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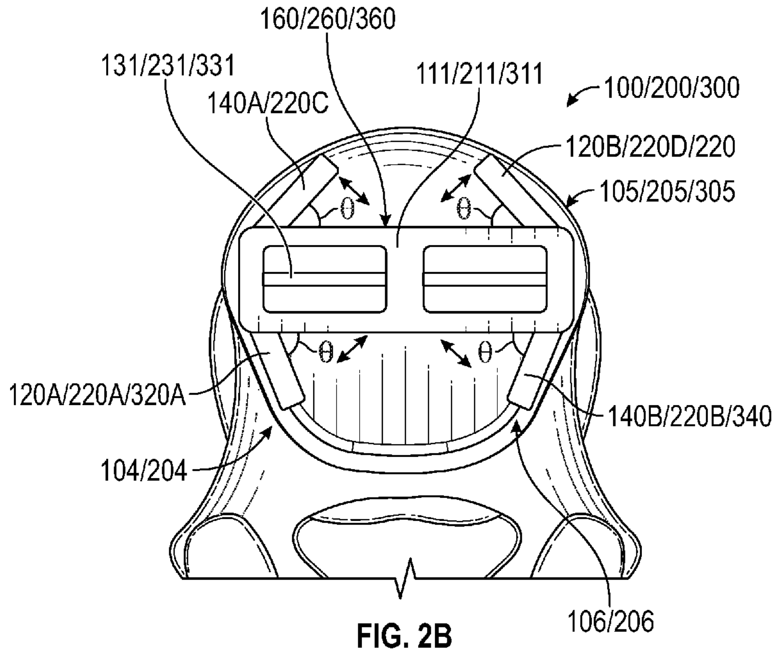

FIG. 2B

(57) Abstract: Various embodiments of an expandable interbody cage device configured to reduce subsidence into an endplate of a vertebral body by including a plurality of arms that engage the cortical tissue of the vertebral body. The plurality of arms increase the surface area and improve distribution of force, especially around stronger parts of the endplate such as the cortical bone at the rim of the endplate. The expandable interbody cage device maintains a low or slim profile while in a "closed" configuration during insertion between vertebrae and is further operable to laterally expand into an "open" configuration that increases the surface area of the expandable interbody cage device after insertion to securely engage the expandable interbody cage device between the vertebra. The expandable interbody cage device further includes one or more ports and/or cavities in which bone graft material can be disposed within.

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SYSTEMS AND METHODS FOR AN EXPANDABLE INTERBODY DEVICE

FIELD

[0001] The present disclosure generally relates to interbody fusion devices, and in particular, to a system and associated method for an expandable interbody device for lateral lumbar interbody fusion procedures.

BACKGROUND

[0002] For interbody fusions such as the lateral lumbar interbody fusion (LLIF), decompression of neural elements occurs indirectly by increasing the height of the disc space, therefore opening up the neural foramen. One of the major complications of placing an interbody cage is the risk for development of subsidence, which is sinking of the interbody cage into the vertebral body (FIG. **1A** shows normal placement of an interbody cage and FIG. **1B** demonstrates subsidence of the interbody cage into the spongy cancellous bone tissue of the vertebral body). This causes loss of disc height and loss of the indirect decompression achieved with surgery, and ultimately a return of symptoms and need for reoperation. Previous research has demonstrated that using wider grafts reduces the risk and grade of subsidence. This is thought to occur due to increased surface area to distribute axial forces, as well as a wider graft taking advantage of the stronger cortical bone around the edge of an endplate of the vertebral body. Biomechanical studies have demonstrated that the cortical bone around the endplate is much stronger than the cancellous bone within the middle of the endplate.

[0003] It is with these observations in mind, among others, that various aspects of the present disclosure were conceived and developed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIGS. **1A** and **1B** are respective images showing normal placement of an interbody cage device and abnormal subsidence of the placed interbody cage into the vertebral body;

[0005] FIGS. **2A-2D** are illustrations showing placement of an expandable interbody cage device on a surface of a vertebral body;

[0006] FIG. **3** is a perspective view of one embodiment of the expandable interbody cage device of FIGS. **2A** and **2B** shown in a closed configuration;

[0007] FIG. **4** is a perspective view of the expandable interbody cage device of FIG. **3** shown an open configuration;

[0008] FIG. **5** is a top plan view of the expandable interbody cage device of FIG. **3** shown in the closed configuration;

[0009] FIG. **6** is a top plan view of the expandable interbody cage device of FIG. **3** shown in an open configuration;

[0010] FIG. **7** is an exploded view of the expandable interbody cage device of FIG. **3**;

[0011] FIG. **8** is a perspective view of the expandable interbody cage device of FIG. **3** shown in a closed configuration with the first cover removed for visibility of internal components of the expandable interbody cage device;

[0012] FIG. **9** is a perspective view of the expandable interbody cage device of FIG. **3** shown in an open configuration with the first cover removed for visibility of internal components of the expandable interbody cage device;

[0013] FIGS. **10A** and **10B** are perspective views of an arm for the expandable interbody cage device of FIG. **3** defining a member portion and a joint portion;

[0014] FIG. **11** is a perspective view of an axle for the expandable interbody cage device of FIG. **3** defining a shaft, a first axle head including a first worm gear, and an opposite second axle head including a second worm gear;

[0015] FIG. **12** is a perspective view of a first or second cage portion of the expandable interbody cage device of FIG. **3** defining a cover body including an axle channel, a first head and an opposite second head, and one or more graft material receptacles;

[0016] FIG. **13** is a perspective view of a second embodiment of the expandable interbody cage device of FIGS. **2A** and **2B** shown in a closed configuration;

[0017] FIG. **14** is a perspective view of the expandable interbody cage device of FIG. **13** shown in an open configuration;

[0018] FIG. **15** is a perspective view of the expandable interbody cage device of FIG. **13** shown in a closed configuration with the first cover removed for visibility of internal components of the expandable interbody cage device;

[0019] FIG. **16** is a perspective view of the expandable interbody cage device of FIG. **13** shown in an open configuration of the expandable interbody cage device with the first cover removed for visibility of internal components of the expandable interbody cage device;

[0020] FIG. **17** is an exploded view of the expandable interbody cage device of FIG. **13**;

[0021] FIGS. **18A** and **18B** are a series of illustrations showing a top plan view of the expandable interbody cage device of FIG. **13** in the closed configuration and in the open configuration.

[0022] FIG. **19** is a perspective view of a third embodiment of the expandable interbody cage device of FIGS. **2A** and **2B** shown in an open configuration;

[0023] FIG. **20** is a perspective view of the expandable interbody cage device of FIG. **19** shown in the closed configuration;

[0024] FIG. **21** is a side view of the expandable interbody cage device of FIG. **19** shown in the open configuration;

[0025] FIG. **22** is a side view of the expandable interbody cage device of FIG. **19** shown in the closed configuration;

[0026] FIG. **23** is a cross-sectional view of the expandable interbody cage device of FIG. **19** taken along line **23**-**23** of FIG. **19**;

[0027] FIG. **24** is a cross-sectional view of the expandable interbody cage device taken along line **24**-**24** of FIG. **19**;

[0028] FIG. **25** is a top plan view of the expandable interbody cage device of FIG. **19** shown in the open configuration; and

[0029] FIG. **26** is a top plan view of the expandable interbody cage device of FIG. **19** shown in a closed configuration.

[0030] Corresponding reference characters indicate corresponding elements among the view of the drawings. The headings used in the figures do not limit the scope of the claims.

DETAILED DESCRIPTION

[0031] Various embodiments of an expandable interbody cage device for interbody fusions such as a lateral lumbar interbody fusion are disclosed herein. In particular, the expandable interbody cage device is configured to reduce subsidence of the expandable interbody cage device into an endplate of a vertebral body by including a plurality of arms that engage the cortical tissue of the vertebral body to increase the surface area and improve distribution of force, especially around stronger parts of the endplate such as the cortical bone at the rim of the endplate. The expandable interbody cage device maintains a low or slim profile while in a “closed” configuration during insertion between vertebrae and is further operable to laterally expand into an “open” configuration that increases the surface area of the expandable interbody cage device after insertion to securely engage the expandable interbody cage device between the vertebrae. The arms enable the expandable interbody cage device to rest on the cortical bone at an edge of the endplate rather than on spongy cancellous bone in a center of the endplate. In some embodiments, dimensions of the expandable interbody cage device while in the open configuration are variable, enabling a practitioner to adapt to vertebrae of varying sizes and ensuring that the expandable interbody cage device securely engages the cortical bone of the vertebral body. The expandable interbody cage device further includes one or more ports and/or cavities in which bone graft material can be disposed within. Referring to the drawings, embodiments of an expandable interbody cage device are illustrated and generally indicated as **100**, **200** and **300** in FIGS. **1**-**26.**

[0032] A common problem with conventional interbody cage devices is subsidence, which is the tendency of the interbody cage device to sink into the cancellous bone tissue in the middle of an endplate of a vertebra. The endplate of the vertebra includes spongy cancellous tissue towards the middle of the endplate and hardened cortical tissue towards the edges of the endplate. FIG. **1A** is an image showing proper placement of a conventional interbody cage device between vertebrae. Interbody cage devices are often packed with bone graft material to encourage bone growth and eventual fusion of the vertebrae. However, even with initially proper implantation of some interbody cage devices, subsidence can still occur as the conventional interbody cage device becomes compressed by the spine into the cancellous tissue of the endplate over time, as shown in FIG. **1B**. This can especially happen if the interbody cage device is not secure and immovable between the vertebrae.

[0033] The expandable interbody cage devices **100/200/300** are intended to address this issue. As shown in FIGS. **2A**-**2D**, the expandable interbody cage devices **100/200/300** includes a respective cage assembly **160/260/360** that increases a height of a disc space between vertebrae when installed between adjacent vertebrae within a body. Each cage assembly **160/260/360** is associated with a respective plurality of arms **105/205/305** that each include a respective first pair of arms **104/204** and a second respective pair of arms **106/206** or at least a respective first arm **120A/220A/320** and a respective second arm **140B/220B/340** associated with a respective axle **131/231/331**. The respective first arm **120A/220A/320** and a respective second arm **140B/220B/340** are operable for each expandable interbody cage device **100/200/300** to assume an open configuration (FIG. **2B**) that increases the surface area of each expandable interbody cage device **100/200/300** across the endplate of the vertebra, as shown. In a preferred embodiment, the each of the arms **105/205/305** of the respective expandable interbody cage device **100/200/300** engages the endplate on or closer towards the edges to better distribute force across the cortical bone of the endplate rather than the cancellous bone in the center of the endplate. In some embodiments, as will be discussed in greater detail below, the arms **105/205/305** can be opened at a variable arm angle **θ** to accommodate differences in anatomy.

[0034] In general, each of the expandable interbody cage devices **100/200/300**, when in a closed configuration shown in FIG. **2A**, maintains a small profile for insertion between two adjacent vertebrae. Smaller devices are generally easier and safer to implant, as interbody devices are usually hammered in between vertebrae. Upon each of the expandable interbody cage devices **100/200/300** assuming the open configuration shown in FIG. **2B**, a greater surface area across the endplate of the vertebra is achieved for improved force distribution and stability when each of the expandable interbody cage devices **100/200/300** is inserted between the vertebrae. In addition, each of the expandable interbody cage devices **100/200/300** can include one or more bone graft material cavities, such as bone graft material cavity **194** (FIGS. **5-6**), that can be packed with bone graft material, or can further include one or more bone graft material ports such as bone graft material ports **222/332** (FIGS. **14** and **19**) for post-insertion packing of bone graft material into the interbody space. Each of the expandable interbody cage devices **100/200/300** enables the bone graft material to contact a larger surface area of the endplate to encourage even distribution of bone growth throughout the interbody space for successful fusion of the joint while increasing the height of the disc space.

[0035] In one method of operation, each of the expandable interbody cage devices **100/200/300** may be first inserted into an interbody space between two adjacent vertebrae while in a closed configuration. In particular, the expandable interbody cage devices **100/200/300** may be hammered between a first vertebra **30** and a second vertebra **40** (FIGS. **2C** and **2D**) such that the expandable interbody cage devices **100/200/300** contacts the endplate surfaces **32** and **42** of both vertebrae **30** and **40**. Upon verification of proper placement (most commonly with intraoperative x-ray) the practitioner opens the plurality of arms **105/205/305** for a respective expandable interbody cage device **100/200/300** to an open configuration (FIG. **2B**) by rotating the respective axle **131/231/331** in a clockwise or counterclockwise direction **C** or **D**. Rotation of each axle **131/231/331** results in rotation of the respective plurality of arms **105/205/305** outwardly in a clockwise or counterclockwise direction **A** or **B** away from each respective axle **131/231/331**. In some embodiments, components of the expandable interbody cage device **100** can be made of titanium, Polyetheretherketone PEEK, or any other suitable material for an interbody device.

[0036] FIGS. **3-12** illustrate a first embodiment of the expandable interbody cage device **100**. In particular, the expandable interbody cage device **100** includes a cage assembly **160** that defines a first outer planar surface **111A** and an opposite second outer planar surface **111B** for engaging the endplate of the vertebra. In a preferred embodiment, the cage assembly **160** and plurality of arms **105** attached to the cage assembly **160** are load-bearing such that the expandable interbody cage device **100** can withstand the force of being positioned between two adjacent vertebrae. The expandable interbody cage device **100** also includes an axle **131** encapsulated by the cage assembly **160** that enables a practitioner to manually "open" the expandable interbody cage **100** and rotate a plurality of arms **105** including first, second, third and fourth arms **120A, 140B, 140A** and **120B** outwardly from a direction of elongation of the axle **131** as illustrated in FIGS. **4, 6** and **9**. While in a "closed" position, shown in FIGS. **3, 5** and **8**, the plurality of arms **105** are disposed within the cage assembly **160** to provide a small profile for ease of insertion between adjacent vertebrae. The axle **131** includes a first axle head **133** defining a first worm threading **136** and an opposite second axle head **134** defining a second worm threading **137** that are each configured to rotate a respective arm pairing **104** and **106** about respective pivot screw **199** in a clockwise or counterclockwise direction **A** or **B** when the axle **131** is rotated in a clockwise or counterclockwise direction **C** or **D**. In some embodiments, the expandable interbody cage device **100** includes a bone graft material receptacle **191** configured for receiving a bone graft material.

[0037] Referring directly to FIGS. **8, 9,** and **11**, the axle **131** rotates each of the arms **120A/120B/140A/140B** in a clockwise or counterclockwise direction **A** or **B** about their respective pivot screws **199** of the expandable interbody cage device **100**. In particular, the axle **131** defines a shaft portion **132** having a first axle head **133** defining the first worm thread **136** and a second axle head **134** defining an opposing second worm thread **137**. The first worm thread **136** is threaded in an opposite direction as the opposing second worm thread **137**. The first and second axle heads **133** and **134** are each engaged with a respective arm pairing **104** and **106** to actuate each respective arm **120A/120B/140A/140B** between the closed configuration of FIG. **8** and the open configuration of FIG. **9**. In particular, the first axle head **133** is associated with the first arm pairing **104** which includes a first arm **120A** and a third arm **140A**. As will be discussed in greater detail below, the first arm **120A** and the third arm **140A** can have opposing thread directions for engagement with the first axle head **133**. When coupled with the first axle head **133**, the first arm **120A** is lateral to the first axle head **133** on a first side of the axle **131**, and the third arm **140A** is lateral to the first axle head **133** on a second side of the axle **131**, as illustrated. Similarly, the second axle head **134** is associated with the second arm pairing **106** which includes a second arm **140B** and a fourth arm **120B**. As will be discussed in greater detail below, the second arm **140B** and the fourth arm **120B** can have opposing thread directions for engagement with the second axle head **134**. When coupled with the second axle head **134**, the fourth arm **120B** is lateral to the second axle head **134** on the second side of the axle **131**, and the second arm **140B** is lateral to the second axle head **134** on the first side of the axle **131**, as illustrated. In some embodiments, the axle **131** includes at least one drive point **135** for engagement with a driving tool (not shown) that enables manual or machine-driven rotation of the axle **131** in the clockwise or counterclockwise rotational direction **C** or **D**. As shown, the axle **131** defines a direction of elongation **X**.

[0038] Referring directly to FIGS. **8-10B**, each of the arms **120A** and **120B** of the expandable interbody cage device **100** define a member portion **114** and a joint portion **124**. The first arm pairing **104** includes the first arm **120A** and the third arm **140A** (as will be discussed in greater detail below). Similarly, the second arm pairing **106** includes the second arm **140B** and the fourth arm **120B**. As shown, the member portion **114** of each arm **120A** and **120B** defines a distal end **116** that follows a first direction of elongation **Q**. Each joint portion **124** is configured for engagement with the first axle head **133** or the second axle head **134** of axle **131** and is also configured for placement within the cage assembly **160**. In addition, each joint portion **124** includes a curved outer surface **125** defining a plurality of teeth **129** configured for engagement with the worm gear threading **136** or **137** of axle **131**. In the embodiment shown, the worm gear threading **136** of the first head **133** of axle **131** associated with the first pair of arms **104** is angled in a first direction, as shown in FIG. **10A**. In contrast, as shown in FIG. **10B**, the worm gear threading **137** of the second head **134** of axle **131** associated with the second pair of arms **106** is angled in a second direction. In addition, the joint portion **124** of each arm **120A** and **120B** includes an arm pivot channel **128** that extends along a second direction of elongation **R** that is perpendicular to the first direction of elongation **Q**. When the joint portion **124** is coupled to the cage assembly **160**, the arm pivot channel **128** aligns with a pivot channel **174** or **188** (FIG. **7**) of the cage assembly **160**. As shown, the expandable interbody cage device **100** includes a plurality of pivot screws **199** that each secure the arms **120A** and **120B** to the cage assembly **160** while still enabling rotation of each arm **120A** and **120B** about the respective pivot screw **199** in the first or opposite second clockwise or counterclockwise directions **A** and **B**.

[0039] As discussed above, the member portion **114** of each arm **120A** and **120B** follows the first direction of elongation **Q** and defines a distal end **116**, a first planar surface **117**, and an opposite second planar surface **118** as shown in FIG. **10A**. The first planar surface **117** and the opposite second planar surface **118** associated with each arm **120A** and **120B** align with respective outer planar surfaces **111A** and **111B** of the cage assembly **160** to engage the endplate. As further illustrated, in some embodiments, the member portion **114** of each arm **120A** and **120B** defines an inner planar surface **112** and an opposite external planar surface **113**. When in the closed configuration, the inner planar surfaces **112** of the first and fourth arms **120A** and **120B** are positioned within respective left and right voids **150** and **152** of the cage assembly **160** with the direction of elongation **Q** of each member portion **114** being positioned parallel with the direction of elongation **X** of the axle **131**. In the closed configuration, each opposite external planar surface **113** of each arm **120A** and **120B** aligns with the outer surface **192** of the cage body **191**.

