



(86) Date de dépôt PCT/PCT Filing Date: 2003/01/31
(87) Date publication PCT/PCT Publication Date: 2003/09/04
(45) Date de délivrance/Issue Date: 2007/07/03
(85) Entrée phase nationale/National Entry: 2004/08/18
(86) N° demande PCT/PCT Application No.: US 2003/002856
(87) N° publication PCT/PCT Publication No.: 2003/071962
(30) Priorité/Priority: 2002/02/25 (US60/359,394)

(51) Cl.Int./Int.Cl. *A61B 17/04* (2006.01),
A61B 17/064 (2006.01), *A61B 17/068* (2006.01),
A61B 17/70 (2006.01), *A61B 17/86* (2006.01)

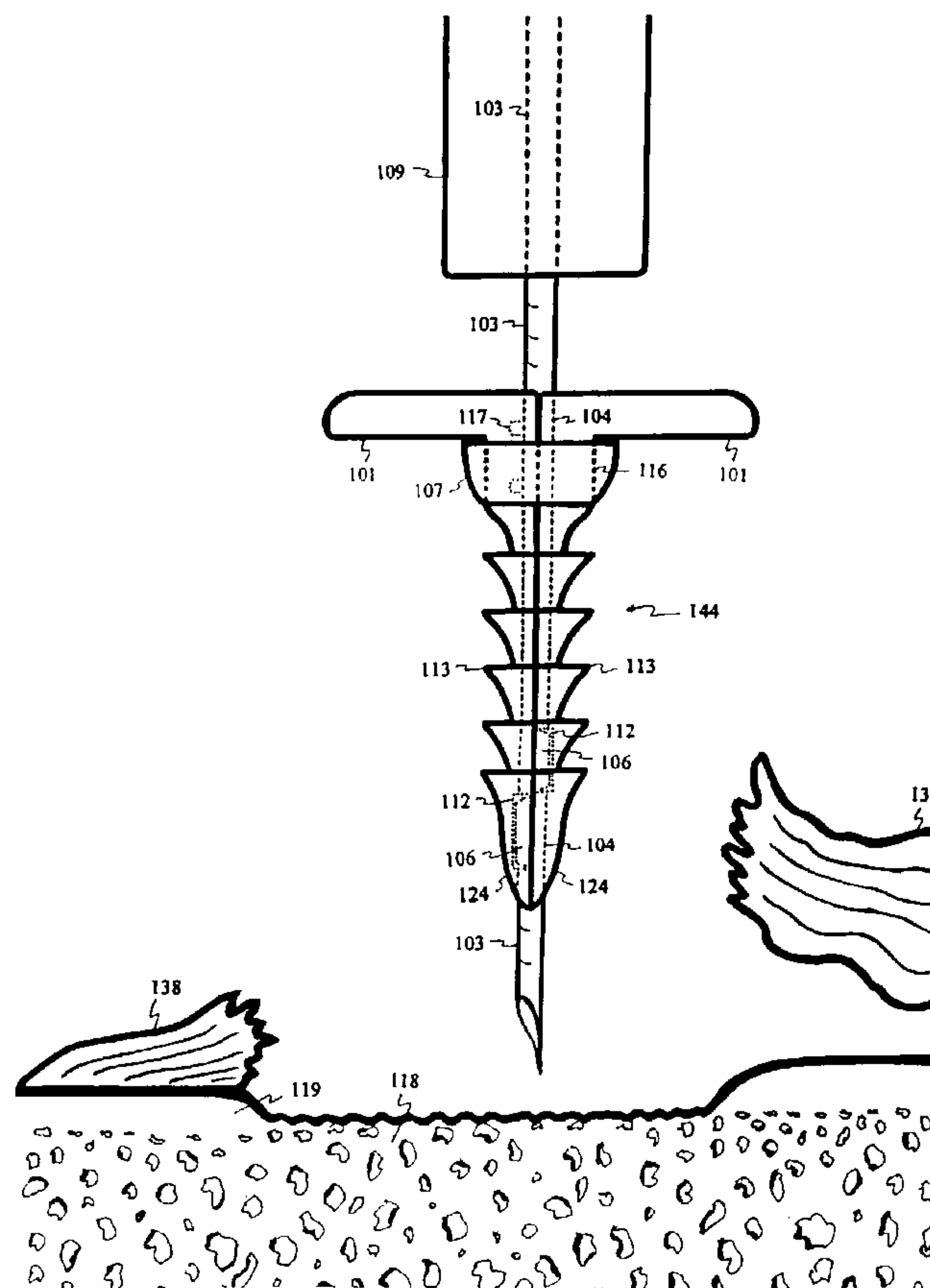
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(54) Titre : ELEMENT DE FIXATION EXPANSIBLE AVEC PRISES COMPRESSIVES

(54) Title: EXPANDABLE FASTENER WITH COMPRESSIVE GRIPS



(57) Abrégé/Abstract:

Anchoring elements of a fastener are made elastically curved. The curvatures of the elements are resiliently straightened by a trocar for tissue insertion. As the trocar is withdrawn, the anchoring elements resume the curved configuration, laterally pressing the elements against tissue to anchor the fastener.

