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(54) LATTICE STRUCTURE IMPLANT AND METHODS FOR MAKING THE SAME

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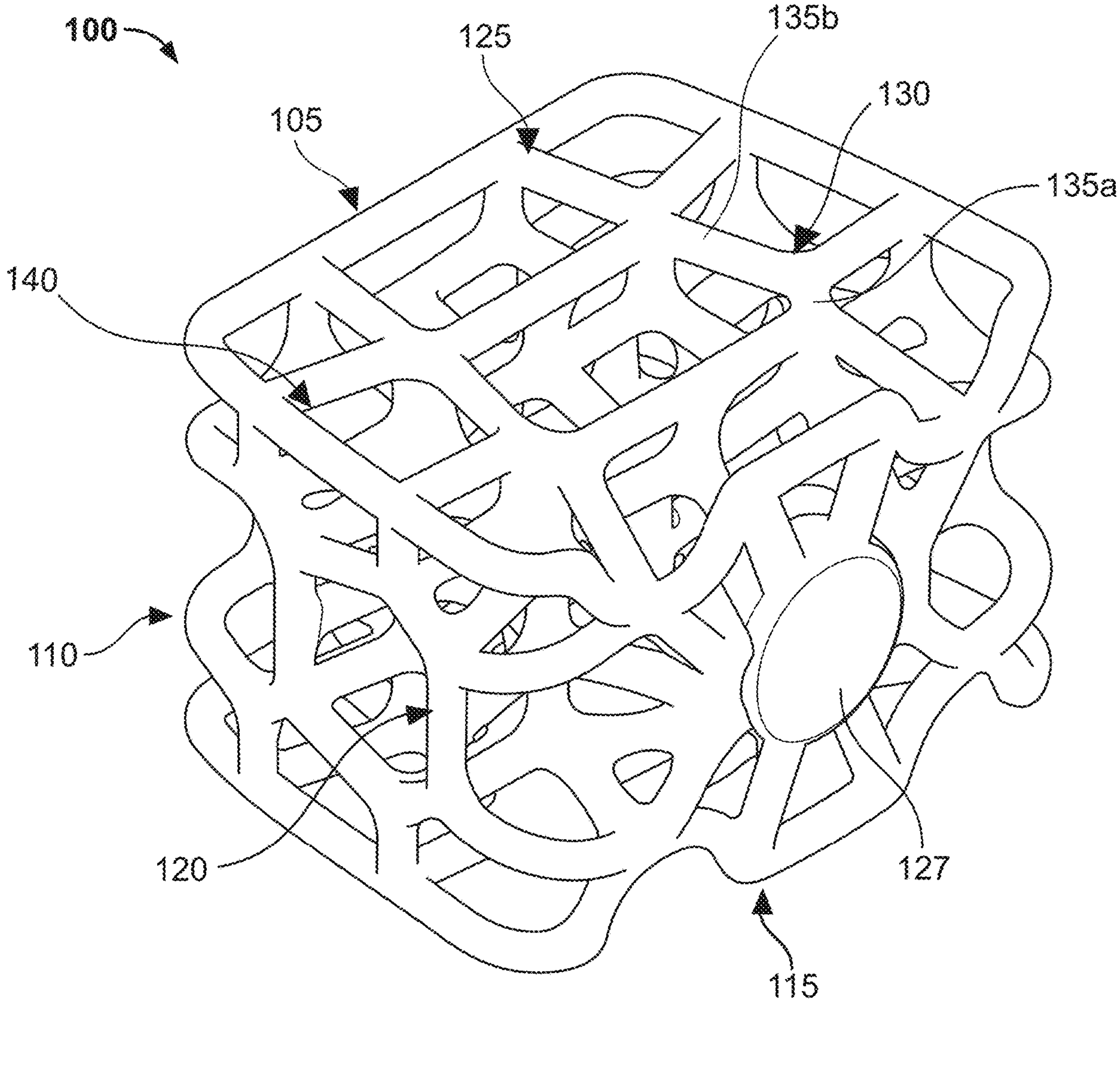
(57) **ABSTRACT**

An implant is provided. The implant may include a top surface, a bottom surface opposite the top surface, and a body positioned between the top surface and the bottom surface. The top surface may include a first surface lattice, and the bottom surface may include a second surface lattice. Additionally, the body may substantially occupy a volume between the top and bottom surfaces, further defining one or more side surfaces of the implant. Moreover, the body, the first surface lattice, and the second surface lattice may include a plurality of lattice structures.



