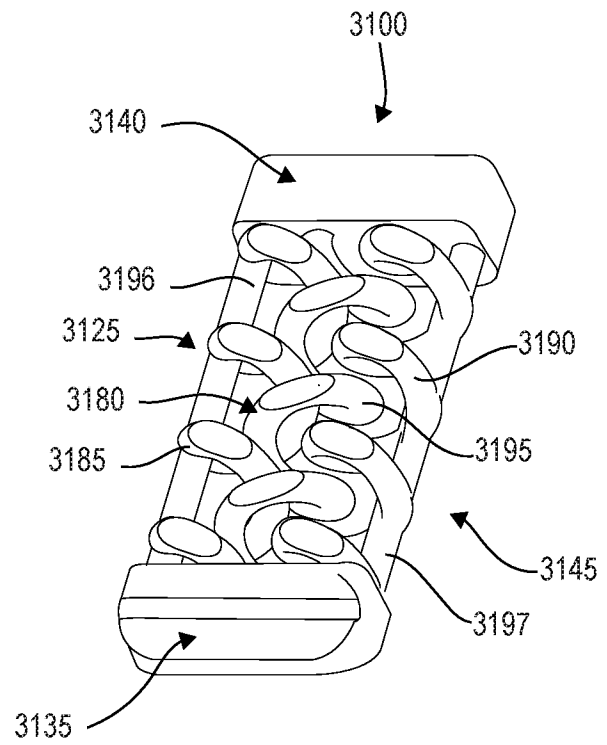


FIG. 31

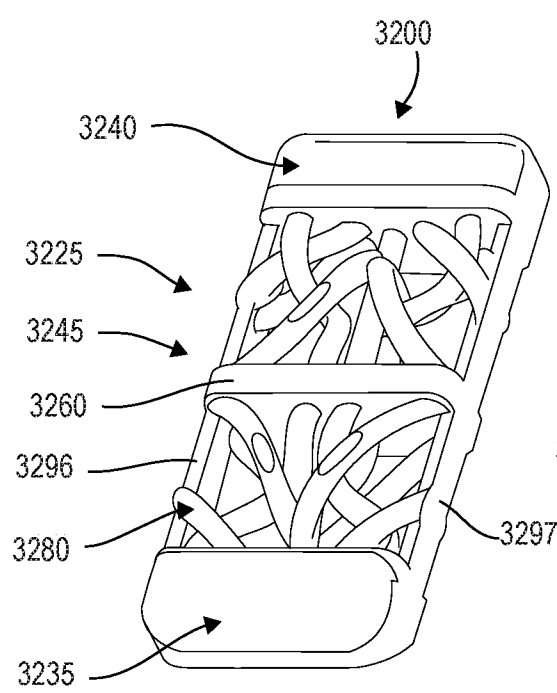


FIG. 32

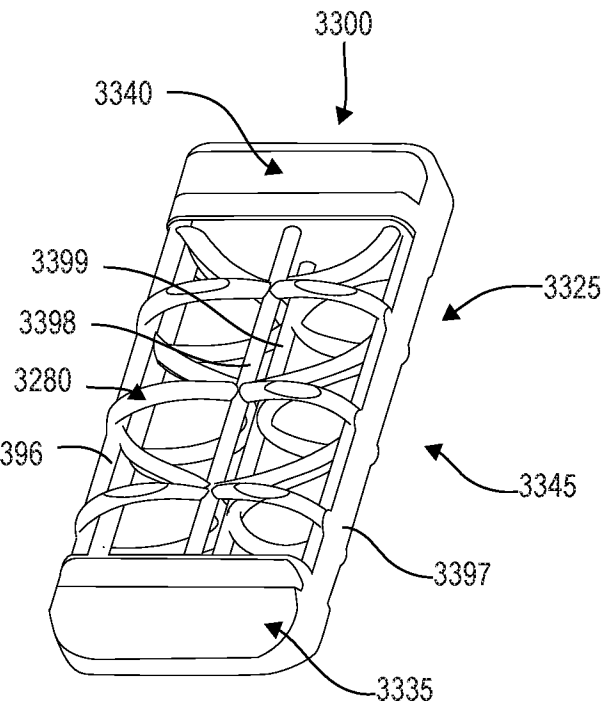


FIG. 33

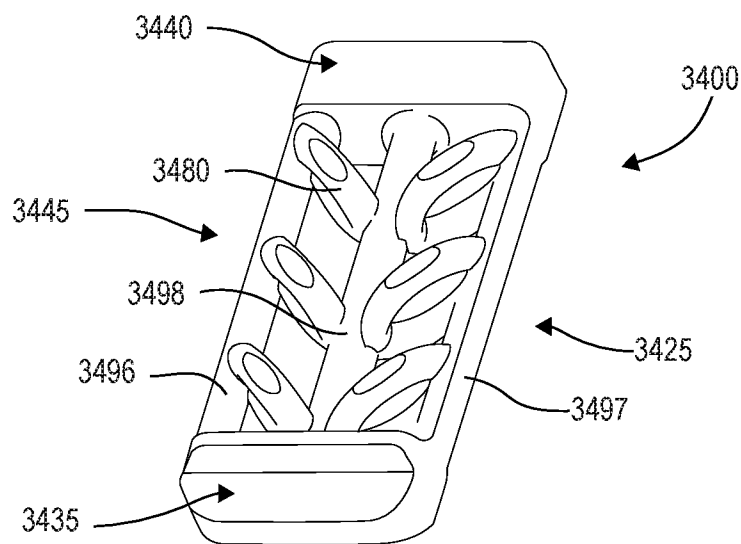


FIG. 34



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US17/58100

## A. CLASSIFICATION OF SUBJECT MATTER

IPC - A61B 17/70; A61F2/02, 2/28, 2/30, 2/44, 2/46 (2017.01)

CPC - A61F 2/44, 2/442, 2/4455, 2/446, 2/4465, 2/4465, 2/4611

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

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

See Search History document

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

See Search History document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, P	US 2017/0042697 A1 (INSTITUTE FOR MUSCULOSKELETAL SCIENCE AND EDUCATION LTD) February 17, 2017; figures 2, 8; paragraphs [0028], [0034], [0050], [0072]	1-23
X, P	"FDA Clears Camber Spine Technologies' 3D Printed SPIRA Open Matrix ALIF" August 15, 2017. Orthopedic Design & Technology. <a href="https://www.odtmag.com/contents/view_breaking-news/2017-08-IS/fda-dears-camber-spine-3d-printed-spira-ope">https://www.odtmag.com/contents/view_breaking-news/2017-08-IS/fda-dears-camber-spine-3d-printed-spira-ope</a> . Last accessed December 15, 2017.	10
X --- Y --- A	US 2006/0212118 A1 (ABERNATHIE, DL) September 21, 2006; figure 6; paragraphs [0029], [0033]	1, 9 ----- 8 ----- 2-7, 10-23
Y --- A	US 8728160 B2 (GLOBERMAN, O et al.) May 20, 2014; figure 7; column 34, lines 34-41	8 ----- 2-7, 10-23
A	US 7261739 B2 (RALPH, JD et al.) August 28, 2007; figures 3-4; column 5, lines 46-56; column 6, lines 1-30	2-7, 10-23



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

18 December 2017 (18.12.2017)

Date of mailing of the international search report

18 JAN 2018

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