[0040] Similarly, the member portion **144** of each arm **140A** and **140B** defines a distal end **146** that follows a first direction of elongation **Q**. The joint portion **154** of the arms **140A** and **140B** may be configured for engagement with the first axle head **133** or the second axle head **134** of axle **131** and is also configured for placement within the cage assembly **160**. Each joint portion **154** includes a curved outer surface **155** defining a plurality of teeth **159** for engagement with the worm gear threading **136** or **137** of axle **131**. In the embodiment shown, the worm gear threading **136** of the first head **133** of axle **131** associated with the first pair of arms **104** is angled in a first direction, as shown in FIG. **10A**. In contrast, as shown in FIG. **10B**, the worm gear threading **137** of the second head **134** of the axle **131** associated with the second pair of arms **106** is angled in a second direction. In addition, the joint portion **154** of each arm **140A** and **140B** includes an arm pivot channel **158** that extends along a second direction of elongation **R** that is perpendicular to the first direction of elongation **Q**. When the joint portion **154** is coupled to the cage assembly **160**, the arm pivot channel **158** aligns with a pivot channel **178** or **184** (FIG. **7**) of the cage assembly **160**. As shown, the expandable interbody cage device **100** includes a plurality of pivot screws **199** that each secure a respective arm **140A** and **140B** to the cage assembly **160** while still enabling rotation of each arm **140A** and **140B** about a respective pivot screw **199** in the first or opposite second clockwise or counterclockwise directions **A** and **B**.

[0041] As discussed above, each member portion **144** of the second and fourth arms **140A** and **140B** follows the first direction of elongation **Q** and defines a distal end **146**, a first planar surface **147**, and an opposite second planar surface **148** as shown in FIG. **10B**. The first planar surface **147** and opposite second planar surface **148** of each arm **140A** and **140B** align with the outer planar surfaces **111A** and **111B** of the cage assembly **160** to engage the endplate. As further illustrated, in some embodiments, the member portion **144** of each arm includes an inner planar surface **138** and an opposite external planar surface **139**. When in the closed configuration, the inner planar surface **138** of the second and third arms **140B** and **140A** are positioned within a respective left and right void **151** and **153** of the cage assembly **160** with the direction of elongation **Q** of the member portion **144** being positioned parallel with the direction of elongation **X** of the axle **131**. In the closed configuration, the opposite external planar surface **113** of each arm **140A** and **140B** aligns with the outer surface **192** of the cage body **191**.

[0042] Referring to FIGS. **5-9**, when the expandable interbody cage device **100** is in the open configuration, a direction of elongation **Q** of each arm **120A/120B/140A/140B** forms a nonzero angle **θ** relative to the direction of elongation **X** of the axle **131**. In particular, to transition from the closed configuration to the open configuration, the axle **131** is operable for manual or machine-driven rotation about the direction of elongation **X** in the clockwise or counterclockwise direction **C** or **D**. Rotation of the axle **131** and associated worm gear threads **136** and **137** of the axle causes each arm **120A/120B/140A/140B** to pivot about their respective pivot screws **199** such that the respective distal portion **116/146** of each respective arm **120A/120B/140A/140B** is directed away from the axle **131**. The continuous nature of the worm threading associated with the axle **131** and each respective arm **120A/120B/140A/140B** enables each arm **120A/120B/140A/140B** to be positioned at a variable angle **θ** ϵ (0°,90°)

relative to the direction of elongation **X** of axle **131** to accommodate differences in anatomy.

[0043] In some embodiments, the cage assembly **160** can be manufactured in at least two parts. In the embodiment of FIG. **7**, the cage assembly **160** includes a first cage portion **161A** and an opposite second cage portion **161B** that collectively form the cage assembly **160** when coupled together. The first and second cage portions **161A** and **161B** collectively encapsulate the axle **131**. Each cage portion **161A** and **161B** includes a first cage head **171** and an opposite second cage head **181** which are each respectively configured to receive the first axle head **133** and the second axle head **134** of axle **131**. The first and second cage heads **171** and **181** each engage the respective first arm pairing **104** and second arm pairing **106**, as shown in FIGS. **7-9**. Assembly of the expandable interbody cage device **100** is illustrated in terms of the second cage portion **161B** and the first cage portion **161A** being oriented facedown and coupled with the second cage portion **161B** to encapsulate the axle **131** and the respective joint portions **124/154** of each arm **120A/120B/140A/140B**.

[0044] As shown in FIGS. **8, 9** and **12**, the first cage head **171** of the cage assembly **160** defines a left shoulder **172** and an opposite right shoulder **176** that are each directly adjacent to a central seat **195**. The left shoulder **172** is configured to receive the first arm **120A** of the first pair of arms **104**, and the right shoulder **176** is also configured to receive a second arm **140A** of the first pair of arms **104**. As shown, the left shoulder **172** defines an inner surface **173** and a shoulder pivot channel **174 is** defined through the inner surface **173** to communicate with an outer planar surface **111** of each cage portion **161A/161B**. The inner surface **173** and the shoulder pivot channel **174** are collectively configured to engage the joint portion **124** of the first arm **120A**. The left shoulder **172** further defines a left lip **175** having a direction of elongation that is perpendicular to the inner surface **173** of the left shoulder **172**. The central seat **195** defines a depression within the first head **171** and is configured to receive a first axle head **133** of the axle **131**. A central notch **196** is located adjacent to the first lip **175** and in association with the central seat **195** for allowing access to the axle **131** to enable manual or powered rotation of the axle **131** when seated within each respective cage portion **161A/161B**. As further shown, the right shoulder **176** also defines an inner surface **177** and a shoulder pivot channel **178** defined through the inner surface **177** to communicate with an outer planar surface **111** of the cage portions **161A/161B**. The inner surface **177** and the shoulder pivot channel **178** collectively engage a joint portion **154** of the second arm **140**. The right shoulder **176** further defines a right lip **175** having a direction of elongation that is perpendicular to the inner surface **177** of the right shoulder **172**. As shown, the components of the left shoulder **172** and the right shoulder **176** are mirrored about the central seat **195**.

[0045] Similarly, the second cage head **181** of each cage portion **161A/161B** defines a left shoulder **182** and an opposite right shoulder **186** that are each directly adjacent to a central seat **197**. As shown, the second cage head **181** is mirrored about an axis **Y** (FIG. **12**). The left shoulder **182** is configured to receive a second arm **140B** of a second pair of arms **106**, and the right shoulder **186** is configured to receive a first arm **120A** of the second pair of arms **106**. It should be noted that the positions of the first and fourth arms **120A/120B** of the first pair of arms **104** and the fourth and second arms **140A/140B** of the second pair of arms **106** are swapped between the first cage head **171** and the second cage head **181** of the cage assembly **160** to accommodate a reversed thread angle between the first axle head **133** and the second axle head **134**.

[0046] As shown, the left shoulder **182** defines an inner surface **183** and a shoulder pivot channel **184** defined through the inner surface **183** to communicate with each outer planar surface **111A/111B**. The inner surface **183** and the shoulder pivot channel **184** are collectively configured to engage a joint portion **154** of the second arm **140B** of the second pair of arms **106**. The left shoulder **182** further defines a left lip **185** having a direction of elongation that is perpendicular to the inner surface **183** of the left shoulder **182**. The central seat **197** defines a depression within the first head **181** and is configured to receive the second axle head **134** of the axle **131**. A central notch **198** is located adjacent to the first lip **185** and in association with the central seat **197** and enables access to the axle **131** to allow manual or powered rotation of the axle **131** when the axle **131** is seated within each cage portion **161A/161B**. As further shown, the right shoulder **186** also defines an inner surface **187** and a shoulder pivot channel **188** is defined through the inner surface **187** to communicate with outer planar surfaces

111A/111B. The inner surface **187** and the shoulder pivot channel **188** are collectively configured to engage a joint portion **124** of the first arm **120A**. The right shoulder **186** further defines a right lip **185** having a direction of elongation that is perpendicular to the inner surface **187** of the right shoulder **182**. As shown, the components of the left shoulder **182** and the right shoulder **186** are mirrored about the central seat **197**.

[0047] Each cage portion **161A/161B** further includes at least a first neck portion **162** defining an axle channel **164** defined axially along a direction of elongation of the respective cage portion **161A/161B** for receipt of the shaft **132** of axle **131**. In some embodiments, a left exterior surface **163** of the first neck portion **162** defines a left void **150** for receipt of the inner planar surface **112** of member portion **114** of the first arm **120A**, and a right exterior surface **168** of the first neck portion **162** defines a right void **152** for receipt of the inner planar surface **138** of the member portion **144** of the second arm **140A**. Further, in the embodiment of FIG. **12**, each cage portion **161A/161B** further includes a second neck portion **165** in association with the second head **181** and defines an axle channel **167** along a direction of elongation of the respective cage portion **161A/161B** for receipt of a shaft **132** of axle **131**. In some embodiments, a left exterior surface **166** of the second neck portion **165** defines a left void **151** for receipt of the inner planar surface **138** of the member portion **144** for the second arm **140B**, while a right exterior surface **168** of the second neck portion **165** defines a right void **153** for receipt of the inner planar surface **112** of the member portion **114** for the first arm **120B**.

[0048] In the embodiment of FIGS. **3-12**, the first neck portion **162** and the second neck portion **165** are mirrored and separated from one another by a cage body **191** that includes at least one cavity **194** for receipt of bone graft material that aids in fusion of the vertebrae. The cage body **191** defines an outer surface **192** and an interior surface **193**. As shown in FIGS. **3** and **8**, when in the closed configuration, the outer surface **192** of the cage body **191** aligns with the external planar surface **113** of the member portions **114** and **154** of each respective arm **120A/120B/140A/140B**. In some embodiments, the axle **131** bisects the cavity **194**. The cavity **194** can also be packed with bone graft material (not shown) to encourage bone growth and fusion of the vertebrae.

[0049] FIGS. **13-18B** illustrate a second embodiment of the expandable interbody cage device, designated **200**. In particular, the expandable interbody cage device **200** includes a cage assembly **260** that defines a first outer planar surface **211A** and an opposite second outer planar surface **211B** for engaging the endplate of the vertebra. In a preferred embodiment, the cage assembly **260** is load-bearing such that the expandable interbody cage device **200** can withstand the force of being positioned between two adjacent vertebrae. The expandable interbody cage device **200** also includes an axle **231** encapsulated by the cage assembly **260** that enables a practitioner to “open” the expandable interbody cage **200** and rotate a plurality of arms **205** outwardly along a direction of elongation of the cage assembly **260** as illustrated in FIGS. **14** and **16**. While in a “closed” position shown in FIGS. **13** and **15**, the arms **205** are tucked into the cage assembly **260** to provide a slim profile for ease of insertion between vertebrae. The axle **231** includes a first axle head **233** defining a first worm threading **236** and an opposite second axle head **234** defining a second worm threading **237** that are each configured to rotate a respective pair of arms **204** and **206** about a respective pivot screw **299** in a clockwise or counterclockwise direction **A** or **B** when the axle **231** is rotated in a clockwise or counterclockwise direction **C** or **D**. In some embodiments, the expandable interbody cage device **200** includes a plurality of bone graft ports **222,** each associated with a respective arm **220A/220B/220C/220D** for packing bone graft material into the opened expandable interbody cage device **200**.

[0050] Referring directly to FIGS. **15, 16** and **17**, the axle **231** rotates each respective arm **220A/220B/220C/220D** in a clockwise or counterclockwise direction **A** or **B** about a respective pivot screw **299**. In some embodiments, the axle **231** defines a shaft portion **232** having a first axle head **233** forming a first worm thread **236** and a second axle head **234** forming an opposing second worm thread **237**. The first worm thread **236** is threaded in an opposite direction as the opposing second worm thread. In some embodiments, the first and second axle heads **233** and **234** are each engaged with a respective arm pairing **204** and **206** to actuate each arm **220** between the closed configuration of FIG. **15** and the open configuration of FIG. **16**.

[0051] In the embodiment shown, the worm gear threading **236** of the first head **233** of axle **231** associated with the first pair of arms **204** is angled in a first direction, and the worm gear threading **237** of the second head **234** of axle **231** associated with the second pair of arms **206** is angled in a second direction. In particular, the first axle head **233** is associated with the first arm pairing **204** which includes a first arm **220A** and a third arm **220C**. In contrast with the first arm **120A** and the third arm **140A** of the first arm pairing **104** in the first embodiment (FIG. **7**), which differ by having teeth **129** angled in opposing directions for engagement with the first axle head **133**, the first arm **220A** and the third arm **220C** of the first arm pairing **204**, include teeth **229** that are not angled, and can therefore be manufactured as two of the same component. When coupled with the first axle head **233**, the first arm **220A** is lateral to the first axle head **233** on a left side of the axle **231**, and the third arm **220C** is lateral to the first axle head **233** on a right side of the axle **231**.

[0052] Similarly, the second axle head **234** is associated with the second arm pairing **206** which includes a second arm **220B** and a fourth arm **220D**. In contrast with the second arm **140B** and the fourth arm **120B** of the second arm pairing **106** of the first embodiment shown in FIG. **7**, the second arm **220B** and the fourth arm **220D** of the second arm pairing **206** include teeth **229** that are not angled and can therefore be manufactured as two of the same component. When coupled with the second axle head **234**, the second arm **220B** is lateral to the second axle head **234** on the left side of the axle **231**, and the fourth arm **220D** is lateral to the second axle head **234** on the right side of the axle **231**. In some embodiments, the axle **231** includes at least one drive point **235** for engagement with a driving tool (not shown) that enables manual or machine-driven rotation of the axle **231** in a clockwise or counterclockwise direction **C** or **D**. As shown, the axle **231** defines a direction of elongation **X**.

[0053] In continued reference to FIGS. **15-18B**, each arm **220A/220B/220C/220D** of the expandable interbody cage device **200** defines a member portion **214** and a joint portion **224**. The first pair of arms **204** of the plurality of arms **205** includes a first arm **220A** and a second arm **220B** associated with the first axle head **233**. Similarly, the second pair of arms **206** of the plurality of arms **205** includes the third arm **220C** and the fourth arm **220D** associated with the second axle head **234**. The member portion **214** of each arm **220A/220B/220C/220D** defines a distal end **216** that follows a first direction of elongation **Q**. The joint portion **224** of each arm

220A/220B/220C/220D is configured for engagement with the first axle head **233** or the second axle head **234** of the axle **231** and is also configured for placement within the cage assembly **260**. The joint portion **224** includes a curved outer surface **225** defining a plurality of teeth **229** for engagement with the worm gear threading **236** or **237** of axle **231**. As shown, the joint portion **224** of each arm **220A/220B/220C/220D** includes an arm pivot channel **228** that extends along a second direction of elongation **R** that is perpendicular to the first direction of elongation **Q**. When each joint portion **224** is coupled to the cage assembly **260**, each arm pivot channel **228** aligns with a respective shoulder pivot channel **274/278/284/288** (FIG. **17**) of the cage assembly **260**. As shown, the expandable interbody cage device **200** includes the plurality of pivot screws **299** that each secures a respective arm **220A/220B/220C/220D** to the cage assembly **260** while still enabling rotation of each arm **220A/220B/220C/220D** about a respective pivot screw **299** in the clockwise or counterclockwise directions **A** or **B**. In some embodiments, each arm **220A/220B/220C/220D** can include a bone graft port **222** for insertion of bone graft material for improved fusion of the joint.

[0054] As discussed above, the member portion **214** of each arm **220A/220B/220C/220D** follows the first direction of elongation **Q** and defines a distal end **216**, a first planar surface **217**, and an opposite second planar surface **218** as shown in FIG. **10**. The first planar surface **217** and the opposite second planar surface **218** of each arm **220A/220B/220C/220D** aligns with the outer planar surfaces **211A** and **211B** of the cage assembly **260** to engage the endplate. As further illustrated, in some embodiments, the member portion **214** of each arm **220A/220B/220C/220D** defines an inner planar surface **212** and an opposite external planar surface **213**. When in the closed configuration, the inner planar surface **212** of each respective arm **220A/220B/220C/220D** is positioned against an elongated neck portion **262** of the cage assembly **260** with the direction of elongation **Q** of the member portion **214** being positioned parallel with the direction of elongation **X** of the axle **231**.

[0055] Referring to FIGS. **15-18B**, when the expandable interbody cage device **200** is in the open configuration, a direction of elongation **Q** of each arm **220A/220B/220C/220D** forms a nonzero angle **θ** relative to the direction of elongation **X** of the axle **231**. In particular, to transition from the closed configuration to the open configuration, the axle **231** is operable for manual or machine-driven rotation about the direction of elongation **X** in a clockwise or counterclockwise direction **C** or **D**. Rotation of the axle **231** and associated worm gear threads **236** and **237** of the axle **231** causes each arm **220A/220B/220C/220D** to pivot about their respective pivot screws **299** such that the distal portion **216** of each respective arm **220A/220B/220C/220D** is directed away from the axle **231**. The continuous nature of the worm threading associated with the axle **231** and each respective arm **220A/220B/220C/220D** enables each arm **220A/220B/220C/220D** to be positioned at a variable angle **θ** ϵ (0°, 90°) relative to the direction of elongation **X** of the axle **231** to accommodate differences in anatomy.

[0056] In some embodiments, the cage assembly **260** can be manufactured in at least two parts. In the embodiment of FIG. **17**, the cage assembly **260** includes a first cage portion **261A** and an opposite second cage portion **261B** that collectively form the cage assembly **260**. The first and second cage portions **261A** and **261B** collectively encapsulate the axle **231**. In addition, each cage portion **261A** and **261B** includes a first cage head **271** and an opposite second cage head **272** which are each respectively configured to receive the first axle head **233** and the second axle head **234** of axle **231**. The first and second cage heads **271** and **272** engage a respective first arm pairing **204** and a second arm pairing **206** as shown in FIGS. **13-17**. Referring to FIGS. **15-17**, assembly of the expandable interbody cage device **200** is illustrated in terms of the second cage portion **261B** and the first cage portion **261A** being oriented facedown and coupled with the second cage portion **261B** to encapsulate the axle **231** and the joint portions **224** of each arm **222A/222B/222C/222D**.