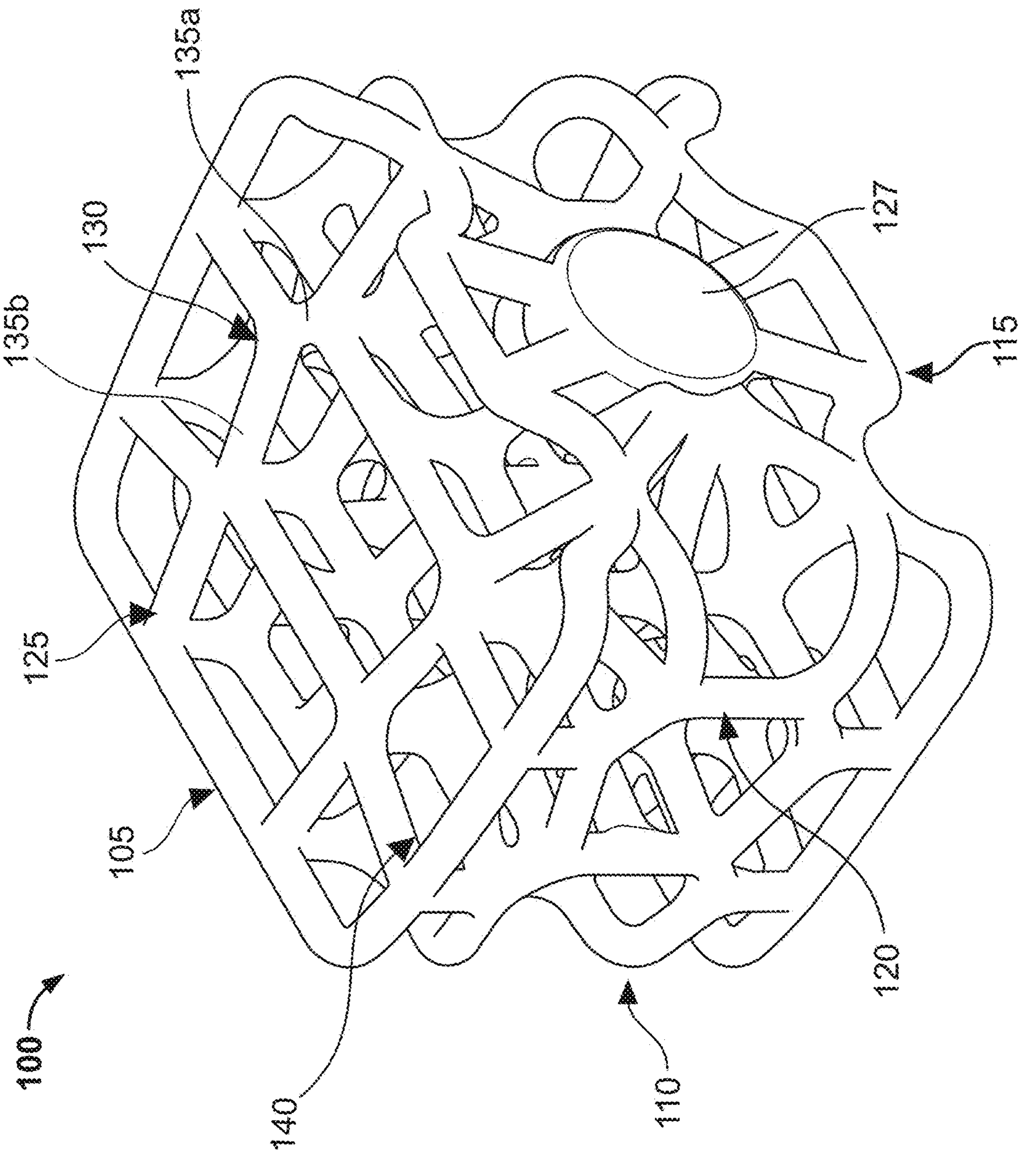


FIG. 1

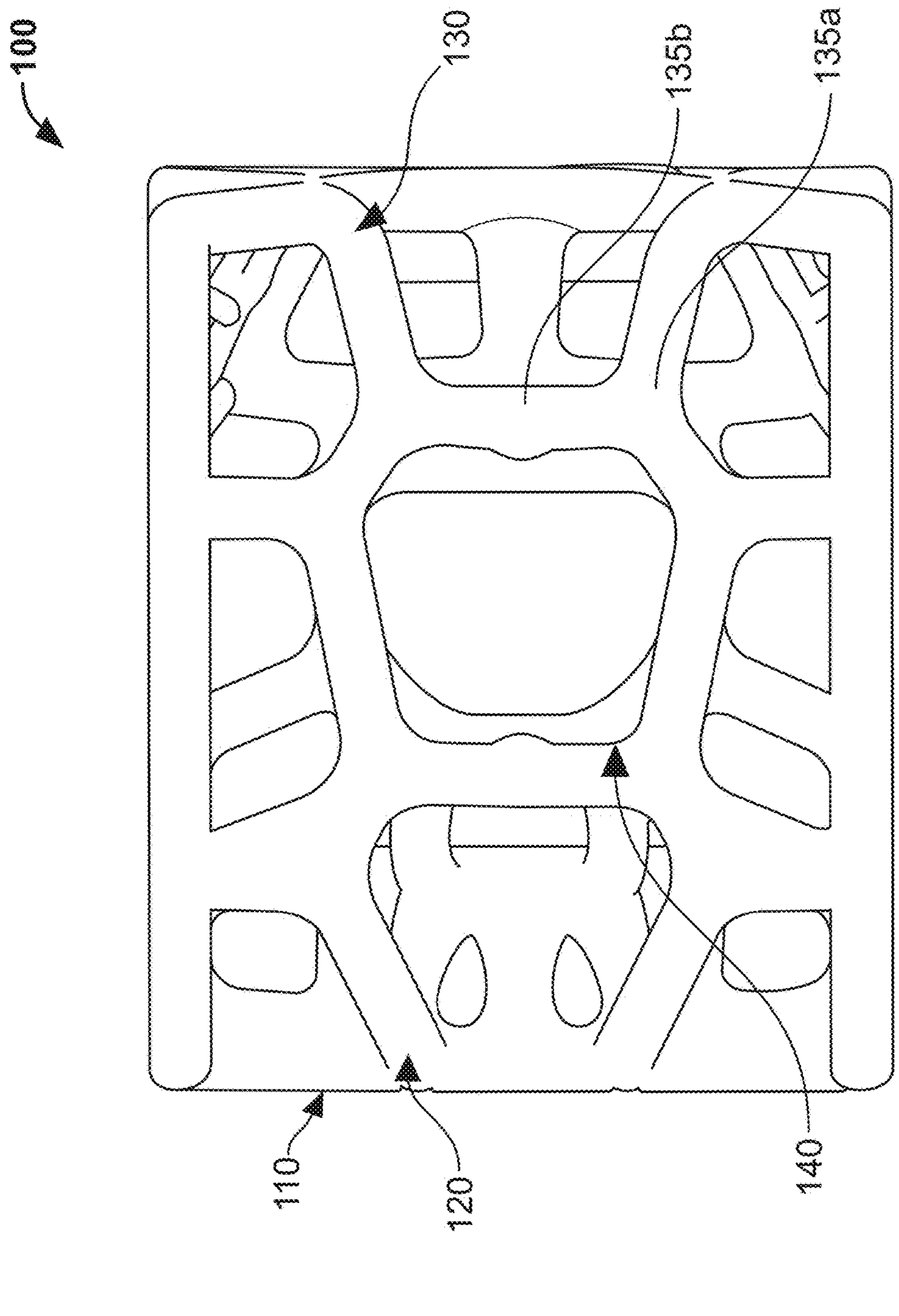


FIG. 2

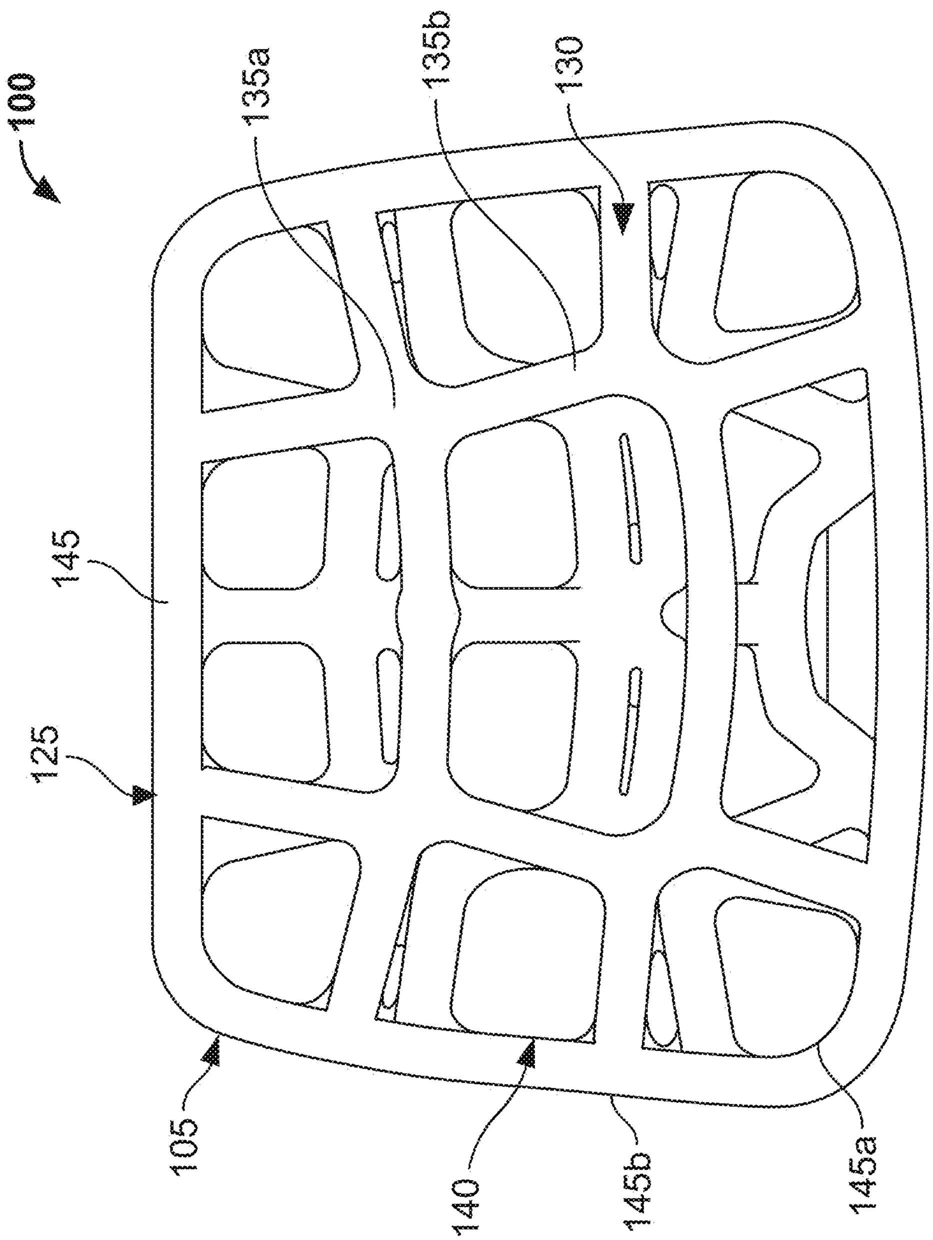


FIG. 3

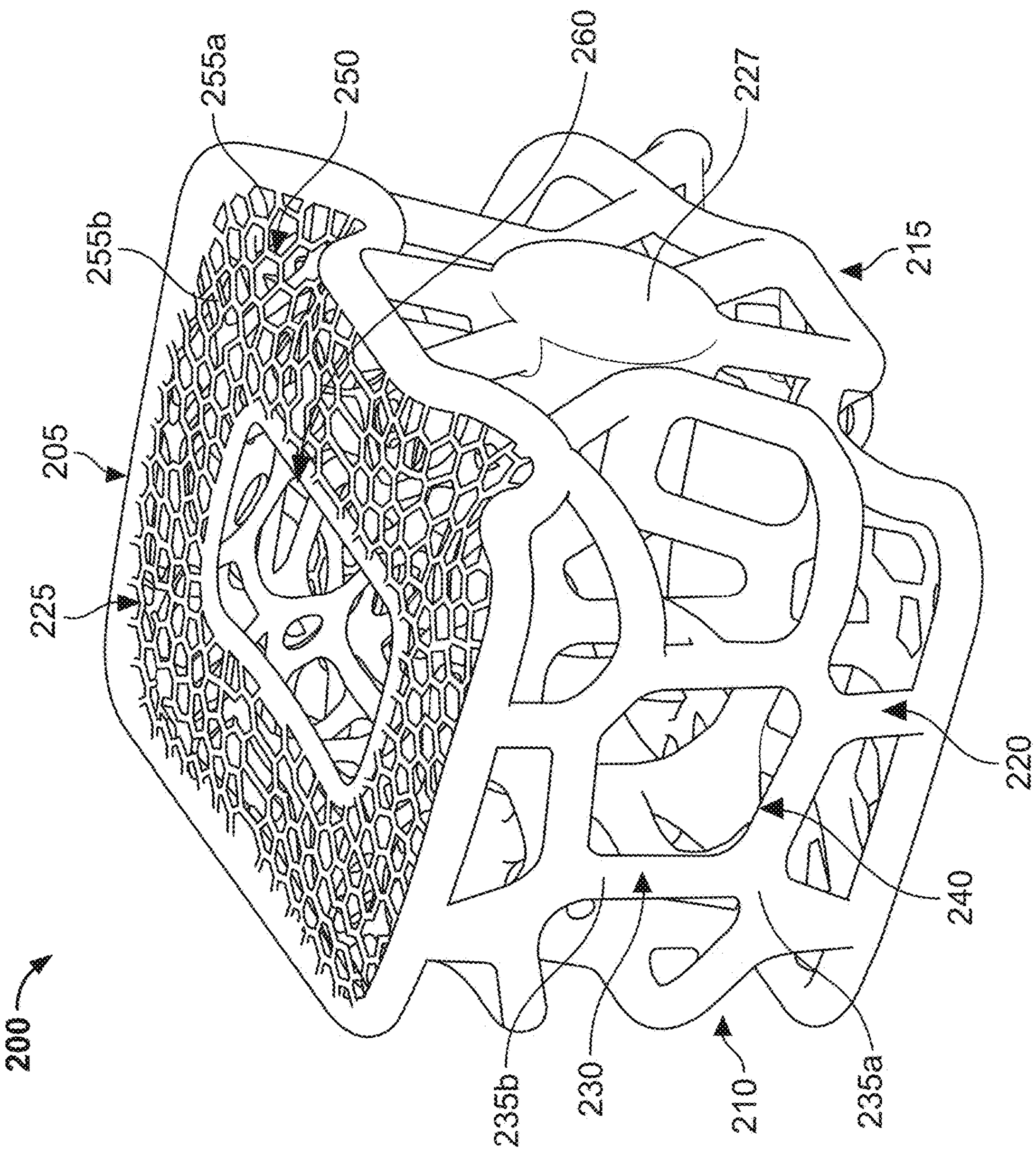


FIG. 4

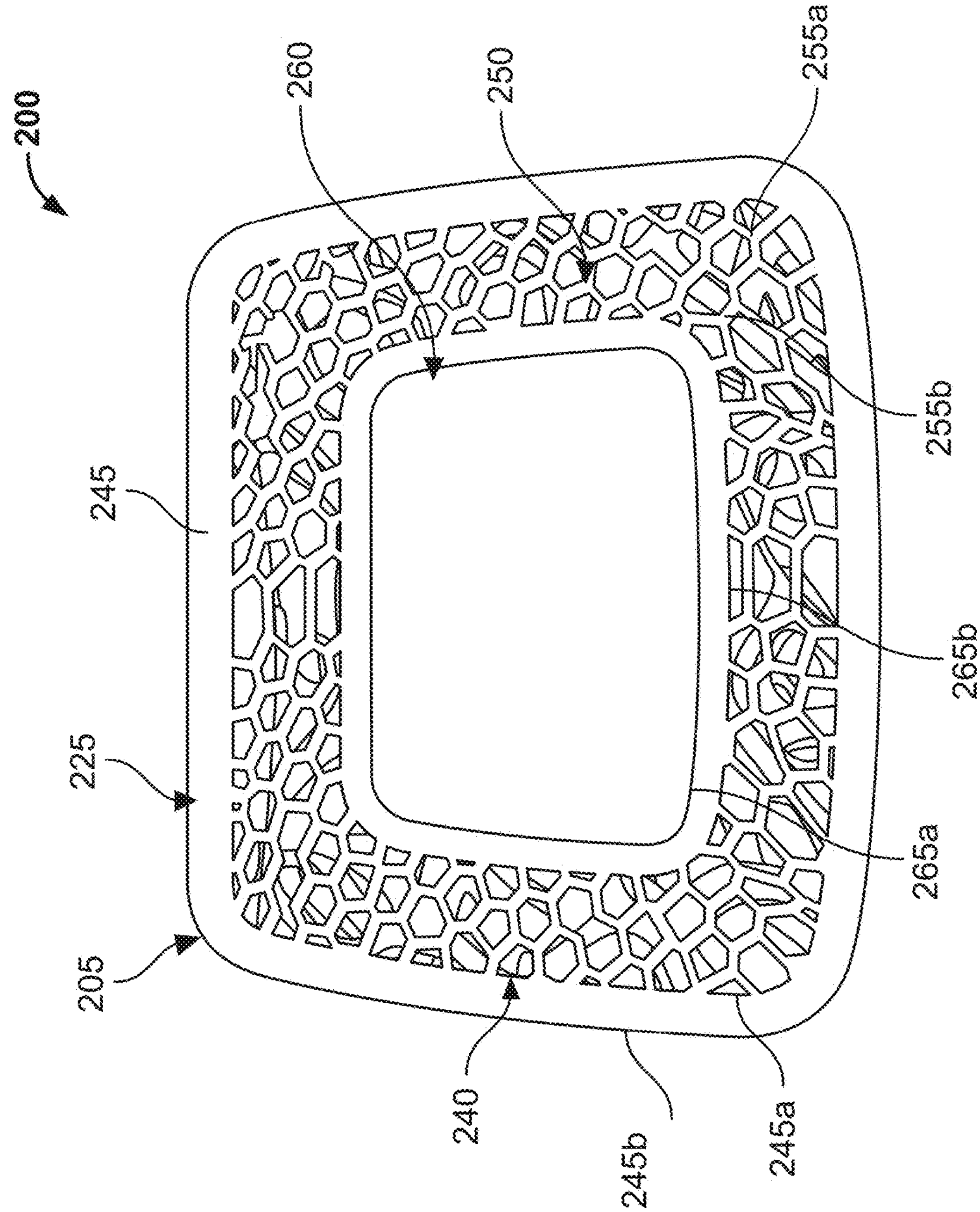


FIG. 5

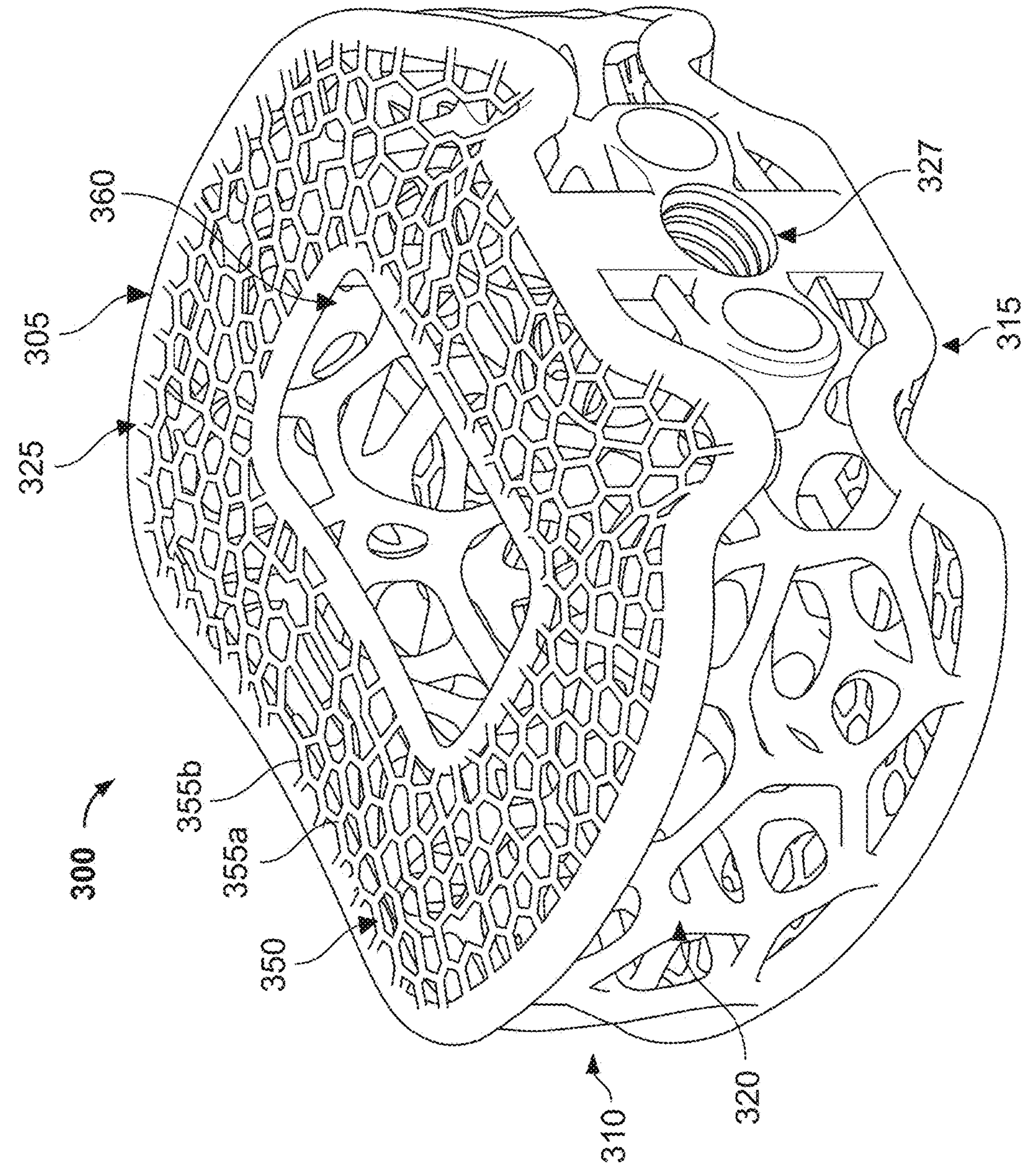


FIG. 6

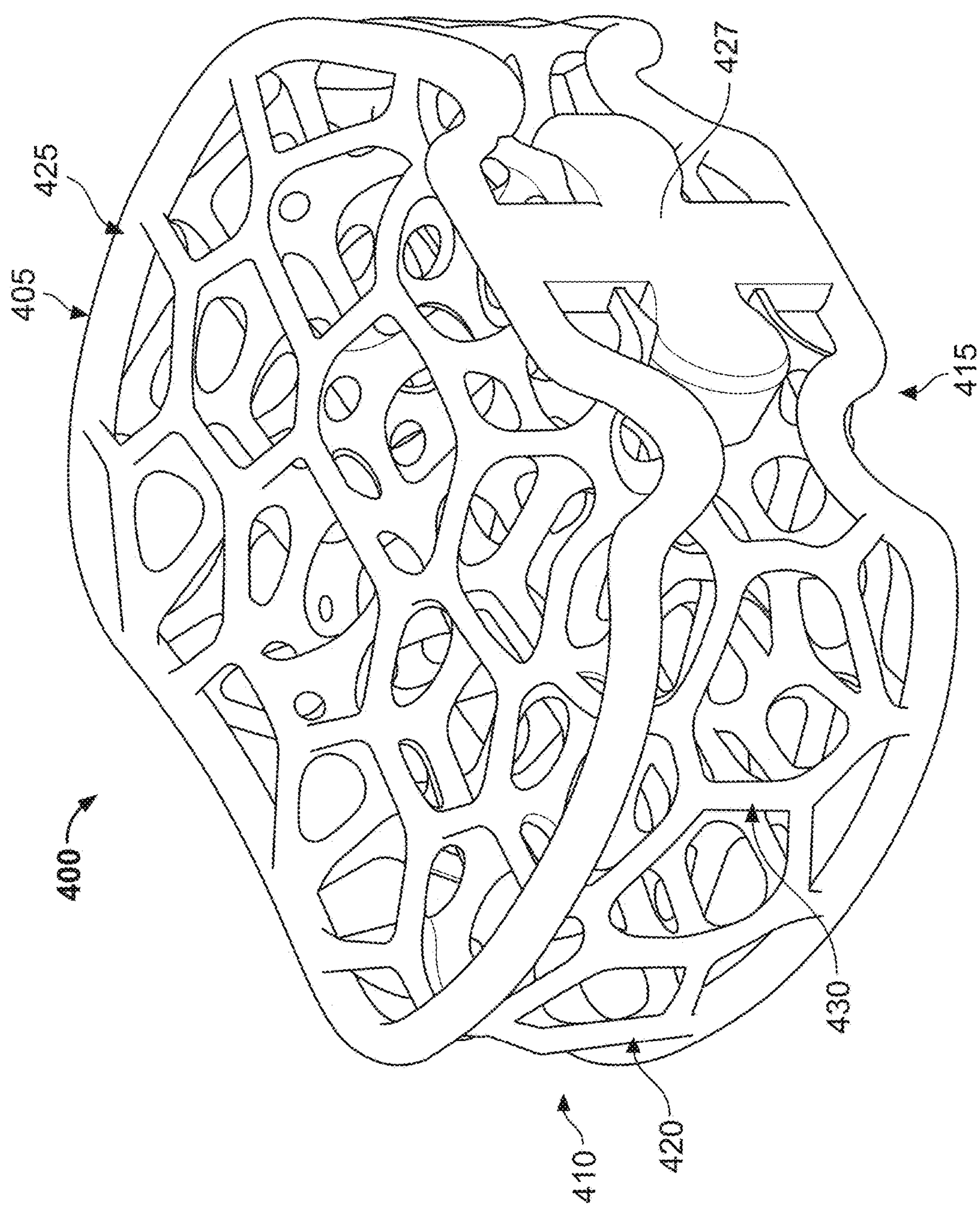


FIG. 7

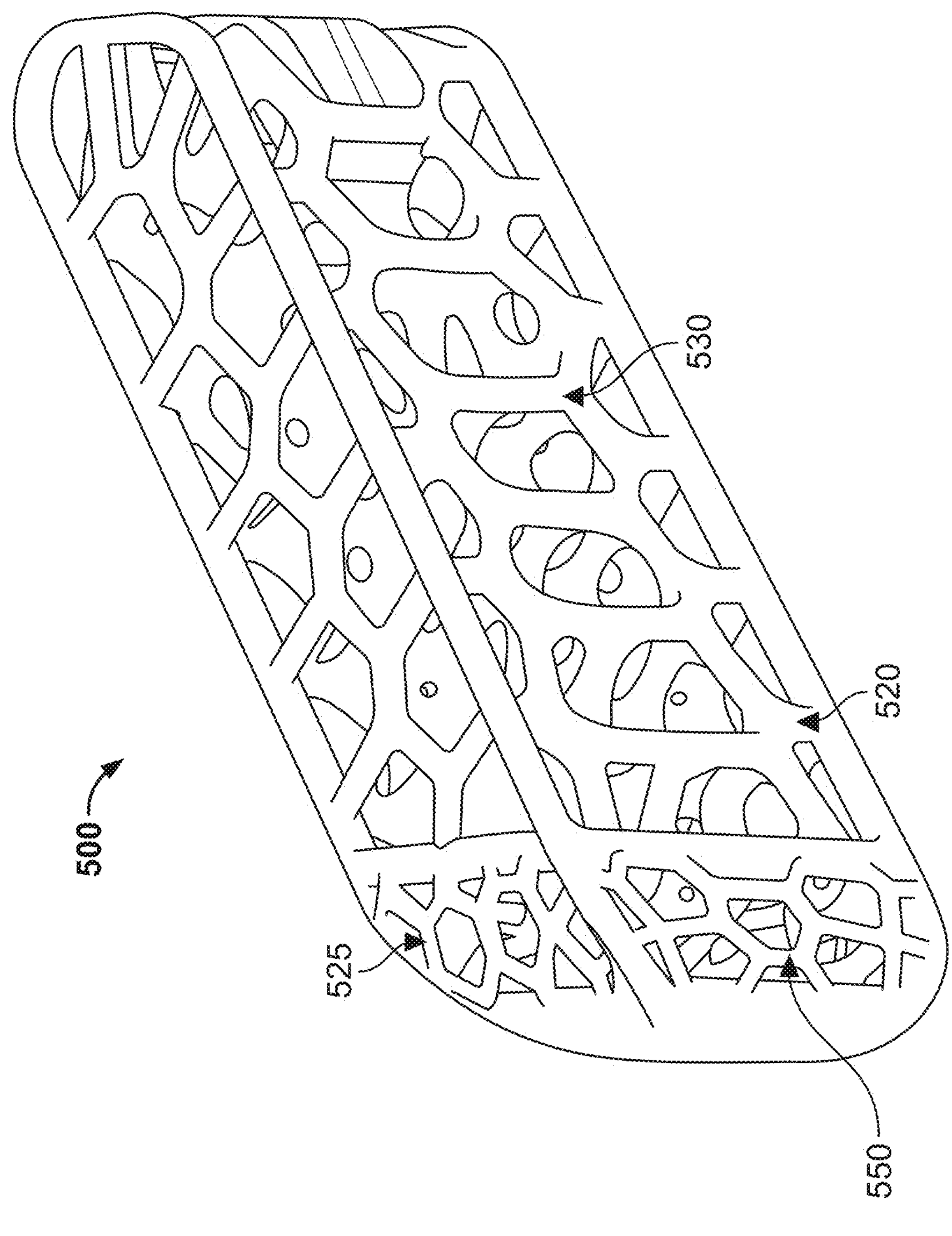


FIG. 8