ABSTRACT

Anchoring elements of a fastener are made elastically curved. The curvatures of the elements are resiliently straightened by a trocar for tissue insertion. As the trocar is withdrawn, the anchoring elements resume the curved configuration, laterally pressing the elements against tissue to anchor the fastener.

EXPANDABLE FASTENER WITH COMPRESSIVE GRIPS

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5 FIELD OF INVENTION

This invention is an expandable fastener delivered by a trocar or a needle into tissue. As the trocar is withdrawn, the fastener opens and anchors within tissue.

BACKGROUND

10 Tendon and ligament tears are common in sports injuries and trauma. Surgical repair of the tears can be invasive with many possible complications, including painful adhesions of scar tissue. Most patients are conservatively treated with immobilization. Only about 35% of orthopaedic trauma cases are treated surgically.

Many bone anchors have been studied and developed to reattach torn tissues. In general, metallic and non-degradable polymeric anchors or staples can fasten torn tissues well; but with time, the non-degradable device can migrate into undesirable places, such as joints. On the other hand, SuretacTM is degradable and easily deployed; however failure due to low pull out strength is a common concern. US Patents 4,884,572 and 4,895,148 issued on December 5, 1989 and January 23, 1990 respectively by F. Barry Bays are related to a tissue repairing tack similar to SuretacTM in the market. The tack contains a head, a cylindrical shaft with barbs and a lumen open from the head to the distal end of the shaft. For delivery of the tack, a needle is inserted into the lumen and protruded beyond the distal end of the shaft of the tack. The needle carrying the tack pierces through the torn tissue into bone. The barbs of the tack engage with bone tissue to hold the torn tissue in place. The needle is then withdrawn from the bone and the tack. 20 The tissue gripping strength of the barbs or threads of the tack is very limited, especially in poor quality bone. Therefore, the pull out strength of the tack is generally low. Healing of the torn tissue requires secure contact to the cancellous bone. The low pull out strength often contributes to tack loosening, forming a gap between the bone and supposedly reattached tissue. As a result, tissue reattachment is unsuccessful; weakness and pain persist. 30

SUMMARY OF INVENTION

Pull out strength is one of the most important criteria in biomechanical testing to evaluate the performance of a tack, staple, anchor or fastener. According to one
5 embodiment of the present invention, there is provided a new type of expandable fastener is made with elastically curved legs containing tissue-gripping elements. The legs contain semi-cylindrical troughs and trocar engaging rings or retainers. The elastically curved legs can be resiliently straightened and closed to form a shaft for tissue penetration. In the closed position, the semi-cylindrical troughs of the elastic legs form a
10 lumen with the retainers aligned in series. A needle or trocar is inserted into the lumen through the aligned retainers to bind or link the elastically straightened legs; then the needle protrudes beyond the distal end of the expandable fastener. The trocar serves two functions: (1) to restrict or bind the elastic legs together and prevent them from opening, and (2) to spearhead the puncturing of tissue for delivering the expandable fastener. As
15 the trocar is withdrawn from tissue and fastener, the elastic curvatures of the legs resume, pressing and anchoring the gripping elements laterally into the tissue.

In another embodiment of the present invention, there is provided an expandable fastener deployable with a trocar, comprising: a first leg formed of an elastic material and having a first retainer passage extending through at least a portion thereof, said first leg
20 having a curved position and a resiliently straightened position, a first plurality of tissue gripping elements located on a concave side of said first leg when said first leg is in said curved position, a second leg formed of an elastic material and having a second retainer passage extending through at least a portion thereof, said second leg having a curved position and a resiliently straightened position, a second plurality of tissue gripping
25 elements located on a concave side of said second leg when said second leg is in said curved position, wherein said first and second retainer passages are sized and configured to retain the trocar.