[0057] As shown in FIG. **17**, each cage portion **261A/261B** includes a first cage head **271** defining a left shoulder **272** and an opposite right shoulder **276** that are each formed directly adjacent to a central seat **295**. The left shoulder **272** is configured to receive the first arm **220A** of the first pair of arms **204**, and the right shoulder **276** is configured to receive a second arm **220B** of the first pair of arms **204**. As shown, the left shoulder **272** defines an inner surface **273**, while a shoulder pivot channel **274** being formed through the inner surface **273** to communicate with the outer planar surface **211** of the cage portions **261A/261B**. The inner surface **273** and the shoulder pivot channel

274 are collectively configured to engage a joint portion **224** of the first arm **220A** of the first pair of arms **204**. The left shoulder **272** further defines a left lip **275** having a direction of elongation that is perpendicular to the inner surface **273** of the left shoulder **272**. The central seat **295** defines a depression within the first head **271** and is configured to receive a first axle head **233** of axle **231**. A central notch **296** is located adjacent to the first lip **275** and in association with the central seat **295** and allows access to the axle **231** to enable manual or powered rotation of the axle **231** when the axle **231** is seated within each cage portion **261A/261B**. As further shown, the right shoulder **276** also defines an inner surface **277** and a shoulder pivot channel **278** defined through the inner surface **277** to communicate with an outer planar surface **211** of each cage portion **261A/261B**. The inner surface **277** and the shoulder pivot channel **278** collectively engage a joint portion **254** of the second arm **220B**. The right shoulder **276** further defines a right lip **275** having a direction of elongation that is perpendicular to the inner surface **277** of the right shoulder **272**. As shown, the components of the left shoulder **272** and the right shoulder **276** are mirrored about the central seat **295**.

[0058] Similarly, the second cage head **281** of each cage portion **261A/261B** defines a left shoulder **282** and an opposite right shoulder **286** that are each directly adjacent to a central seat **297**. As shown, the second cage head **281** is mirrored about an axis **Y**. The left shoulder **282** is configured to receive a third arm **220C** of the second pair of arms **206**, and the right shoulder **286** is configured to receive a fourth arm **220D** of the second pair of arms **206**.

[0059] As shown, the left shoulder **282** defines an inner surface **283** and a shoulder pivot channel **284** defined through the inner surface **283** to communicate with each outer planar surface **211A/211B** of cage portions **261A/261B**. The inner surface **283** and the shoulder pivot channel **284** are collectively configured to engage a joint portion **254** of the third arm **220C**. The left shoulder **282** further defines a left lip **285** having a direction of elongation that is perpendicular to the inner surface **283** of the left shoulder **282**. The central seat **297** defines a depression within the first head **281** and is configured to receive a second axle head **234** of axle **231**. A central notch **298** is located adjacent to the first lip **285** and is in association with the central seat **297**, thereby enabling access to the axle **231** for manual or machine-driven rotation of the axle **231** when seated within each cage portion **261A/261B**. As further shown, the right shoulder **286** also defines an inner surface **287** and a shoulder pivot channel **288** defined through the inner surface **287** to communicate with the respective outer planar surface **211A/211B** of each cage portion **261A/261B**. The inner surface **287** and the shoulder pivot channel **288** are collectively configured to engage a joint portion **224** of the fourth arm **220D**. The right shoulder **286** further defines a right lip **285** having a direction of elongation that is perpendicular to the inner surface **287** of the right shoulder **282**. As shown, the components of the left shoulder **282** and the right shoulder **286** are mirrored about the central seat **297**.

[0060] Each cage portion **261A/261B** has an elongated neck portion **262** defining an axle channel **264** formed axially along a direction of elongation of each cage portion **261A/261B** for receipt of a shaft **232** of axle **231**. In some embodiments, the elongated neck portion **262** defines a left exterior surface **263** for receipt of the inner planar surfaces **212** of the member portions **214** for the first and third arms **220A** and **220C**. In addition, the elongated neck portion **262** defines a right exterior surface **268** for receipt of the inner planar surfaces **212** of the member portions **244** for the second and fourth arms **220B** and **220D**.

[0061] Referring back to the first embodiment of FIGS. **3-12**, the first neck portion **162** and the second neck portion **165** are mirrored and are separated from one another by a cage body **191** that includes at least one cavity **194** for receipt of bone graft material that aids in fusion of the vertebrae. The cage body **191** includes an outer surface **192** and an opposite interior surface **193**. The cavity **194** can be packed with bone graft material (not shown) to encourage bone growth and fusion of the vertebrae. In contrast, in the second embodiment of FIGS. **14** and **16**, the “opened” plurality of arms **205** along the left side including the first and third arms **220A** and **220C** collectively form a left void **250** for packing bone graft material for improved fusion of the joint. Specifically, a bone graft material can be packed through the bone graft ports **222** of the first and third arms **220A** and **220C** and into the left void **250** formed by the open first and third arms **220A** and **220C**. Similarly, the “opened” plurality of arms **205** along the right side including the second and fourth arms **220B** and **220D** form a right void **252** for packing bone graft material for improved fusion of the joint. Specifically, bone graft material can be packed through the bone graft ports **222** of the second and fourth arms **220B** and **220D** and into the right void **252** formed by the open second and fourth arms **220B** and **220D**. This alteration of the embodiment allows each arm **220A/220B/220C/220D** to have a longer length and thus the expandable interbody cage device **200** can be expanded to contact a larger surface area of the endplate.

[0062] FIGS. **19-26** illustrate a third embodiment of the expandable interbody cage device **300**. In particular, the expandable interbody cage device **300** includes a cage assembly **360** that defines a first outer planar surface **311A** and an opposite second outer planar surface **311B** for engaging the endplate of the vertebra. In a preferred embodiment, the cage assembly **360** is load-bearing such that the expandable interbody cage device **300** can withstand the force of being positioned between two vertebrae. The expandable interbody cage device **300** also includes an axle **331** encapsulated by the cage assembly **360** that enables a practitioner to "open" the expandable interbody cage device **300** and rotate a plurality of arms **305** outwardly from a direction of elongation of the cage assembly **360** as illustrated in FIGS. **19**, **21** and **23-25**. While in a "closed" position shown in FIGS. **20, 22** and **26**, the arms **305** are tucked into the cage assembly **360** as shown to provide a slim profile for ease of insertion between adjacent vertebrae. The axle **331** includes a first axle head **333** defining a first worm threading **336** and an opposite second axle head **334** defining a second worm threading **337** that are each configured to rotate a respective arm **320** and **340** about a respective pivot screw **399** in a clockwise or counterclockwise direction **A** or **B** when the axle **331** is rotated in a clockwise or counterclockwise direction **C** or **D**. In some embodiments, an arm **320** or **340** of the expandable interbody cage device **300** may include a bone graft port **322** for packing bone graft material into the opened expandable interbody cage device **300**.

[0063] The axle **331** rotates each arm **320** and **340** in a clockwise or counterclockwise direction **A** or **B** about a respective pivot screw **399** of the expandable interbody cage device **300**. In particular, the axle **331** defines the shaft portion **332** having a first axle head **333** defining the first worm thread **336** and the second axle head **334** defining an opposing second worm thread **337**. The first worm thread **336** is threaded in an opposite direction as the opposing second worm thread **337**. The first and second axle heads **333** and **334** each engage a respective arm **330** and **340** to actuate each arm **320** and **340** between the closed configuration of FIG. **20** and the open configuration of FIG. **19**.

[0064] In the embodiment shown, the worm gear threading **336** of the first head **333** for axle **331** associated with the first arm **320** is angled in a first direction, as shown in FIG. **10A**. In contrast, as shown in FIG. **10B**, the worm gear threading **337** of the second head **334** for axle **331** associated with the second arm **340** is angled in a second direction. As illustrated, when coupled with the first axle head **333**, the first arm **320** is lateral to the first axle head **333**, and the second arm **340** is lateral to the second axle head **334**. In some embodiments, the axle **331** includes at least one drive point **335** for engagement with a driving tool (not shown) that enables manual or machine-driven rotation of the axle **331** in the clockwise or counterclockwise direction **C** or **D**. As shown, the axle **331** defines a direction of elongation **X**.

[0065] In reference to FIGS. **19-24**, each arm **320/340** of the expandable interbody cage device **300** is illustrated defining a member portion **314** and a joint portion **324**. The first arm **320** is associated with the first axle head **333** and the second arm **340** is associated with the second axle head **334**. Member portion **314** of arm **320** defines a distal end **316** that follows a first direction of elongation **Q**. Similarly, member portion **344** of arm **340** defines a distal end **346** that also follows a first direction of elongation **Q**. The joint portion **324** of each arm **320/340** is configured for engagement with the first axle head **333** or the second axle head **334** of the axle **331** and is also configured for placement within the cage assembly **360**, as illustrated. In addition, each joint portion **324** includes a curved outer surface **325** defining a plurality of teeth **329** for engagement with the worm gear threading **336** or **337** of the axle **331**. As shown, the joint portion **324** of each arm **320/340** includes an arm pivot channel **328** that runs along a second direction of elongation **R** and is perpendicular to the first direction of elongation **Q**. When each joint portion **324** is coupled to the cage assembly **360**, the arm pivot channel **328** aligns with a respective shoulder pivot channel **374/384** of the cage assembly **360**. As shown, the expandable interbody cage device **300** includes the plurality of pivot screws **399** that each secures a respective arm **320/340** to the cage assembly **360** while still enabling rotation of each arm **320/340** about a respective pivot screw **399** in the opposite clockwise or counterclockwise directions **A** and **B**. As illustrated, each arm **320/340** can include a bone graft port **322** for insertion of bone graft material for improved fusion of the joint.

[0066] As discussed above, the member portion **314** of each arm **320/340** follows the first direction of elongation **Q** and defines a respective distal end **316**, a first planar surface **317**, and an opposite second planar surface **318** as shown in FIG. **21**. Each first planar surface **317/347** and each opposite second planar surface **318** of the arms **320/340** align with respective outer planar surfaces **311A** and **311B** of the cage assembly **360** to engage the endplate. In the embodiment of FIG. **21**, the first planar surface **317** and the opposite second planar surface **318** each define an angle **ϕ** relative to a direction of elongation of the member portion **314** of each arm **320/340**. As further illustrated, in some embodiments, the member portion **314/344** of each arm **320/340** includes a respective inner planar surface **312/338** and an opposite external planar surface **313/339**. When in the closed configuration, the inner planar surface **312/338** of each arm **320/340** is positioned within a respective pocket **350/351** of the cage assembly **360** along the direction of elongation **Q** of each member portion **314/344** positioned parallel along the direction of elongation **X** of the axle **331**.

[0067] When the expandable interbody cage device **300** is in the open configuration, the direction of elongation **Q** of each arm **320/340** forms a nonzero angle **ϕ** relative to the direction of elongation **X** of the axle **331**. In particular, to transition from the closed configuration to the open configuration, the axle **331** is operable for manual or machine-driven rotation about the direction of elongation **X** in the clockwise or counterclockwise direction **C** or **D**. Rotation of the axle **331** and associated worm gear threads **336** and **337** of the axle **331** causes each arm **320/340** of the plurality of arms **305** to pivot about their respective pivot screws **399** such that the distal portion **316** of each respective arm **320/340** of the plurality of arms **305** is directed away from the axle **331**. The continuous nature of the worm threading associated with the axle **331** and each respective arm **320/340** enables each arm **320/340** to be positioned at a variable angle $\theta \in (0°, 90°)$ relative to the direction of elongation **X** of the axle **331** to accommodate differences in anatomy. In some embodiments, the expandable interbody cage device **300** includes one or more bone graft ports **322** associated with each arm

324/340 for packing bone graft material into the opened expandable interbody cage device **300**.

[0068] In some embodiments, the cage assembly **360** of the expandable interbody cage device **300** can be manufactured in at least two parts. As shown in FIGS. **21** and **22**, in some embodiments the cage assembly **360** includes a first cage portion **361A** and an opposite second cage portion **361B** that collectively form the cage assembly **360**. The first and second cage portions **361A** and **361B** also collectively encapsulate the axle **331**. In some embodiments, each cage portion **361A** and **361B** includes a first cage head **371** and an opposite second cage head **372** which are each respectively configured to receive the first axle head **333** and the second axle head **334** of the axle **331**. The first and second cage heads **371** and **372** each engage a respective first arm **320** and a second arm **340** as specifically shown in FIGS. **23**. Assembly of the expandable interbody cage device **300** is illustrated in terms of the second cage portion **361B** and the first cage portion **361A** being oriented facedown and coupled with the second cage portion **361B** to encapsulate the axle **331** and the joint portions **324/354** of each arm **320/340**.

[0069] As shown specifically with the cage portion **361B** in FIG. **23**, the first cage head **371** defines a first shoulder **372** that is directly adjacent to a first seat **395**. The first shoulder **372** is configured to receive the first arm **320**. As shown, the first shoulder **372** defines an inner surface **373** and a shoulder pivot channel **374** defined through the inner surface **373** to communicate with an outer planar surface **311** of each cage portion **361A/361B**. The inner surface **373** and the shoulder pivot channel **374** are collectively configured to engage a joint portion **324** of the first arm **320**. The first shoulder **372** further defines a first lip **375** having a direction of elongation that is perpendicular to the inner surface **173** of the left shoulder **172**. The first seat **395** defines a depression within the first head **371** and is configured to receive a first axle head **333** of axle **331**. A first notch **396** is located adjacent to the first lip **375** and in association with the first seat **395** and permit access to the axle **331** to enable manual or powered rotation of the axle **331** when the axle **331** is seated within each cage portion **361A/361B**.

[0070] Similarly, the second cage head **381** defines a second shoulder **382** that is directly adjacent to a second seat **391**. The second shoulder **382** is configured to receive the second arm **340**. As shown, the second shoulder **382** defines an inner surface **383** and a shoulder pivot channel **384** defined through the inner surface **383** to communicate with the outer planar surface **311** of each cage portion **361A/361B**. The inner surface **383** and the shoulder pivot channel **384** are collectively configured to engage a joint portion **354** of the second arm **340**. The second shoulder **382** further defines a second lip **385** having a direction of elongation that is perpendicular to the inner surface **183** of the second shoulder **182**. The second seat **391** defines a depression within the second head **381** and is configured to receive a second axle head **334** of axle **331**. A second notch **392** is located adjacent to the second lip **385** and in association with the second seat **391** and enables access to the axle **331** to enable manual or powered rotation of the axle **331** when the axle **331** is seated within each cage portion **361A/361B**.

[0071] Each cage portion **361A/361B** further includes at least a first neck portion **362** defining an axle channel **364** formed axially along a direction of elongation of each respective cage portion **361A/361B** for receipt of a shaft **332** of the axle **331**. In some embodiments, each cage portion **361A/361B** defines a first pocket **350** for receipt of the member portion **314** of first arm **320**. Additionally, each cage portion **361A/361B** includes at least a central neck portion **378** defining an axle channel **377** formed axially along the direction of elongation of the cage portion **361A/361B** for receipt of the shaft **332** of the axle **331**. In some embodiments, each cage portion **361A/361B** defines the central pillar **376** located between the first arm **320** and a second arm **340** that provides structural support to the cage assembly **360**. Further, in the embodiment of FIG. **23**, each cage portion **361A/361B** further includes a second neck portion **365** in association with the second head **381** and defining an axle channel **367** along a direction of elongation of each cage portion **361A/361B** for receipt of the shaft **332** of the axle **331**. In some embodiments, the cage portion **361A/361B** defines the second pocket **351** for receipt of the member portion **344** of the second arm **340**. As shown, each cage portion **361A/361B** defines a sidewall surface **393** opposite to the first and second pockets **350** and **351**.

[0072] As shown and as discussed above, the first planar surface **317** and the opposite second planar surface **318** of each arm **320/340** align with the outer planar surfaces **311A** and **311B** of the cage assembly **360** to engage the endplate. In the embodiment of FIG. **21**, the first planar surface **317** and the opposite second planar surface **318** each define a tapered profile such that a lordotic angle **2*ϕ** is defined relative to the direction of elongation **Q** of the member portion **314** of each arm **320/340**. The first outer planar surface **311A** and the opposite second outer planar surface of the cage assembly **360** also define the lordotic angle **2*ϕ** relative to a direction of elongation of the member portion **314** of each arm **320/340**. This arrangement with the first and second outer planar surfaces **311A** and **311B** and the arms **320** and **340** at the lordotic angle **2*ϕ** induces lordosis of the joint to be fused.

[0073] In some embodiments, the pockets **350** and **351** each include an associated pocket surface **352** and **353**. As shown, each pocket surface **352/353** can be angled to fit the grade of the associated arm **320/340**. In some embodiments, each pocket surface **352/353** includes a plurality of perforations **321** that allow bone graft material packed within the expandable interbody cage device **300** to grow onto the endplate surface below and above the expandable interbody cage device **300**. In addition, each pocket **350/351** communicates with a respective bone graft cavity **394** associated with the axle **331**, as shown, in which bone graft material can be packed. Bone graft material can be packed in the bone graft cavities **394** and can also packed in through the bone graft port **322** of an associated arm **320/340**.

[0074] It should be understood from the foregoing that, while particular embodiments have been illustrated and described, various modifications can be made thereto without departing from the spirit and scope of the invention as will be apparent to those skilled in the art. Such changes and modifications are within the scope and teachings of this invention as defined in the claims appended hereto.

CLAIMS

What is claimed is:

1. An expandable interbody cage device, comprising:

an axle including a first axle head and an opposite second axle head, wherein the axle is rotatable about a direction of elongation of the axle in a clockwise or counterclockwise direction C or D;

a plurality of arms in association with the axle, including:

a first arm in association with the first axle head, wherein the first arm includes a joint portion and a member portion and wherein the first arm is rotatable in a clockwise or counterclockwise direction A or B about the joint portion by the first axle head of the axle, and wherein the first arm defines a first planar surface and an opposite second planar surface configured to contact a cortical bone surface; and

a second arm in association with the second axle head, wherein the second arm includes a joint portion and a member portion, wherein the second arm is rotatable in a first or opposite second clockwise or counterclockwise direction A or B about the joint portion by the second axle head of the axle, and wherein the second arm defines a first planar surface and an opposite second planar surface configured to contact the cortical bone surface; and

a cage assembly encapsulating the axle and the joint portion of the first arm and the joint portion of the second arm, wherein the cage assembly includes a first external planar surface and an opposite second external planar surface configured to contact an endplate surface.

2. The device of claim 1, wherein the expandable interbody cage device is operable to assume a closed configuration, wherein a direction of elongation of each

member portion of the first arm and the second arm is parallel with the direction of elongation of the axle.

3. The device of claim 1, wherein the expandable interbody cage device is operable to assume an open configuration wherein a direction of elongation of each member portion of the first arm and the second arm forms an angle $\theta \in (0°,90°)$ relative to the direction of elongation of the axle.

4. The device of claim 1, wherein a distal portion of each first arm and second arm of the plurality of arms is extended beyond the cage assembly when in an open configuration such that the member portion of the first arm and the second arm engages the cortical bone surface.

5. The device of claim 1, wherein the first axle head defines a first worm threading and wherein the second axle head defines an opposite second worm threading.

6. The device of claim 5, wherein the joint portion of the first arm and the second arm defines a curved outer surface and a plurality of teeth thereon, wherein the plurality of teeth are configured for engagement with the worm threading of the first or second axle head

7. The device of claim 1, wherein the cage assembly defines a first cage head configured to receive the first axle head, and a second cage head configured to receive the second axle head.