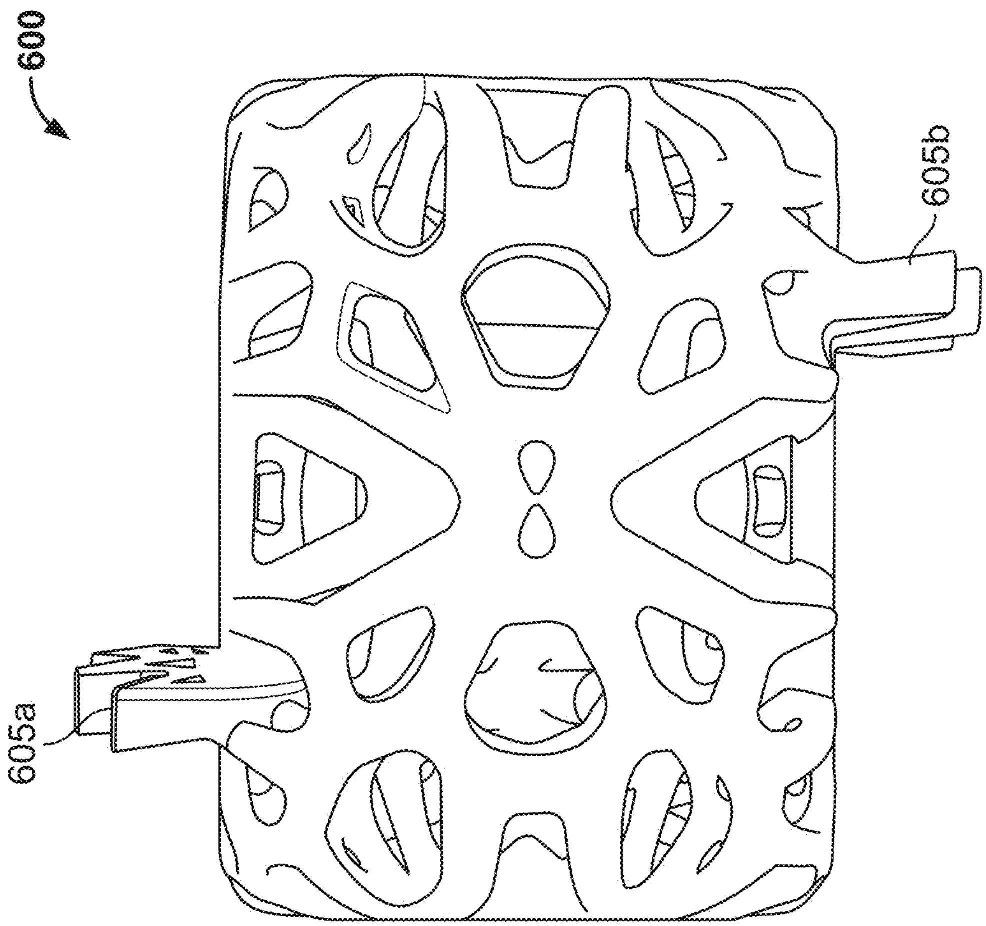


FIG. 9

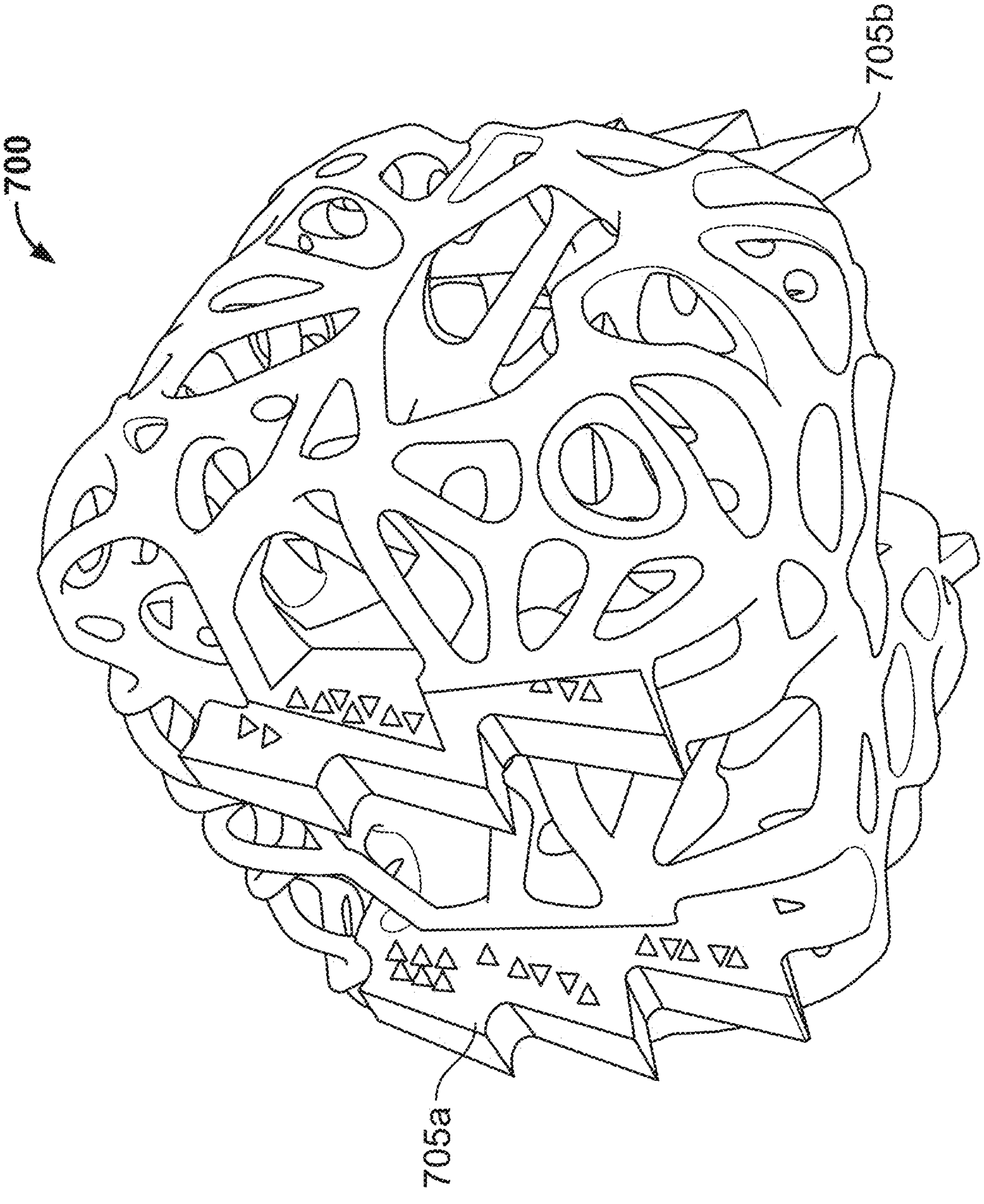


FIG. 10

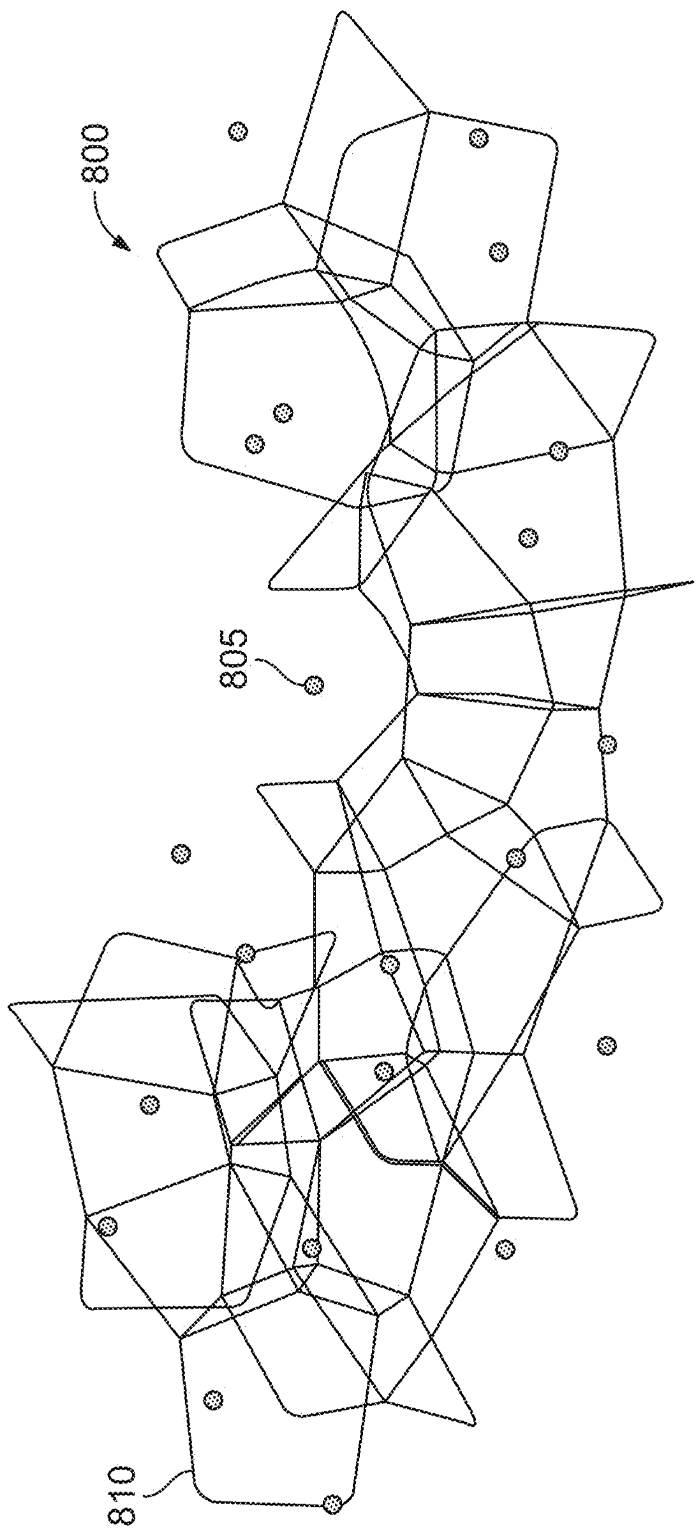
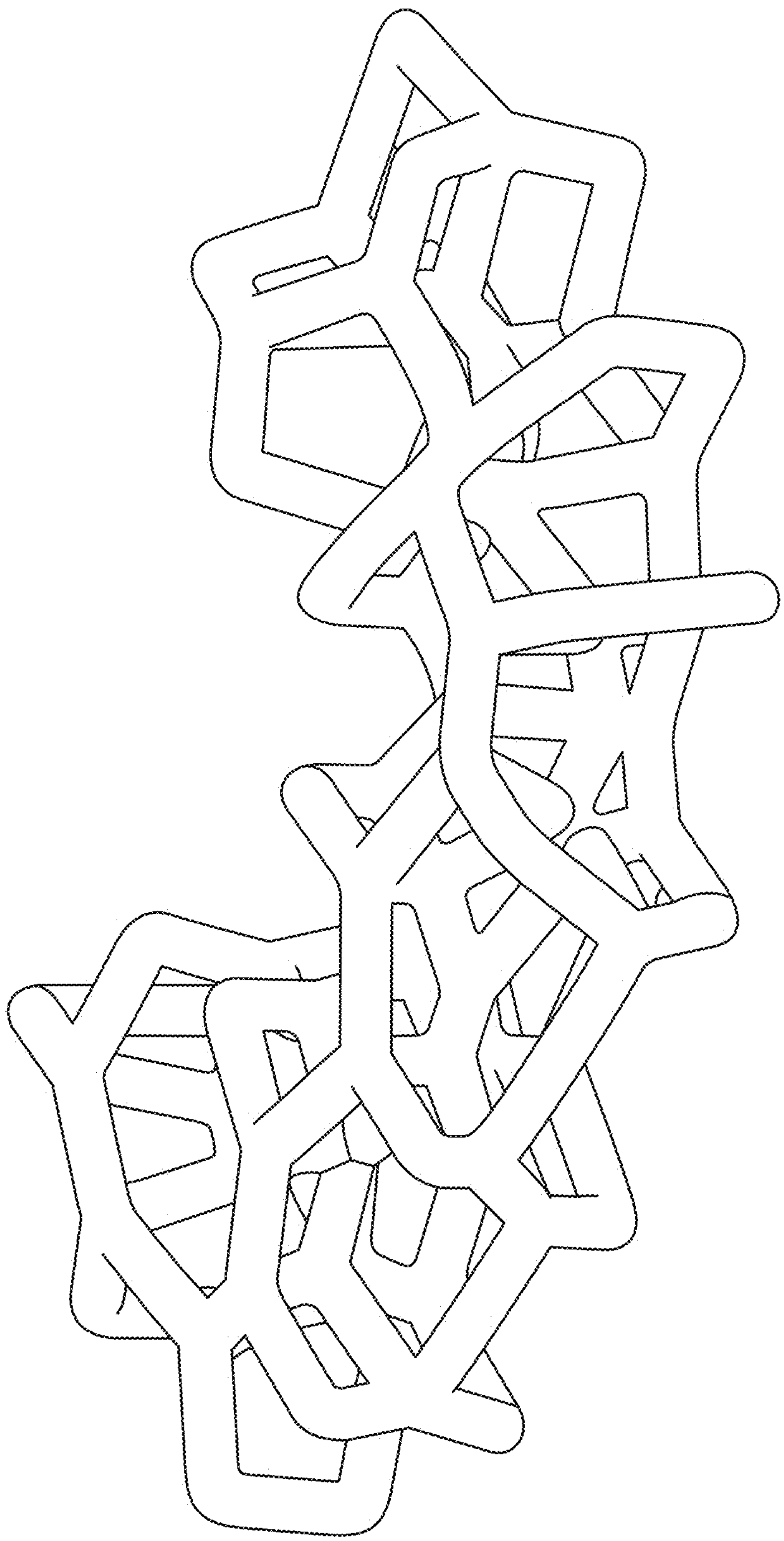
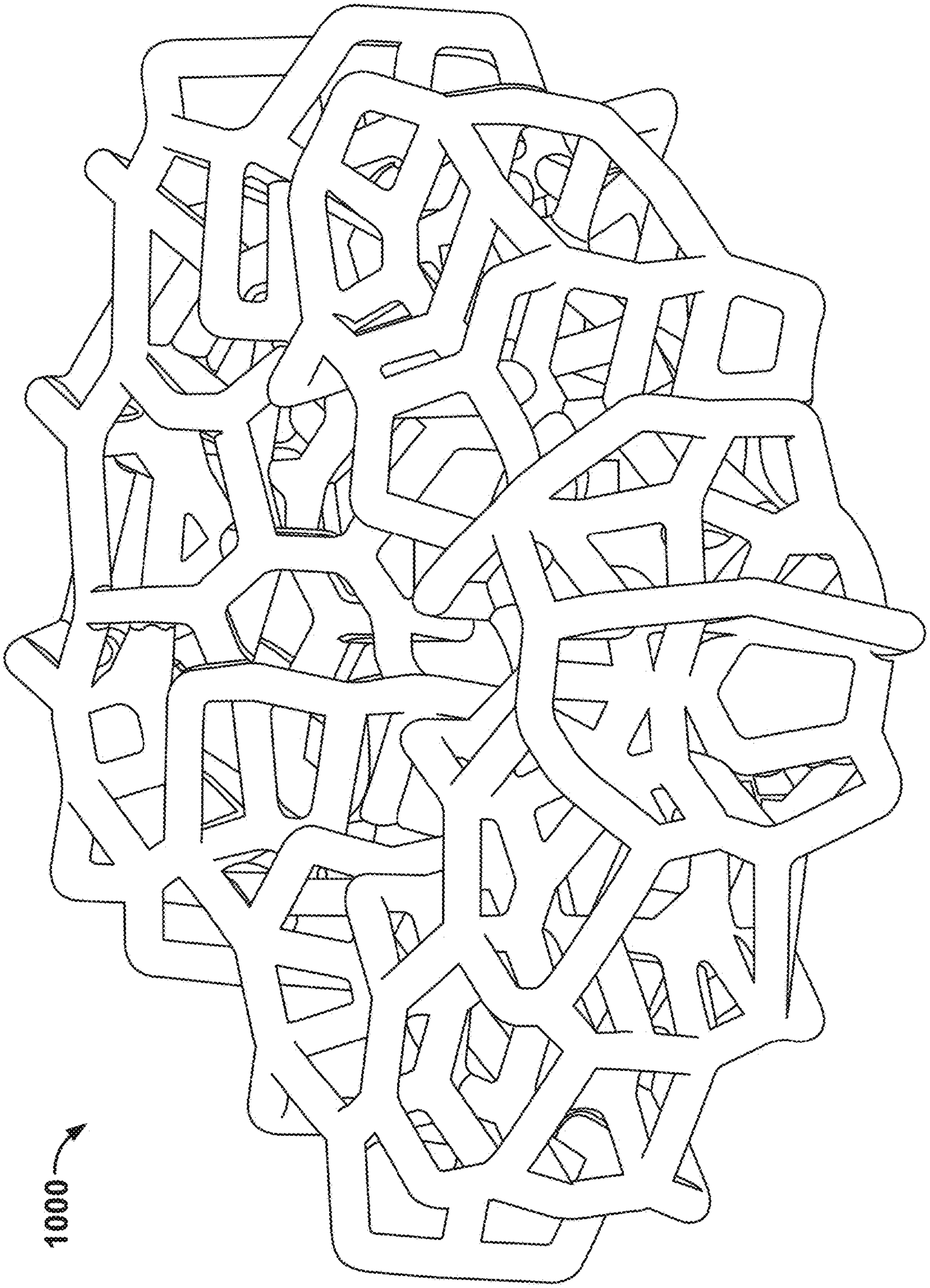


FIG. 11



900

FIG. 12



1000

FIG. 13

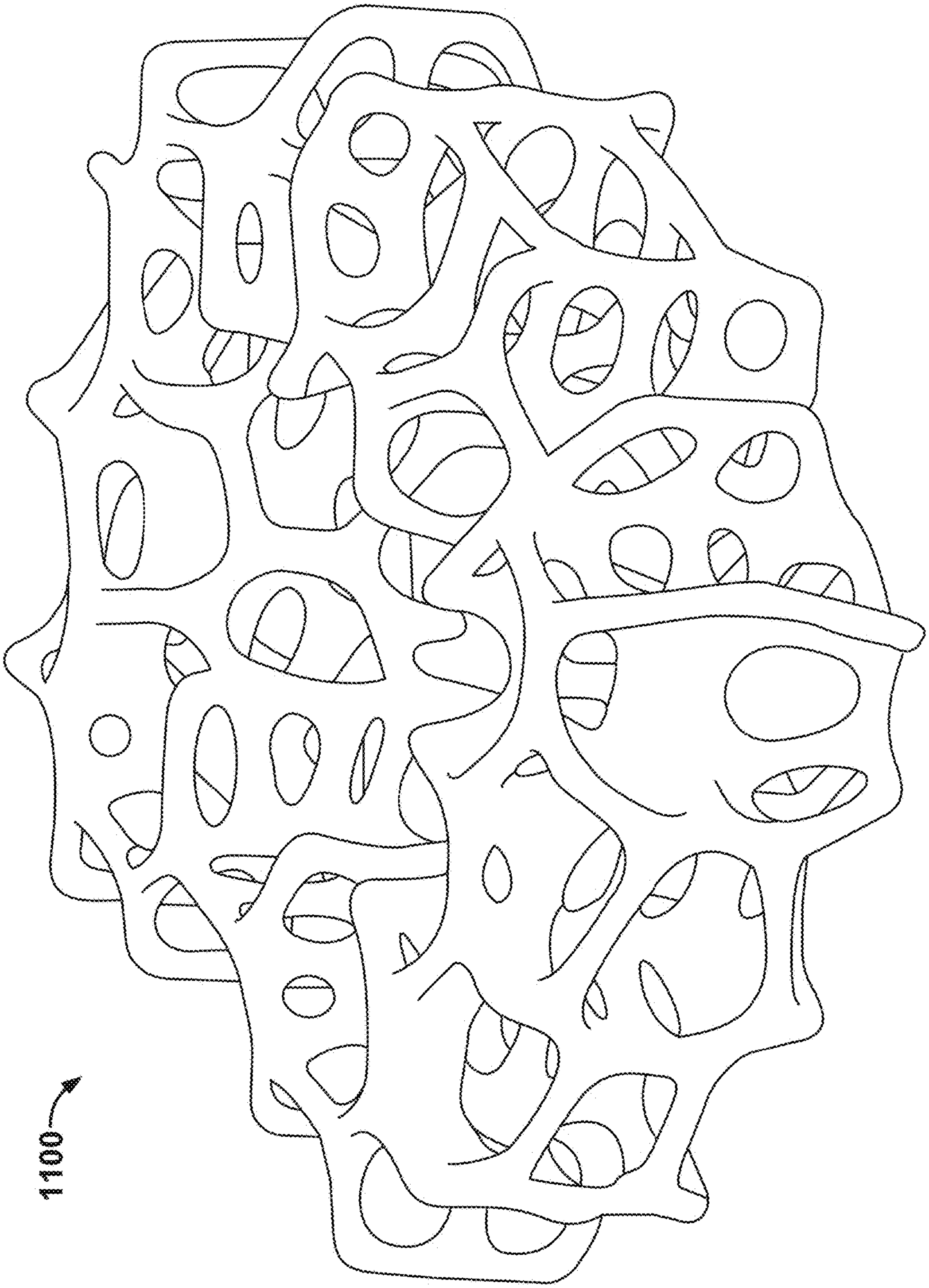


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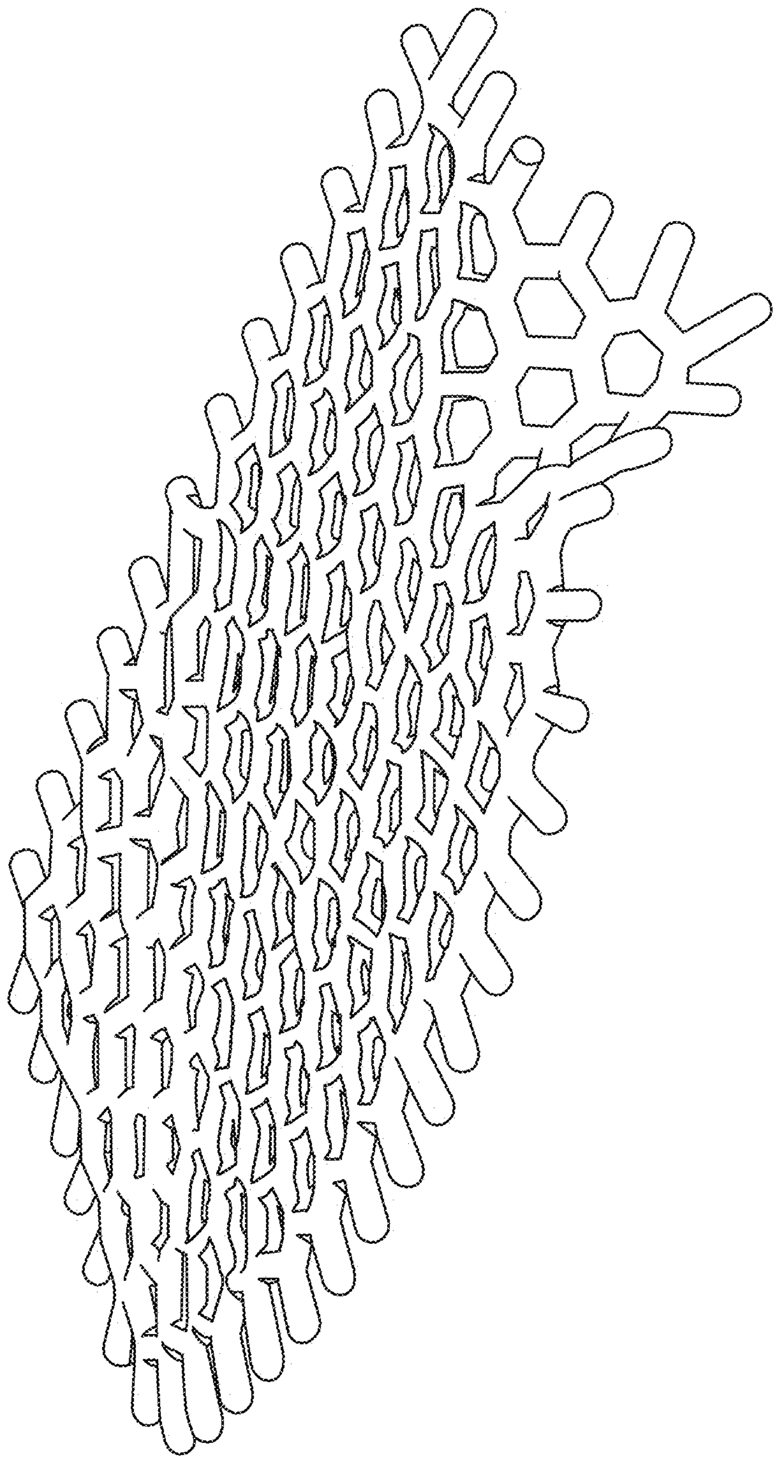
FIG. 14



