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(54) Title: COMPOSITE IMPLANT FOR TOTAL MENISCUS RECONSTRUCTION

(57) Abstract: Artificial meniscal scaffolds characterized by a composite of circumferential polymer fiber network and orthogonal polymer fiber network embedded in an arcuate bioresorbable matrix comprised of collagen and hyaluronic acid. The orthogonal polymer fiber network prevents separation of the circumferential polymer fiber networks. The polymer fiber networks convert axial compressive forces on the scaffolds to tensile loads on the circumferential polymer fibers. The composite scaffold can be anchored to bone by novel anchoring components that protect the polymer fibers and ensure immediate securement of the artificial meniscal scaffold to bone.

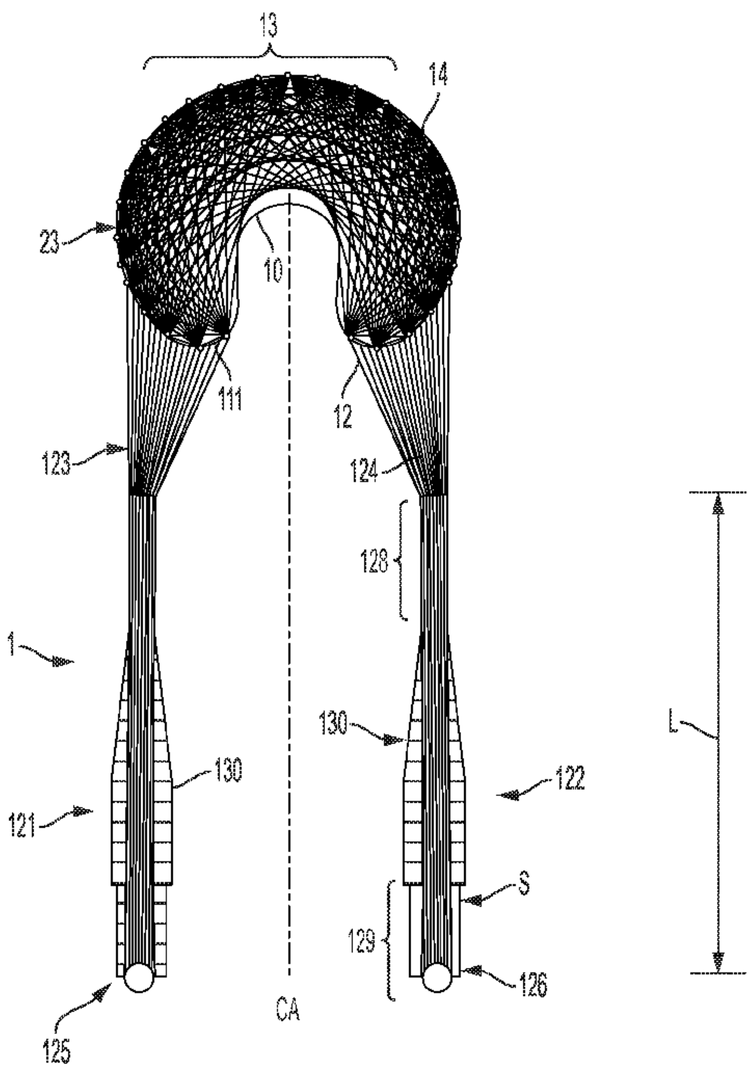

FIG. 1

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COMPOSITE IMPLANT FOR TOTAL MENISCUS RECONSTRUCTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Application Ser. No. **62/931,500** filed **November 6, 2019**, the disclosure of which is incorporated herein by reference in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] This invention was made with Government support under Grant Number W81XWH-14-2-0003 awarded by the U.S. Department of Defense. The Government has certain rights in this invention.

FIELD OF THE INVENTION

[0003] This invention relates to methods and devices for replacement of severely damaged fibrocartilage tissue and, in particular, to the replacement of the lateral or medial meniscus of the knee.

BACKGROUND OF THE INVENTION

[0004] The menisci are two C-shaped discs of fibrocartilage found between the condyles of the femur and the tibial plateau which play a critical role in the load transmission, load distribution, shock absorption, joint stability, and lubrication of the knee. Despite the recognized importance of the tissue, arthroscopic removal of a torn meniscus is one of the most common orthopedic procedures performed in the United States, with almost one million meniscal surgeries performed annually. The public health burden and long-term effects of meniscal injuries are substantial,

particularly in physically active populations, because of the increased risk for early-onset osteoarthritis and long-term disability and the health care costs associated with degenerative joint disease. Because the meniscus has limited healing potential, the clinical outcomes of subtotal meniscectomies are generally poor. At this time, a reliable surgical procedure to replace significant loss of meniscal tissue does not exist. There is no autologous procedure to replace the meniscus and the results of allograft replacement are unreliable.

[0005] Another approach is that of tissue engineering. Current approaches include synthetic polymer scaffolds and collagen meniscus implants. With synthetic polymer scaffolds, polyurethane sponges are used to replace the meniscus. This approach has led to inconsistent results. Fibrocartilage growth is seen in some studies using this technology while in others fibrous tissue did not remodel into fibrocartilage. The underlying cartilage was protected in some studies but not protected in others. Another type of meniscus implant uses a sponge containing collagen, hyaluronic acid and chondroitin sulfate. There is promising preliminary data for this implant, but it is not widely accepted by the orthopedic community because of issues with cytotoxic byproducts of cross-linking and scaffold shrinkage. Both of these approaches generate an amorphous structure, the mechanical properties of which may not be appropriate for a device designed to replace the meniscus. Thus, while scaffold technology holds promise, no methods have met with the clinical success necessary for acceptance by the orthopedic community.

[0006] US 9078756 describes a tissue engineered scaffold with the necessary mechanical properties and biocompatibility for treatment of significant meniscal damage and is incorporated by reference herein. Any information in this patent is only incorporated by reference to the extent that no conflict exists between such information and the other statements and drawings set forth herein. In the event of such conflict, including a conflict that would render invalid any claim herein

or seeking priority hereto, then any such conflicting information in such incorporated by reference material is specifically not incorporated by reference herein. US patent 9078756 discloses a composite meniscal scaffold comprised of a collagen–hyaluronic acid matrix reinforced with a fibers extending in a circumferential direction along the scaffold, the fibers of which are in turn held together by other fibers embedded orthogonally to the circumferential fibers. US patent 9078756 also describes how the anterior and posterior attachment segments of the meniscal scaffold may be inserted into these bone tunnels to generate hoop stresses in the scaffold. The resulting configuration behaves like natural fibrocartilage that translates an axial compressive load into a circumferential tensile load. The ability of the meniscal scaffold to translate axial loads to circumferential hoop stress is dependent on the entire length of fiber remaining intact during the initial period of healing. However, securement of the attachment segments into bone tunnels by using existing metal or polymeric interference screws may result in damage to the fibers. Thus, there is a need to protect the fibers of the attachment segments from nicks or cuts that may occur while they are surgically fixed to the tibial plateau. An ideal artificial meniscal scaffold should be able to be fixed to the tibial plateau and protect the polymeric fibers from being cut or nicked during implantation.

SUMMARY OF THE INVENTION

[0007] The present invention incorporates the discovery that the attachment segments of prior art scaffolds can be improved with novel anchoring devices provided by the present invention. For prior art scaffolds that are reinforced with a fiber scaffold extending in a circumferential direction that is in turn held together by other fibers embedded orthogonally to the circumferential fibers, novel anchoring devices are provided that can be incorporated onto such scaffold devices to protect the fiber networks from damage during implantation. The resulting configuration

behaves like natural fibrocartilage that translates an axial compressive load into a circumferential tensile load.

[0008] The invention is an artificial meniscal scaffold comprising an arcuate bioresorbable matrix that has circumferential bioresorbable fibers embedded therein. A network of orthogonal bioresorbable fibers is also embedded in the arcuate bioresorbable matrix to prevent separation of the circumferential fibers. The bioresorbable circumferential and orthogonal fibers define a three-dimensional shape and geometry which is substantially the same as natural meniscal tissue. The artificial meniscal scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between the anterior and posterior ends. In addition, the network of circumferential bioresorbable fibers extends between the anterior and posterior ends along the curved path and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments. The anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface.