8. The device of claim 1, wherein the first cage head is configured to receive the joint portion of the first arm in association with the first axle head and wherein the second cage head is configured to receive the joint portion of the second arm in association with the second axle head.

9. The device of claim 1, wherein the cage assembly includes a cavity for receipt of bone graft material.

10. The device of claim 1, further defining a void between the first arm or second arm of the plurality of arms and the cage assembly when the device is in an open configuration.

11. The device of claim 10, wherein the void is operable to be packed with bone graft material.

12. The device of claim 10, wherein the first or second arm of the plurality of arms includes a bone graft port.

13. The device of claim 1, further comprising a third arm of the plurality of arms in association with the first axle head and a fourth arm of the plurality of arms in association with the second axle head.

14. The device of claim 1, wherein the cage assembly and the first arm and second arm defines a tapered profile such that a lordotic angle 2*ϕ is defined relative to a direction of elongation Q of the member portion of the first arm and second arm of the plurality of arms.

15. A method, comprising:

providing an expandable interbody cage device, comprising:

an axle including a first axle head and an opposite second axle head, wherein the axle is rotatable about a direction of elongation of the axle in a clockwise or counterclockwise direction C or D;

a plurality of arms in association with the axle, including:

a first arm in association with the first axle head, wherein the first arm includes a joint portion and a member portion and wherein the first arm is rotatable in a first or opposite second clockwise or counterclockwise direction A or B about the joint portion by the first axle head of the axle; and

a second arm in association with the second axle head, wherein the second arm includes a joint portion and a member portion, wherein the second arm is rotatable in the first or opposite second clockwise or counterclockwise direction A or B about the joint portion by the second axle head of the axle; and

wherein the expandable interbody cage device is operable to assume a closed configuration and an open configuration;

inserting the expandable interbody cage device between a first endplate surface of a first vertebra and a second endplate surface of a second vertebra; and

rotating the axle in the clockwise or counterclockwise direction C or D such that each arm of the plurality of arms is resultantly rotated in the clockwise or counterclockwise direction A or B such that the expandable interbody cage device assumes the open configuration.

16. The method of claim 15, wherein in the closed configuration a direction of elongation of the member portion is parallel with the direction of elongation of the axle and wherein in the open configuration the direction of elongation of the member portion forms an angle $\theta \in (0°, 90°)$ relative to the direction of elongation of the axle.

17. The method of claim 15, wherein the first arm defines a first planar surface and an opposite second planar surface configured to contact a cortical bone surface and wherein the second arm defines a first planar surface and an opposite second planar surface configured to contact the cortical bone surface.

18. The method of claim 15, wherein the expandable interbody cage device further comprises a cage assembly encapsulating the axle and the joint portion of the first arm and the joint portion of the second arm, wherein the cage assembly includes a first external planar surface and an opposite second external planar surface configured to contact an endplate surface.

19. The method of claim 18, further comprising:

inserting bone graft material into a void defined between the first arm or second arm of the plurality of arms and the cage assembly when the device is in an open configuration.

20. The method of claim 15, wherein the expandable interbody cage device is in a closed configuration during insertion.

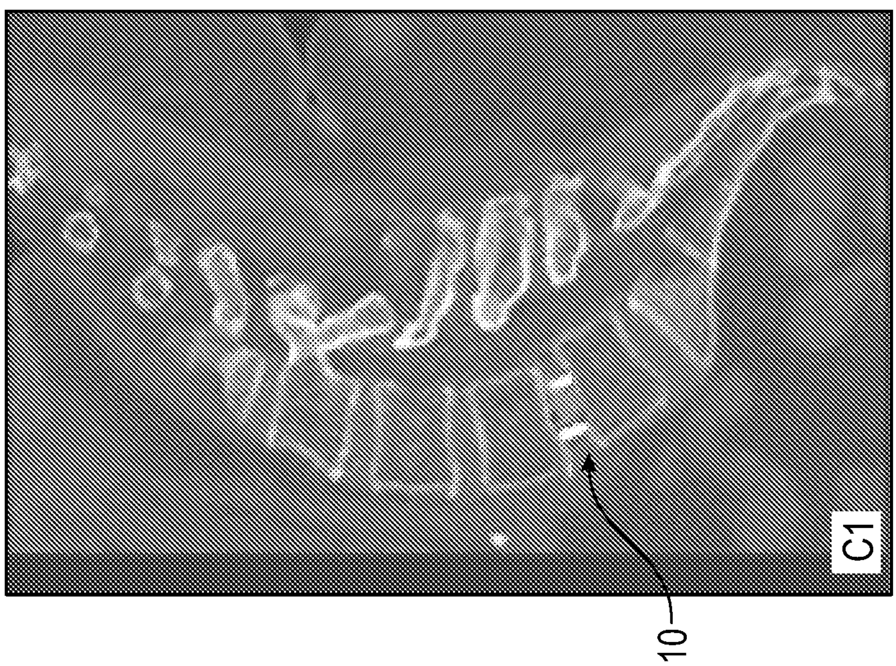


FIG. 1A

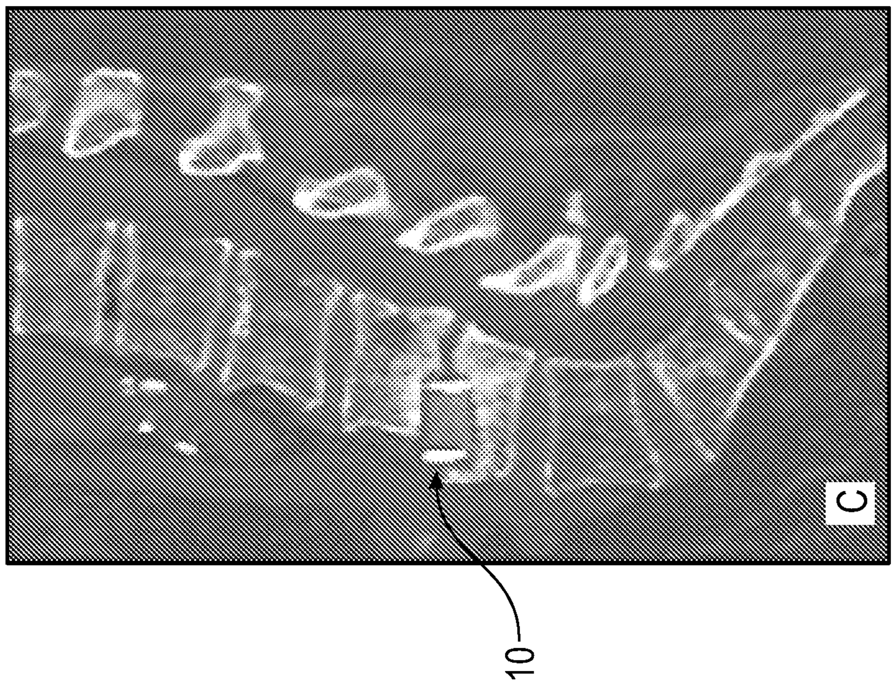


FIG. 1B

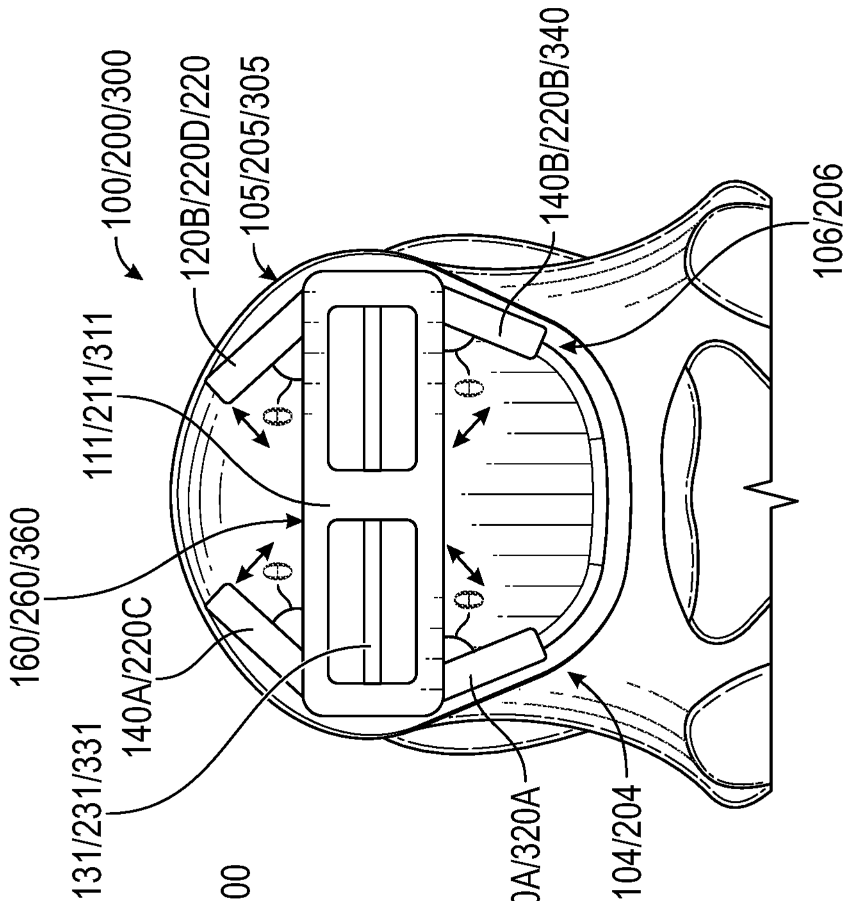

100/200/300
120B/220D/220
105/205/305
140B/220B/340
106/206
111/211/311
160/260/360
140A/220C
131/231/331
120A/220A/320A
104/204
θ
θ
θ
θ

FIG. 2B

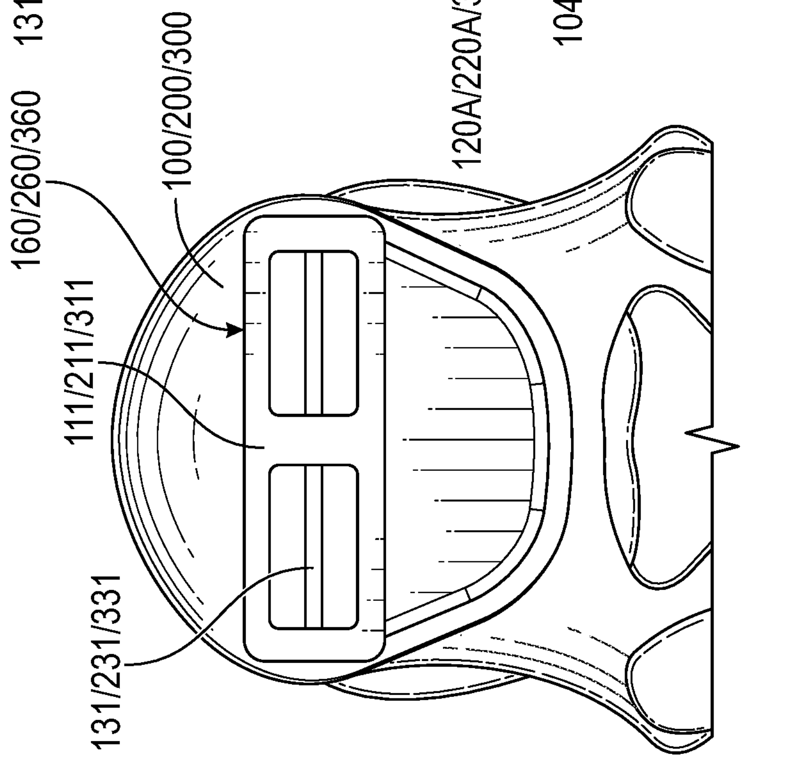
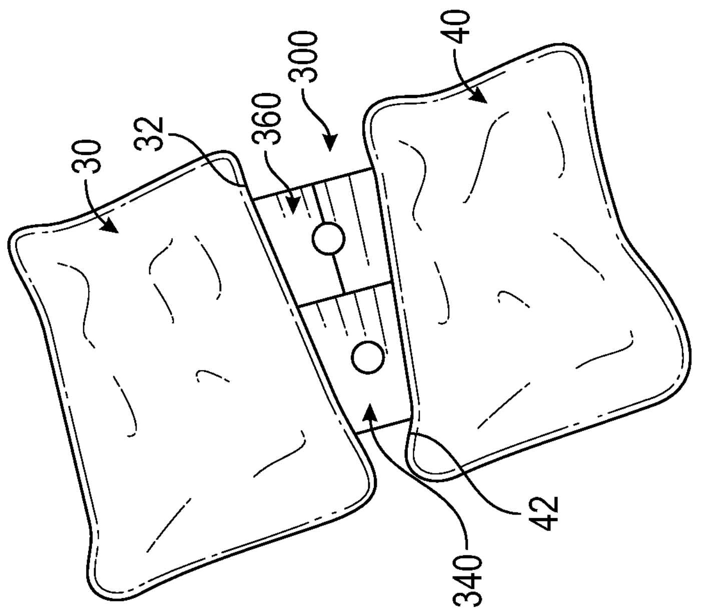

160/260/360
100/200/300
111/211/311
131/231/331

FIG. 2A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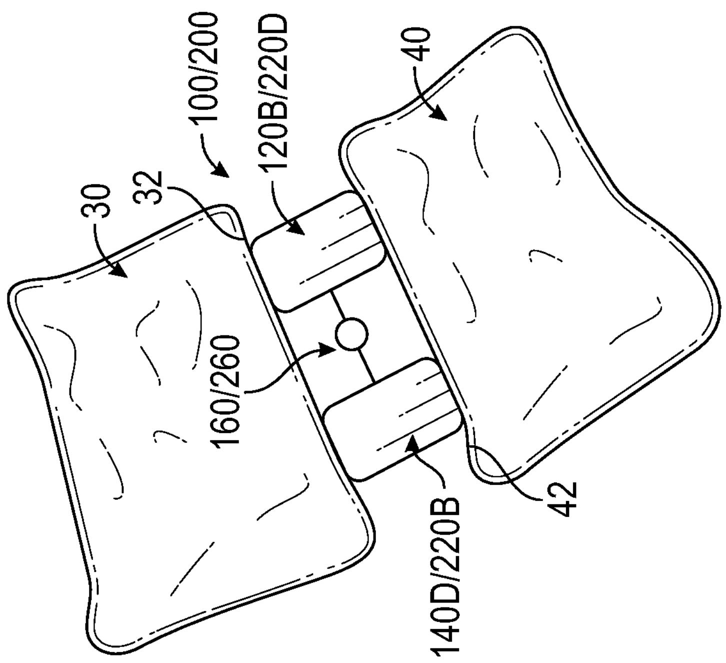
40
42
340

FIG. 2D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32
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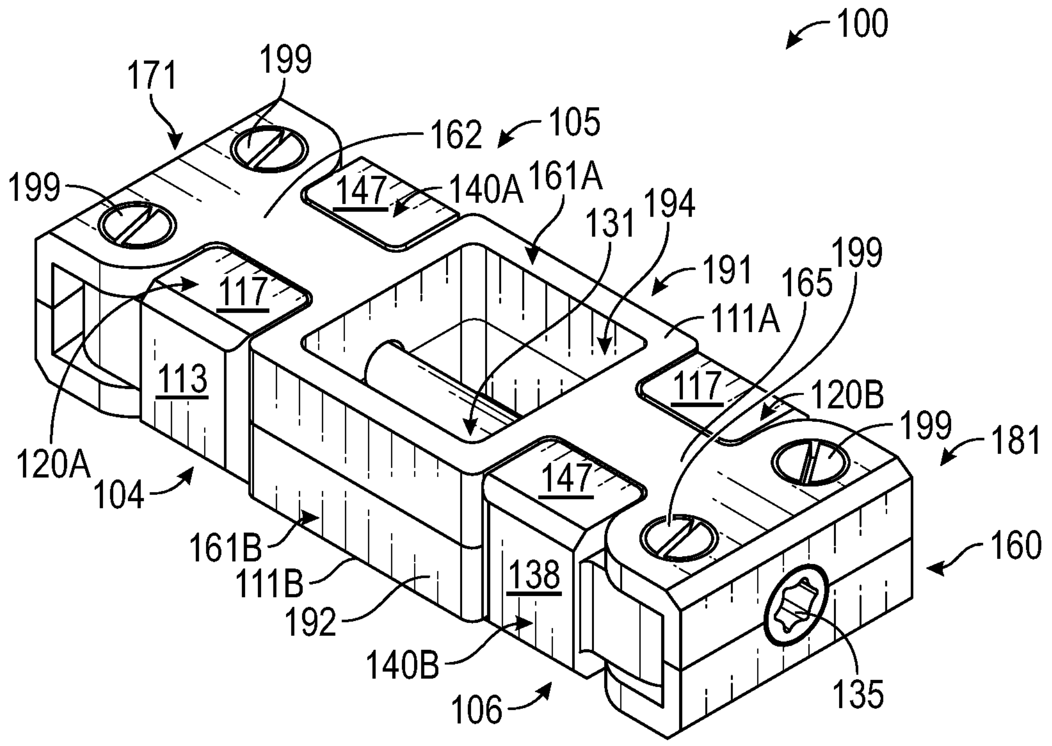
160/260
140D/220B
42

FIG. 2C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160
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140B
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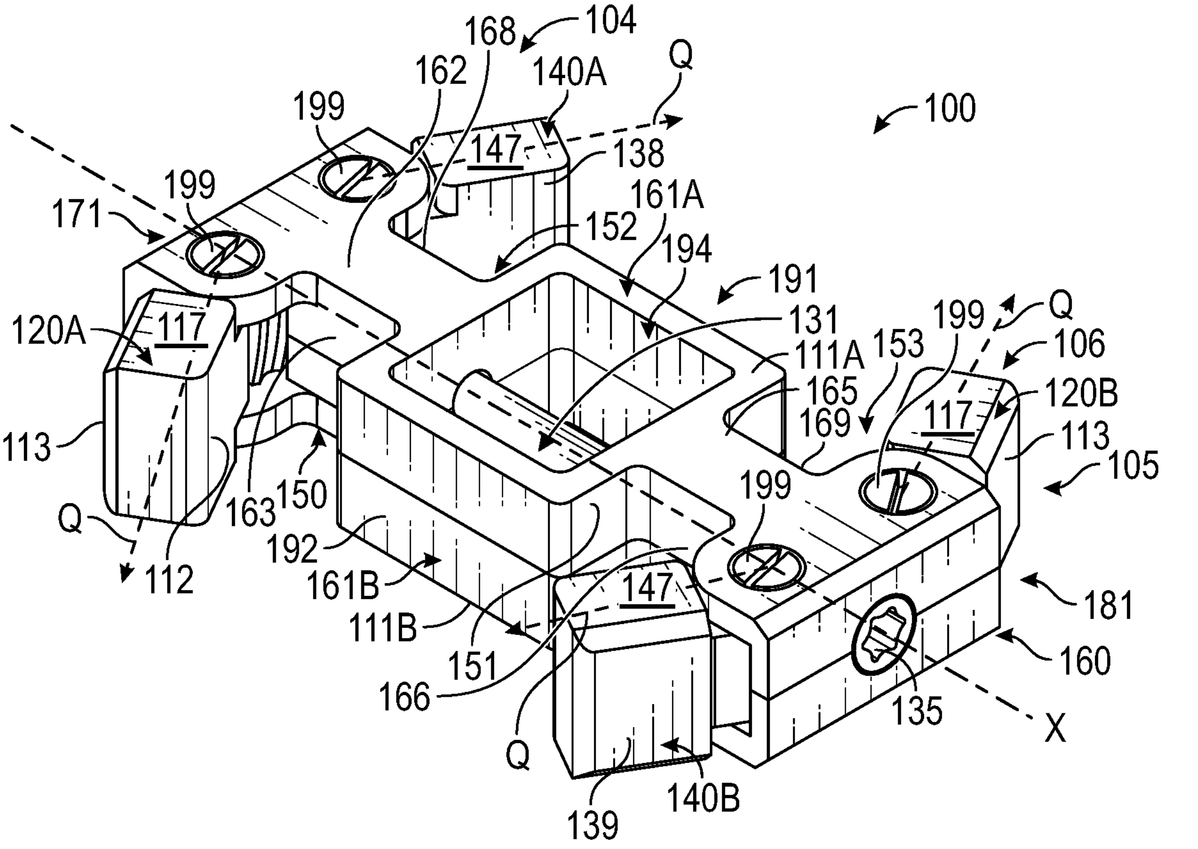
106