1200

FIG. 15

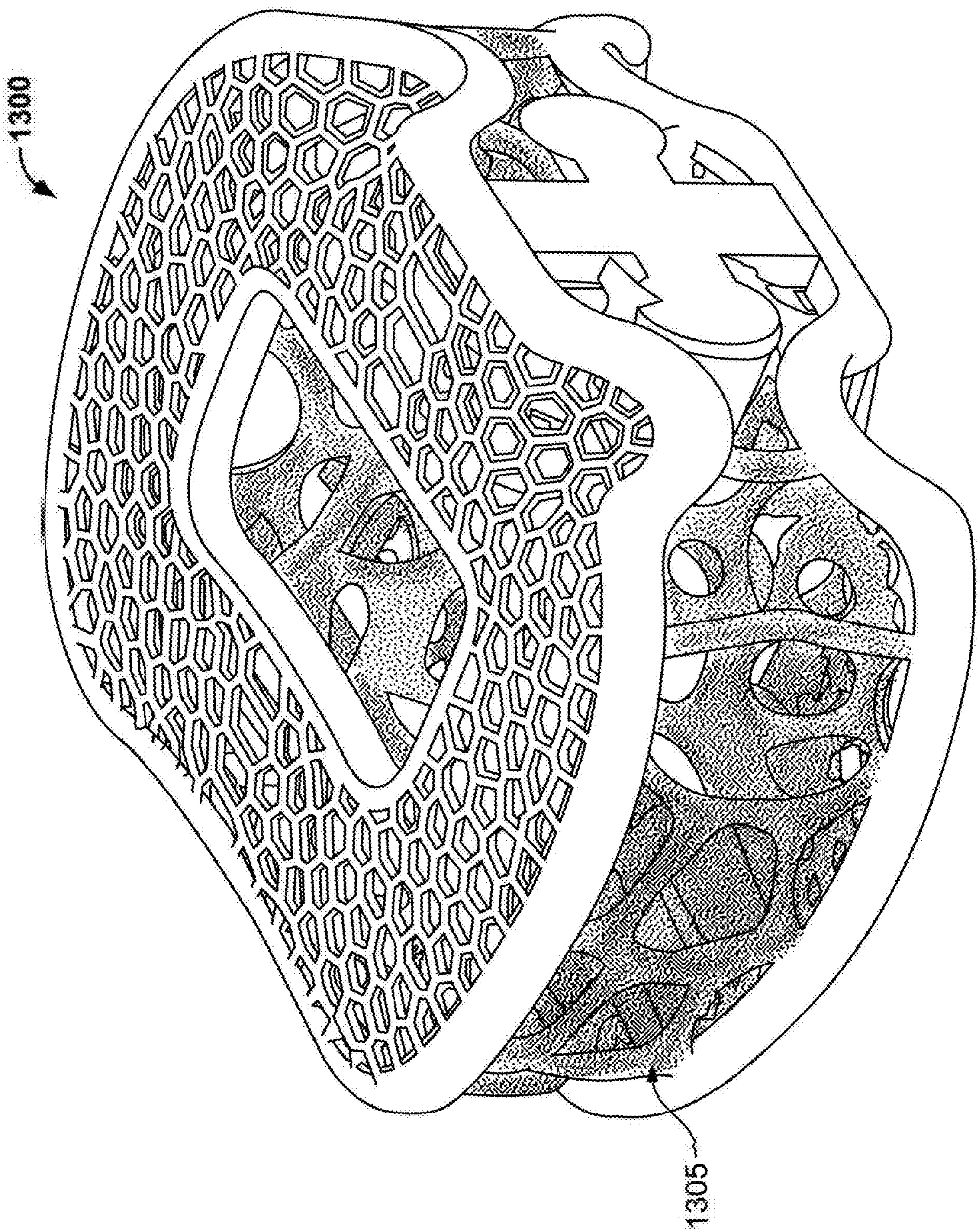


FIG. 16

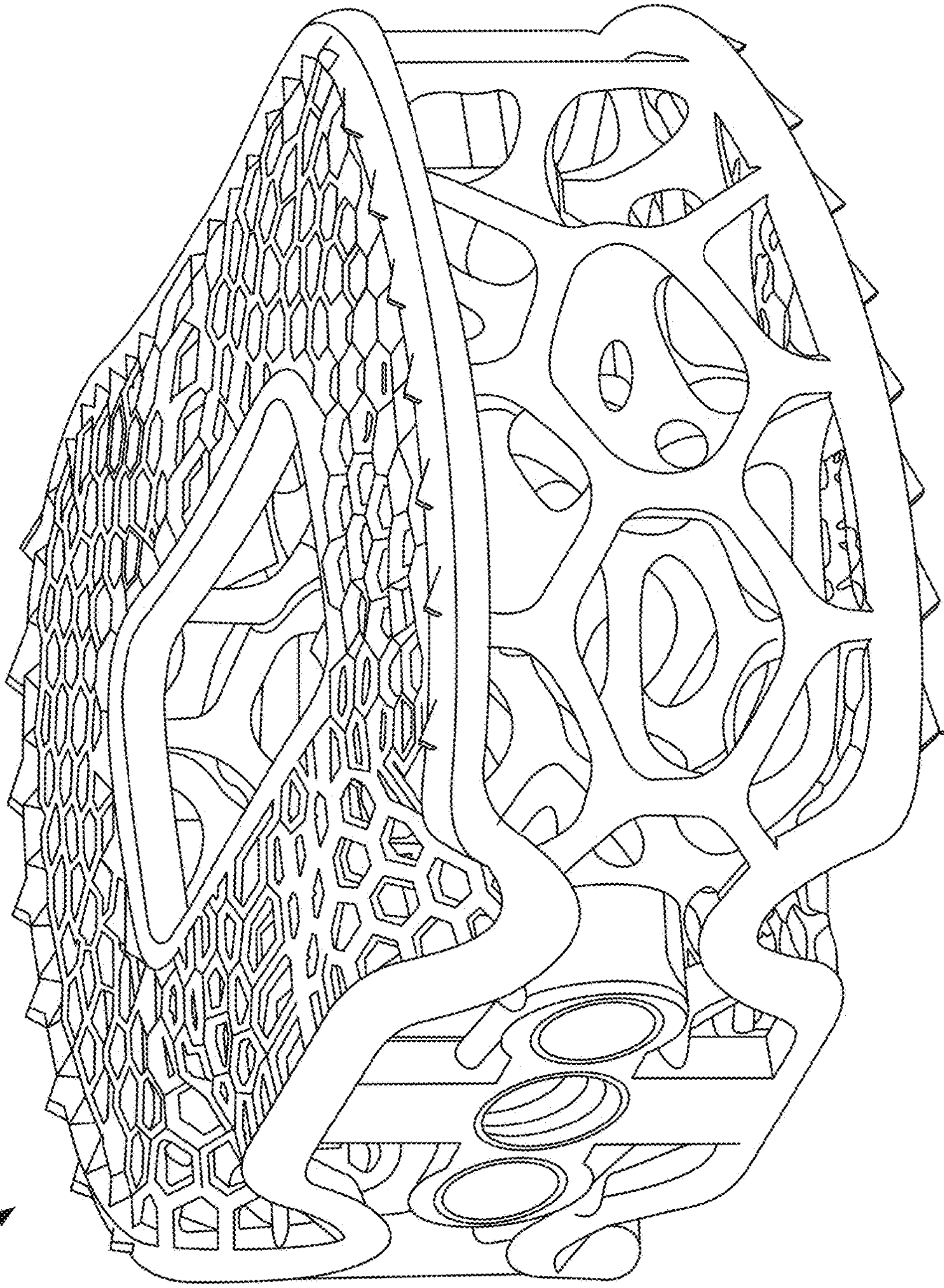


FIG. 17

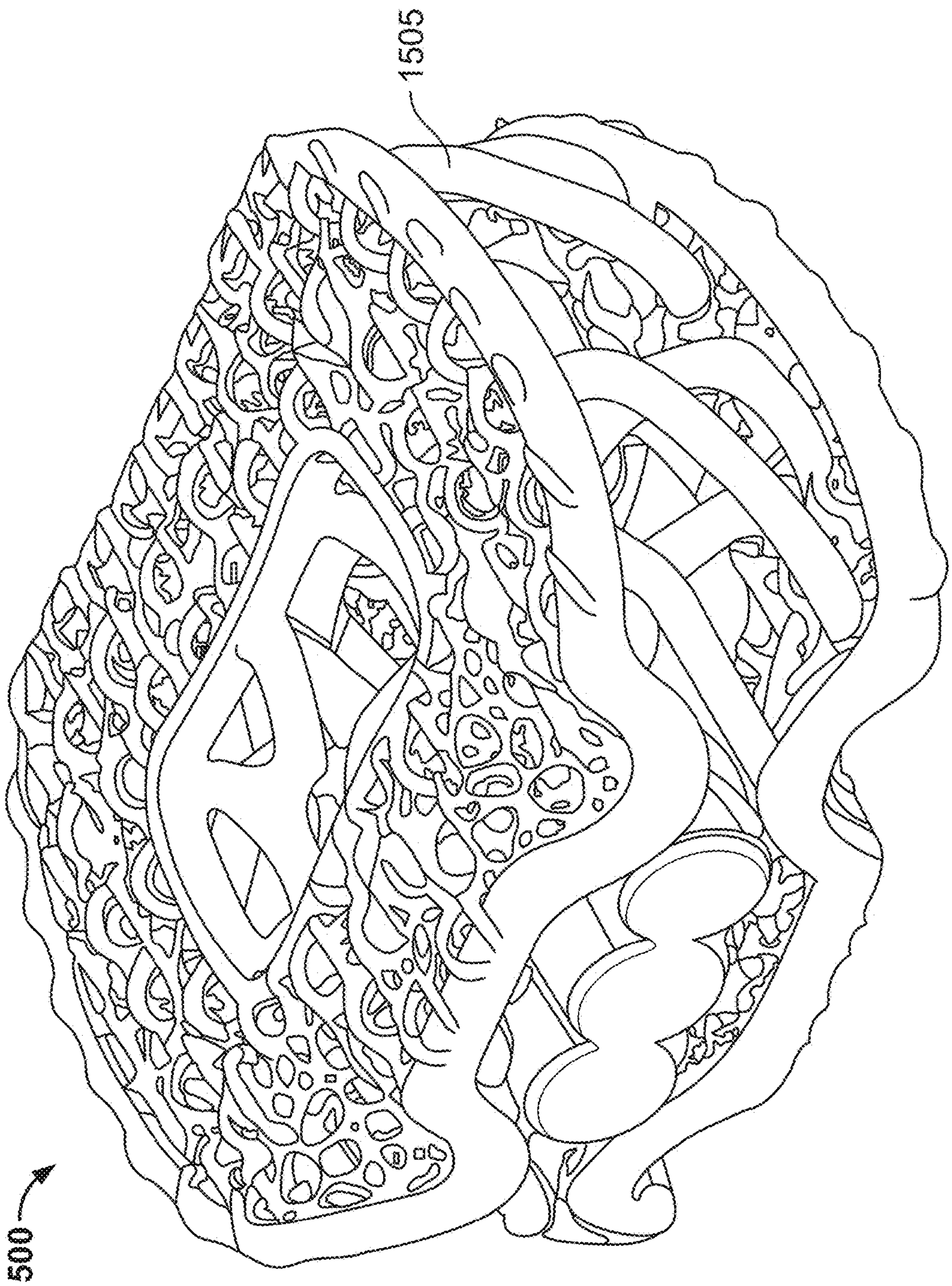


FIG. 18

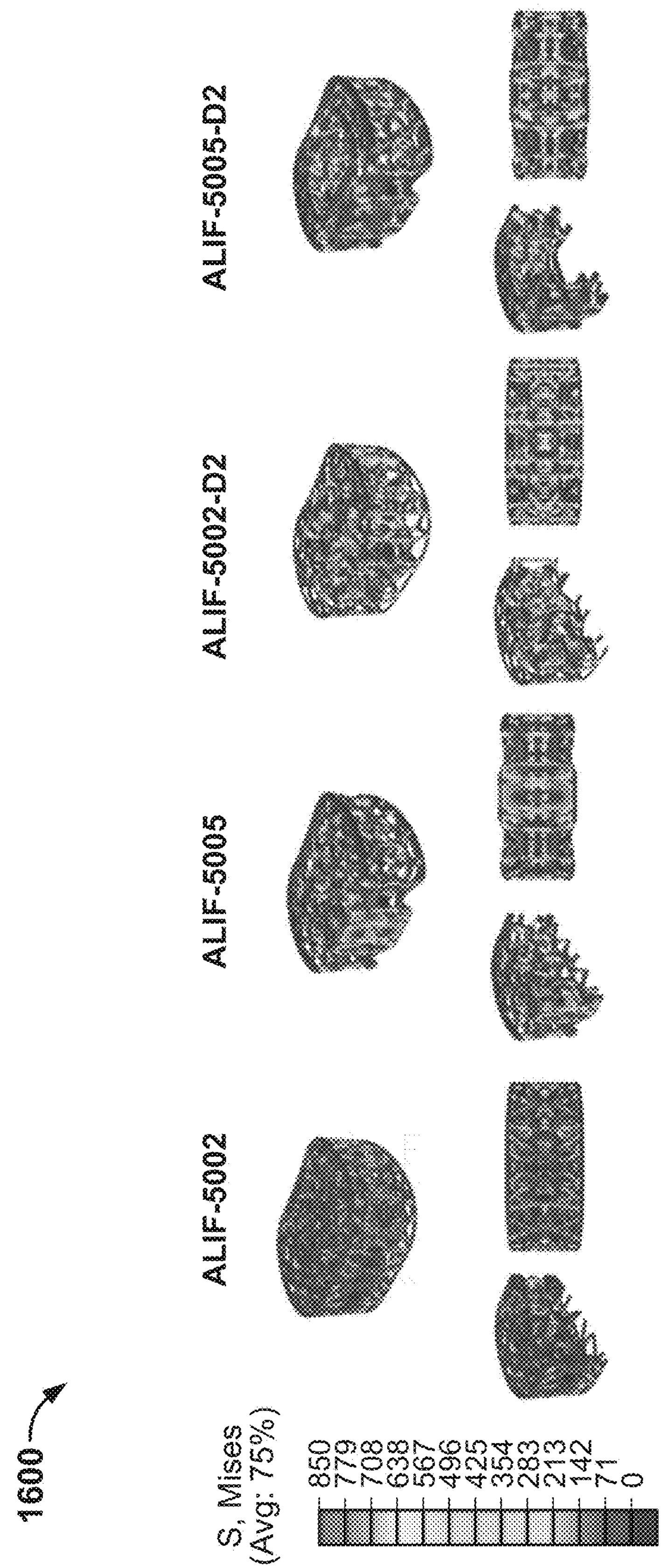

1600
S, Mises
(Avg: 75%)
850
779
708
638
567
496
425
354
283
213
142
71
0
ALIF-5002
ALIF-5005
ALIF-5002-D2
ALIF-5005-D2

FIG. 19

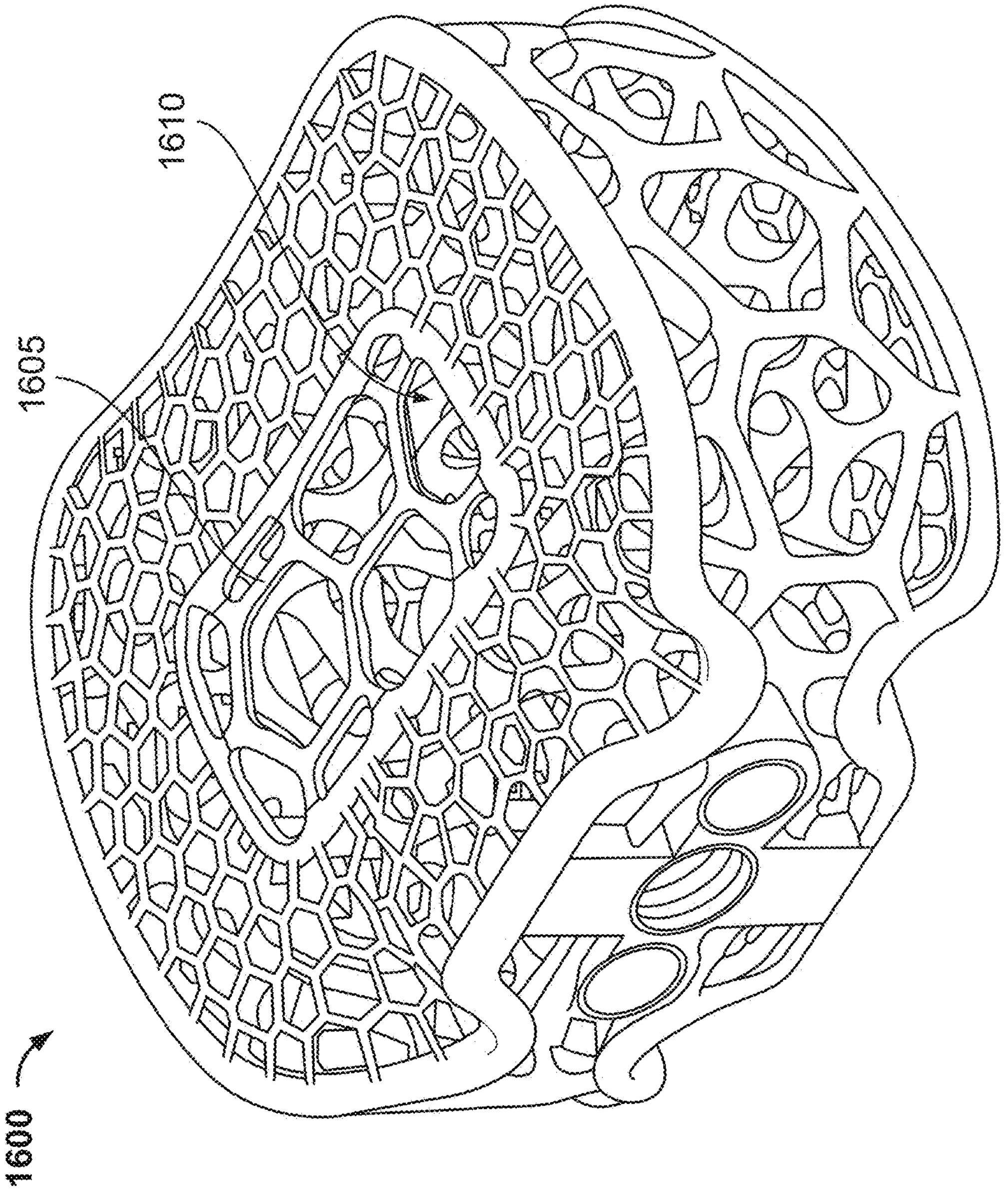


FIG. 20

1700

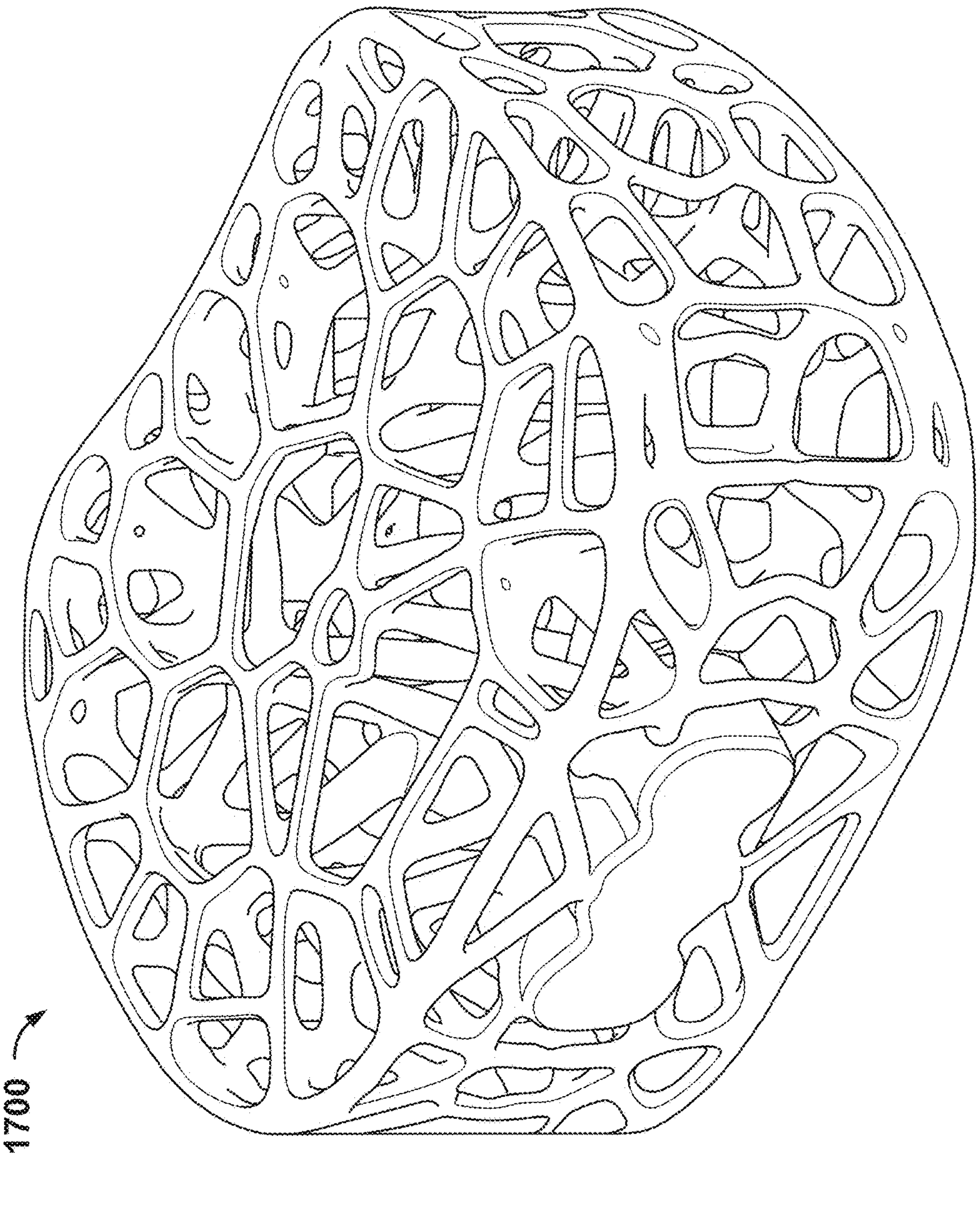


FIG. 21

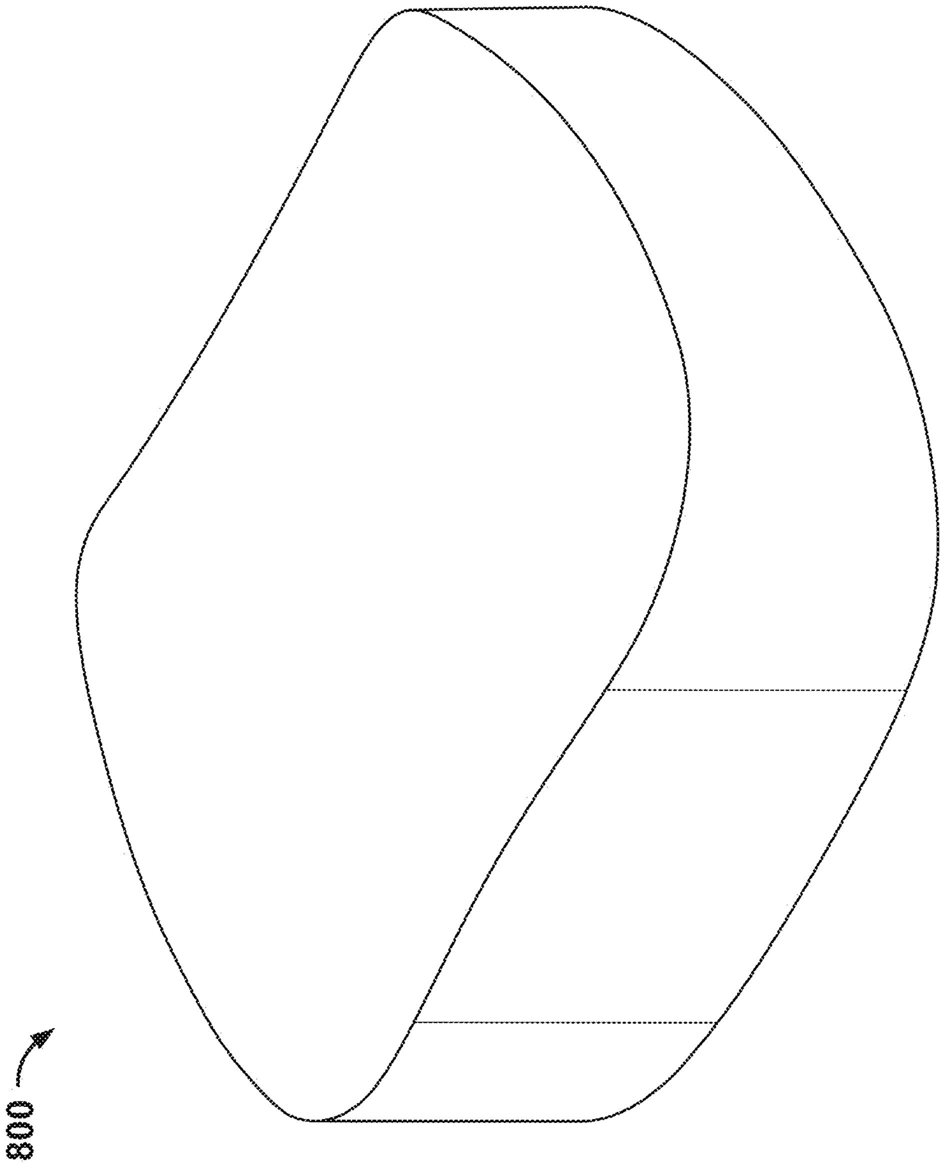


FIG. 22

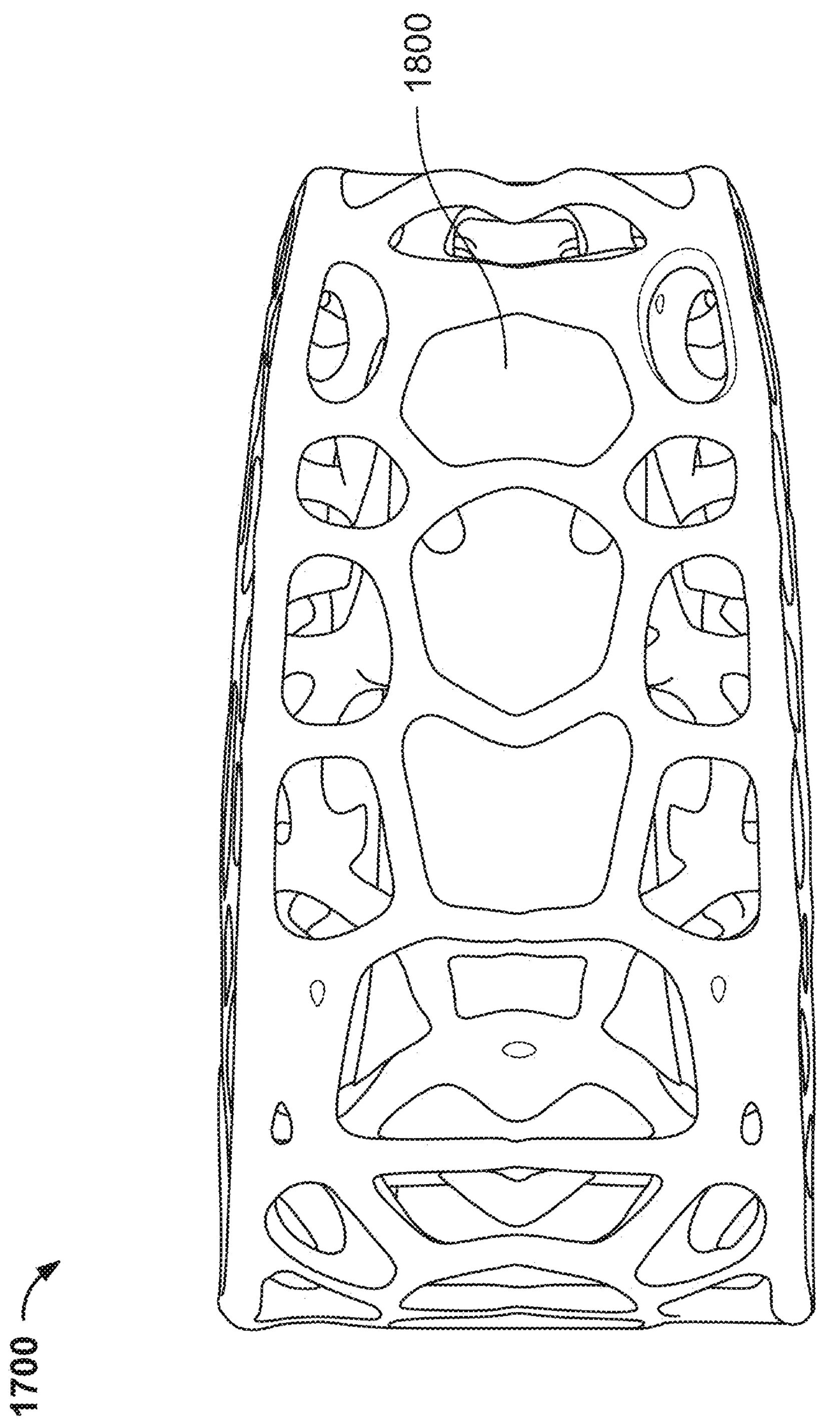


FIG. 23

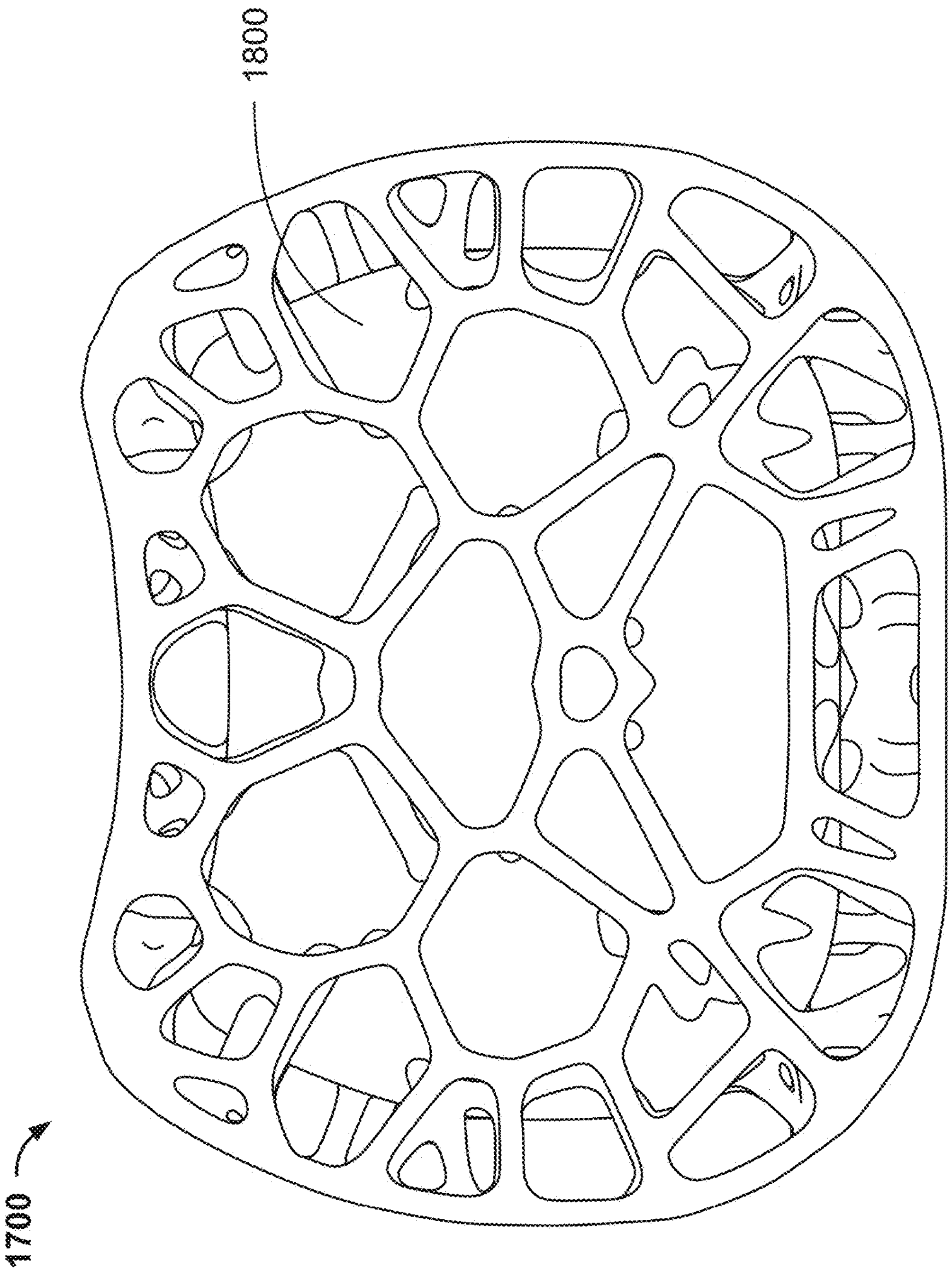


FIG. 24

LATTICE STRUCTURE IMPLANT AND METHODS FOR MAKING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims priority to U.S. Provisional Patent Application Ser. No. 63/551,396, filed on Feb. 8, 2024, entitled "LATTICE STRUCTURE IMPLANT SYSTEM AND METHODS FOR MAKING THE SAME," currently pending, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

[0002] Spinal implants are used to stabilize the spine, alleviate pain, and restore function in cases of back pain, deformity, and disorders such as scoliosis, kyphosis, degenerative disc disease, and fractures. These implants can be categorized as fusion and non-fusion types. Whereas fusion implants promote the joining of vertebrae into a single unity for stability, non-fusion implants support the spine without restricting movement, preserving flexibility. Surgical techniques and approaches vary depending on the type of implant. An Anterior Lumbar Interbody Fusion ("ALIF") approach includes removing a damaged disc in the lumbar spine through an incision in the abdomen. In contrast, a Transforaminal Lumbar Interbody Fusion ("TLIF") is performed through a posterior approach, where the damaged disc is removed through an incision at the back. Further, an Anterior Cervical Discectomy and Fusion ("ACDF") surgery may remove the damaged or herniated disc in the neck and fuse adjacent vertebrae to relive pain, stabilize the spine, and prevent further nerve compression. For the ALIF, TLIF, and ACDF approaches, a spinal implant may be inserted to provide stability, promote fusion, and maintain proper alignment.

[0003] Spinal implants may include rods, plates, screw, and interbody cages. Current interbody cages may be cylindrical or tubular in shape and filled with a bone graft. The interbody cages may then be inserted between two adjacent vertebrae to promote bone growth over time, thus fusing the two adjacent vertebrae. Although widely used in the field, current interbody cages present many complications and limitations. First, current interbody cages may not be patient specific nor biomechanically compatible with the spine, leading to complications such as subsidence (i.e., the cage sinking into the spine), misalignment, and inadequate bone growth. Second, the materials used in the interbody cages may not provide optimal strength, flexibility, or proper mechanical properties which may result in long-term outcomes. Moreover, interbody cages may not mimic the natural curvature and movement of the spine. Further, current interbody cages may include a unit cell lattice structure which inhibits optimal osteogenesis. Thus, there is a need for a spinal implant that is not only biocompatible but also biomechanically compatible, where the spinal implant enhances stability, encourages osseointegration, complements patient anatomy, and provides optimal mechanical properties to promote effective healing and minimize the need for future revision surgeries.

SUMMARY