[0009] In one embodiment, the exterior surface of at least one of the anterior and posterior attachment segments is coated with a polymer. In another embodiment, a polymeric fiber is wound around at least a portion of the exterior surface of at least one of the anterior and posterior attachment segments. In yet another embodiment, a polymeric fiber is wound around at least a portion of the anterior end, posterior end, or middle section of the artificial meniscal scaffold. In still yet another embodiment, an aperture is present between the proximal region and distal region of at least one of the anterior and posterior attachment segments. In one embodiment, an anchoring component is attached to the distal region of at least one of the anterior and posterior attachment segments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG 1.** is a top view of an artificial meniscal scaffold with a polymer coating on the attachment segments.

[0011] **FIG 2.** is a top view of an artificial meniscal scaffold with a polymer coating on the attachment segments of different lengths.

[0012] **FIG 3.** is a top view of an artificial meniscal scaffold with a polymer fiber winding over the attachment segments.

[0013] **FIG 4.** is a top view of an artificial meniscal scaffold with a polymeric sleeve over the attachment segments.

[0014] **FIG 5.** is a top view of an artificial meniscal scaffold with an aperture on the attachment segments.

[0015] **FIG 6A.** is a top view of an artificial meniscal scaffold with attachment segments that have been coupled to an anchoring component with a threaded surface.

[0016] **FIG 6B.** is a top view of an artificial meniscal scaffold with attachment segments that have been coupled to an anchoring component with a ribbed surface.

[0017] **FIG 6C.** is a top view of an artificial meniscal scaffold with attachment segments that have been coupled to an anchoring component with a flanged surface.

[0018] **FIG 7.** is a top view of an artificial meniscal scaffold with a polymer fiber winding over the arcuate portion of the scaffold.

DETAILED DESCRIPTION

[0019] One aspect of the artificial meniscal scaffold **1** comprising a reinforcing network of circumferential polymeric fibers **23** and orthogonal polymeric fibers **14** embedded in an arcuate

bioresorbable matrix **10** is shown in **FIG. 1**. The term "circumferential polymeric fibers" refers to fibers that extend between the anterior end and posterior end of the scaffold along the middle section of the scaffold and are positioned at least in part substantially parallel to the circumferential axis. The term "orthogonal polymeric fibers" refers to fibers that cross the circumferential polymeric fibers at various angles to keep them from separating. Keeping the circumferential polymeric fibers from separating increases the durability and longevity of the implant. For convenience, terms "circumferential fiber network" and "orthogonal fiber network" may be used herein to refer to multiple circumferential fibers or multiple orthogonal fibers, respectively. The scaffold **1** includes an anterior end **11**, a posterior end **12** and a middle section **13** between the anterior end **11** and the posterior end **12**. The middle section **13** is essentially arc-shaped and defines a curved path between the anterior end **11** and posterior end **12**. The shape and geometry of the scaffold is based on the shape and geometry of a natural human meniscus, and thus the scaffold **1** generally forms a c-shaped disc with a wedge-like cross-section. The reinforcing network of circumferential fibers **23** extend between the anterior end **11** and posterior end **12** of the scaffold **1** and extend further to form an anterior attachment segment **121** and a posterior attachment segment **122**. The attachment segments **121**, **122** extend generally parallel to a central axis CA of the scaffold **1**. The attachment segment **121** is formed by fibers **23** extending from the anterior end **11** through a tapering horn section **123** to an extended end **125**. Similarly, the attachment segment **122** is formed by fibers **23** extending from the posterior end **12** through a tapering horn section **124** to an extended end **126**. The horns **123**, **124** accommodate placement of the attachment segments **121**, **122** through bone tunnels and also prevent joint impingent on the scaffold **1**. The elongated attachment segments **121**, **122** have proximal region **128,** a distal region **129**, a length **L,** and an exterior surface **S**.

[0020] The attachment segments **121 and 122** are configured to traverse the entire length of a bone tunnel (not shown). This allows for a fixation method wherein the attachment segments **121** and **122** extend through the bone tunnel and then are fixed to the tibia using interference screws (not shown) or the like. This provides a more rigid attachment. However, use of interference screws may potentially damage the extension fibers **23** that extend through the tapering horn section **123** and into the attachment segments **121** and **122**. The invention described and shown herein reduces or eliminates the chance that damage to these fibers occurs.

[0021] In one embodiment, the exterior surface **S** of at least one of the anterior attachment segments **121** or posterior attachment segment **122** has a coating **130** to protect the fibers **23**. In one embodiment, the coating **130** is a polymer that is applied by a spraying process. In one embodiment, the coating is applied by dipping the attachment segments **121** and **122** in a solution containing the polymer, removing it from the solution, and allowing it to dry under controlled conditions of humidity and temperature. In one embodiment the coating **130** is a resorbable polymer selected from the group consisting of poly(lactic acid) and polyglycolic acid, poly(4-hydroxybutyrate), polydioxanes, polyoxalates, polylactones, polyester hydrogels, and co-polymers of polyglycolide and polylactide. In one embodiment, the thickness of the coating **130** is greater than 0.10 mm and less than 5.0 mm. In one embodiment, the polymeric coating **130** is coated with collagen. In one embodiment of the artificial meniscal scaffold **20** shown in **FIG. 2**., the length $\mathbf{L_a}$ of the anterior attachment segment **221** is greater than the length $\mathbf{L_p}$ of the posterior attachment segment **222**. In another embodiment (not shown), the length $\mathbf{L_a}$ of the anterior attachment segment **221** is less than the length $\mathbf{L_p}$ of the posterior attachment segment **222.**

[0022] In one embodiment of the artificial meniscal scaffold **30** shown in **FIG. 3**, the elongated attachment segments **321**, **322** have a proximal region **328,** distal region **329**, length **L,** an exterior

surface **S,** and a polymeric fiber **310** wound around at least a portion of the exterior surface **S** of the anterior attachment segment **321** and posterior attachment **322** segment. In one embodiment, the polymeric fiber **310** is attached to the exterior surface **S** by an adhesive (not shown). In another embodiment, a collagen coating (not shown) is placed over the polymeric fiber **310**. In another embodiment, the polymeric fiber **310** is fixed to the exterior surface **S** by using the polymeric fiber **310** to tie a knot around the proximal region **328** and distal region **329** of the attachment segments **321** and **322**. In yet another embodiment, the polymeric fiber **310** is wound between and around the fibers **323** that comprise the attachment segments **321** and **322**. In one embodiment, the diameter of the polymeric fiber **310** is between 0.05 mm and 1 mm. In one embodiment, the polymeric fiber **310** is comprised of a resorbable polymer selected from the group consisting of poly(lactic acid) and polyglycolic acid, poly(4-hydroxybutyrate), polydioxanes, polyoxalates, polylactones, polyester hydrogels, and co-polymers of polyglycolide and polylactide. In one embodiment of the artificial meniscal scaffold **70** shown in **FIG. 7**, the polymeric fiber **71** is used to protect fibers **73** that form the arcuate portion **75** of the scaffold **70.** The polymeric fiber **71** is laced through holes **74** in the arcuate portion **75** and can be secured by knots **79** formed in the anterior end **76**, posterior end **78,** and middle section **77**.

[0023] In one embodiment of the artificial meniscal scaffold **40** shown in **FIG. 4**, the elongated attachment segments **421**, **422** have a proximal region **428,** distal region **429**, length **L,** an exterior surface **S,** and a cylindrical polymeric sleeve **410** covering the exterior surface **S** of at least one of the anterior attachment segment **421** and posterior attachment **422** segment. In one embodiment, the cylindrical polymeric sleeve **410** is attached to the exterior surface **S** by an adhesive (not shown). The polymeric sleeve is preferably comprised of a resorbable polymer selected from the group consisting of poly(lactic acid) and polyglycolic acid, poly(4-hydroxybutyrate),

polydioxanes, polyoxalates, polylactones, polyester hydrogels, and co-polymers of polyglycolide and polylactide. In one embodiment, the thickness of the polymeric sleeve **410** is between 0.1 mm and 2.0 mm. In another embodiment, the polymeric sleeve **410** is porous, with the average pore diameter between 0.1 mm and 1 mm.