FIG. 3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111A
153
106
165
169
120B
117
113
113
105
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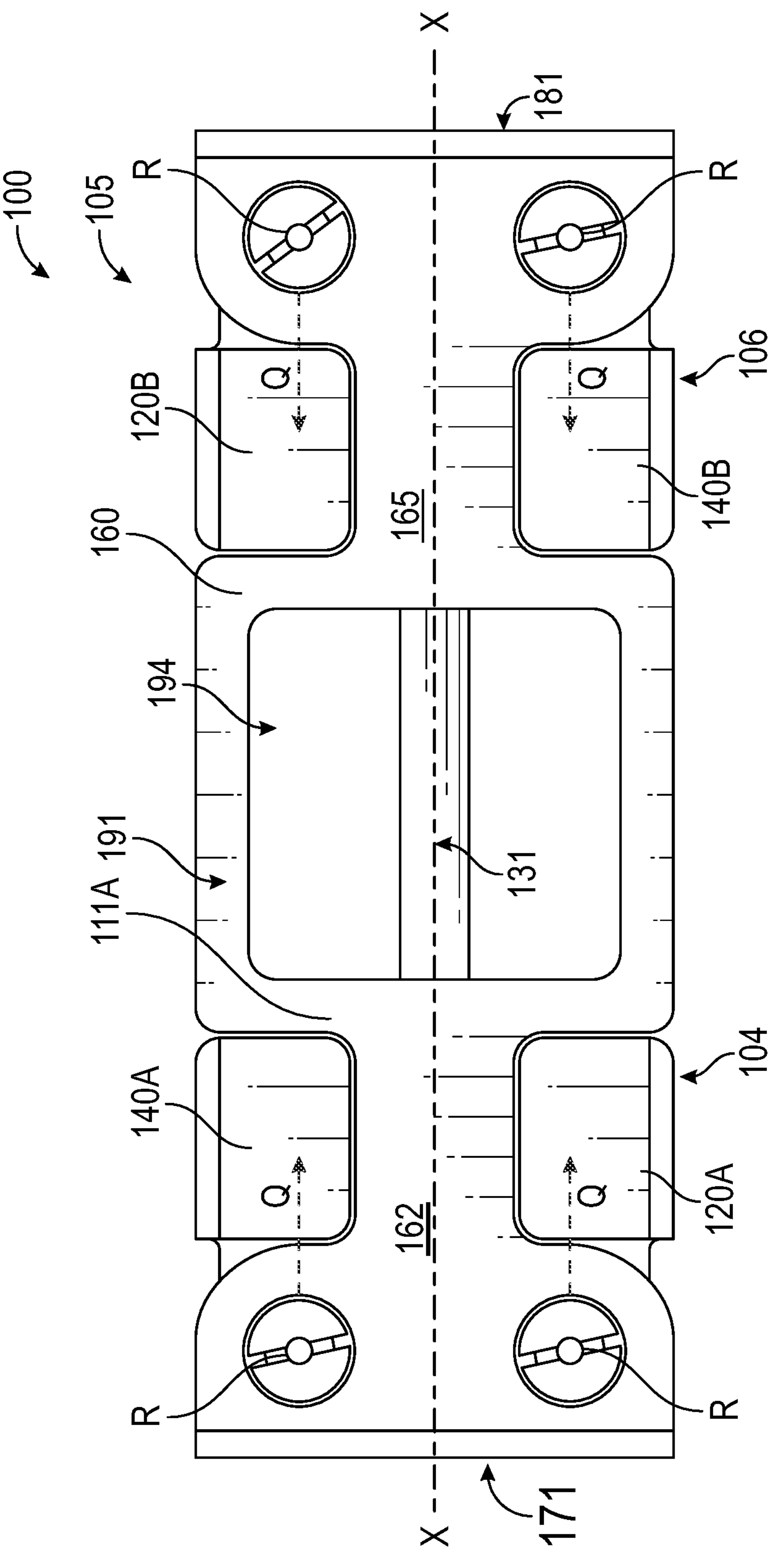
Q
140B
139

FIG. 4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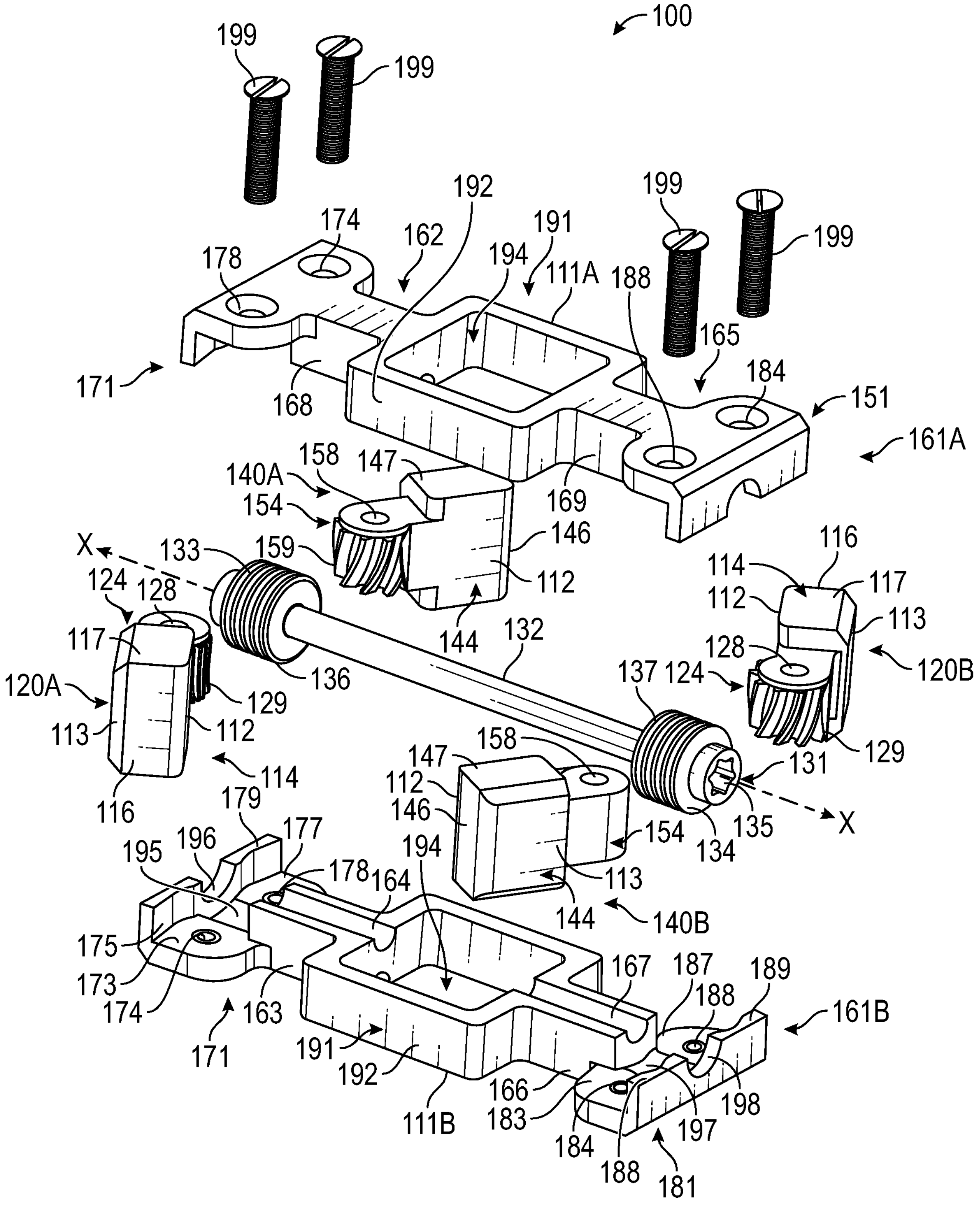
Q
120A
162
R
R
171
X

FIG. 5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X
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159
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140B
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173
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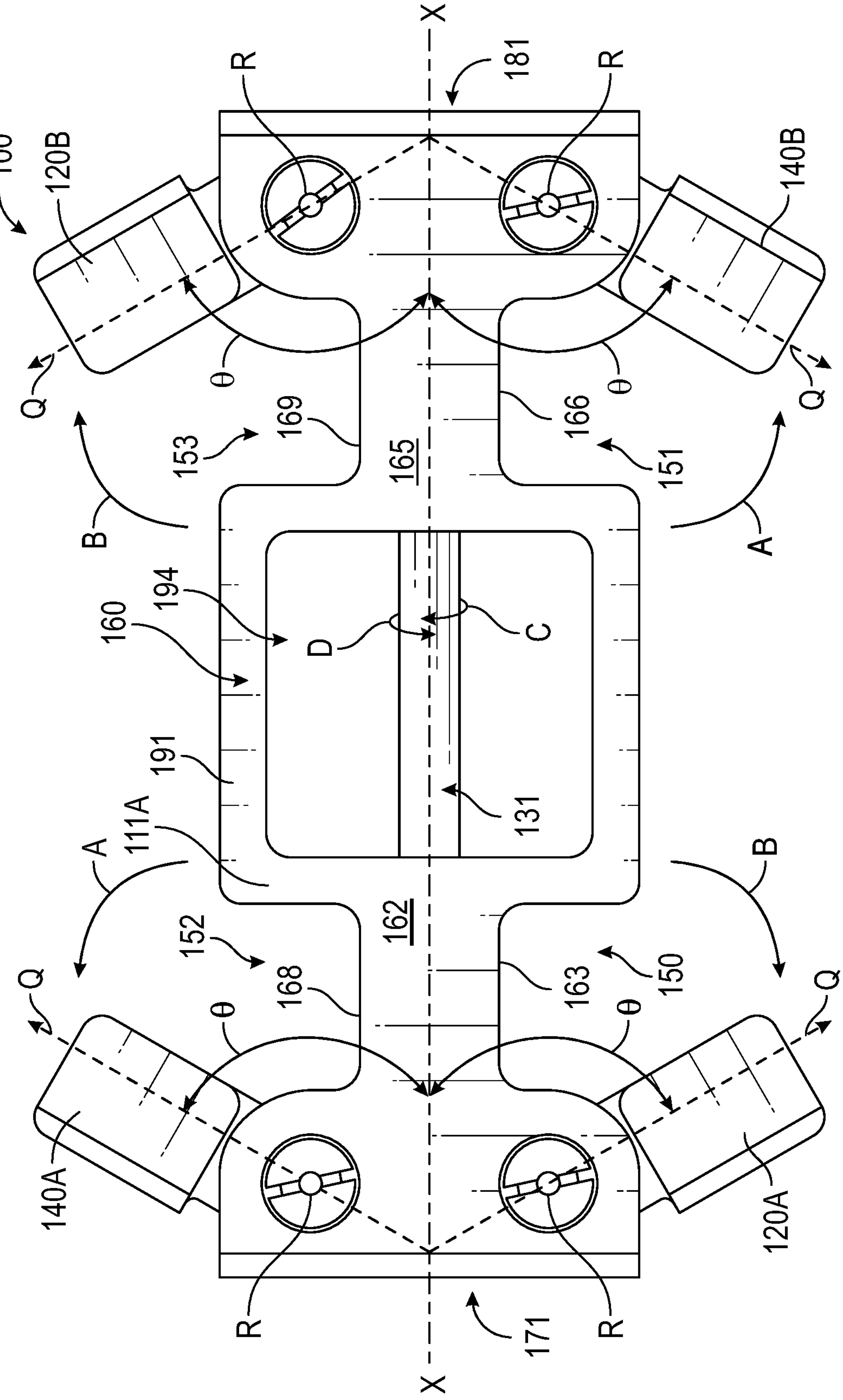
181

FIG. 7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120A
171

FIG. 6

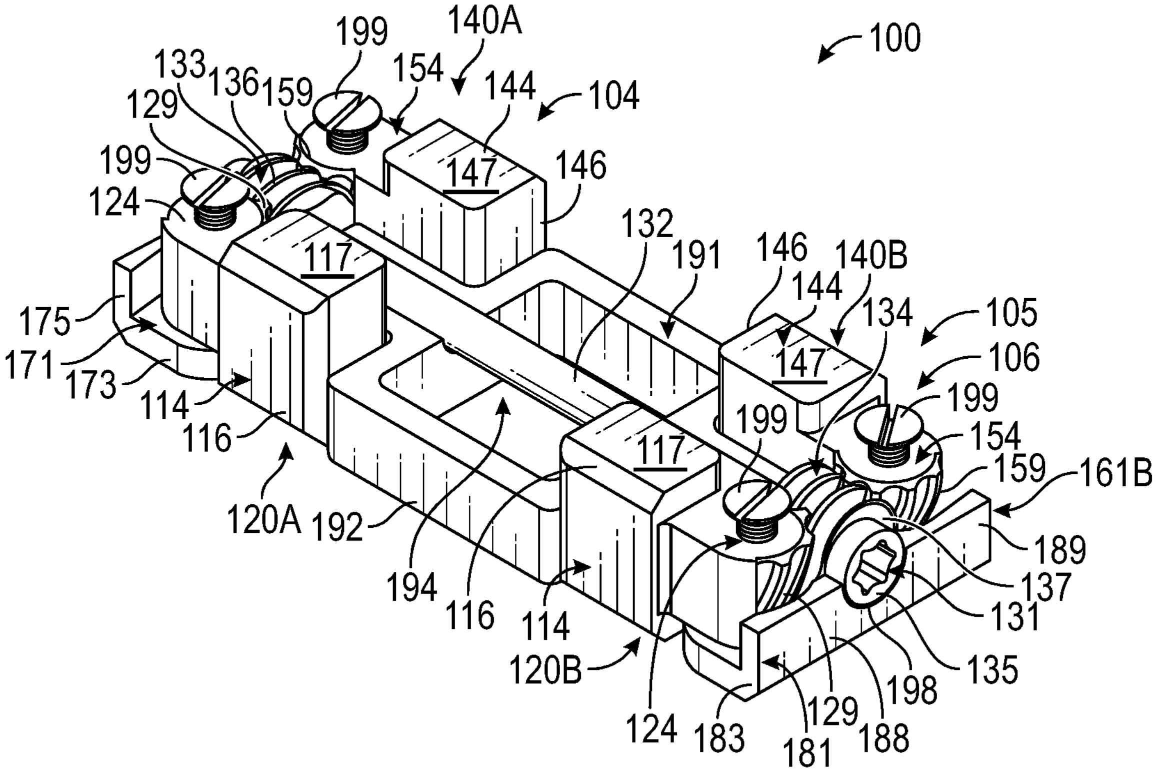
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FIG. 8

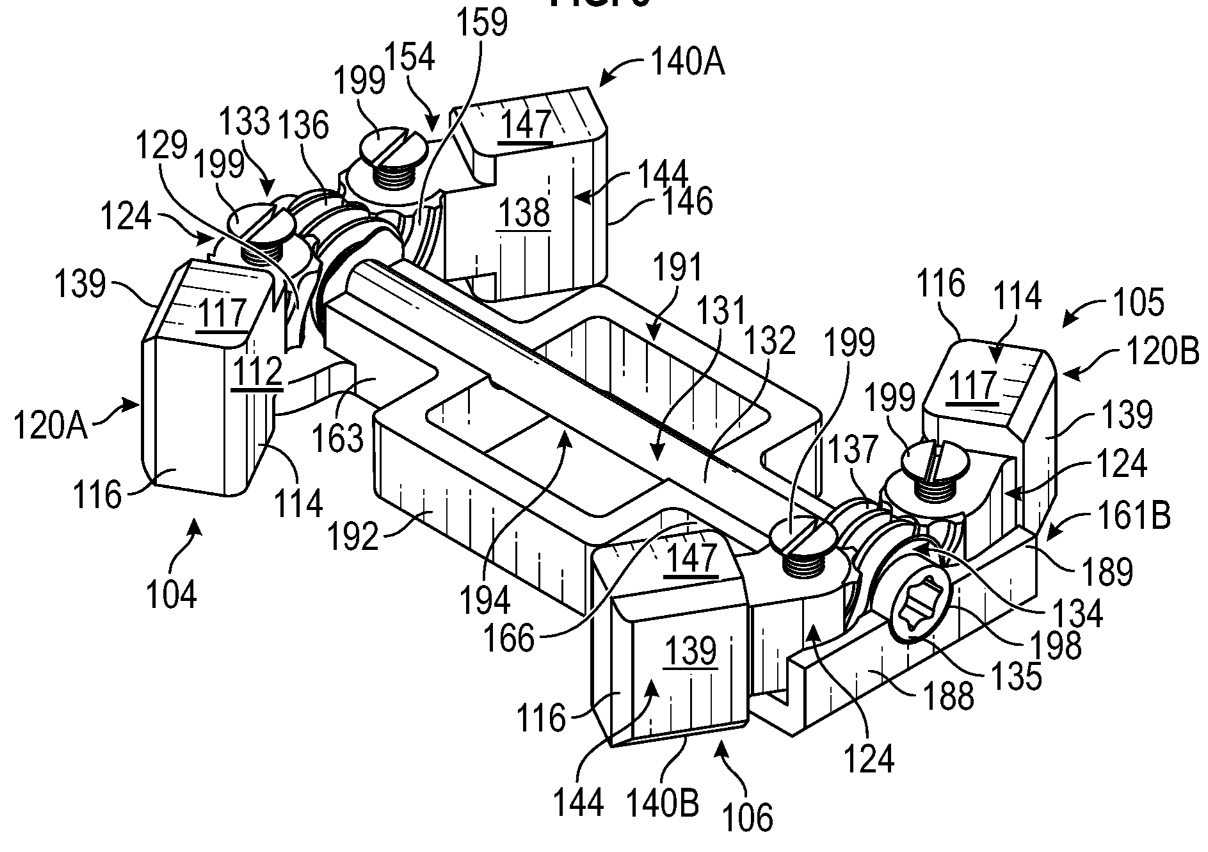
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FIG. 9