[0004] In accordance with some embodiments of the present disclosure, a lattice structure implant including one or more lattice structures is provided. The implant and methods disclosed herein provide for the ability to develop a lattice structure implant that meets patient-specific needs and overcomes the shortcomings related to current interbody cages.

[0005] In one aspect, an implant is provided. The implant may include a top surface having a first surface lattice and a bottom surface opposite the first surface. In some instances, the bottom surface may include a second surface lattice. Additionally, the implant may include a body positioned between the top and bottom surfaces. In some instances, the body may include a first plurality of lattice structures. Moreover, the body may at least partially define one or more side surfaces of the implant. In some instances, the first surface lattice, the second surface lattice, and the body may be integrally formed.

[0006] In some instances, the first surface lattice, the second surface lattice, and the body are at least partially smooth. In other instances, the first surface lattice, the second surface lattice, and the body may be at least partially coarse. In yet other instances, the implant may further comprise a first surface lattice comprising a second plurality of lattice structures, and a second surface lattice comprising a third plurality of lattice structures.

[0007] In some instances, each lattice structure of the first plurality of lattice structures may comprise one or more lattice struts that converge at one or more lattice junctures. In such instances, the first plurality of lattice structures may include one or more geometric patterns formed from the convergence of the one or more lattice struts at the one or more lattice junctures.

[0008] In other instances, the first plurality of lattice structures may be formed from a series of repeated lattices structures mirrored over at least one of a vertical axis and a horizontal axis. In yet other instances, the implant may be symmetrical with respect to at least one of a horizontal axis and a vertical axis.

[0009] In some instances, the implant may be configured to be inserted into a spine of a user to provide stability, promote osseointegration, and maintain proper spinal alignment. In other instances, the implant may be at least partially formed from at least one of a Titanium alloy and nitinol.

[0010] In another aspect, an implant to provide stability and promote osseointegration is provided. The implant may include a top surface having a first surface lattice and a bottom surface, opposite the top surface, having a second surface lattice. The implant may also include one or more side surfaces. In certain instances, the one or more side surfaces may include a bore configured to receive a screw. Additionally, the implant may include a substantially hollow body that is disposed between the top and bottom surfaces. In some instances, the body may at least partially define the one or more side surfaces. In other instances, the first surface lattice and the second surface lattice at least partially overlay the body about the top surface and the bottom surface, respectively.

[0011] In yet other instances, the implant may further comprise a first solid perimeter that defines an outer periphery of the top surface. Additionally, the implant may comprise a similar second solid perimeter defining an outer periphery of the bottom surface. In such instances, the first and second solid perimeter may bound the first and second surface lattices, respectively.