[0024] In one embodiment of the artificial meniscal scaffold **50** shown in **FIG. 5**, the elongated attachment segments **521**, **522** have a proximal region **528,** distal region **529**, length **L,** an exterior surface **S,** and an aperture **510** present between the proximal region **528** and distal region **529** of the elongated attachment segments **521** and **522**. The aperture **510** can be used to pass sutures through, to further assist the surgeon in placing the elongated attachment segments into the tibia. In one embodiment, the aperture **510** is a circular or ellipsoidal shaped ring with a diameter between 1 mm and 5 mm that is comprised of a resorbable polymer selected from the group consisting of poly(lactic acid) and polyglycolic acid, poly(4-hydroxybutyrate), polydioxanes, polyoxalates, polylactones, polyester hydrogels, and co-polymers of polyglycolide and polylactide. In one embodiment, the aperture **510** is bound to the fibers **523** that extend into the attachment segments **521** and **522** by an adhesive (not shown). In another embodiment, the aperture **510** is sewn into the fibers 523 by use of resorbable sutures (not shown) commonly used in surgery such as Vicryl™, PDS™, or Monocryl™.

[0025] In one embodiment of the artificial meniscal scaffold **60** shown in **FIG. 6A**, the elongated attachment segments **621**, **622** have a proximal region **628,** distal region **629**, length **L,** an exterior surface **S,** and an anchoring component **610** attached to the distal region of the anterior and posterior attachment segments **621** and **622**. The anchoring component **610** has an opening **612** for attachment segment **621** to pass through. The anchoring component **610** also has a lumen (not shown) to allow for coupling an attachment segment to the anchoring component. This

fixation can be accomplished with an adhesive such as cyanoacrylate or fibrin glue. A threaded surface **611** enables the anchoring component **610** to be screwed into a bone tunnel. In one embodiment shown in **FIG. 6B**, the anchoring component **620** has an opening **630** to receive a portion of attachment segment **621.** A ribbed surface **631** enables the anchoring component **620** to be pushed into a bone tunnel. The ribbed surface **631** will prevent pull-out of the attachment segment **621**. The anchoring component **620** may also have a slit **632** that allows the attachment segment **621** to be slidably engaged within the anchoring component **620**. In one embodiment shown in **FIG. 6C**, the anchoring component **640** has an opening **641** to receive a portion of attachment segment **621.** A ribbed surface **641** enables the anchoring component **640** to be pushed into a bone tunnel. The ribbed surface **641** will prevent pull-out of the attachment segment **621** from a bone tunnel. In addition to a slit **642** that allows the attachment segment **621** to be slidably engaged within the anchoring component **640,** the anchoring component **640** also has at least one flange **644** to prevent further fix the anchoring component within a bone tunnel. In one embodiment, at least one flange exists within the lumen (not shown) of the anchoring component **640** that would prevent the attachment segment **621** from sliding out of the anchoring component **640**.

[0026] In one embodiment of the artificial meniscal scaffold, the anchoring component on one attachment segment is different than the anchoring component on the other attachment segment. For example, the anterior attachment segment may be coupled to a threaded anchoring component like that shown in **FIG. 6A**, while the posterior attachment segment is coupled to an anchoring component like that shown in **FIG. 6B** that is pushed into a bone tunnel. In some embodiments, the anchoring components shown in **FIGS. 6A**, **6B**, and **6C** are comprised of a resorbable polymer selected from the group consisting of poly(lactic acid) and polyglycolic acid, poly(4-

hydroxybutyrate), polydioxanes, polyoxalates, polylactones, polyester hydrogels, and co-polymers of polyglycolide and polylactide. In one embodiment, the anchoring components shown in **FIGS. 6A**, **6B**, and **6C** are comprised of a metal selected from the group consisting of stainless steel, nitinol, tantalum, or titanium.

[0027] Referring back to FIGS. 1-7, the arcuate bioresorbable matrix **10** of the artificial meniscal scaffold is comprised of collagen and hyaluronic acid. In one embodiment, the matrix **10** fills all of the inter-fiber spaces and coats the entire scaffold, including the attachment segments. In one embodiment, the matrix **10** fills only the inter-fiber spaces of the arcuate portion of the artificial meniscal scaffold. In one embodiment, the collagen is type I collagen purified from bovine tendon. In one embodiment, an acidic dispersion of collagen and hyaluronic acid matrix is forced into the inter-fiber spaces of the scaffold described *supra* and lyophilized. In one embodiment, the collagen within the matrix is crosslinked with physical treatments such as dehydrothermal crosslinking or ultraviolet light. Alternatively, chemical crosslinking of the collagen can be achieved by use of aldehydes or carbodiimides. In one embodiment, the carbodiimide is 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide, also known as EDC.

[0028] Post-operative imaging and assessment of the artificial meniscal scaffold is critical to both surgeons and patients. In one embodiment of the artificial meniscal scaffold, the arcuate bioresorbable matrix contains a radiopaque material such as iodine, barium, tantalum, bismuth, or gold. In one embodiment of the artificial meniscal scaffold, the arcuate bioresorbable matrix contains platelet rich plasma or mammalian cells. In one embodiment of the artificial meniscal scaffold, the arcuate bioresorbable matrix contains an antimicrobial agent, antibiotic, or anti-fungal agent. In one embodiment of the artificial meniscal scaffold, the arcuate bioresorbable matrix contains bone derivatives or calcium-phosphate compounds. In one embodiment, the matrix is

comprised of bone derivatives from an allograft, autograft or xenograft source. In one embodiment, the calcium phosphate compound is hydroxyapatite or tricalcium phosphate. In one embodiment, the tricalcium-phosphate compound is beta-tricalcium-phosphate.

[0029] Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention which is defined by the following claims.

CLAIMS

1. An artificial meniscal scaffold comprising:

an arcuate bioresorbable matrix;

a network of circumferential bioresorbable fibers independent from and embedded in said matrix; and

a network of orthogonal bioresorbable fibers independent from and embedded in said matrix to prevent separation of said circumferential fiber network;

wherein the bioresorbable circumferential fibers and the bioresorbable orthogonal fibers have a three-dimensional shape and geometry which is substantially the same as the three-dimensional shape and geometry of the matrix;

wherein the scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between said anterior and posterior ends;

wherein the network of circumferential bioresorbable fibers extends between said anterior and posterior ends along the path of said curve and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments;

wherein the anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface; and,

wherein the exterior surface of at least one of said anterior and posterior attachment segments is coated with a polymer.

2. The artificial meniscal scaffold of claim 1, wherein the polymer is resorbable.

3. The artificial meniscal scaffold of claim 1, wherein the length of the anterior attachment segment is less than the length of the posterior attachment segment.

4. An artificial meniscal scaffold comprising:

an arcuate bioresorbable matrix;

a network of circumferential bioresorbable fibers independent from and embedded in said matrix; and

a network of orthogonal bioresorbable fibers independent from and embedded in said matrix to prevent separation of said circumferential fiber network;

wherein the bioresorbable circumferential fibers and the bioresorbable orthogonal fibers have a three-dimensional shape and geometry which is substantially the same as the three-dimensional shape and geometry of the matrix;

wherein the scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between said anterior and posterior ends;

wherein the network of circumferential bioresorbable fibers extends between said anterior and posterior ends along the path of said curve and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments;

wherein the anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface; and,

wherein a polymeric fiber is wound around at least a portion of the exterior surface of at least one of the anterior and posterior attachment segments.

5. The artificial meniscal scaffold of claim 4, wherein the polymeric fiber wound around at least a portion of the exterior surface of at least one of the anterior and posterior attachment segments is resorbable.

6. The artificial meniscal scaffold of claim 4, wherein the length of the anterior attachment segment is less than the length of the posterior attachment segment.

7. An artificial meniscal scaffold comprising:

an arcuate bioresorbable matrix;

a network of circumferential bioresorbable fibers independent from and embedded in said matrix; and

a network of orthogonal bioresorbable fibers independent from and embedded in said matrix to prevent separation of said circumferential fiber network;

wherein the bioresorbable circumferential fibers and the bioresorbable orthogonal fibers have a three-dimensional shape and geometry which is substantially the same as the three-dimensional shape and geometry of the matrix;

wherein the scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between said anterior and posterior ends;

wherein the network of circumferential bioresorbable fibers extends between said anterior and posterior ends along the path of said curve and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments;

wherein the anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface; and,

wherein at least a portion of the exterior surface of at least one of said anterior and posterior attachment segments is covered with a polymeric sleeve.