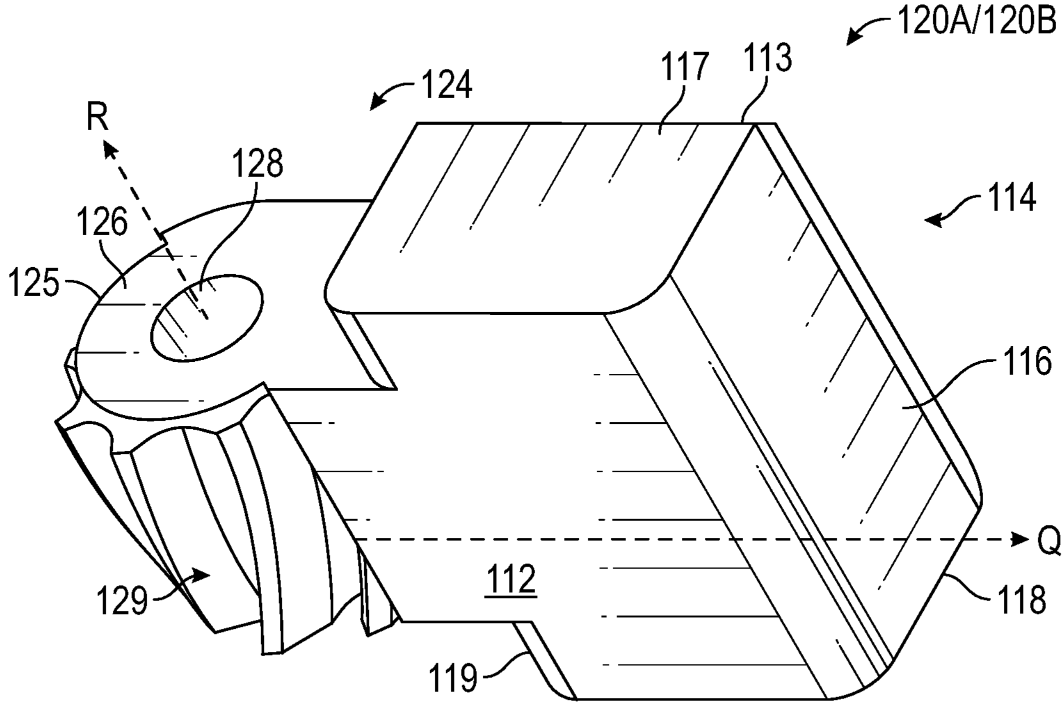

FIG. 10A

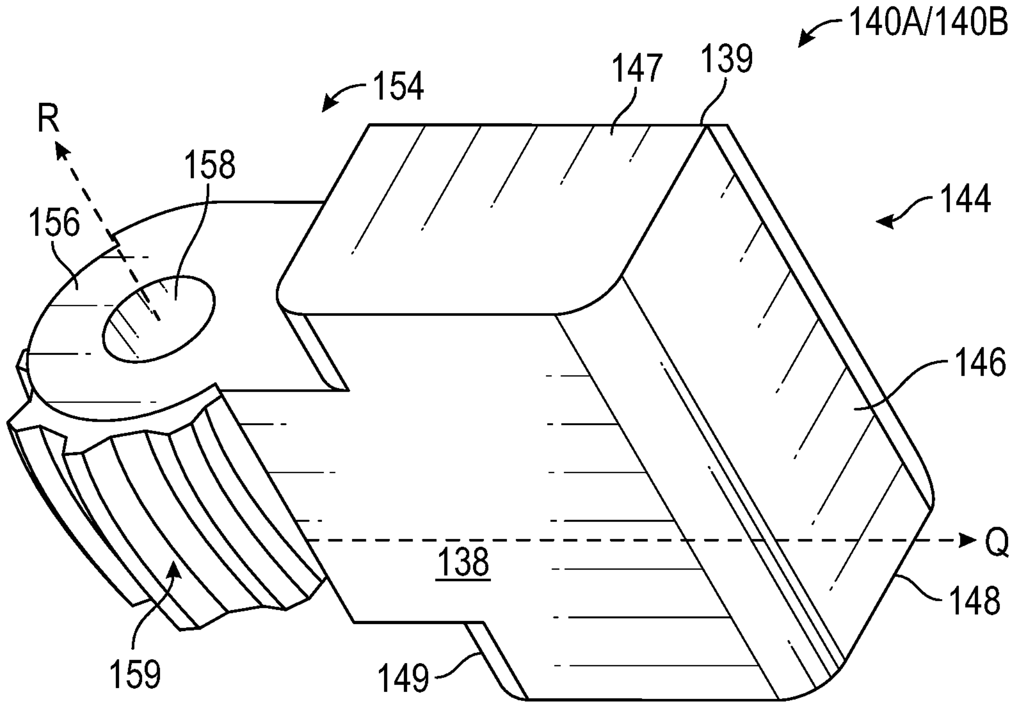

FIG. 10B

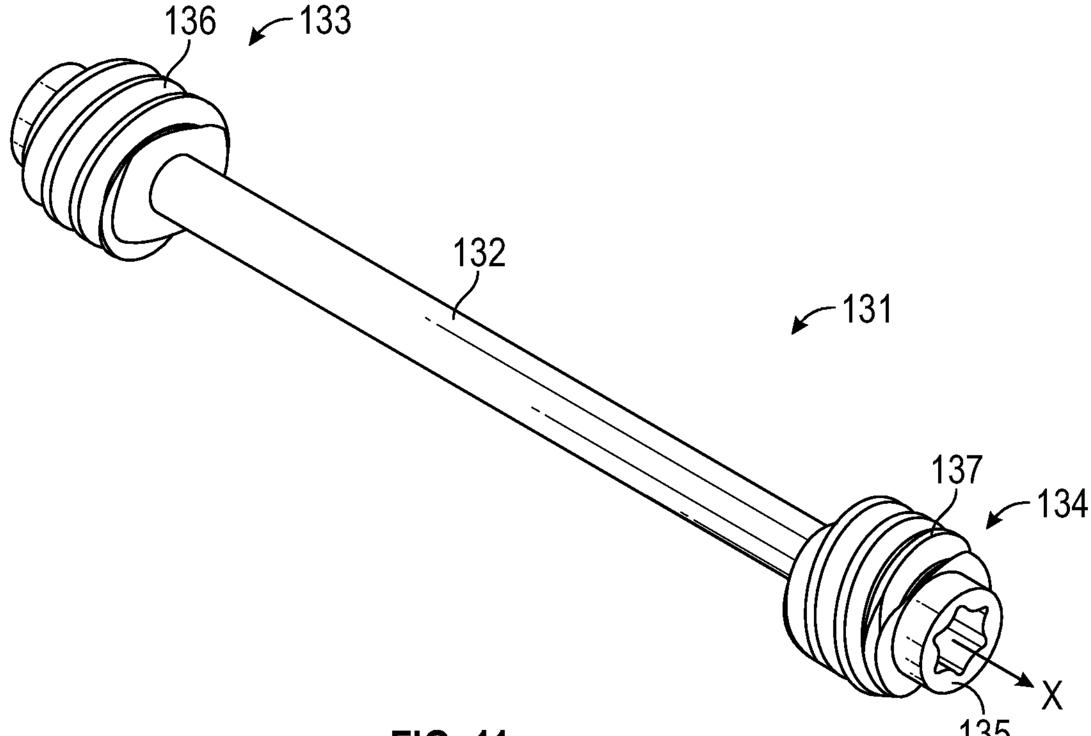
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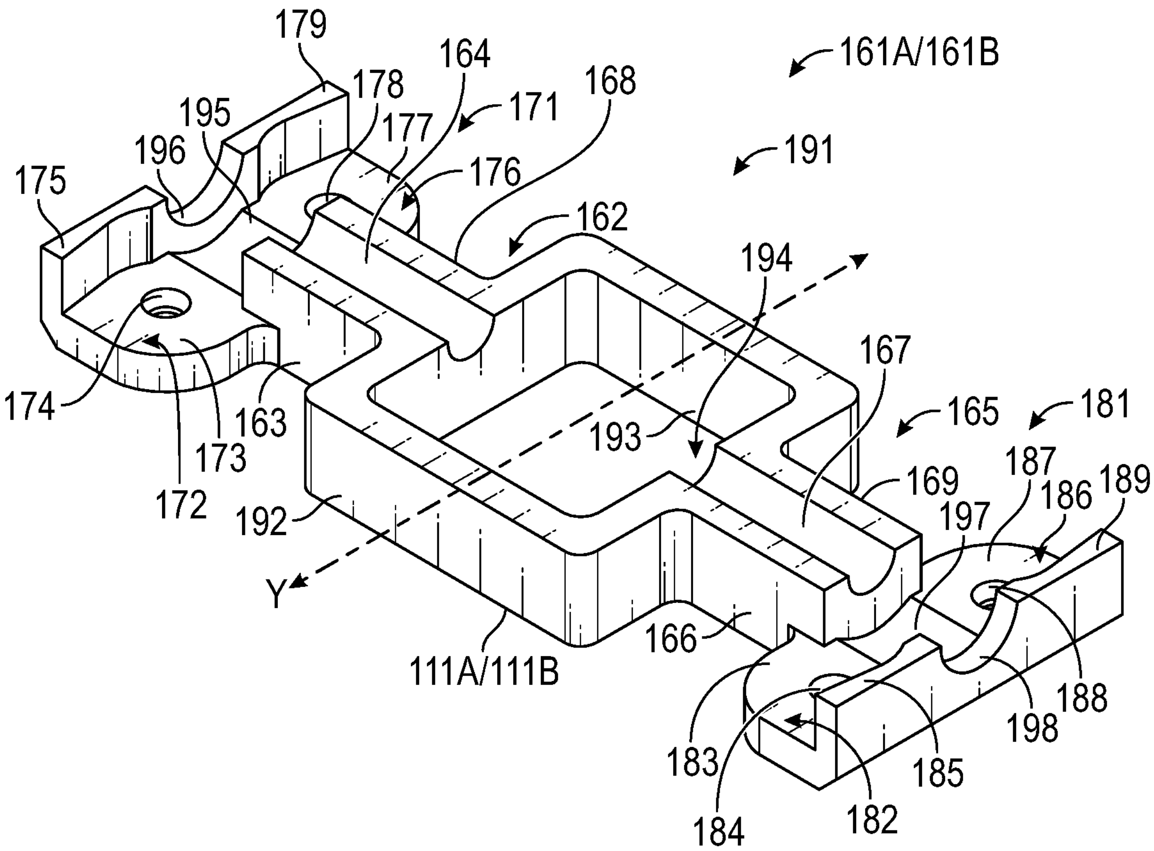
FIG. 11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189
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111A/111B
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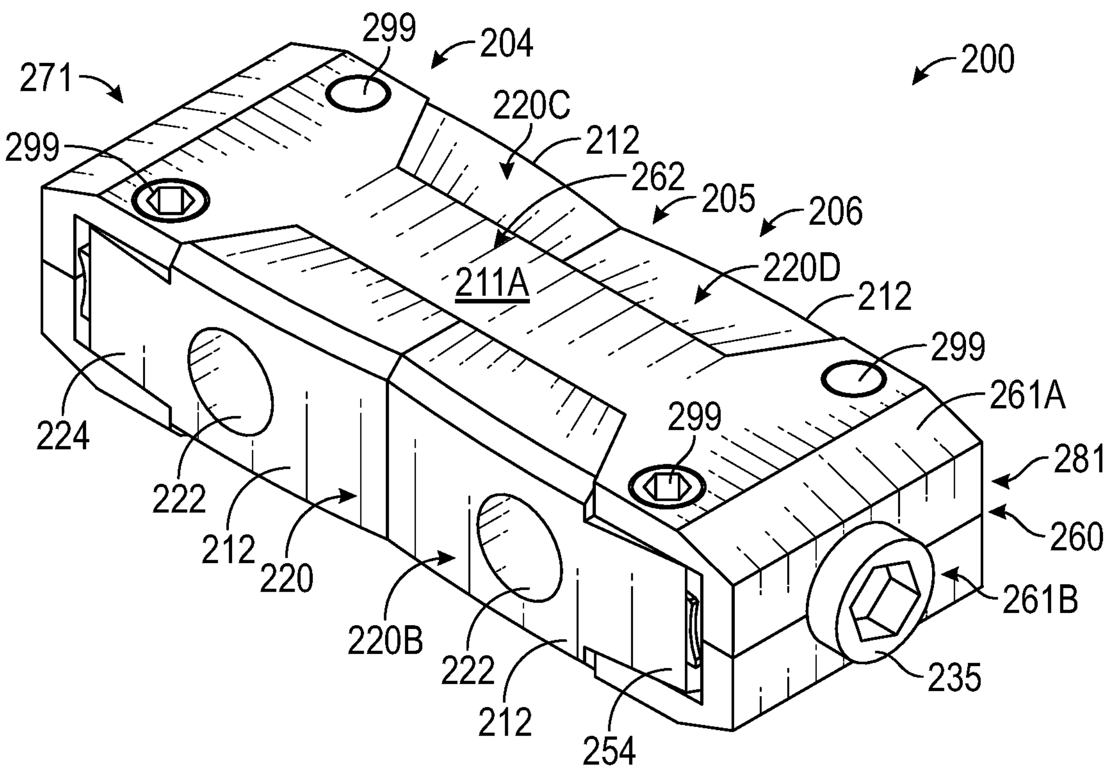
185
184
182

FIG. 12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261B
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220B
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212
222
224

FIG. 13

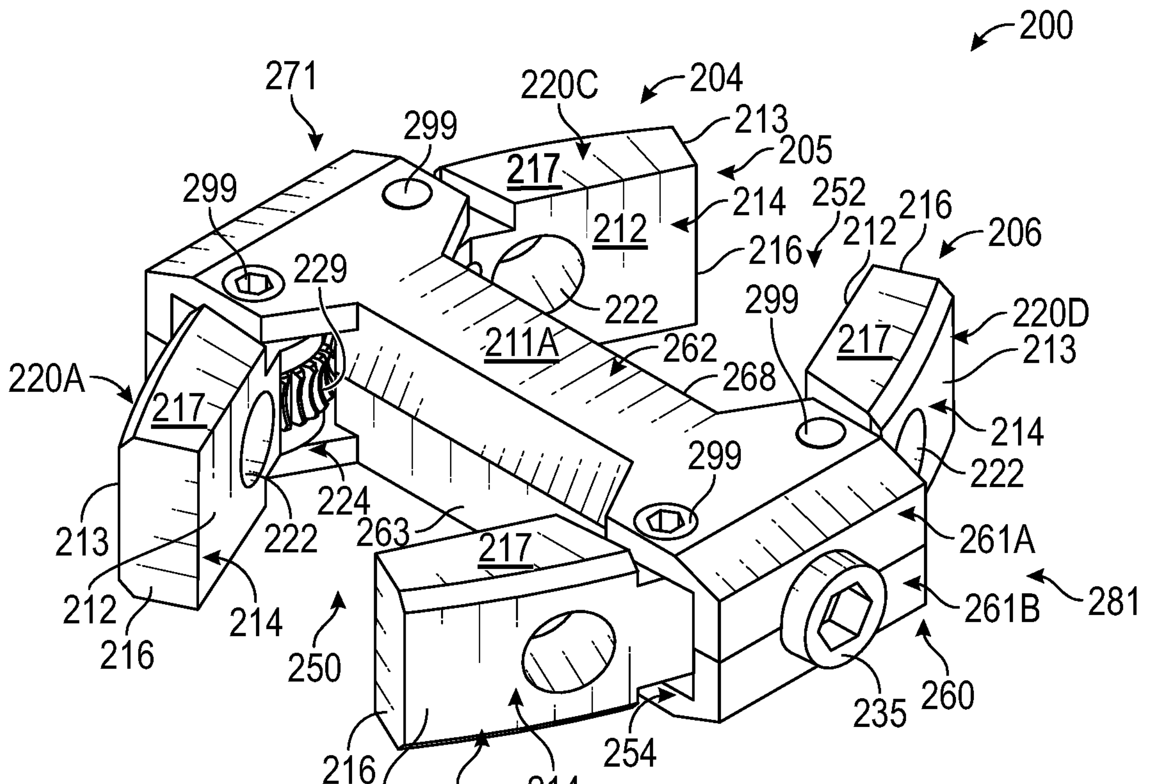
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FIG. 14