[0012] In some instances, each of the first surface lattice and the second surface lattice may comprise a plurality of microlattice structures. In such instances, the plurality of microlattice structures may be substantially thinner than the plurality of lattice structures.

[0013] In other instances, the body may couple to the first surface lattice and the second surface lattice. In yet other instances, the body may be integrally formed with the first surface lattice and the second surface lattice.

[0014] In some instances, the implant may further comprise one or more keels configured to couple the implant to one or more surroundings bones upon insertion.

[0015] In yet another aspect, a spinal implant is provided. The spinal implant may include a top surface including a first surface lattice and a bottom surface, opposite the top surface, including a second surface lattice. Further, the spinal implant may include a substantially hollow body including an open framework formed from a plurality of lattice structures. In certain instances, the body may define one or more side surfaces of the spinal implant. In some instances, the first surface lattice and the second surface lattice may at least partially overlay the body about the top surface and the bottom surface, respectively. Moreover, the spinal implant may include an annular channel that extends linearly from the top surface to at least a center of the spinal implant. In some instances, the annular channel may define a space between the top surface and the center of the spinal implant that is free of lattice structures.

[0016] In some instances, the annular channel may be configured to house a bone graft. In other instances, the annular channel may extend from the top surface to the bottom surface.

[0017] These and other aspects and advantages of the present invention will become apparent to those skilled in the art after considering the following detailed description in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** is a perspective view of a lattice structure implant according to a first embodiment.

[0019] FIG. **2** is a planar top view of the lattice structure implant of FIG. **1**.

[0020] FIG. **3** is an isometric side view of the lattice structure implant of FIG. **1**.

[0021] FIG. **4** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, according to a second embodiment.

[0022] FIG. **5** is a planar top view of the lattice structure implant of FIG. **4**.

[0023] FIG. **6** is perspective view of a lattice structure implant constructed following the teachings of the present disclosure, according to a third embodiment.

[0024] FIG. **7** is perspective view of a lattice structure implant constructed following the teachings of the present disclosure, according to a fourth embodiment.

[0025] FIG. **8** is perspective view of a lattice structure implant constructed following the teachings of the present disclosure, according to a fifth embodiment.

[0026] FIG. **9** is an isometric front view of a lattice structure implant constructed following the teachings of the present disclosure, the lattice structure implant configured to include keels, according to a sixth embodiment.

[0027] FIG. **10** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, the lattice structure implant configured to include keels, according to a seventh embodiment.

[0028] FIG. **11** is an isometric view of a wire graph.

[0029] FIG. **12** is a perspective view of a one-fourth portion of a body lattice.

[0030] FIG. **13** is a perspective view a body structure formed by the mirror of the one fourth portion of FIG. **1**.

[0031] FIG. **14** is a perspective view of the body structure from FIG. **13** having varying thickness.

[0032] FIG. **15** is a perspective view of a surface lattice.

[0033] FIG. **16** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, the lattice structure implant having a surface roughness, according to an eighth embodiment.

[0034] FIG. **17** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, the lattice structure implant including serrations, according to a ninth embodiment.

[0035] FIG. **18** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, the lattice structure implant having a torus structure, according to a tenth embodiment.

[0036] FIG. **19** is a stress distribution diagram of a lattice structure implant according to various embodiments.

[0037] FIG. **20** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, the lattice structure implant including a lattice covering over a window of an annular channel, according to an eleventh embodiment.

[0038] FIG. **21** is a perspective view of a lattice structure implant constructed following the teachings of the present disclosure, according to a twelfth embodiment.

[0039] FIG. **22** is a perspective view of a body representing an offset volume.

[0040] FIG. **23** is an isometric side view of a configuration between the lattice structure implant and body of FIGS. **21** and **22**, respectively.

[0041] FIG. **24** is a planar top view of the configuration of FIG. **23**.

[0042] While the disclosure is susceptible to various modifications and alternative forms, a specific embodiment thereof is shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description presented herein are not intended to limit the disclosure to the particular embodiment disclosed, but to the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure as defined by the appended claims.

DETAILED DESCRIPTION

[0043] Before any embodiments are described in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings, which is limited only by the claims that follow the present disclosure. The disclosure is capable of other embodiments, and of being practiced, or of being carried out, in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

[0044] Briefly described, the following discussion is presented to enable a person skilled in the art to make and use embodiments of the system. Various modifications to the illustrated embodiments will be readily apparent to those skilled in the art, and the generic principles herein can be applied to other embodiments and applications without departing from embodiments of the system. Thus, embodiments of the invention are not intended to be limited to embodiments shown but are to be accorded the widest scope consistent with the principles and features disclosed herein. The following detailed description is to be read with reference to the figures, in which like elements in different figures may include differing or like reference numerals. The figures, which are not necessarily to scale, depict selected embodiments and are not intended to limit the scope of embodiments of the system.

[0045] Additionally, while the following discussion may describe features associated with specific devices or embodiments, it is understood that additional devices and/or features can be used with the described systems and methods, and that the discussed devices and features are used to provide examples of possible embodiments, without being limited.

[0046] Referring to FIGS. **1**-**3**, an example of a lattice structure implant **100** is provided. Generally, the lattice structure implant **100** may be inserted into a patient's body to support, stabilize, and facilitate healing of the spine. In various instances, the lattice structure implant **100** may be a corpectomy device. The lattice structure implant **100** maybe inserted in place of a damaged or removed disc. In particular, the lattice structure implant **100** may be positioned between two adjacent vertebrae to provide structural support, maintain proper alignment, promote fusion, restore disc height, reduce movement, and the like. In various instances, the lattice structure implant **100** may be inserted into a patient during an Anterior Cervical Discectomy and Fusion ("ACDF") surgical process. Although, in other instances, the lattice structure implant **100** may support various spinal fusion techniques including, but not limited to, anterior lumbar interbody fusion ("ALIF") and transforaminal lumbar interbody fusion ("TLIF"). Although described herein with reference to humans, it is to be understood that the lattice structure implant **100** is similarly applicable for use in other animals. Further, the lattice structure implant **100** is not so limited as solely being applicable for spinal fusions. In various instances, the lattice structure implant **100** may also be configured to support knee replacements, hip replacements, and the like. Moreover, the lattice structure implant **100** may be substantially formed from a material that is suitable for biomedical and industrial applications such as Titanium alloy. In other instances, the lattice structure implant **100** may be formed from a combination of biocompatible materials. For example, in some instances, the lattice structure implant **100** may be include nitinol. In various, the lattice structure implant **100** may be formed from one or more biocompatible materials that impart the lattice structure implant **100** with properties such as elasticity and memory.

[0047] The lattice structure implant **100** may include a top surface **105**, one or more side surfaces **110**, and a bottom surface **115** that is opposite the top surface **105**. Further, between the top surface **105** and bottom surface **11**, the lattice structure implant **100** may have a volume. In some instances, the volume may be substantially hollow. In various instances, the lattice structure implant **100** may include at least four side surfaces **110**, each of the four side surface **110** coupling to the top and bottom surfaces **105**, **115**. In some instances, edges of any of the top surface **105**, side surfaces **110**, and bottom surface **115** may taper inwardly or outwardly. For example, an edge of a first side surface **110** may taper inwardly towards the top surface **105**. In such instances, the taper may be gradual and linear. Alternatively, the taper may be abrupt and curved. In some instances, the lattice structure implant **100** may be substantially cuboidal, trapezoidal, or otherwise include relatively angular features. In other instances, the lattice structure implant **100** may be substantially rounded. For example, rather than having distinct top and bottom surfaces **105**, **115** and side surfaces **110**, the lattice structure implant **100** may be spherical. In yet other instances, the lattice structure implant **100** may be substantially cylindrical.

[0048] As best illustrated in FIG. **1**, the lattice structure implant **100** may comprise a body **120** and one or more surface lattices **125**. The body **120** may substantially fill a volume of the lattice structure implant **100**, where the volume is a space between the top surface **105**, the side surfaces **110**, and the bottom surface **115**. In some instances, the top surface **105**, the side surfaces **110**, and the bottom surface **115** may bound the body **120**. Generally, each the top surface **105** and the bottom surface may include a surface lattice **125**. In some instances, the surface lattices **125** of the top and bottom surfaces **105**, **115** may be substantially similar. In other instances, the surface lattices **125** of the top and bottom surfaces **105**, **115** may be substantially different. In various instances, the surface lattices **125** may substantially extend through an entire length and width of each the top and bottom surfaces **105**, **115**, thus defining the top and bottom surfaces **105**, **115**. Moreover, the body **120** and the one or more surface lattice **125** may be substantially hollow. That is, the body **120** and the one or more surface lattices **125** may include a combination of solid and porous elements.

[0049] In various instances, the top surface **105**, the side surface **110**, the bottom surface **115**, the body **120**, and the surface lattices **125** may be connected. In some instances, the top surface **105**, the side surface **110**, the bottom surface **115**, the body **120**, and the surface lattices **125** may be integrally formed. In various instances, the body **120** may substantially define the size and volume of the lattice structure implant **100**. Further, the body **120** may substantially define the side surfaces **110** of the lattice structure implant **100**. Similarly, the surface lattices **125** may substantially define top and bottom surfaces **105**, **115** of the lattice structure implant **100**. In some instances, a shape of the lattice structure implant **100** may be at least partially based on the body **120**. In other instances, a shape of the lattice structure implant **100** may be based on patient anatomy, where the body **120** may be configured to impart designed and patient specific mechanical properties for providing support, alignment, and osseointegration.

[0050] Continuing to reference FIG. **1**, in some instances, the lattice structure implant **100** may include a substantially solid element positioned relatively central to at least one side surface **110**. For example, as illustrated in FIG. **1**, a rounded, substantially solid element **127** may be medially disposed about one side surface **110**. In some instances, an opposing side surface **110** may include a substantially similar solid element (not illustrated). In other instances, the solid element **127** may be substantially angular. In various instances, the solid element **127** may be an attachment mechanism configured to receive additional hardware for further securing the lattice structure implant **100** to the surrounding environment. For example, in some instances, the solid element **127** may be a bore configured to receive a screw or a rod.

[0051] Each the body **120** and the surface lattices **125** may include one or more porous lattice structures **130** configured to promote osseointegration. In some instances, when the lattice structure implant **100** is inserted into a spine of a patient, the open and porous structure of the lattice structures **130** may enhance affixation of the lattice structure implant **100** by providing a scaffolding for the vertebrae to grow therethrough. In various instances, the lattice structures **130** may directly contact the one or more bones designated for anchoring the lattice structure implant **100**. In some instances, the lattice structures **130** may be treated with an osseo-integration coating to promote direct bonding between the lattice structure implant **100** and the surrounding bone tissue. Although the lattice structures **130** may be generally smooth, in some instances, the lattice structures **130** may be relatively coarse to encourage cellular adhesion between the lattice structure implant **100** and bony areas.

[0052] Generally, a plurality of lattice structures **130** may form the body **120**. Similarly, a plurality of lattice structures **130** may form the surface lattices **125**. In various instances the body **120** and the surface lattices **125** may be integrally formed. That is, the body **120** and the surface latices **125** may comprise the same lattice structures **130**. Alternatively, the lattice structures **130** of the body **120** may be different than the lattice structures **130** of the surface lattices **125**. For example, the shape, size, and/or distance between lattice structures **130** of the body **120** may be smaller or larger than the shape, size, and/or distance between the lattice structures **130** of the surface lattices **125**. Moreover, the lattice structures **130** of the body **120** may be denser than the lattice structure of the surface lattices **125**.

[0053] As best illustrated in FIGS. **1** and **2**, a body **120** may comprise a plurality of lattice structures **130**. In various instances, a lattice structure **130** may include a framework consisting of a series of intersecting elements, thus forming a grid-like or network pattern. The lattice structure **130** may comprise a plurality of lattice junctures **135*a*** connected by a plurality of lattice struts **135*b***. Generally, lattice junctures **135*a*** may be points or nodes at which one or more lattice struts **135*b*** may converge, forming lattice structures **130**. For example, two lattice struts **135*b*** may converge at a single lattice juncture **135*a***. In another example, three lattice struts **135*b*** may converge at a single lattice juncture **135*a***. In yet another example, four lattice struts **135*b*** may converge at a single lattice juncture **135*a***.

[0054] To form the lattice structure **130** in a body **120**, a plurality of lattice junctures **135*a*** may be dispersed throughout a volume, where the volume is the space at which the body **120** may occupy in the lattice structure implant **100**. In various instances, the volume is the space between the top surface **105**, side surfaces **110**, and bottom surface **115**. Each of the lattice junctures **135*a*** may be connected by one or more lattice struts **135*b***, where the interconnections between the lattice struts **135*b*** at each of the lattice junctures **135*a*** substantially forms the overall grid-like or network pattern of the lattice structures **130**. In various instances, the positioning of the lattice junctures **135*a*** may at least partially determine a 3-dimmensional shape of the body **120**. In such instances, the 3-dimmensional shape of the lattice structure implant **100** may be at least partially based on the body **120** formed from the plurality of lattice structures **130**. For example, the lattice junctures **135*a*** may be positioned at points within the volume with respect to an X-axis, a Y-axis, and a Z-axis. As such, the lattice struts **135*b*** may move with respect to the X-axis, the Y-axis, and the Z-axis to connect each of the lattice junctures **135*a***, forming an overall 3-dimensional body **120** of the lattice structure implant **100**. In some instances, the lattice structure implant **100** may be imparted with an overall 3-dimmensional shape that is substantially similar to a cube, a tetrahedron, a rectangular prism, a trapezoidal prism, and the like. Alternatively, the lattice structure implant **100** may be imparted with an overall 3-dimmensional shape that is substantially rounded.

[0055] As lattice struts **135*b*** connect to one more lattice junctures **135*a***, a geometric pattern **140** of a lattice structure **130** may be formed. The geometric pattern **140** may be at least partially based on the surrounding lattice junctures **135*a*** and lattice struts **135*b***. In particular, in some instances, the positioning, amount, and distance between the lattice junctures **135*a*** and the curvature or linearity of the lattice struts **135*b*** connecting each lattice junctures **135*a*** may at least partially influence the geometric pattern **140**. For example, four lattice junctures **135*a*** may be connected via four substantially linear lattice struts **135*b***, thus forming four convergence areas. Accordingly, the lattice structure **130** formed from the four lattice junctures **135*a*** and the four lattice struts **135*b*** may be imparted with a geometric pattern **140** that is substantially rectangular. In some instances, a lattice structure **130** may be imparted with a geometric pattern **140** that is substantially trapezoidal or rectilinear. In another example, the lattice structure **130** may be imparted with a geometric shape **140** that is substantially rounded, circular, and the like. For example, a lattice strut **135*b*** connecting two lattice junctures **135*a*** may have a substantially arcuate, bowed, or curved shape. As such, the arced lattice strut **135*b*** may provide a rounded aspect to the formed geometric pattern **140**. In yet another example, the lattice structure **130** may be imparted with a geometric pattern **140** that is substantially amorphous. In some instances, a lattice strut **135*b*** connecting two lattice junctures **135*a*** may be imparted with a substantially hour-glass shape. In other instances, a lattice strut **135*b*** connecting two lattice junctures **135*a*** may be imparted with a substantially sinusoidal shape, such that the lattice strut **135*b*** forms peaks and troughs between the two lattice junctures **135*a***. In various instances, the lattice structure **130** includes various geometric patterns **140**.

[0056] As previously discussed, the body **120** may comprise a plurality of lattice structures **130**. In some instances, the plurality of lattice structures **130** may be substantially identical to each other. For example, a first lattice structure **130** may be formed, and a second lattice structure **130** may be formed by substantially duplicating and translating the positioning, shape, and elements of the first lattice structure **130** (e.g., the lattice junctures and struts **135*a***, **135*b***), thus forming a substantially identical second lattice structure **130**. In other instances, a first lattice structure **130** may be formed, and a second lattice structure **130** may be formed by reflecting, rotating, or translating elements of the first lattice structure **130** (e.g., the lattice junctures and struts **135***a*, **135***b*) over the X-axis, the Y-axis, and/or the Z-axis. In such instances, the second lattice structure **130** may be substantially similar to the first lattice structure **130**. Generally, the body **120** may comprise a plurality of lattice structures **130**, where each lattice structure **130** of the plurality of lattice structures **130** includes repeated elements that are either substantially identical or substantially similar (e.g., mirrored over the X-axis, Y-axis, or Z-axis). In some instances, the lattice structure implant **100** may be substantially symmetrical with respect to a horizontal axis (e.g., the X-axis). In other instances, the lattice structure implant **100** may be substantially symmetrical with respect to a vertical axis (e.g., the Y-axis). Alternatively, the lattice structure **130** may be substantially complex, consisting of non-repetitive or irregular configurations of the lattice junctures and struts **135***a*, **135***b*.

[0057] It is to be understood that the surface lattices **125** may comprise substantially similar components as the body **120**. In particular, the surface lattices **125** may likewise include a plurality of lattice structure **130** including a plurality of lattice junctures **135***a* and a plurality of lattice struts **135***b*, where the lattice struts **135***b* are configured to connect to lattice junctures **135***a*, resulting in a geometric pattern **140** of the lattice strut. In various instances, the same lattice junctures **135***a* and lattice struts **135***b* may be used for forming the body **120** and the surface lattices **125**. In some instances, the body **120** and the surface lattices **125** may be integrally formed. That is, the body **120** and the surface lattices **125** may be formed from the same plurality of lattice structures **130**. In some instances, the body **120** and the surface lattices **125** may be coupled to one another. For example, a lattice strut **135***b* of the body **120** may extend to a lattice juncture **135***a* or a lattice struts **135***b* of the surface lattice **125**.

[0058] Referring to FIG. **3**, a perimeter **145** of the top surface **105** may include a first edge **145***a* and a second edge **145***b*, where the first edge **145***a* is an inner edge and the second edge **145***b* is an outer edge. In various instances, the first edge **145** may be configured to bound the surface lattice **125**. Further, the perimeter **145** may be substantially solid and free of lattice structures **130**. In various instances, although not illustrated, the bottom surface **115** may be substantially similar to the top surface **105**. That is, the bottom surface **115** may similarly include a perimeter bounding the surface lattice **125**.

[0059] Advantageously, the open framework of the lattice structures **130** may provide improved mechanical properties and stability. More particularly, in certain instances, the open framework of the lattice structures **130** may be configured to impart a uniform distribution of forces across the lattice structure implant **100**. In some instances, the mechanical strength and the modulus of elasticity of the lattice structure implant **100** may substantially mimic the strength, porosity, and mechanical properties of the surrounding bone of a patient. Alternatively, the lattice structure implant **100** may be relatively softer or harder. In various instances, the organic and variable lattice structures **130** may improve the endurance and adaptability of the lattice structure implant **100** while under compression and compression-shear loads. For example, the lattice structures **130** may reduce the stiffness of the lattice structure implant **100**, thus allowing for the lattice structure implant **100** to bend, conform, or otherwise endure applied loads.

[0060] In various instances, the lattice structure implant **100** may be imparted with a Young's Modulus of about 5 GPa to about 20 GPa, although the Young's Modulus may be somewhat less than or even greater than these values. For example, the lattice structure implant **100** may be imparted with a Young's Modulus of at least about 5 GPa, or at least about 6 GPa, or at least about 7 GPa, or at least about 8 GPa, or at least about 9 GPa, or at least about 10 GPa, or at least about 11 GPa, or at least about 12 GPa, or at least about 13 GPa, or at least about 14 GPa, or at least about 15 GPa, or at least about 16 GPa, or at least about 17 GPa, or at least about 18 GPa, or at least about 19 GPa, or at least about 20 GPa. In some instances, the Young's Modulus may fall within a range bounded by any minimum value or maximum value as described above. In other instances, the Young's Modulus may be provided as a range that may be bounded by any minimum value and any maximum value as described above. For example, the lattice structure implant **100** may be imparted with a Young's Modulus that is about 8 GPa to about 15 GPa.