In a still further embodiment, there is provided an expandable fastener, comprising a first elastically curved section having a first head portion, a first leg portion
30 extending from said first head portion, a first groove indenting along a length of said first

head portion and said first leg portion, and a first passage covering a portion of said first groove, a second elastically curved section having a second head portion, a second leg portion extending from said second head portion, a second groove indenting along a length of said second head portion and said second leg portion, and a second passage
 5 covering a portion of said second groove, and a retainer ring sized and configured to fit around said first and second elastically curved sections.

Another embodiment of the present invention provides an expandable fastener, comprising a first elastically curved section having a first head portion, a first leg portion extending from said first head portion, at least one groove indenting along a length of said
 10 first head portion and said first leg portion, a second elastically curved section having a second head portion, a second leg portion extending from said second head portion, at least one tongue extending along a length of said second head portion and said second leg portion, wherein said at least one tongue is sized and configured to fit in said at least one groove, and a retainer ring sized and configured to fit around said first and second
 15 elastically curved sections.

The invention also provides an expandable fastener for deployment with a needle, said expandable fastener comprising a first leg having tissue gripping elements located on a concave surface thereof, said first leg having a first curved position and a second resiliently straightened position, a second leg having tissue gripping elements located on a
 20 concave surface thereof, said second leg having a first curved position and a second resiliently straightened position, a head portion located at an end of said first and second legs, at least one passage extending through at least one of said first and second legs, said at least one passage sized and configured to allow the needle to be located therein, wherein, when the needle is located within said at least one passage, at least one of said
 25 first and second legs is held in said resiliently straightened position.

REFERENCE NUMBERS

100	Intervertebral disc	104	Trough, groove or lumen
101	Head of fastener	105	End plate
30 103	Trocar, needle or K-wire	106	Trocar retainer or passage

107	Assembly ring or clip	168	Tongue
108	Tack grips	169	Groove
109	Compressive sleeve	174	Handle of driver
110	Peg hole	175	Bridge of staple
5 111	Disc compressor	30 189	Socket
112	Indentation or recess	194	Nerve
113	Gripping element	196	Retractor
116	Neck of fastener	235	Suture opening
117	Peg	228	Phillips cross slot
10 118	Cancellous bone	35 236	Screw thread
119	Cortical bone	276	Annular contact surface
120	Counter junction	277	Base of double trocar
121	Puncture hole	278	Semiconic tip
122	Suture	279	Sleeve
15 123	Spinal cord	40 280	Distal end of compressive sleeve
124	Expandable leg	281	Recess for gripping element
128	Nucleus pulposus	282	Spine restrictive device
129	Facet joint	283	Hook & loop, or VELCRO TM
133	Drive	284	Screw fastener
20 144	Tack fastener	45 285	Counter-gripping fastener
153	Marker	286	Staple fastener
159	Vertebral body	287	Enlarged distal surface of sleeve
160	Tissue ingrowth opening	288	Inner surface of the bridge
161	Threaded portion	289	Retainer or passage of staple
25 165	Step of a needle or trocar		

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BRIEF DESCRIPTION OF DRAWINGS

Figure 1 depicts a side view of elastically curved pieces containing heads **101** and legs **124** above a ring **107** for composing an expandable tack fastener **144**.

Figure 2 depicts the interior of the curved pieces with trocar retainers **106** arching over, and indentations **112** dipping beneath the longitudinal troughs **104**.

Figure 3 shows the elastically curved legs **124** resiliently straightened to fit the trocar retainers **106** into the indentations **112**.

Figure 4 indicates sliding of the ring **107** over the straightened legs **124** to restrain the neck **116** of the tack fastener **144**. The joined troughs **104** form a lumen **104**.

5 Figure 5 shows elastic opening of the curved legs **124** with the tightly fitted ring **107** holding the assembled tack fastener **144**.

Figure 6 depicts a trocar **103** inserted into the lumen **104** of the tack fastener **144**. A compressive sleeve **109** is loosely fitted over the trocar **103**, positioned to press the tack fastener **144** into tissue.

10 Figure 7 shows a side view of the trocar **103** inserted into the lumen **104** through both trocar retainers **106** to keep the resilient legs **124** from spreading open.

Figure 8 depicts puncturing of the trocar **103** through a torn ligament **138** into bone **118**, followed by compressive sleeve **109** pressing the tack fastener **144** into bone **188**.

15 Figure 9 shows tacking of the torn ligament **138** by pressing the tack fastener **144** into the bleeding cancellous bone **118**.

Figure 10 depicts trocar **103** withdrawal and elastic opening of the legs **124** to laterally press and fasten the gripping elements **113** into the porous bone **118**.

Figure 11 shows an expandable tack fastener **144** with tack grips **108** on the underside of the head **101** to improve gripping power upon the ligament **138** or tacked tissue.