8. The artificial meniscal scaffold of claim 7, wherein the polymeric sleeve is resorbable.

9. The artificial meniscal scaffold of claim 7, wherein the length of the anterior attachment segment is less than the length of the posterior attachment segment.

10. An artificial meniscal scaffold comprising:

an arcuate bioresorbable matrix;

a network of circumferential bioresorbable fibers independent from and embedded in said matrix; and

a network of orthogonal bioresorbable fibers independent from and embedded in said matrix to prevent separation of said circumferential fiber network;

wherein the bioresorbable circumferential fibers and the bioresorbable orthogonal fibers have a three-dimensional shape and geometry which is substantially the same as the three-dimensional shape and geometry of the matrix;

wherein the scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between said anterior and posterior ends;

wherein the network of circumferential bioresorbable fibers extends between said anterior and posterior ends along the path of said curve and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments;

wherein the anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface; and,

wherein an aperture is present between the proximal region and the distal region of at least one of the anterior and posterior attachment segments.

11. The artificial meniscal scaffold of claim 10, wherein the length of the anterior attachment segment is less than the length of the posterior attachment segment.

12. The artificial meniscal scaffold of claim 10, wherein the aperture is comprised of a polymeric circular ring.

13. The artificial meniscal scaffold of claim 11, wherein the polymeric circular ring is resorbable.

14. The artificial meniscal scaffold of claims 10-13, further comprising a suture passing through the aperture.

15. An artificial meniscal scaffold comprising:

an arcuate bioresorbable matrix;

a network of circumferential bioresorbable fibers independent from and embedded in said matrix; and

a network of orthogonal bioresorbable fibers independent from and embedded in said matrix to prevent separation of said circumferential fiber network;

wherein the bioresorbable circumferential fibers and the bioresorbable orthogonal fibers have a three-dimensional shape and geometry which is substantially the same as the three-dimensional shape and geometry of the matrix;

wherein the scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between said anterior and posterior ends;

wherein the network of circumferential bioresorbable fibers extends between said anterior and posterior ends along the path of said curve and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments;

wherein the anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface; and,

wherein an anchoring component is attached to the distal end of at least one of the anterior and posterior attachment segments.

16. The artificial meniscal scaffold of claim 15, wherein the length of the anterior attachment segment is less than the length of the posterior attachment segment.

17. The artificial meniscal scaffold of claim 15, wherein the anchoring component is comprised of a metal selected from the group consisting of tantalum, stainless steel, nitinol, and titanium.

18. The artificial meniscal scaffold of claim 15, wherein the anchoring component is a hollow polymeric screw.

19. The artificial meniscal scaffold of claim 18, wherein the hollow polymeric screw is resorbable.

20. An artificial meniscal scaffold comprising:

an arcuate bioresorbable matrix;

a network of circumferential bioresorbable fibers independent from and embedded in said matrix; and

a network of orthogonal bioresorbable fibers independent from and embedded in said matrix to prevent separation of said circumferential fiber network;

wherein the bioresorbable circumferential fibers and the bioresorbable orthogonal fibers have a three-dimensional shape and geometry which is substantially the same as the three-dimensional shape and geometry of the matrix;

wherein the scaffold is comprised of an anterior end, a posterior end, and a middle section therebetween defining a curved path between said anterior and posterior ends;

wherein a polymeric fiber is wound around at least a portion of said anterior end, posterior end, or middle section;

wherein the network of circumferential bioresorbable fibers extends between said anterior and posterior ends along the path of said curve and exits the anterior and posterior ends of the scaffold to form respective anterior and posterior attachment segments; and,

wherein the anterior and posterior attachment segments have a proximal region, a distal region, a length, and an exterior surface.

21. The artificial meniscal scaffold of claims 1-20, wherein the matrix is formed from a material selected from the group consisting of proteins, proteoglycans, biocompatible synthetic polymers and combinations thereof.

22. The artificial meniscal scaffold of claim 21, wherein the protein is collagen.

23. The artificial meniscal scaffold of claim 22, wherein the collagen is cross-linked.

24. The artificial meniscal scaffold of claims 1-20, wherein the matrix is comprised of a radiopaque material containing iodine, barium, tantalum, bismuth, or gold.

25. The artificial meniscal scaffold of claims 1-20, wherein the matrix is comprised of platelet rich plasma or mammalian cells.

26. The artificial meniscal scaffold of claims 1-20, wherein the matrix is comprised of an antimicrobial agent, antibiotic, or anti-fungal agent.

27. The artificial meniscal scaffold of claims 1-20, wherein the matrix is comprised of bone derivatives or calcium-phosphate compounds.

28. The artificial meniscal scaffold of claim 27, wherein the calcium phosphate compound is hydroxyapatite, tricalcium-phosphate, or beta tricalcium-phosphate.

29. The artificial meniscal scaffold of claim 27, wherein the bone derivative is derived from an allograft, autograft, or xenograft.