[0061] As previously described, the lattice structures **130** may include an open framework, where the open framework may include hollow areas, allowing for enhanced osteogenesis. More particularly, the relatively hollow areas may permit bone from the surrounding area to grow from and through the lattice structure implant **100**. In various instances, a center of the lattice structure implant **100** may be hollow to receive and retain a bone graft. In some instances, the lattice structures **130** may be configured to impart an air to solid ratio of the lattice structure implant **100** of about 70% to about 90%, although the air to solid ratio may be less than or even greater than these values. For example, the lattice structure implant **100** may be imparted with an air to solid ratio of at least about 70%, or at least about 75%, or at least about 80%, or at least about 85%, or at least about 90%. In some instances, the air to solid ratio may fall within a range bounded by any minimum value or maximum value as described above. In other instances, the air to solid ratio may be provided as a range that may be bounded by any minimum value and any maximum value as described above. For example, the lattice structure implant **100** may be imparted with an air to solid ratio that is about 73% to about 86%.

[0062] In various instances, the lattice structure implant **100** may be configured to reduce load deflection while optimizing the strain distribution amongst the lattice structures **130**. In such instances, outer edges of the lattice structure implant **100** (e.g., the first and second edges **145***a*, **145***b* and relative surrounding regions of the lattice structure implant **100**) may be stiffer than an inner area (e.g., towards a center or core of the lattice structure implant **100**). For example, the perimeter **145** of the top and bottom surface **105**, **115** may be the stiffest regions of the lattice structure implant **100**, while, towards a central and inner region of the lattice structure implant **100**, the stiffness may gradually decrease. In another example, the most exterior regions of the lattice structure implant **100** may be the stiffest regions of the lattice structure implant **100**, where the stiffness of the lattice structure implant **100** decreases towards a center. In some instances, the lattice structures **130** may be formed such that strain may be driven to and converge at one or more sections of the lattice structure implant **100**. Further, under normal loading conditions, due to the tension and compression of the surrounding bodily environment, the strain endured by the lattice structure implant **100** may facilitate osseointegration and thereby permit fusion to occur throughout at least a portion of the lattice structure implant **100**. In some instances, fusion may occur throughout the entirety of the lattice structure implant **100**, due to at least the porous construction of the lattice structure implant **100**.

[0063] In some instances, specific regions, areas, or portions of the lattice structure implant **100** may be altered to influence mechanical performance. For example, before, during, or after manufacturing of the lattice structure implant **100**, a specific region of the lattice structure implant **100** may be selected to have a desired mechanical performance. To achieve the desired mechanical performance, components of the lattice structure implant **100**, such as the lattice struts **135***b*, may be altered (e.g., thickness, smoothness, coarseness, and the like). One benefit of targeted alterations is that the lattice structure implant **100** may be patient specific. In some instances, the lattice structure implant **100** may have certain areas modulated to provide support for patient specific anatomy and address patient-specific needs. For example, a lattice structure implant **100** may include surface lattices **125** having thicker lattice structures **130** relative to the body **120**. In this example, the lattice structure implant **100** may withstand larger loads.

[0064] Turning to FIGS. **4** and **5**, an example lattice structure implant **200** is provided. The lattice structure implant **200** may be substantially similar to the lattice structure implant **100** described with reference to FIGS. **1-3**. For example, the lattice structure implant **200** may incorporate similar numbers and/or names as those corresponding elements of the lattice structure implant **100** with reference to FIGS. **1-3**. Like the lattice structure implant **100**, the lattice structure implant **200** may comprise a top surface **205**, one or more side surfaces **210**, and a bottom surface **215** that is opposite the top surface **205**. Positioned about medially of one of the side surfaces **210**, the lattice structure implant **200** may include a solid element **227** that is substantially similar to the solid element **127** of the lattice structure implant **100**. In some instances, the solid element **227** may be configured to receive screws, rods, bars, and the like to enhance coupling of the lattice structure implant **200** to the surrounding environment upon insertion. Further, similar to the body **120** and the surface lattices lattices **125**, the lattice structure implant **200** may include a body **200** and lattice surfaces **225**, where the body **220** is positioned in a volume between the top surface **205**, the one or more side surfaces **210**, and the bottom surface **215**. Moreover, the surface lattice **225** may be positioned about each the top surface **205** and the bottom surface **215**. Yet further, the body **220** and the surface lattices **225** may include a plurality of lattice structure **230** that are substantially similar to the lattice structure **130**. Each the lattice structures **230** may comprise one or more lattice junctures **235***a* connected by one or more lattice struts **235***b*, thus forming one or more geometric patterns **240**. Additionally, the top surface **205** may be defined by a perimeter **245** having a first edge **245***a* and a second edge **245***b*, where the first and second edges **245***a*, **245***b* bound one of the surface lattices **225**. In various instances, like the lattice structure implant **100**, the bottom surface **215** may also include a perimeter similarly having a first edge and second edge bounding another surface lattice **225**.

[0065] As illustrated in FIG. **4**, the lattice structure implant **200** may include a plurality of microlattice structures **250**. Whereas the body structure **220** may comprise a plurality of lattice structures **230**, the surface lattices **225** may comprise a plurality of microlattice structures **250**. Compared to the lattice structures **130**, **230**, the microlattice structures **250** may be smaller. In some instances, the microlattice structures **250** may be less dense. In other instances, the microlattice structures **250** may be scaled down relative to the lattice structures **230**. For example, the microlattice structures **250** may be about 20% the density of the lattice structures **230**. In other examples, the microlattice structures **250** may be less than or greater than 20% the density of the lattice structures **230**. In alternative instances, the body structure **220** and the surface lattices **225** may both comprise entirely of microlattice structures **250**. In yet other alternative instances, the body structure **220** and the surface lattices **225** may comprise a combination of lattice structures **230** and microlattice structures **250**.

[0066] Further, the lattice structure implant **200** may also include an annular channel **260** configured to facilitate bone growth. The annular channel **260** may be an opening through the lattice structure implant **200** extending from the top surface **205** to at least a center of the lattice structure implant **200**. In various instances, the annular channel **260** may linearly extend from the top surface **205** to the bottom surface **215**. In various instances, the annular channel **260** may be positioned about a center of the lattice structure implant **200**. As best illustrated in FIG. **5**, the annular channel **260** may include four sides, forming a generally trapezoidal or rectangular shape. In alternative instances, the annular channel may be imparted with a relatively rounded periphery such that, extending from the top surface **205** to the bottom surface **215**, the annular channel **260** may be relatively cylindrical. A length and a width of the annular channel **260** may be at least partially based on a size of a bone graft, patient anatomy, location of the implant, and patient needs. For example, if a bone graft is relatively block-shaped, then the periphery of the annular channel may be substantially angular such that, from the top surface **205** to the bottom surface **215**, the annular channel **260** may be imparted with a substantially cubic or rectangular shape. In some instances, the annular channel may be substantially rectangular having rounded corners.

[0067] In various instances, the annular channel **260** may have a perimeter that is defined by a third edge **265***a* and a fourth edge **265***b*, where the third edge **265***a* is the inner most edge, defining an opening for a bone graft, and the fourth edge **265***b* is an outer edge, relative to third edge **265***a*. In some instances, a width dimension may separate the third edge **265***a* from the fourth edge **265***b*. In some instances, the annular channel **260** may comprise at least four sides. In alternative instance, the annular channel **260** may comprise less than four sides.

[0068] Continuing to reference FIG. **5**, the top surface **205** may include a surface lattice **225** consisting of a plurality of microlattice structures **250**. As previously described, the microlattice structures **250** may be substantially similar to the lattice structures **130**, **230**. That is, the microlattice structures **250** may be configured to function substantially similarly as the lattice structures **130**, **230**. Further, the microlattice structures **250** may be formed substantially similar as the lattice structures **130**, **230**.

[0069] Specifically, the surface lattices **225** may comprise a plurality of microlattice structures **250**. Like the lattice structures **130**, **230**, the microlattice structures **250** may include a framework consisting of a series of intersecting elements, thus forming a grid-like or network pattern. The microlattice structures **250** may comprise a plurality of microlattice junctures **255*a*** connected by a plurality of microlattice struts **255*b***. Generally, microlattice junctures **255*a*** may be points or nodes at which one or more microlattice struts **255*b*** may converge. For example, two microlattice struts **255*b*** may converge at a single microlattice juncture **255*a***. In another example, three microlattice struts **255*b*** may converge at a single microlattice juncture **255*a***. In yet another example, four microlattice struts **255*b*** may converge at a single microlattice juncture **255*a***.

[0070] To form the microlattice structure **250** in a surface lattice **225**, a plurality of microlattice junctures **255*a*** may be dispersed throughout an area of the top surface **205**. Each of the microlattice junctures **255*a*** may be connected by one or more microlattice struts **255*b***. The interconnections between the microlattice struts **255*b*** at each of the microlattice junctures **255*a***, may substantially formed the overall grid-like or network pattern of the microlattice structures **250**.

[0071] As microlattice struts **255*b*** connect to one more microlattice junctures **255*a***, a geometric pattern **240** of a microlattice structure **250** may be formed. The geometric pattern **240** may be at least partially based on the surrounding microlattice junctures **255*a*** and microlattice struts **255*b***. In particular, in some instances, the positioning, amount, and distance between the microlattice junctures **255*a*** and the curvature or linearity of the microlattice struts **255*b*** connecting each microlattice junctures **255*a*** may at least partially influence the geometric pattern **240**. For example, four microlattice junctures **255*a*** may be connected via four substantially linear microlattice struts **255*b***, thus forming four convergence areas. Accordingly, the microlattice structure **250** formed from the four microlattice junctures **255*a*** and the four microlattice struts **255*b*** may be imparted with a geometric pattern **240** that is substantially rectangular. In some instances, a microlattice structure **250** may be imparted with a geometric pattern **240** that is substantially trapezoidal or rectilinear. In another example, the microlattice structure **250** may be imparted with a geometric shape **240** that is substantially rounded, circular, and the like. For example, a microlattice strut **255*b*** connecting microlattice junctures **255*a*** may have a substantially arcuate, bowed, or curved shape. As such, the microlattice strut **255*b*** may provide a rounded aspect to the formed geometric pattern **270**. In yet another example, the microlattice structure **250** may be imparted with a geometric pattern **270** that is substantially abstract. In some instances, a microlattice strut **255*b*** connecting two microlattice junctures **255*a*** may be imparted with a substantially hour-glass shape. In other instances, a microlattice strut **255*b*** connecting two lattice microlattice junctures **255*a*** may be imparted with a substantially sinusoidal shape, such that the microlattice strut **255*b*** forms peaks and troughs between the two microlattice junctures **255*a***. In various instances, the microlattice structure **250** includes various geometric patterns **270**.

[0072] The surface lattice **225** may comprise a plurality of microlattice structures **250**. In some instances, the plurality of microlattice structures **250** may be substantially identical to each other. For example, a first microlattice structure **250** may be formed, and a second microlattice structure **250** may be formed by substantially duplicating and translating the positioning, shape, and elements of the first microlattice structure **250** (e.g., the microlattice junctures and struts **255*a***, **255*b***), thus forming a substantially identical second microlattice structure **250**. In other instances, a first microlattice structure **250** may be formed, and a second microlattice structure **250** may be formed by reflecting, rotating, or translating elements of the first microlattice structure **250** (e.g., the microlattice junctures and struts **255*a***, **255*b***) over the X-axis, the Y-axis, and/or the Z-axis. In such instances, the second microlattice structure **250** may be substantially similar to the first microlattice structure **250**. Generally, the surface lattice **225** may comprise a plurality of microlattice structures **250**, where each microlattice structure **250** of the plurality of microlattice structures **250** includes repeated elements that are either substantially identical or substantially similar (e.g., mirrored over the X-axis, Y-axis, or Z-axis). Alternatively, the microlattice structures **250** may be substantially complex, consisting of non-repetitive or irregular configurations of the microlattice junctures and struts **255*a***, **255*b***

[0073] In various instances, the microlattice structures **250** may couple to the lattice structures **230**, such that the body **220** and the surface lattices **225** are connected. In such instances, about the top surface **205**, the lattice struts **235*b*** may gradually become thinner until achieving a desired thickness and density of a microlattice struts **255*b***. In various instances the body **120** and the surface lattices **125** may be integrally formed.

[0074] Although not illustrated, the features of the top surface **205** and the corresponding surface lattice **225** may be similarly implemented to the bottom surface **215**. That is, the bottom surface **215** may be substantially similar to the top surface **205** and may include substantially similar microlattice structures **250**.

[0075] As illustrated in FIG. **5**, the surface lattice **225**, comprising a plurality of microlattice structures **250**, may be positioned between a first edge **245*a*** and a fourth edge **265*b***. In some instances, the lattice structure implant **200** may not include the fourth edge **265*b***. In such instances, the surface lattice **225** may be positioned between the first edge **245*a*** and a third edge **265*a***. In other instances, the lattice structure implant **200** may not include the first edge **245*a***. In such instances, the surface lattice **225** may be positioned between a second edge **245*b*** and the fourth edge **265*b***. In yet other instances, the lattice structure implant **200** may not include the first edge **245*a*** and the fourth edge **265*b***. In such instances, the surface lattice **225** may be positioned between the second edge **245*b*** and the third edge **265*a***. In some instances, the microlattice structures **250** and/or lattice structures **230** may be bounded by any of the four or more edges. In alternative instances, the microlattice structures **250** and/or lattice structures **230** may not be bounded by any one or more edges. In yet other alternative embodiments, the lattice structure implant **200** may not include any edges.

[0076] The distance between the third edge **265*a*** and the fourth edge **265*b*** may be of substantially similar thickness as the microlattice struts **235*a***. In other instances, the distance between the third edge **265*a*** and the fourth edge **265*b*** may be of lesser or greater thickness than the microlattice struts **255*a***. In some instances, the first edge **245*a*** and the second edge **245*b*** may be of substantially similar thickness as the lattice struts **235***b*. In other instances, the distance between the first edge **245***a* and second edge **245***b* may be of lesser or greater thickness than the lattice struts **235***b*. In other instances, the distance between the first edge **245***a* and second edge **245***b* may be substantially similar to the distance between the third edge **265***a* and fourth edge **265***b*. In other instances, the distance between the first edge **245***a* and second edge **245***b* may be different than the distance between the third edge **265***a* and fourth edge **265***b*.

[0077] Moreover, the lattice structure implant **200** may be imparted with a microlattice offset. The microlattice offset may be a gap between the surface lattice **225** and the body **220**. The microlattice offset may be controlled by a user-defined variable. In various instances, the microlattice offset may remain constant across a line of the lattice structure implant **200**.

[0078] Turning to FIG. **6**, another example of a lattice structure implant **300** is provided. The lattice structure implant **300** may be substantially similar to the lattice structure implant **100**, **200** described with reference to FIGS. **1**-**5**. In some instances, the lattice structure implant **300** may be substantially similar to the lattice structure implant **200** described with reference to FIGS. **4** and **5**. For example, the lattice structure implant **300** may incorporate similar numbers and/or names as those corresponding elements of the lattice structure implant **200** with reference to FIGS. **4** and **5**. Like the lattice structure implant **200**, the lattice structure implant **300** may include a top surface **305**, one or more side surface **310**, and bottom surface **315** opposite the top surface **305**. Further, like the lattice structure implant **200**, the lattice structure implant **300** may include a body **320** including a plurality of lattice structures **330**, and surface latices **325** including a plurality of microlattice structures **350**. Generally, the lattice structure implant **300** may be formed similarly as lattice structure implants **100**, **200** described with reference to FIGS. **1**-**5**. Further, the lattice structure implant **300** may include one or more bores **327** configured to engage with other hardware such as screws, inserts, and rods, amongst others. In some instances, the lattice structure implant **300** may be utilized for surgical techniques such as ALIF.

[0079] Turning to FIG. **7**, yet another example of a lattice structure implant **400** is provided. The lattice structure implant **400** may be substantially similar to the lattice structure implant **100**, **200** described with reference to FIGS. **1**-**6**. In some instances, the lattice structure implant **400** may be substantially similar to the lattice structure implant **100** described with reference to FIGS. **1**-**3**. For example, the lattice structure implant **400** may incorporate similar numbers and/or names as those corresponding elements of the lattice structure implant **100** with reference to FIGS. **1**-**3**. Like the lattice structure implant **100**, the lattice structure implant **400** may include a top surface **405**, one or more side surface **410**, and bottom surface **415** opposite the top surface **405**. Further, like the lattice structure implant **100**, the lattice structure implant **400** may include a body **420** and surface lattices **425** including a plurality of lattice structures **430**. Generally, the lattice structure implant **400** may be formed similarly as lattice structure implants **100**, **200**, **300** described with reference to FIGS. **1**-**6**. In some instances, like the lattices structure implant **300**, the lattice structure implant **400** may be utilized for ALIF. In various instances, a solid element **427** of the lattice structure implant **400** may be substantially linear.

[0080] Turning to FIG. **8**, an example of a lattice structure implant **500** is provided. In various instances, the lattice structure implant **500** may be utilized for surgical techniques such as TLIF. The lattice structure implant **500** may be substantially similar to the lattice structure implant **100**, **200**, **300**, **400** described with reference to FIGS. **1**-**7**. In some instances, lattice structure implant **500** may be substantially similar to the lattice structure implant **200**, **300**, described with reference to FIGS. **4**-**6**. Like the lattice structure implant **200**, **300** the lattice structure implant **500** may include a body **520** and surface lattices **525**. The body **520** may include a plurality of lattice structures **530**, and the surface lattices **525** may include a plurality of microlattice structure **550**. In various instances, the lattice structure implant **500** may include the plurality of microlattice structures **550** on one or more lateral sides of the lattice structure implant **500**. In such instances, the lattice structures **530** and the microlattice structures **550** may substantially occupy a volume of the lattice structure implant **500**. Further, the lattice structure implant **500** may be imparted with a shape that is substantially similar to rectangular prism (i.e., the lattice structure implant **500** may be longer than wider).

[0081] Turning to FIGS. **9**, an example lattice structure implant **600** is provided. The lattice structure **600** may be substantially similar to lattice structure **100**, **200**, **300**, **400**, **500**, described with reference to FIGS. **1**-**8**, and may further include one or more keels **605**. The keels **605** may be configured to facilitate bone fixation between the lattice structure implant **600** and the surrounding environment. In other words, the keels **605** may function substantially similar to an anchor, where the keels **605** may couple the lattice structure implant **600** to surrounding bones. The keels **605** may be coupled to any side of the lattice structure implant **600**. As illustrated in FIGS. **9**, a first pair of keels **605***a* may be positioned about a first side of the lattice structure implant **600**, and a second pair of keels **605***b* may be positioned about an opposite side of the lattice structure implant **600**. In some instances, the first pair of keels **605***a* may be positioned about a top surface and a second pair of keels **605***b* may be positioned about an opposing, bottom surface. Generally, the keels **605** may have a spiked, triangular form, with a point of the triangle facing exteriorly from the center of the lattice structure implant **600** such that the point may engage with at least one of the surrounding rigid bones. In other instances, keels **605** may be of any other angular shape such that a point of the shape is configured to couple to a surrounding rigid bony feature of a patient's body.

[0082] Turning to FIG. **10**, an example lattice structure implant **700** is provided. The lattice structure implant **700** may be substantially similar to the lattice structure implant **600**, described with reference to FIG. **9**, in that the lattice structure implant **700** may include one or more pairs of keels **705**. Like the lattice structure implant, the lattice structure implant **700** may include a first pair of keels **705***a* and a second pair of keels **705**, both pair of keels **705** (i.e., the first pair of keels **705***a* and the second pair of keels **705***b*) may be configured to anchor or secure the lattice structure implant **700** to the surrounding environment.