20 Figure 12 shows another three-piece assembled screw fastener **284** with self-tapping thread functioning as the gripping elements **113**. The cross section of the head **101** is shown in Figure 13.

Figure 13 depicts the adjoining surfaces of the top and bottom pieces containing tongues **168** and grooves **169** with a Phillips cross-slot **228** on the screw head **101**.

25 Figure 14 shows the fit between the tongues **168** and grooves **169** to prevent twisting between the top and bottom pieces during tightening of the screw fastener **284**. The lumen **104** is extended into the screw fastener **284** from the bottom of the Phillips slot **228**.

Figure 15 shows a trocar **103** protruding from the tip of a Phillips screwdriver **133**.

Figure 16 shows the trocar **103** inserted through the screw fastener **284**, binding the trocar retainers **106** together to keep the legs **124** from resiliently opening.

Figure 17 depicts a bulging disc **100** impinging upon a nerve root **194**.

Figure 18 shows the screw fastener **284** holding a disc compressor **111** while
5 advancing into the bulging disc **100**.

Figure 19 shows bulge compression by the disc compressor **111** as the screw fastener **284** advances into the disc **100**.

Figure 20 depicts medial repositioning of the disc compressor **111** toward the neuroforamen after initial bulge compression.

10 Figure 21 shows further advancement of the screw fastener **284** into the disc **100** by pressing in a large section of bulging anulus to free the nerve **194** from impingement.

Figure 22 depicts anchoring of the open legs **124** in the distal anulus to fasten the proximal bulge following withdrawal of the trocar **103** and driver **133**.

Figure 23 shows another three-piece fastener **284** with a threaded portion **161**
15 attachment and a nut **101**.

Figure 24 shows the assembled fastener **284** tightened by the nut **101** over the threaded portion **161**.

Figure 25 depicts a socket **189** and a trocar **103** protruding from the tip of a socket driver **133**.

20 Figure 26 shows trocar **103** inserted through the lumen **104** holding both retainers **106**, shown in Figure 24, to keep the legs **124** from resiliently spreading apart.

Figure 27 shows the screw fasteners **284** with threaded portion **161** being used as pedicle screws in the vertebral body **159**.

Figure 28 shows a cross section of the screw fastener **284** with matching tongues **168**
25 and grooves **169** on the adjoining surfaces.

Figure 29 shows engagement of the tongues **168** and grooves **169** bridging the adjoining surfaces to prevent twisting of the legs **124** during advancement into bone.

Figure 30 shows a three piece screw fastener **284** with curved legs **124** containing tongues **168** and grooves **169**.

Figure 31 shows the legs **124** of the screw fastener **284**, shown in Figure 30, glued and bound by a water degradable adhesive.

Figure 32 shows that the legs **124** of the screw fastener **284**, shown in Figure 30, are externally tied or bound with degradable sutures **122** or band.

5 Figure 33 depicts a counter-gripping fastener **285** with four elastic legs **124** resiliently straightened by a trocar **103**.

Figure 34 depicts a mid-longitudinal view of the fastener **285**, as shown in Figure 33, with the trocar **103** linking the retainers **106** to keep the elastic legs **124** from opening.

10 Figure 35 shows the elastically curved legs **124** of the counter-gripping fastener **285** with trocar retainers **106** sized and configured to fit into opposing indentations **112**.

Figure 36 indicates the assembly of the counter-gripping fastener **285**. The ring **107**, as shown in Figure 33, is used to cover and latch over the counter junction **120**.

Figure 37 depicts a portion of a meniscus **135** with a tear **139**.

15 Figure 38 shows bridging and fastening of the meniscal tear **139** by multiple counter-gripping fasteners **285**.

Figure 39 depicts a sleeve **279** extending from the distal end **280** of a compressive sleeve **109**.

Figure 40 shows the proximal legs **124** of the counter-gripping fastener **285** housed within the sleeve **279** to ease tissue insertion.

20 Figure 41 depicts puncturing of the sleeve **279** covered counter-gripping fastener **285** into a bulging disc **100**, spearheaded by the trocar **103**.

Figure 42 shows partial withdrawal of the needle **103** to open and fasten the distal legs **124** within the distal portion of the disc **100**.

25 Figure 43 depicts pushing of the bulging anulus using an outer sleeve **279** having an enlarged distal end **287**.

Figure 44 shows withdrawal of both needle **103** and compressive sleeve **109**, while compression of the distal end **287** continues, to open and fasten the proximal legs **124** within the compressed anulus.

30 Figure 45 depicts bulge fastening by the counter-gripping fastener **285** within the disc **100**, after retrieval of the outer sleeve **279**.