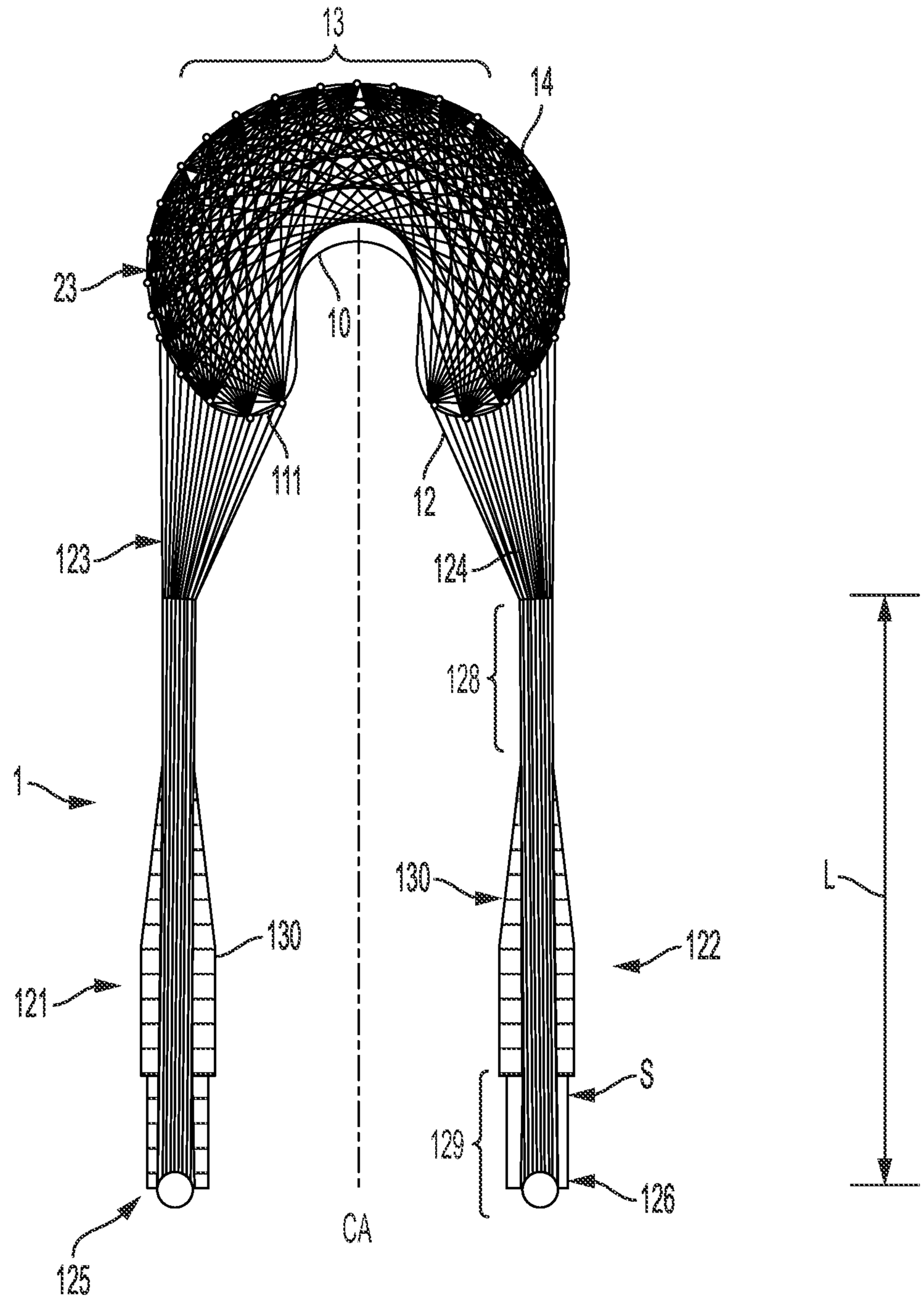

FIG. 1

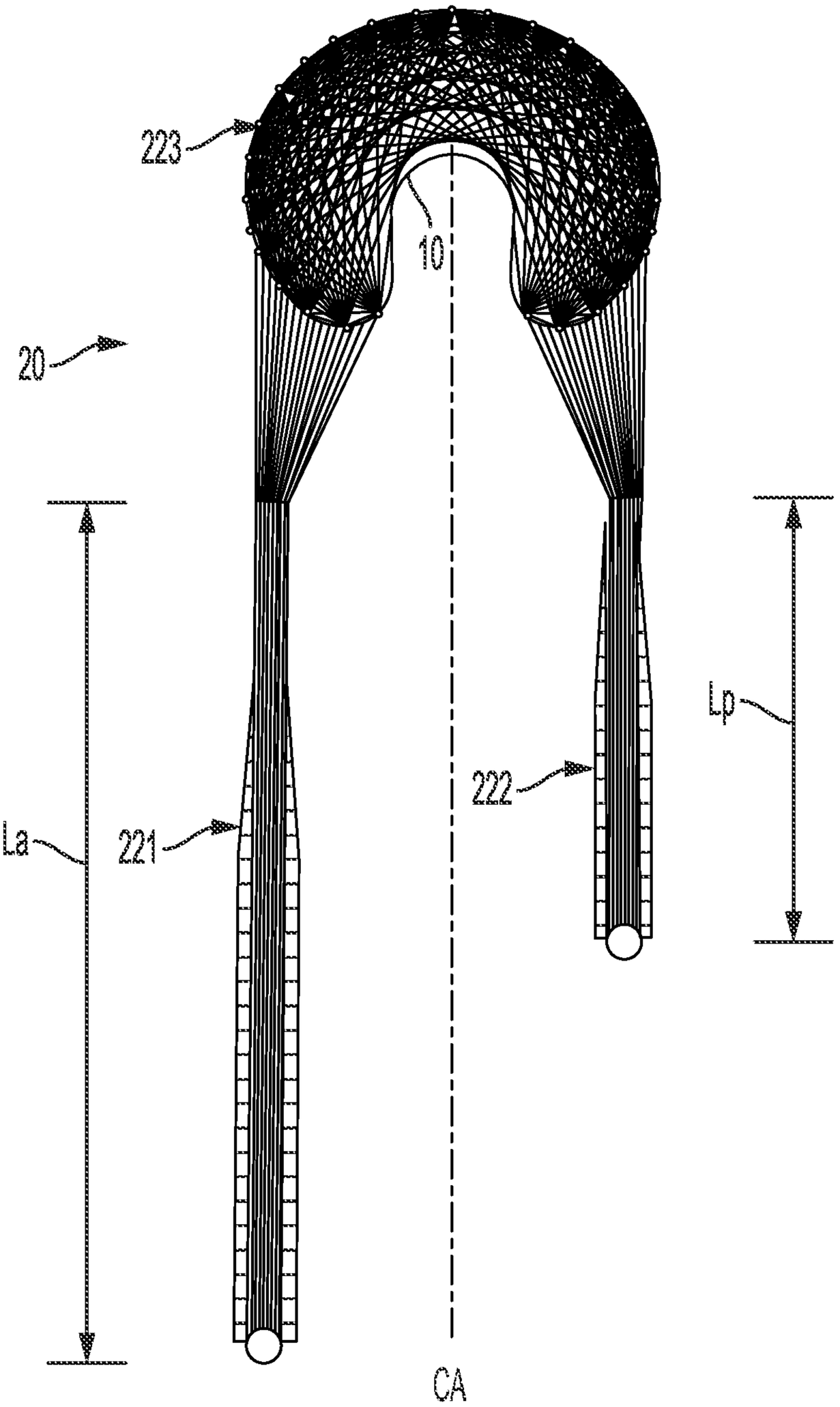

FIG. 2

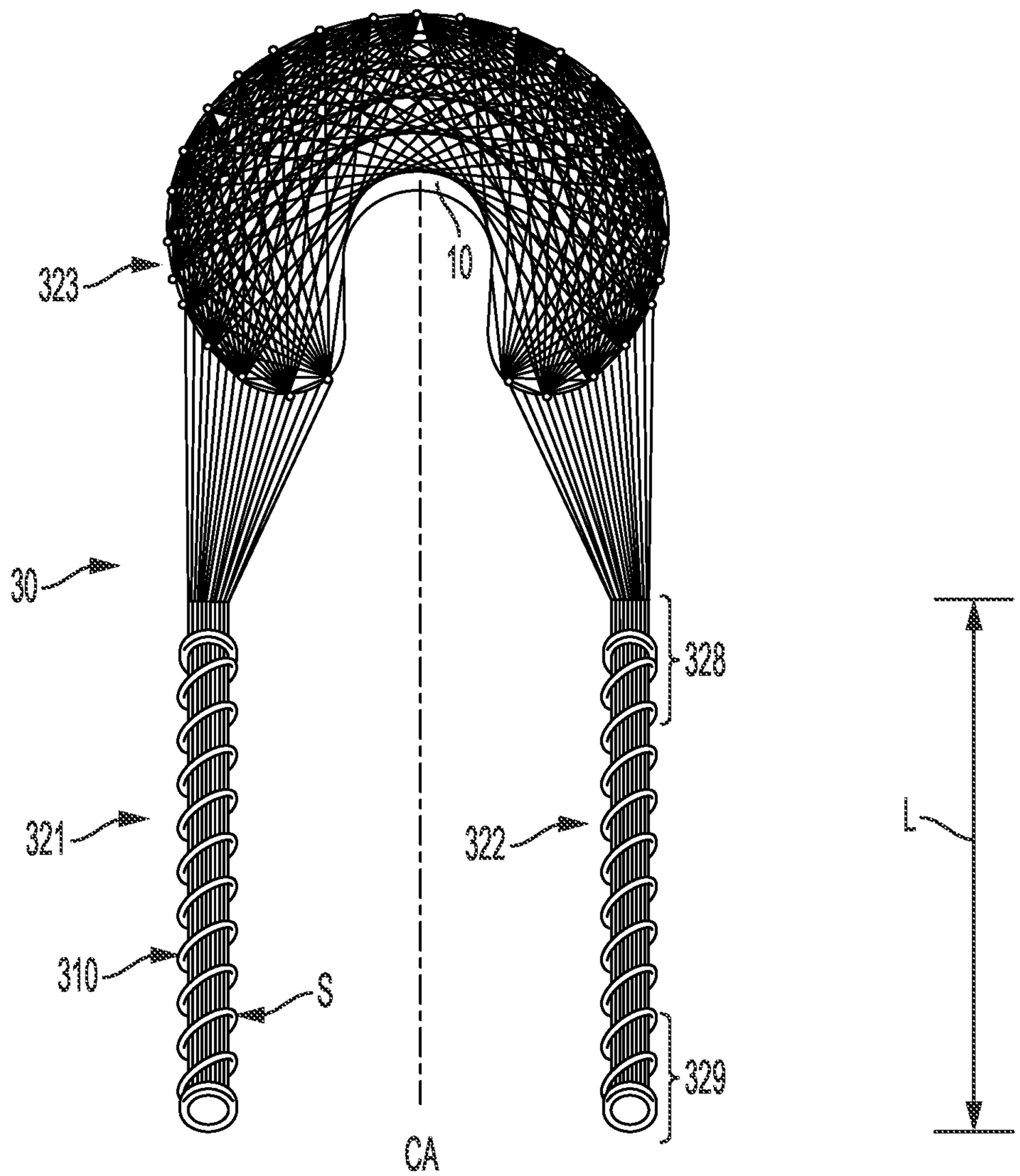

FIG. 3

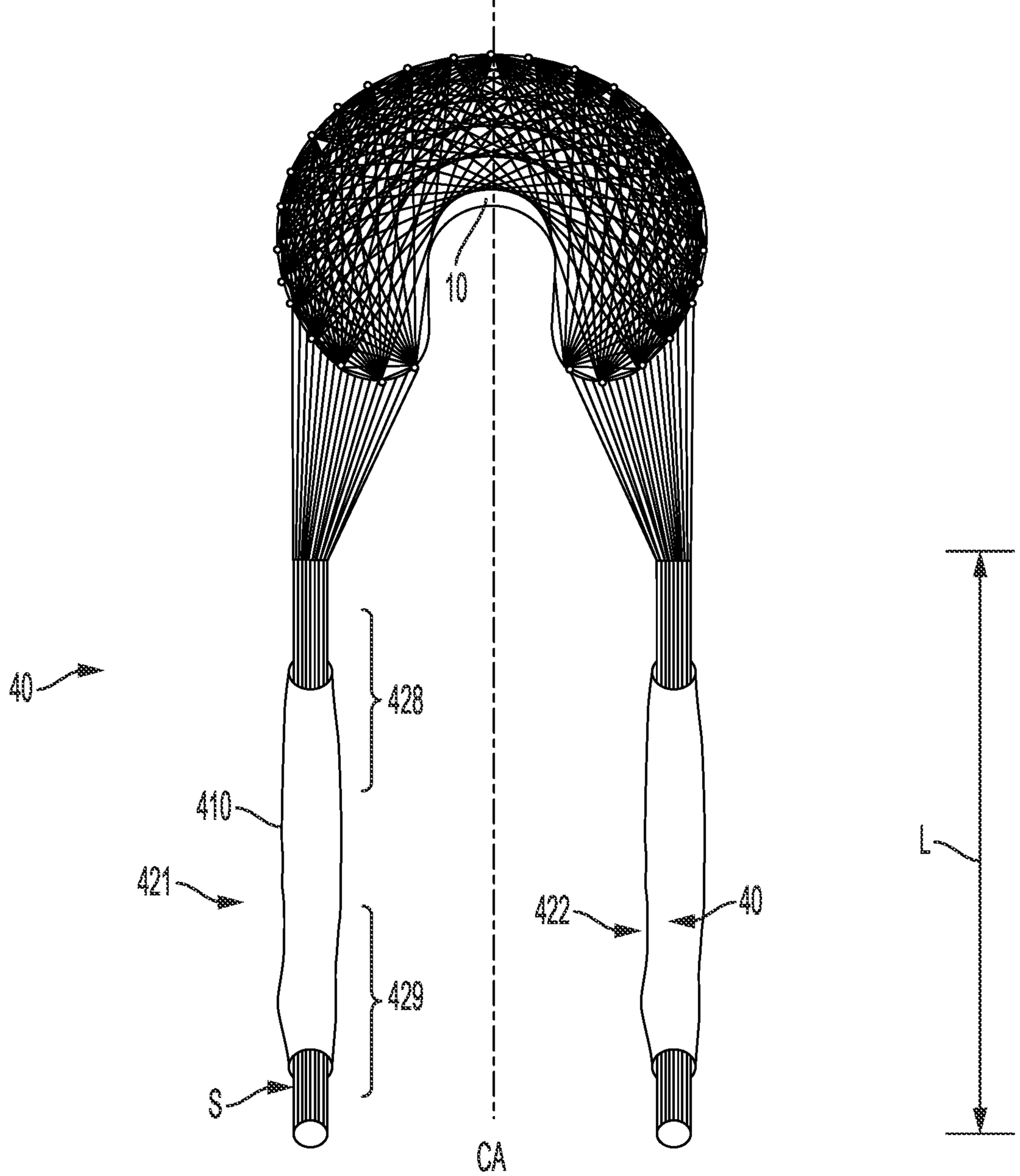

FIG. 4

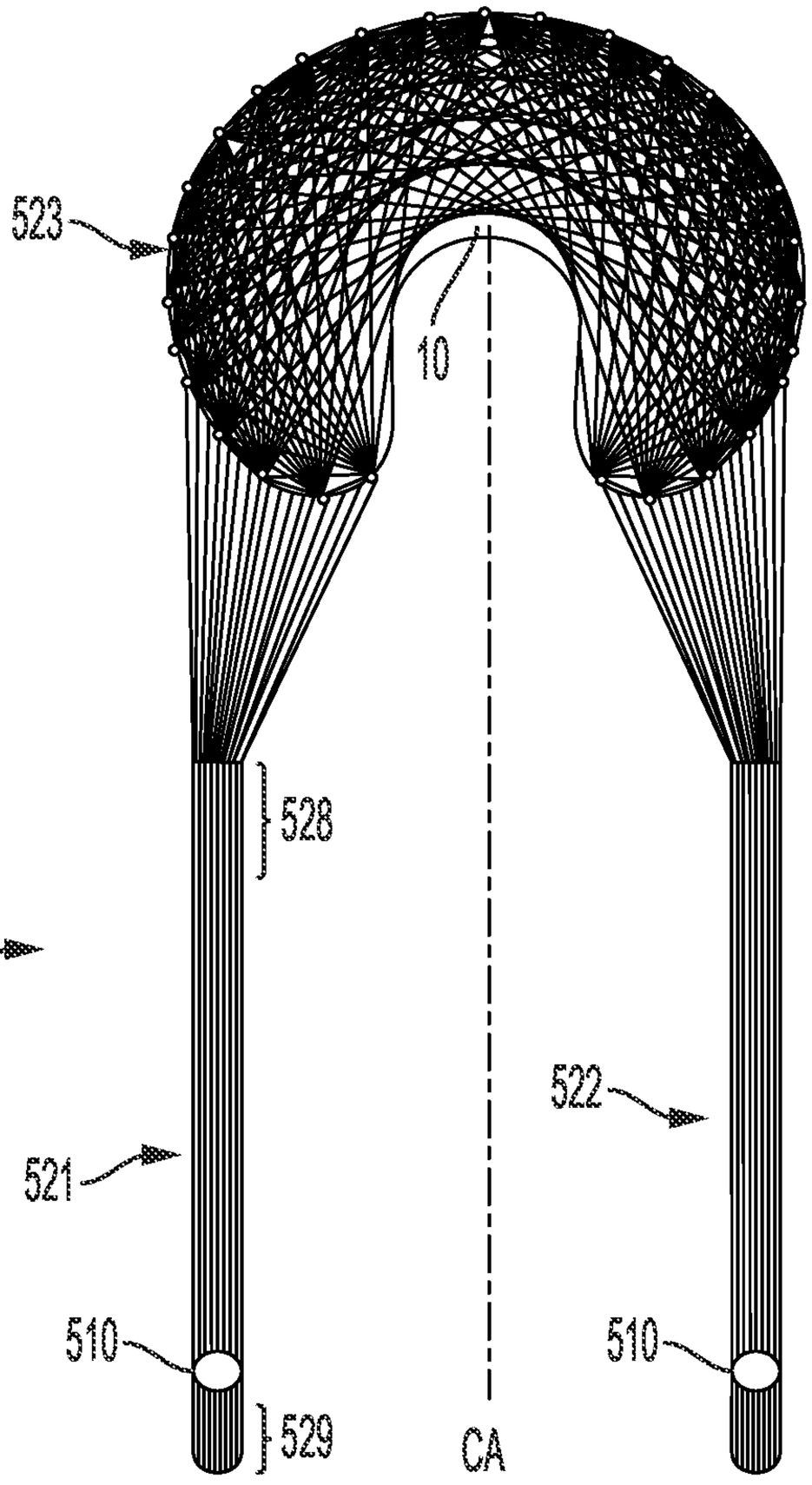

FIG. 5

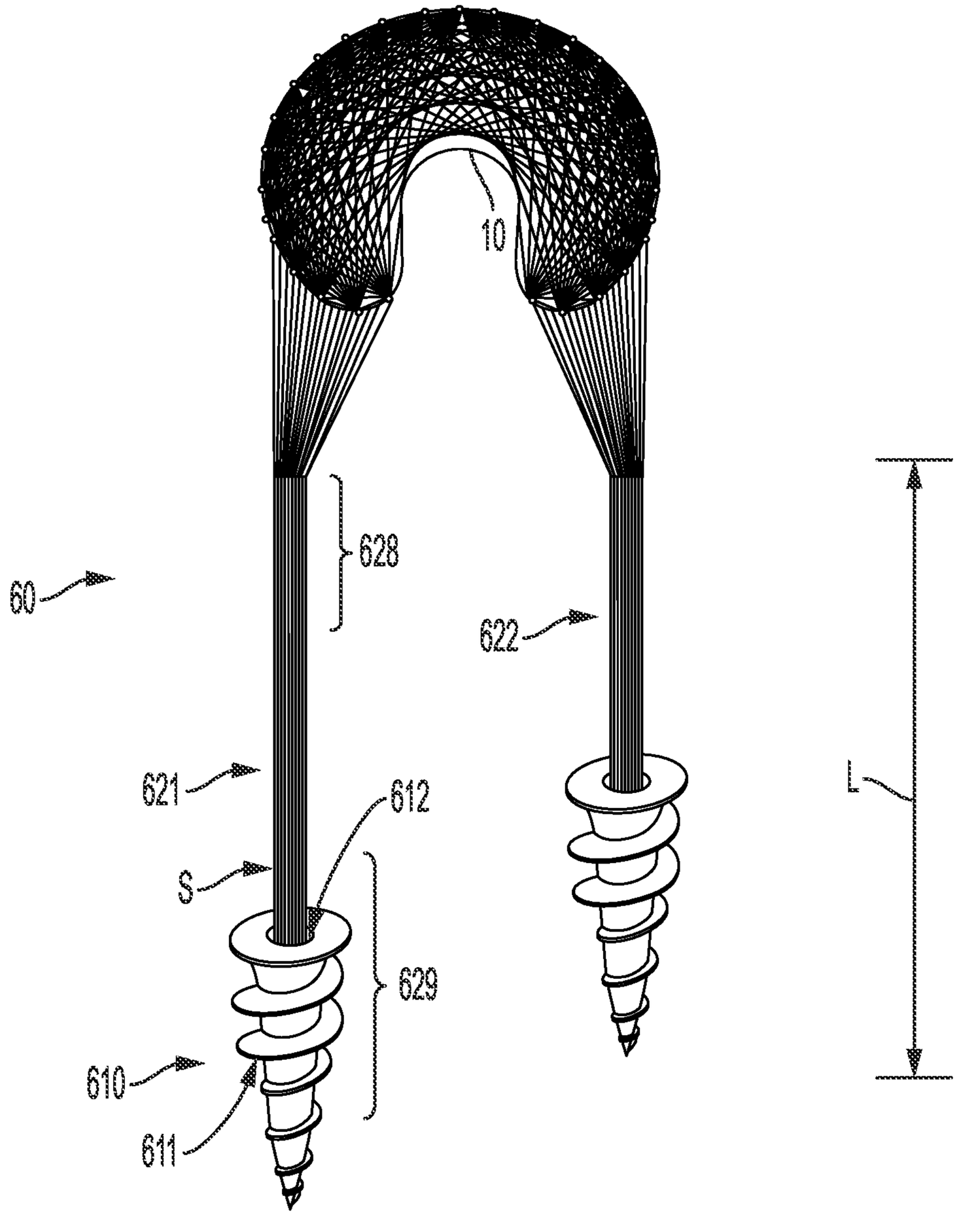

FIG. 6A

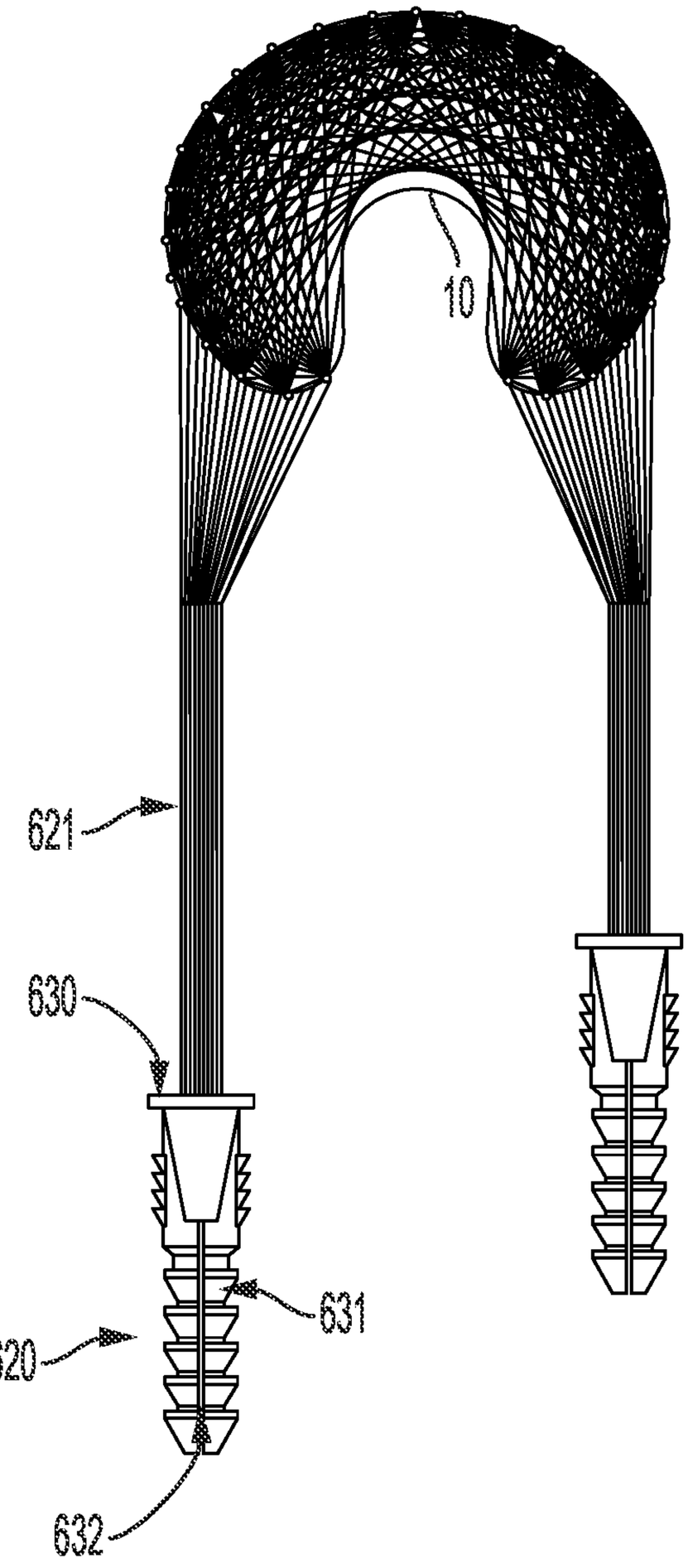

FIG. 6B

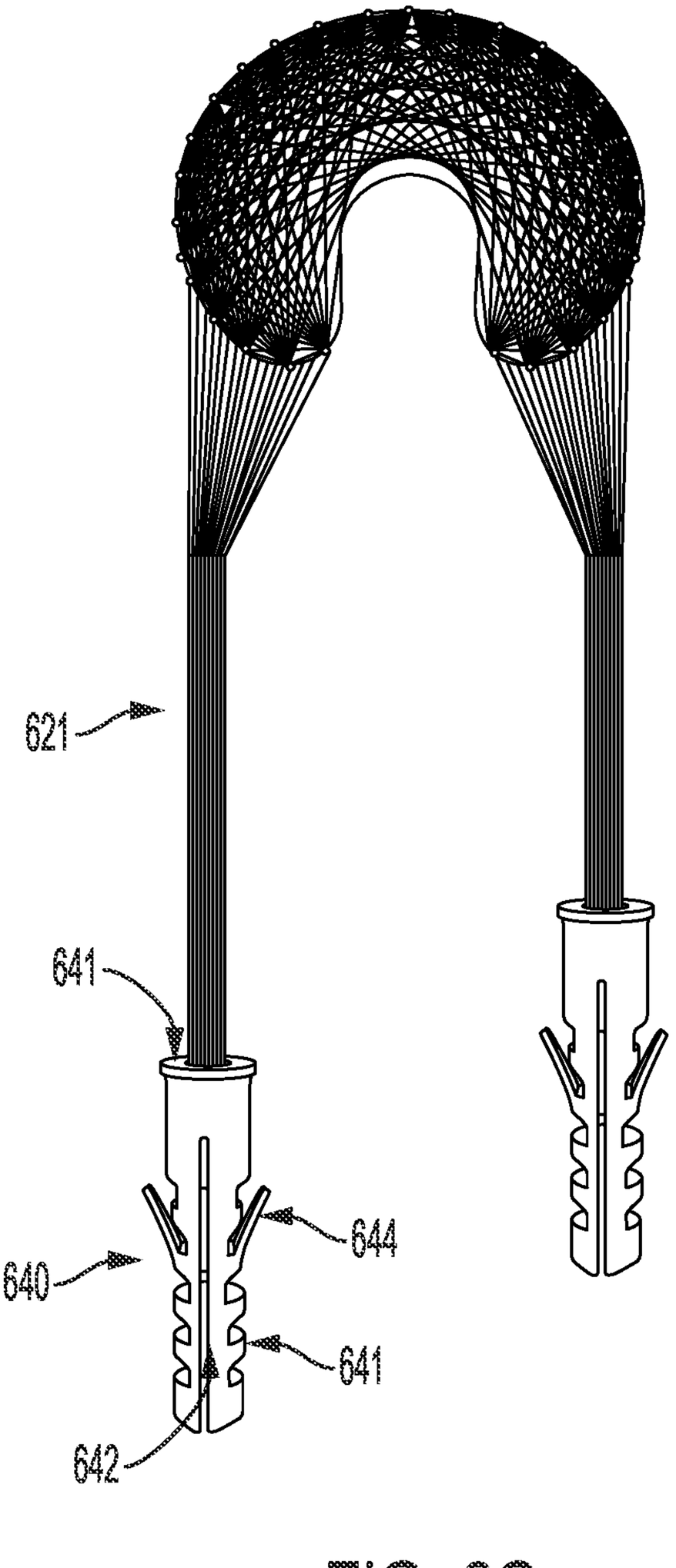

FIG. 6C

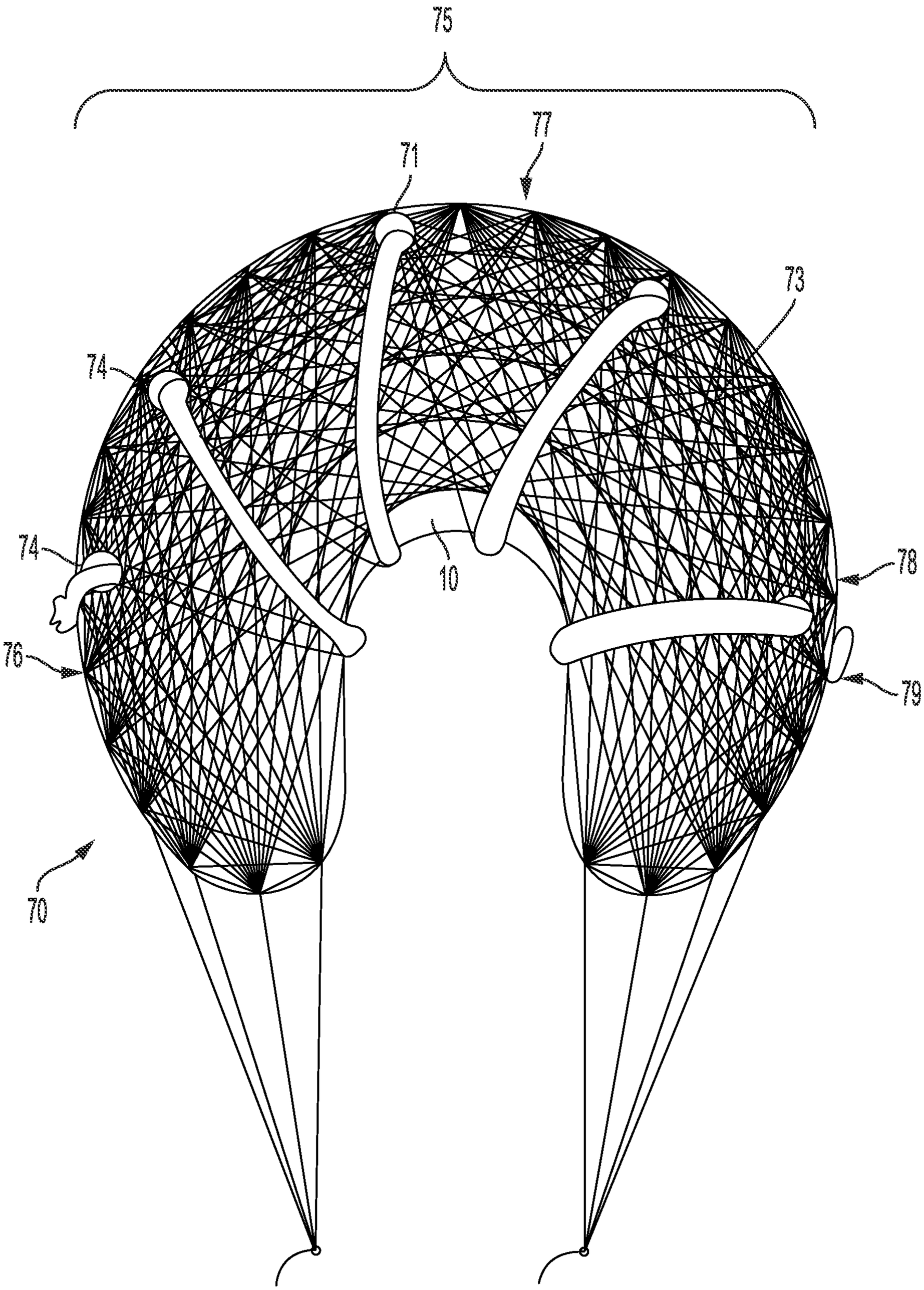

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 20/59424

A. CLASSIFICATION OF SUBJECT MATTER