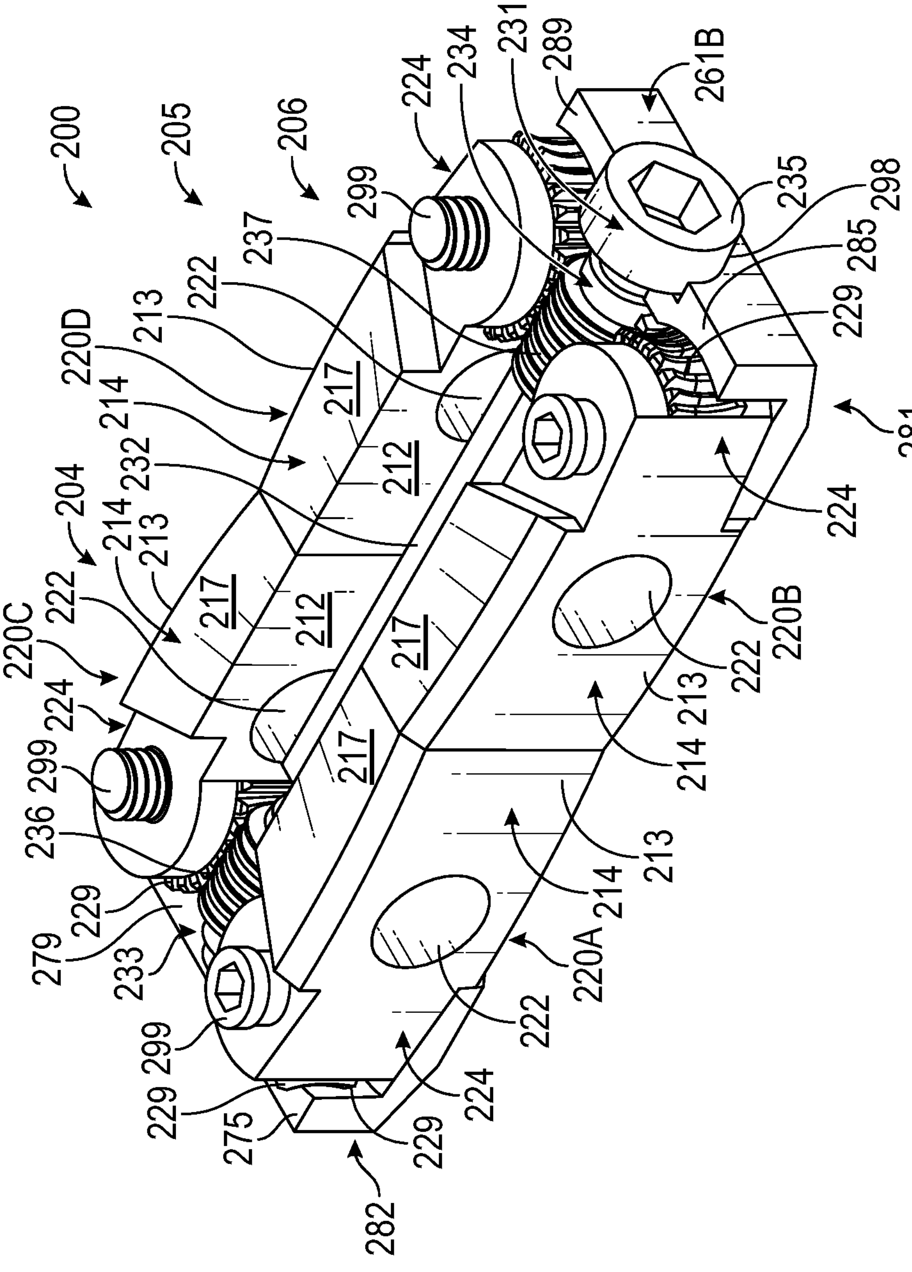
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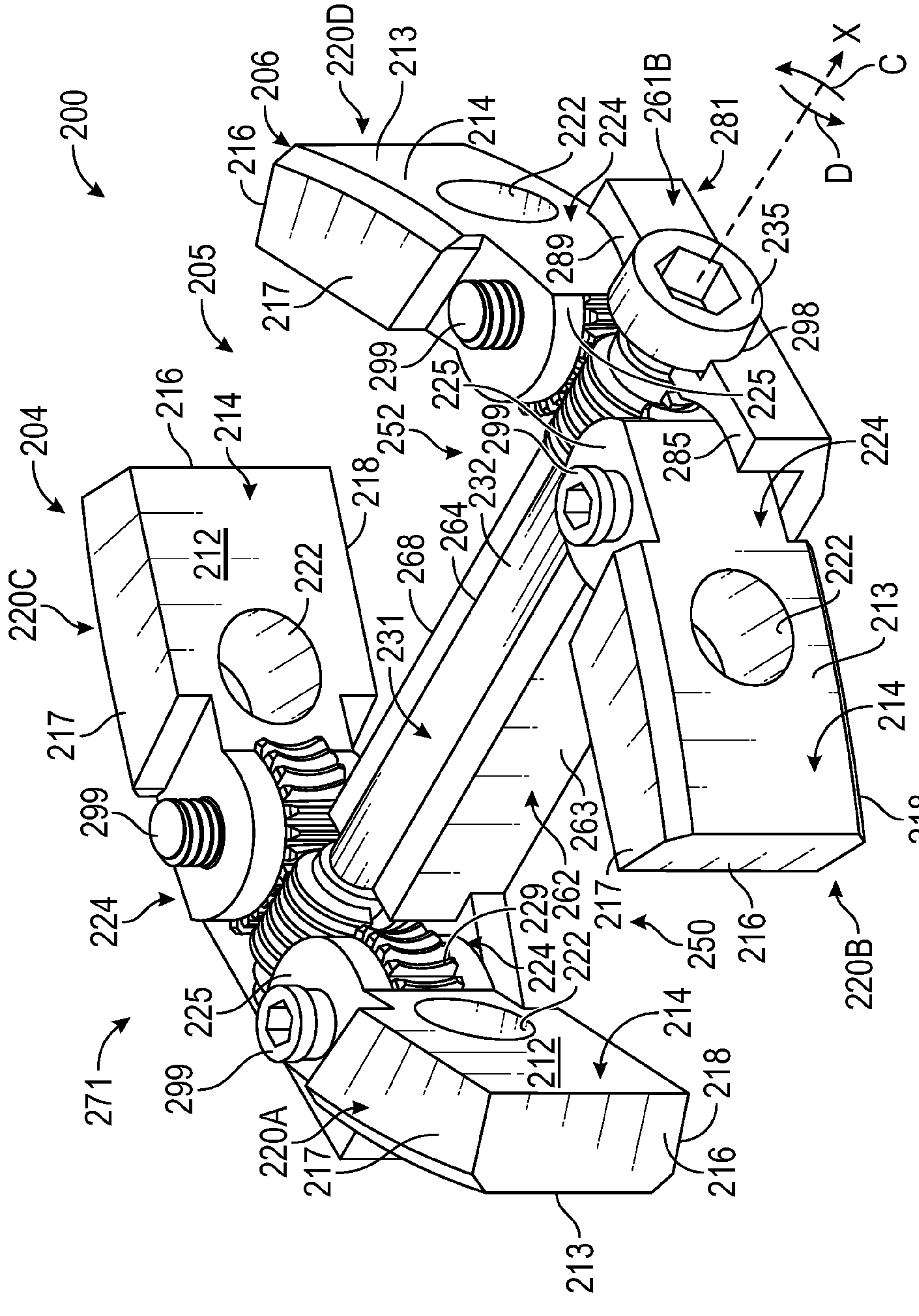
FIG. 15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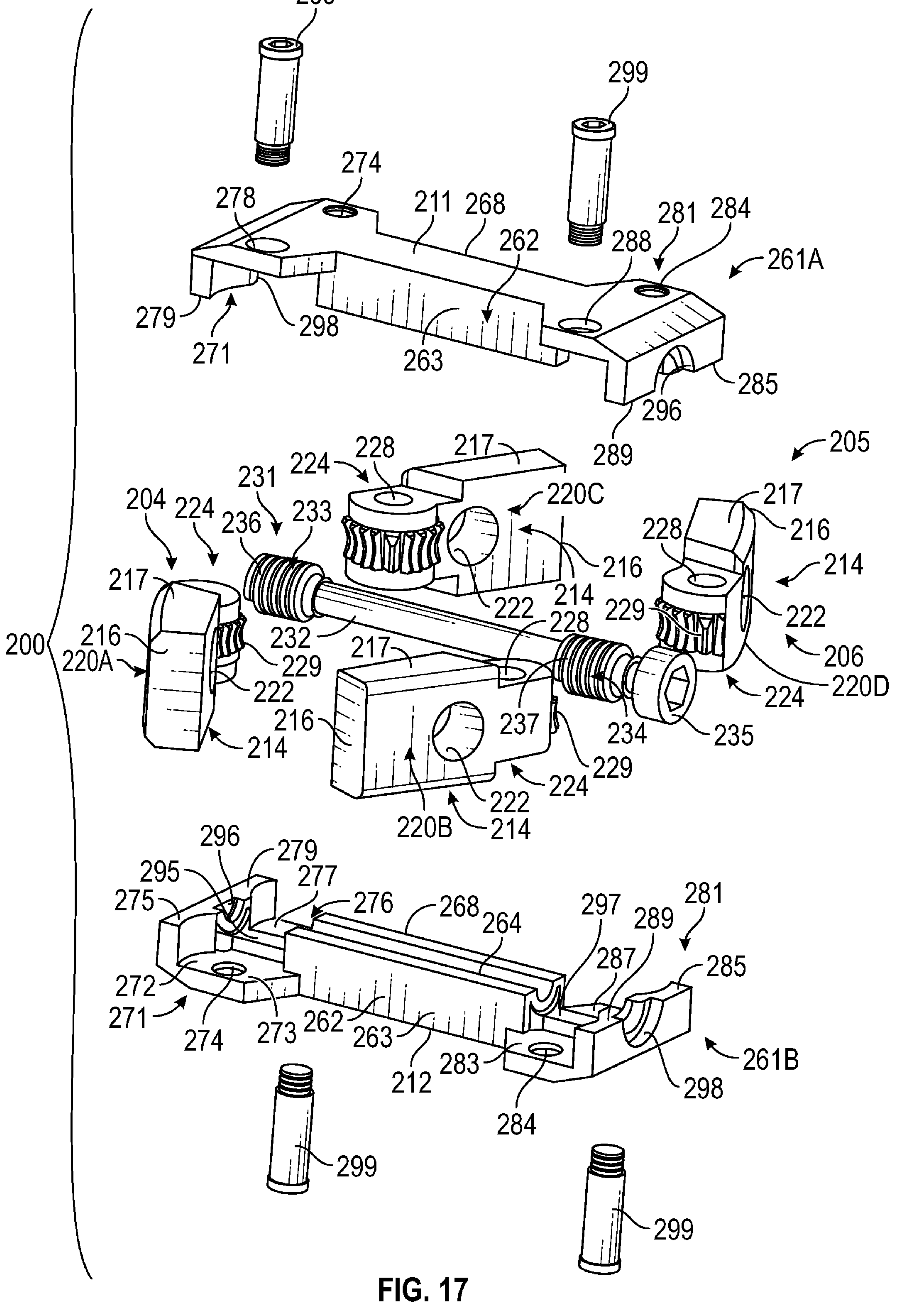
C
D

FIG. 16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220C
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204
224
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216
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214
216
214
217
222
229
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216
220A
229
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228
217
222
206
237
234
220D
224
216
214
235
229
224
222
220B
214
296
279
295
277
275
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268
264
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261B
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200

FIG. 17

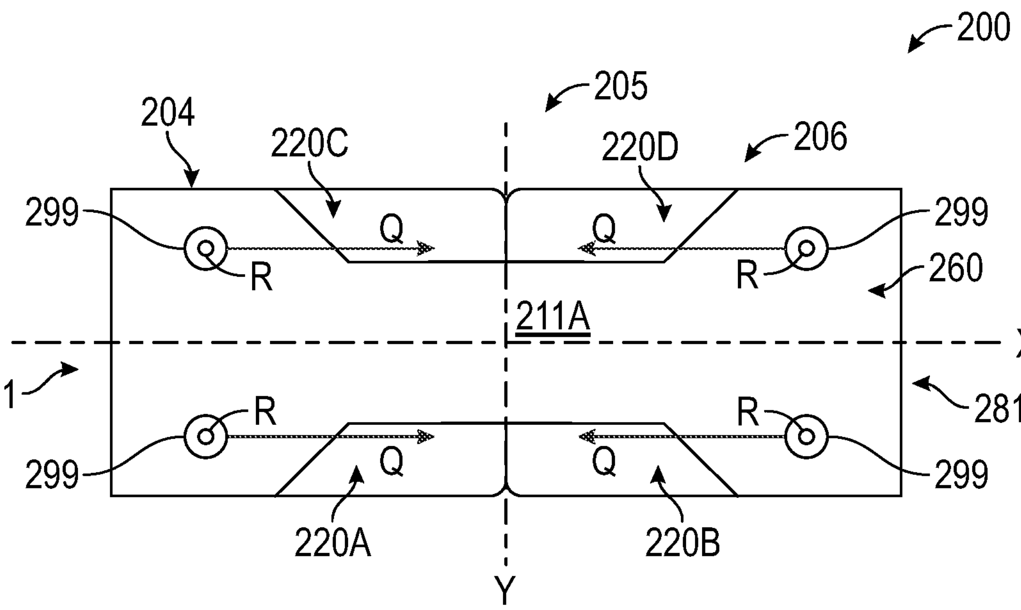


FIG. 18A

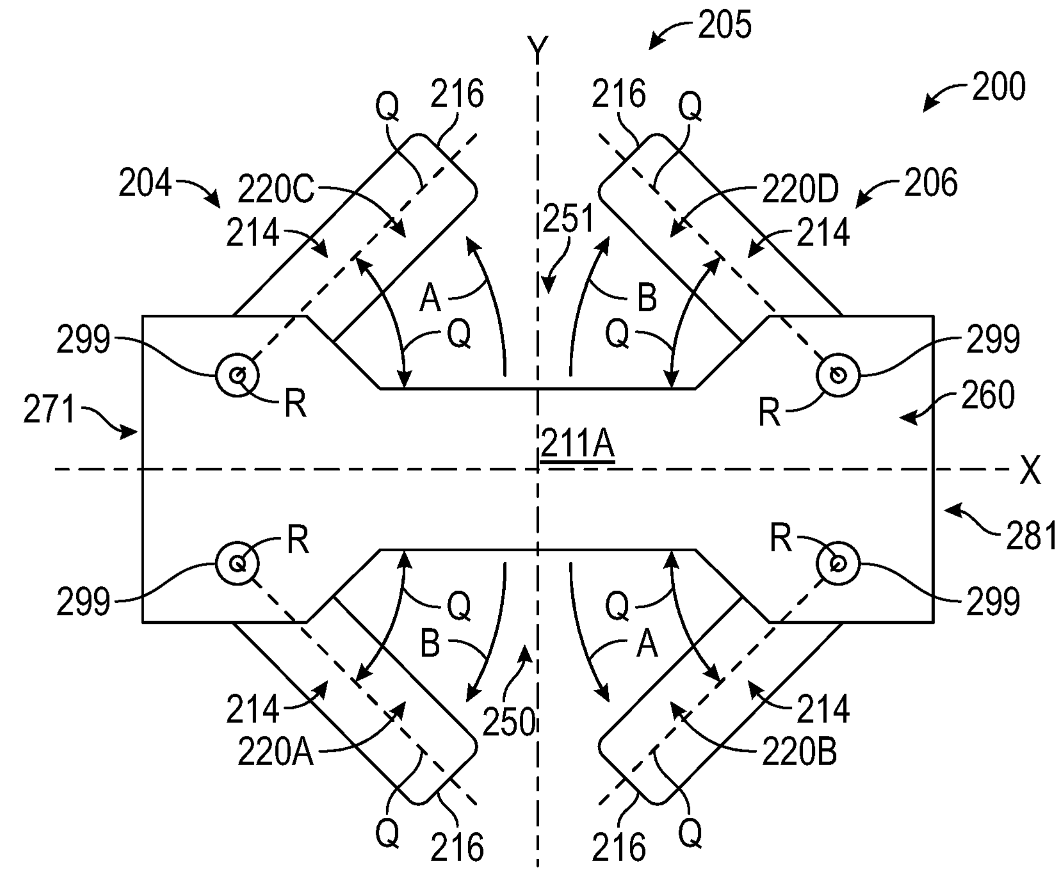
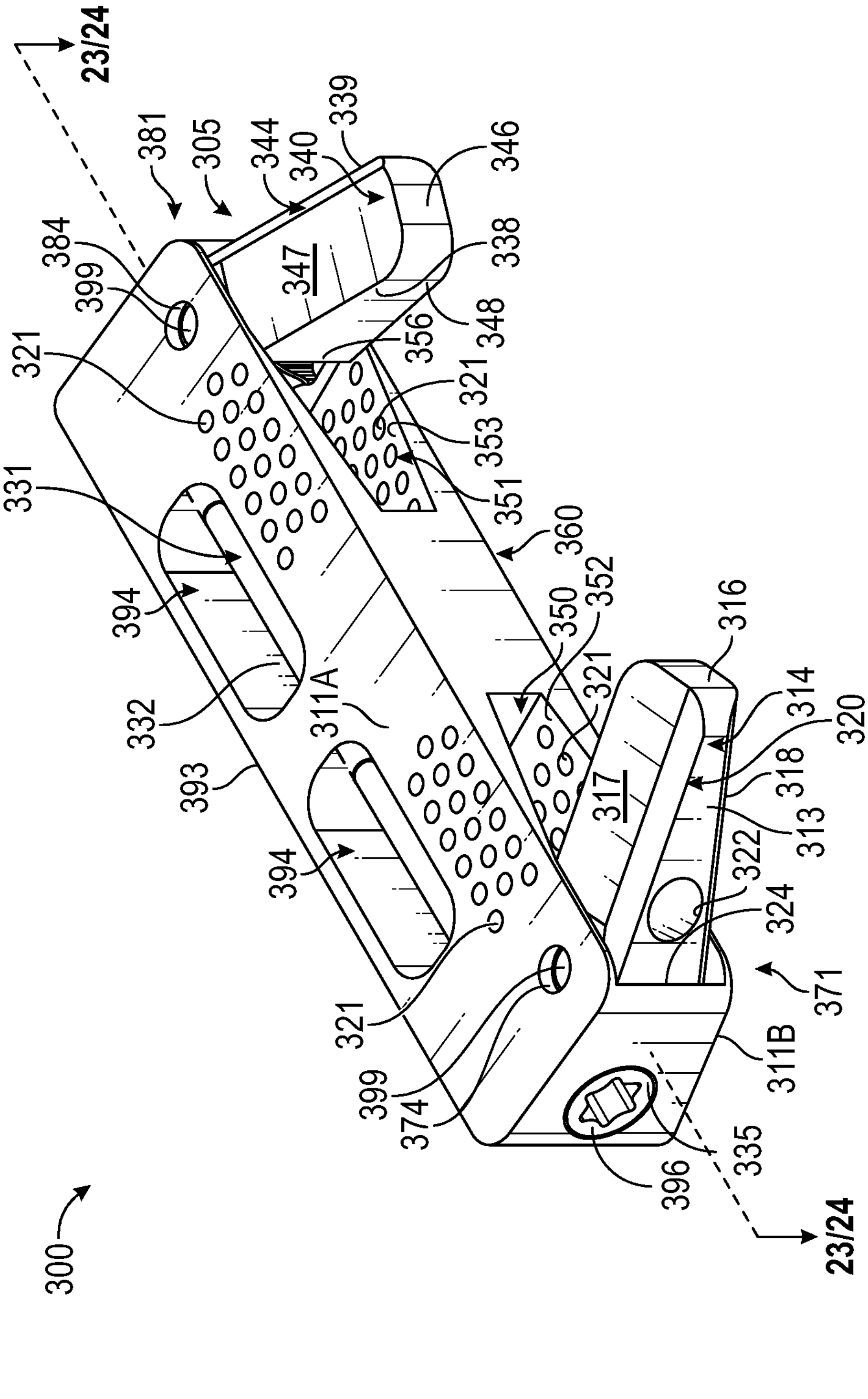


FIG. 18B


23/24
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311A
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311B
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300
23/24