[0083] In various instances, a method for manufacturing the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, described with reference to FIGS. **1**-**10**, may include the execution of a specific algorithm. In particular, the algorithm provides an outcome (e.g., the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**) that otherwise could not be provided, achieved, accomplished, or done without the use of said specific algorithm. In some instances, a remote device or a computation component that is configured (e.g., via one or more processors) to execute the algorithm. Generally, the method of manufacturing may include a step directed to executing an algorithm configured to generate, develop, and form the entirety of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**. In some instances, the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** may be manufactured by 3D printing using direct metal laser sintering (DMLS). In various instances, the lattice structure implant **100**, **200**, **300**, **400**, **500 600**, **700** may be modified via Boolean operations such as Boolean union, Boolean subtract, and Boolean Intersect may be used.

[0084] Moreover, the algorithm may include three phases. A first phase may be directed to forming the body **120**, **220**, **320**, **420**, **520**. A second phase may be directed to forming the surface lattices **125**, **225**, **325**, **425**, **525**. A third phase may be directed to forming, if applicable, at least one or more additional solid elements **127**, **227**, **327**, **427** or keels **600** and combining the body **120**, **220**, **320**, **420**, **520** and surface lattices **125**, **225**, **325**, **425**, **525** to form the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**. It is to be understood that, although not illustrated, the lattice structure implants **100**, **200**, **300**, **400**, **500**, **600**, **700** described herein may all include substantially similar components such as a body and one or more surface lattices, the body and the one or more surface lattices each comprising a plurality of lattices structures.

[0085] The first phase of the algorithm may comprise multiple steps. First, the algorithm may generate Voronoi lattices that may be at least partially based on point mapping and expanding points therefrom. In some instances, the method may include a step of developing an initial framework or foundation of the desired points for the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**. In various instances, the first part of the algorithm may be directed to forming one or more lattice structures **130**, **230**, **330**, **430**, **530** for at least about one-fourth of a defined initial or final volume of the lattice structure implant **100**, **200**, **300**, **400**, **500**. The initial framework may include defining and/or identifying the width, shape, volume limits (e.g., a desired final volume of the implant), depth, implant posterior height, and lordotic angle.

[0086] As illustrated in FIG, **11**, another step may include generating points (i.e., a point map **800**) within about a quarter segment (i.e., a fourth) of the lattice structure implant **100**. The points may be generated according to one or more input parameters that may be entered by a user via the remote device or the computational component. The parameters may relate to point density (e.g., a point per volume), tolerance and limit values, points in a volume, infill volume, spacing between points, surface structure of the infill volume, patient-specific values, additional user-desired input, amongst others. Using the input parameters, the point map **800** may be generated. In some instances, the points may be bounded by the volume limits previously inputted by the user. By bounding the points to be within volume limits, the lattice structures **130**, **230**, **330**, **430**, **530** may maintain a closed configuration. That is, the lattice structures **130**, **230**, **330**, **430**, **530** may have substantially no opening between the points (e.g., lattice juncture **135***a*), thus maintain connection between the lattice structures **130**, **230**, **330**, **430**, **530**. Therefore, the desired final shape of the lattice structure implant **100** may be maintained.

[0087] In some instances, the positioning of the one or more points may be described with respect to an abscissa axis ("X-axis"), an ordinate axis ("Y-axis"), and an applicate axis ("Z-axis") of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**. For example, a first point may be positioned on an anterior face of the lattice structure implant **100** (such as the top surface **105**) at about a 45° angle with respect to the X-and/or Y-axes. In some instances, a point may be made at either a center of the anterior face, where the "center" may be a point of intersection between the X-axis, Y-axis, and Z-axis. In various instances, the point of intersection between the X-axis, Y-axis, and Z-axis may be the middle of the lattice structure implant **100** with respect to length, width, and depth. After the first point is generated on the point map **800**, one or more points may be generated on the same surface outwardly from the first point following volume limits and tolerance parameters inputted by a user. In some instances, the maximum allowable and/or desired quantity of points may be based on a predetermined quantity calculated by the algorithm. Generally, points may be made according to the parameters inputted by a user into the algorithm and according to a patient's individual needs.

[0088] The point map **800** may be configured to generate the body **120**, **220**, **320**, **420**, **520** by creating points **805** and forming a wire graph consisting of one or more spheres **810** that may expand from each point **805** on the point map. A line may be formed at each point of intersection between each expanded sphere **810** (i.e., a tangent line may be formed between each expanded sphere). In various instances, the expanded spheres **810** may be similarly bounded to be within the volume limits. For example, the volume limits may be set to represent the edges of the final lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**. Continuing this example, by maintaining points **805** within the boundaries, the integrity and desired shape of the final lattice structure implant **100**, **200**, **300**, **400**, **500** may be maintained. At each point **805** on the point generated map, the surrounding volume may spherically expand therefrom until reaching the volume limit. Generally, the sphere **810** may be an initial outline of the lattice structures **130**, **230**, **330**, **430**, **530**.

[0089] One benefit amongst others of generating a point map **800** and wire graphing is that the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** may formed at least partially independent of parameters. For example, upon generating the point map **800** and wire graphing, changing parameter values may minimally impact the overall design of the lattice structure implant **100**. In alternative instances, changing a number of parameter values, or changing at least one integral parameter value, may impact the design of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**.

[0090] In various instances, the generation of the lattice structures **130**, **230**, **330**, **430**, **530** may be at least partially based on patient-specific parameters, creating a robust and unique lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** for each individual patient. In some instances, the lattice structures **130**, **230**, **330**, **430**, **530** may be of differing shapes and sizes from each other within the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**. In alternative embodiments, the lattice structures **130**, **230**, **330**, **430**, **530** may be of uniform shapes and sizes.

[0091] Turning to FIG. **12**, an example of a quarter segment **900** of a body **120**, **220**, **320**, **420**, **520** is provided. As illustrated in FIG. **12**, the method of manufacturing may include a step of thickening the quarter segment **900**. In other words, the method of manufacturing may include a step directed to giving weight to the lattice structures **130**, **230**, **330**, **430**, **530**. In some instances, the quarter segment **900** may be symmetrical with respect to the horizontal and vertical planes.

[0092] Turning to FIG. **13**, after creating the first thickened quarter segment **900**, the quarter segment **900** may be mirrored over the horizontal and vertical planes to form the body lattices **1000**. In various instances, the body lattices **1000** may be foundational to the body **120**, **220**, **320**, **420**, **520**. Moreover, due to the mirroring of the quarter segment **900**, the entire lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** may be symmetrical with respect to the horizontal and vertical axes and planes. In other words, in various instances, the lattice structure implant **100**, **200**, **300**, **400**, **500** may be symmetric about two planes. Benefits of the symmetry may include (1) a substantially even distribution of forces throughout the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, regardless of the orientation of the lattice structure implant **100**, **200**, **300**, **400**, **500** in a patient's body, and (2) equal load distribution in at least the medial-lateral direction on both halves of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**.

[0093] The algorithm may further include a smoothing step. The smoothing step may be directed to creating a variable thickness, resulting in a final body lattice **1100**, as illustrated in FIG. **14**. In various instances, the final body lattice **1100** may be the body **120**, **220**, **320**, **420**, **520**. In some instances, the user may input variables (i.e., body lattice variables) such as the smoothing factor, offset, point density, and shape of space. In such instances, the final body lattice **1100** may be selectively adjusted to accommodate specific patients. For example, a thickness may be identified based on the inputted body lattice variables. In various instances, the thickness may be about 1 mm to about 2 mm, although the thickness may be somewhat less than or even greater than these values. For example, the thickness may be at least about 1 mm, or at least about 1.1 mm, or at least about 1.2 mm, or at least about 1.3 mm, or at least about 1.4 mm, or at least about 1.5 mm, or at least about 1.6 mm, or at least about 1.7 mm, or at least about 1.8 mm, or at least about 1.9 mm, or at least about 2 mm. In some instances, the thickness may fall within a range bounded by any minimum value or maximum value as described above. In other instances, the thickness may be provided as a range that may be bounded by any minimum value and any maximum value as described above.

[0094] Following the formation of the final body lattice **1100**, or simultaneously during the formation of the final body lattice **1100**, the surface lattices **125**, **225**, **325**, **425**, **525** may be formed. Similar to the final body lattice **1100**, at least a quarter portion of the one or more surface lattices **1200** may be made first. Forming the surface lattices **125**, **225**, **325**, **425**, **525** may include the step of identifying a top face. In some instances, the top face may be the face that interacts with vertebral body endplates. In some instances, the top face may become the top surface **105**, **205**, **305**, **405** in the lattice structure implant **100**, **200**, **300**, **400**. Another step may include meshing, isolating, and downwardly translating the top face from its original position. In some instances, the top face may be translated downwards an amount that is at least about half of the thickness of the final body lattice **1100**. Benefits of translating the top face downwards may include ensuring that the one or more surface lattices **1200** stay within the original bounds of the lattice structure implant **100**. After a quarter potion of the surface lattice is formed, like the body lattice **1000**, the quarter portion may be mirrored to form the surface lattice **1200**, as best illustrated in FIG. **15**.

[0095] Alternatively, but without substantially deviating from the methods and processes for manufacturing a lattice structure implant **100** described herein, rather than developing a quarter segment **900**, a half segment may be developed (not illustrated). For example, the generation of the point map **800** and wire graphing may be within a half segment. Continuing this example, body lattices **1000** may be thickened for the half segment. Further, the half segment may be mirrored or substantially replicated over a single plane (e.g., a horizontal plane or a vertical plane). In some instance, when the half segment is reflected over a horizontal plane, a top and a bottom of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** may be symmetrical. In other instances, when the half portion is reflected over a vertical plane, a left side and a right side of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** may be symmetrical. In various instances, lattice structure implants **100**, **200**, **300**, **400**, **500**, **600**, **700** that are directed to supporting TLIF may be manufactured by developing a half segment rather than a quarter segment. As such, the lattice structure implants **100**, **200**, **300**, **400**, **500**, **600**, **700** directed to supporting TLIF may only have single-plane symmetry. In such instances, the symmetry may still support a substantially even distribution of forces throughout the implant and equal load distribution in a medical or lateral direction.

[0096] In some instances, the smoothing step may be accomplished by a Gaussian smoothing algorithm. In such instances, the inputs may include a grid size of about 0.125 mm to about 0.4 mm. The grid size may be used or indicative of the spacing between sample points used in the algorithm for manufacturing the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** or how many times the algorithm is executed to generate a final smoothened body. In some instances, a larger grid size may result in a relatively smoother body, as there is greater space between sample points. For larger grid sizes, the geometry of the resulting smoothened body may deviate from the original structure of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** more than a body that was smoothed following a smaller grid size. A larger grid size may also impact the lattice struts **135*b***, **235*b***. For example, a larger grid size may cause the lattice struts **135*b***, **235*b*** to taper such that the lattice struts **135*b***, **235*b*** have an hourglass shape.

[0097] Turning to FIG. **16**, an example lattice structure implant **1300** is provided. The lattice structure implant **1600** may be substantially similar to the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700** described with reference to FIGS. **1-10**. Further, the lattice structure implant **1300** may have a surface roughness **1305** about one or more sections of the lattice structure implant **1300**.

[0098] Turning to FIG. **17**, an example of a lattice structure implant **1400** is provided. The lattice structure implant **1400** may be substantially similar to the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300** described with reference to FIGS. **1-10** and **16**. Further, the lattice structure implant **1400** may include serrations **1405**. The serrations **1405** may be configured to secure the placement of the lattice structure implant **1400** such that lattice structure implant **1400** is resistant to expulsion or migration.

[0099] Turning to FIG. **18**, another example of a lattice structure implant **1500** is provided. The lattice structure implant **1500** may be similar to lattice structure implants **100**, **200**, **300**, **400**, **500**, **600**, **1300**, **1400** described with reference to FIGS. **1-10**, **16**, and **17**. Further, the lattice structure implant **1500** may comprise a torus structure **1505**. Rather than lattice structures, the lattice structure implant **1500** may include a torus structure **1505** that may extend through a volume of the lattice structure implant **1500**.

[0100] In various instances, stress may be uniformly distributed across the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500**. In some instances, the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** may be configured to concentrate stress to one or more designated areas and regions. In some instances, the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** may be configured to include one or more monomers that mimic the shape and formation of tissue cells. In other instances, the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** may mimic the elasticity of bony, thus reducing the possibility of stress fractures throughout the device. In such instances, the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** may be substantially smooth. Referring to FIG. **19**, a stress diagram **1600** of various instances of the lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** is provided. The stress diagram **1600** illustrates the distribution of stress under static compression with a load of about 22 kN, although the lattice structure implant **100100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** may be configured to endure a load that is greater than or less than about 22 kN.

[0101] Turning to FIG. **20**, yet another example of a lattice structure implant **1600** is provided. The lattice structure implant **1600** may similar to lattice structure implant **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500** described with reference to FIGS. **1-10**, **16**, **17**, and **18**. Further, the lattice structure implant **1600** may include an annular lattice covering **1605**. The annular lattice covering **1605** may be configured to extend across an annular channel **1610**. In some instances, the annular lattice covering **1605** may only superficially cover an opening to the annular channel **1610**. In other instances, the annular channel covering **1605** may cover an opening to the annular channel **1610** about both a top and bottom surface.

[0102] Turning to FIG. **21**, a lattice structure implant **1700** is provided. The lattice structure implant **1700** may comprise substantially similar elements as the lattice structure **100**, **200**, **300**, **400**, **500**, **600**, **700**, **1300**, **1400**, **1500**, **1600**. Further, the lattice structure implant **1700** may be formed based on location. In some instances, generating the lattice structure implant **1700** may include substantially similar steps from the methods and processes for manufacturing previously described. However, while developing points on the map, the points may be generated according to one or more additional parameters relating to location and/or distance rather than density. For example, the points for a lattice structure implant **1700** may be generated based upon a location within a certain volume which may result in the lattice struts and junctures being generated with a substantial dependence upon the location within the volume.

[0103] To support location and distance-based lattice generation, a body **1800** representing an offset volume may be used. As best illustrated in FIG. **22**, the body **1800** may have an angular shape, a rounded shape, or a combination of angular and rounded shapes. In various instances, the body **1800** may have a tapered outer surface. In some instances, the body **1800** may be customized for each implant. During the first phase of the algorithm, the body **1800** may occupy a space or “field” such that lattice generation may be controlled and/or influenced by said field. For example, the distance between the ends of the body **1800** may determine or influence the distance between the points during lattice generation. That is, the body **1800** may substantially influence lattice generation to be dependent upon volume and distance rather than density. The points may be generated throughout the first one-fourth portion based on a minimum distance from other points, and, by basing point positions on the point map on distance, the resulting lattice density may be controlled throughout the entire volume of the lattice structure implant **1700**.

[0104] Referring to FIGS. **23** and **24**, a configuration of the body **1800** within the lattice structure implant **1700** is provided. In some instances, a distance between the body **1800** and the edges of the lattice structure implant **1700** may be constant. Alternatively, the distance may be greater in some areas relative to others.

[0105] Many embodiments of an implant have been discussed in this disclosure. It is to be understood that these embodiments and examples are nonlimiting-the implant may be adapted to support various surgical techniques not fully disclosed herein. In various instances, the implant may be applicable for any procedure that may require a biocompatible implant designed to positively impact the quality of life by either treating deformities, stabilizing and strengthening the spine, facilitating fusion, promoting osseointegration, relieving pain, amongst others. Moreover, one benefit of the implant as described herein is the body, surface lattices, rims, edges, inserts, and other features that together the performance of the implant such that implant may better adapt and endure stress, compression, and other mechanical forces of the body.

[0106] It will be appreciated by those skilled in the art that while the above disclosure has been described above in connection with particular embodiments and examples, the above disclosure is not necessarily so limited, and that numerous other embodiments, examples, uses, modifications and departures from the embodiments, examples and uses are intended to be encompassed by the claims attached hereto. The entire disclosure of each patent and publication cited herein is incorporated by reference as if each such patent or publication were individually incorporated by reference herein. Various features and advantages of the above disclosure are set forth in the following claims.

We claim:

1. An implant comprising:

a top surface including a first surface lattice;

a bottom surface opposite the top surface, the bottom surface including a second surface lattice; and

a body positioned between the top surface and the bottom surface, the body including a first plurality of lattice structures, wherein the body at least partially defines one or more side surfaces; and wherein first surface lattice, the second surface lattice, and the body are integrally formed.

2. The implant of claim **1**, wherein the first surface lattice, the second surface lattice, and the body are at least partially smooth.

3. The implant of claim **1**, wherein the first surface lattice, the second surface lattice, and the body are at least partially coarse.

4. The implant of claim **1** further comprising:

a first surface lattice comprising a second plurality of lattice structures; and

a second surface lattice comprising a third plurality of lattice structures.

5. The implant of claim **1**, wherein each lattice structure of the first plurality of lattice structures comprises one or more lattice struts that converge at one or more lattice junctures.

6. The implant of claim **1**, wherein the first plurality of lattice structures is formed from a series of repeated lattice structures mirrored over at least one of a vertical axis and a horizontal axis.

7. The implant of claim **1**, wherein the implant is symmetrical with respect to at least one of a horizontal axis and a vertical axis.

8. The implant of claim **1**, wherein the implant is substantially porous.

9. The implant of claim **1**, wherein the implant is configured to be inserted into a spine of a user to provide stability, promote osseointegration, and maintain proper spine alignment.

10. The implant of claim **1**, wherein the implant is at least partially formed from at least one of a Titanium alloy and nitinol.

11. An implant to provide stability and promote osseointegration comprising:

a top surface including a first surface lattice;

a bottom surface opposite the top surface, the bottom surface including a second surface lattice;

one or more side surfaces; and

a substantially hollow body including an open framework formed from a plurality of lattice structures, the substantially hollow body disposed between the top surface and the bottom surface, wherein the substantially hollow body at least partially defines the one or more side surfaces; and

wherein the first surface lattice and the second surface lattice at least partially overlay the substantially hollow body about the top surface and the bottom surface, respectively.

12. The implant of claim **11** further comprising:

a first solid perimeter defining an outer periphery of the top surface; and

a second solid perimeter defining an outer periphery of the bottom surface;

wherein the first solid perimeter and the second solid perimeter each bound the first surface lattice and the second surface lattice, respectively.

13. The implant of claim **11**, wherein each the first surface lattice and the second surface lattice comprise a plurality of microlattice structures, and wherein the plurality of microlattice structures is substantially thinner than the plurality of lattice structures.

14. The implant of claim **11**, wherein the substantially hollow body couples to the first surface lattice and the second surface lattice.

15. The implant of claim **11**, wherein the substantially hollow body is integrally formed with the first surface lattice and the second surface lattice.

16. The implant of claim **11**, wherein at least one of the one or more side surfaces includes a bore configured to receive a screw.

17. The implant of claim **11** further comprising one or more keels configured to couple the implant to one or more bones.

18. A spinal implant comprising:

a top surface including a first surface lattice;

a bottom surface opposite the top surface, the bottom surface including a second surface lattice;

a substantially hollow body including an open framework formed from a plurality of lattice structures, the substantially hollow body disposed between the top surface and the bottom surface, wherein the substantially hollow body at least partially defines one or more side surfaces, and wherein the first surface lattice and the second surface lattice at least partially overlay the body about the top surface and the bottom surface, respectively; and

an annular channel extending linearly from the top surface to at least a center of the spinal implant, wherein the annular channel defines a space between the top surface and the center of the spinal implant that is free of lattice structures.

19. The implant of claim **18**, wherein the annular channel is configured to house a bone graft.

20. The implant of claim **18**, wherein the annular channel extends from the top surface to the bottom surface.

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