IPC - A61F 2/30; A61F 2/38; A61F 2/42; A61F 2/44; A61L 27/38; A61L 27/48; A61L 27/58 (2020.01)

CPC - A61F 2/30; A61F 2/38; A61F 2/42; A61F 2/44; A61L 27/38; A61L 27/48; A61L 27/58; A61F 2/30756; A61F 2/30965; A61F 2/3872; A61F 2002/30007; A61F 2002/30014; A61F 2002/30062; A61F 2002/30576

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

B. FIELDS SEARCHED

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X – Y	US 9,078,756 B2 (RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY) 14 July 2015 (14.07.2015); entire document, especially col 8 ln 8-19, col 9 ln 1-32, and Fig. 16 and 18-20.	15-16 – 1-13, 17-20
Y	US 6,103,255 A (LEVENE et al.) 15 August 2000 (15.08.2000); especially col 2 ln 48-60, and Fig. 1.	1-3
Y	US 2016/0193033 A1 (DODD et al.) 7 July 2016 (07.07.2016); especially para [0084], and Fig. 5.	4-6, 20
Y	US 2014/0222149 A1 (AMIS et al.) 7 August 2014 (07.08.2014); especially para [0175]-[0176], and Fig. 9.	7-13
Y	US 2014/0243911 A1 (UNIVERSITY OF PITTSBURGH OF THE COMMONWEALTH SYSTEM OF HIGHER EDUCATION) 28 August 2014 (28.08.2014); especially para [0034], and Fig. 1A-D.	17
Y	US 2003/0125744 A1 (CONTILIANO et al.) 3 July 2003 (03.07.2003); especially para [0024], [0034], and Fig. 1A-D.	18-19
A	US 7,157,428 B2 (KUSANAGI et al.) 2 January 2007 (02.01.2007); entire document.	1-13, 15-20
A	US 2017/0007411 A1 (BIOMET UK LIMITED) 12 January 2017 (12.01.2017); entire document.	1-13, 15-20

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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
30 December 2020	04 FEB 2021
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Lee Young Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 20/59424

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 14, 21-29
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.