FIG. 19

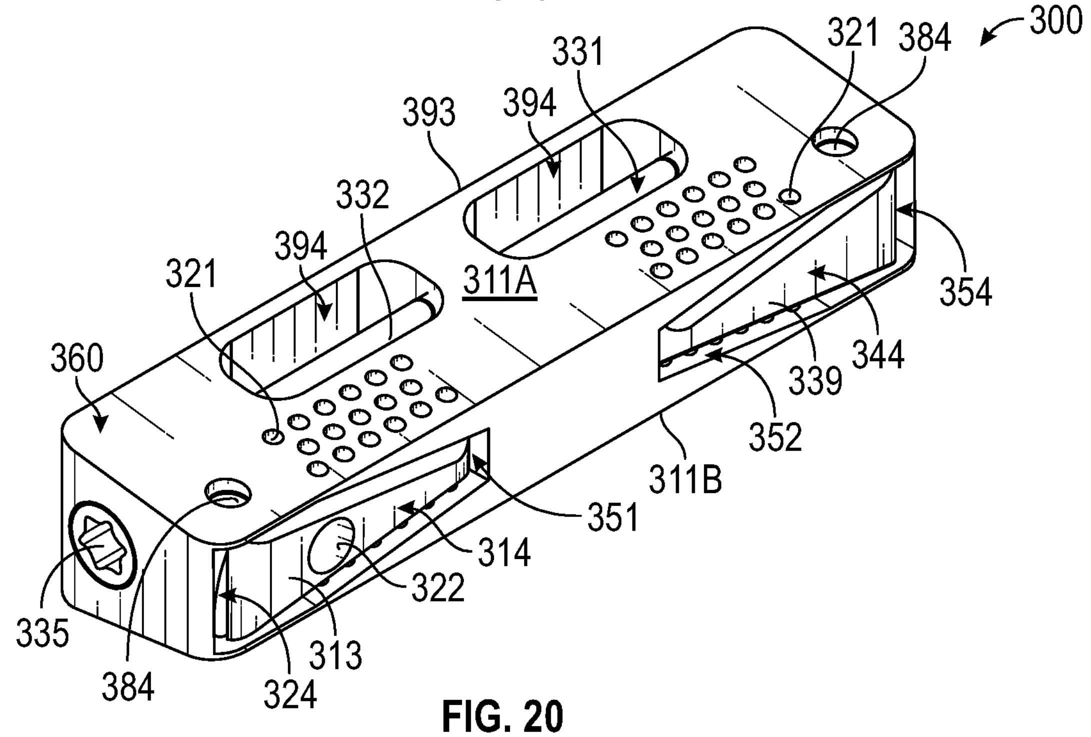

FIG. 20

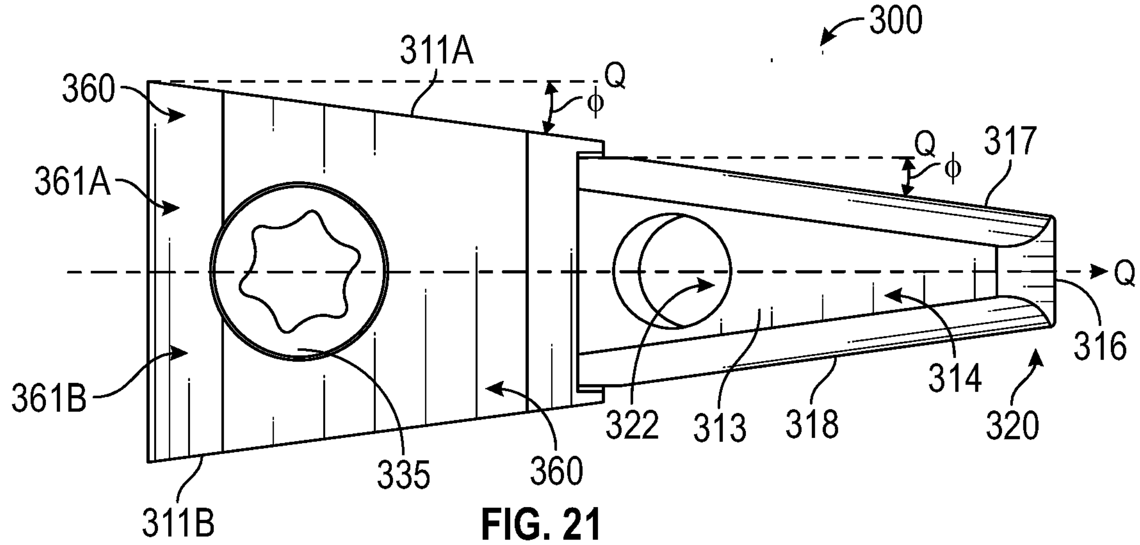

FIG. 21

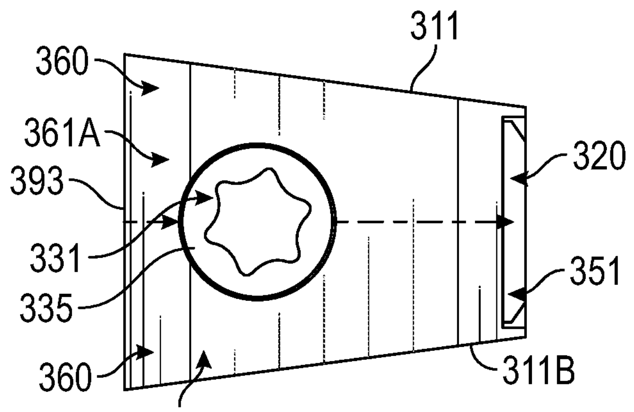

FIG. 22

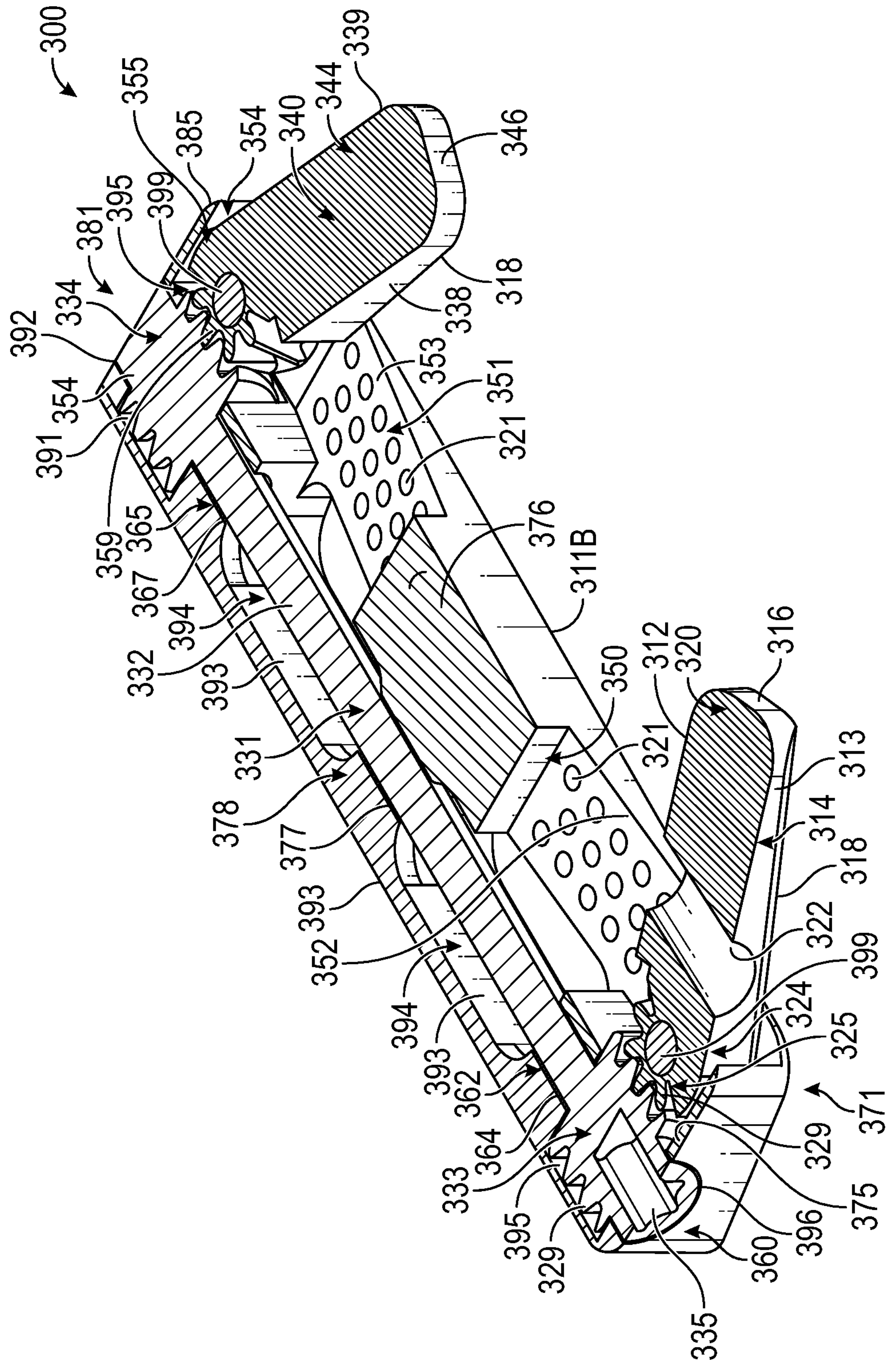
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FIG. 23

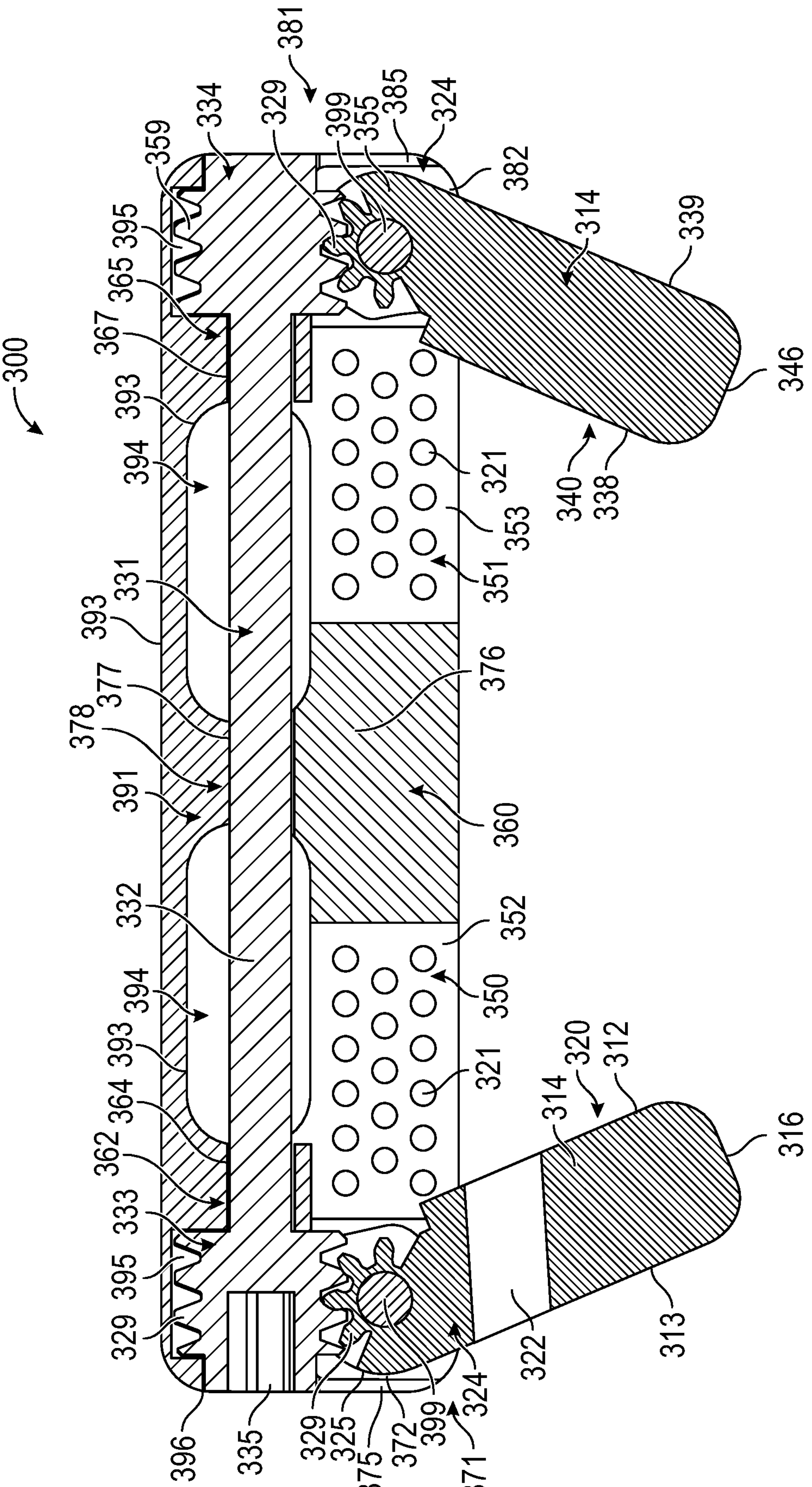
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FIG. 24

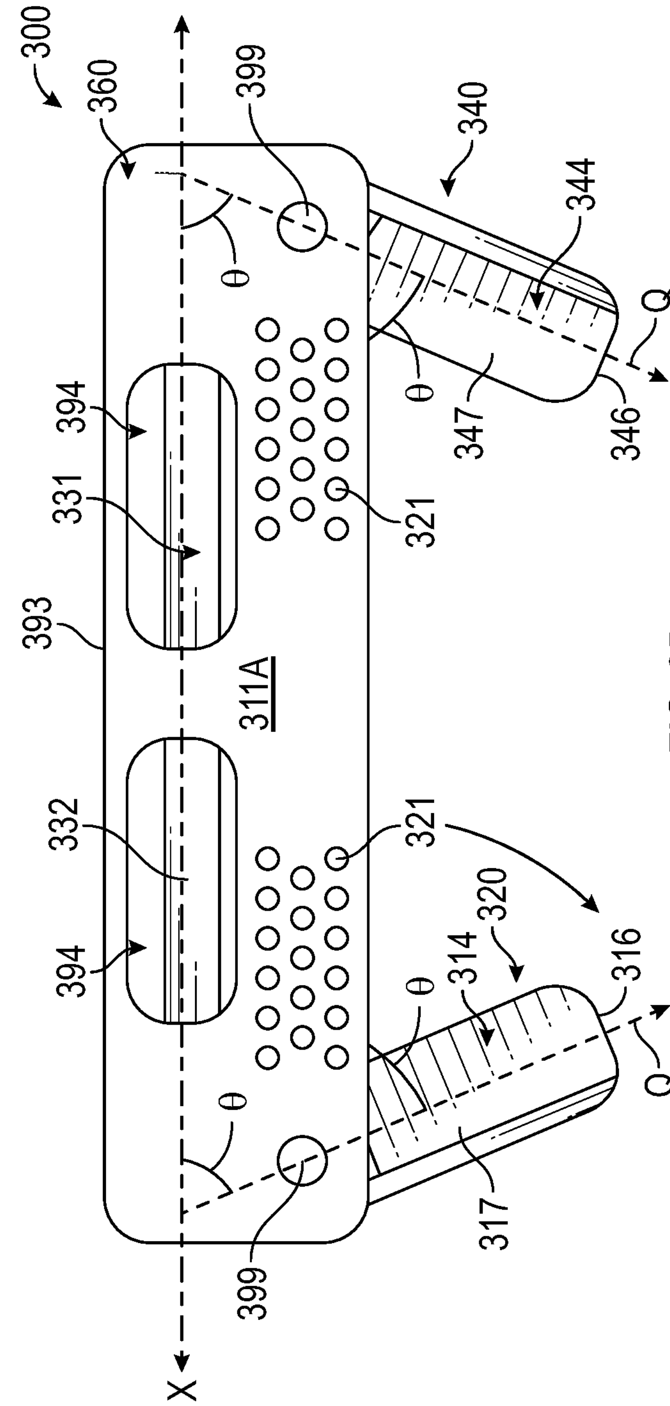
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FIG. 25

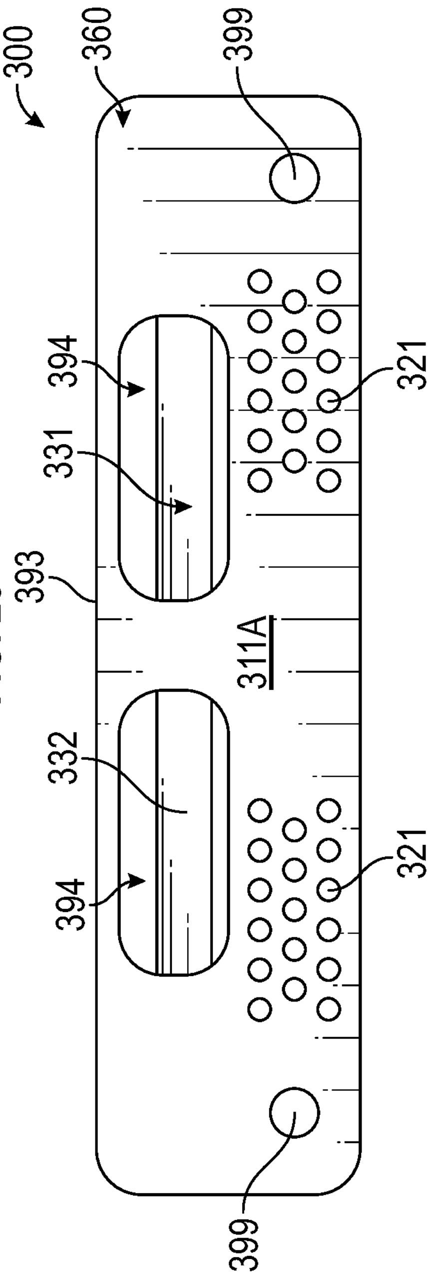
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FIG. 26

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US21/48689

A. CLASSIFICATION OF SUBJECT MATTER
IPC - A61F 2/44 (2021.01)

CPC - A61F 2/4425; A61F 2/4455; A61F 2/447

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/0245767 A1 (AMICUS DESIGN GROUP, LLC) 19 September 2013; figures 2, 5C, 7; paragraphs [0065], [0072]	1-20
A	US 2020/0246157 A1 (BERRY, BM) 06 August 2020; figures 2-7; paragraphs [0034]-[0035]	1-20
A	US 2005/0049590 A1 (ALLEYNE, N et. al) 03 March 2005; figures 6A-G; paragraphs [0054]-[0057]	1-20
A	US 2012/0004732 A1 (GOEL, VK et. al) 05 January 2012; figures 1, 2A; paragraphs [0030]-[0033]	1-20
A	US 8,114,131 B2 (KOHM, A et. al) 14 February 2012; entire document	1-20
A	US 2007/0270961 A1 (FERGUSON, JW) 22 November 2007; entire document	1-20
A	US 8,920,505 B2 (AFERZON, J et. al) 30 December 2014; entire document	1-20

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2021 (16.11.2021)	DEC 15 2021

Name and mailing address of the ISA/US	Authorized officer
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