Figure 46 shows a counter-gripping fastener **285** with distal and proximal gripping elements **113** independently operated.

Figure 47 depicts binding of the distal legs **124** in a closed position by a trocar **103** having a step **165** covered by a compressive sleeve **109**.

5 Figure 48 depicts a sleeve **279** shielding and elastically compressing the proximal gripping elements **113** in a closed position.

Figure 49 shows penetration of the sleeve-covered-counter-gripping fastener **285** into a bulging disc **100**.

10 Figure 50 depicts withdrawal of the sleeve **279**, allowing the proximal gripping elements **113** to elastically open within and outside the anulus.

Figure 51 shows the stepped trocar **103** advancing the fastener **285** into the disc **100** and pushing the bulging layers of anulus inward by the proximal gripping elements **113**.

Figure 52 depicts bulge fastening with the counter-gripping fastener **285** by withdrawing the stepped trocar **103** while holding the compressive sleeve **109** stationary.

15 Then, the compressive sleeve **109** is also withdrawn.

Figure 53 shows a staple fastener **286** with two lumens **104** open from a bridge **175** through elastically curved legs **124** containing gripping elements **113**.

Figure 54 shows the ridges and supports at the underside **288** of the bridge **175** and the lumens **104** extending to the distal ends of the legs **124**.

20 Figure 55 depicts a double trocar **103** with semiconic tips **278** for inserting into the lumens **104** of the staple fastener **286**, as shown in Figure 53.

Figure 56 shows trocar **103** insertion by sliding the semiconic tips **278** against the inner wall of the legs **124** of the staple fastener **286**.

Figure 57 shows resilient straightening of the elastic legs **124** by the rigid trocars **103**.

25 Figure 58 shows the distal tip of a leg **124** and a protruding trocar **103**.

Figure 59 shows the interior side of the leg **124** with trocar **103** protruding beyond the tapered distal tip of the leg **124** of the staple fastener **286**.

Figure 60 shows a cross section of the leg **124** with a generally semi-circular lumen **104** and the outwardly facing rectangular gripping element **113**.

30 Figure 61 depicts a bulging and herniated disc **100** impinging upon a nerve **194**.

Figure 62 depicts the bulging layers of anulus and a channel of leaking nucleus pulposus **128**.

Figure 63 shows insertion of the double trocar **103** and delivery of the staple fastener **286** into the bulging and herniated intervertebral disc **100**.

5 Figure 64 depicts further insertion of the trocars **103** without exiting the disc **100**.

Figure 65 shows the compressive sleeve **109** pressing the bridge **175** and the bulge to advance the legs **124** of the staple fastener **286** by sliding over the trocars **103**.

Figure 66 depicts bulge fastening by withdrawing the trocars **104** to open and fasten the elastic legs **124** within the distal portion of the disc **100** while the compressive sleeve
10 **109** continues to press against the bridge **175** and the disc **100**.

Figure 67 shows the bulge compressed and fastened by the staple fastener **286**.

Figure 68 depicts the result of the fastened disc **100**: the bulging anulus is pressed in by the bridge **175** to alleviate nerve **194** impingement.

Figure 69 indicates a wide belt as a spine restricting device **282** to limit the mobility
15 of the repaired vertebral **159** segment and protect the staple fastener **286**.

Figure 70 shows posteriorly bulging disc **100** exposed after a laminotomy.

Figure 71 shows bulge compression and fastening by the bridge **175** of the staple fastener **286** to alleviate nerve **194** impingement.

Figure 72 shows normal bulging of a disc **100** responding to weight loading.

20 Figure 73 indicates a longitudinal cross-section of a normal vertebral segment responding to weight loading by bulging of the anular layers outward.

Figure 74 indicates diminishing nucleus pulposus **128** resulting in delamination of anulus within the degenerated disc **100**.

Figure 75 shows swaying of the vertebral **159** segment caused by the degenerated disc
25 **100**.

Figure 76 indicates intervertebral instability above the facet joint **129**.

Figure 77 indicates binding of the anular layers by the staple fastener **286** and restoring intervertebral stability to the repaired disc **100**.

Figure 78 shows binding or linking the anulus of the repaired disc **100** by the staple
30 fastener **286** to restore intervertebral stability.

Figure 79 indicates nerve **194** ingrowth into a degenerated disc **100**, transmitting painful sensation during intervertebral instability.

Figure 80 shows nerve **194** ingrowth into a degenerated disc **100**, transmitting painful sensations during bulging or bending of the annulus.

5 Figure 81 indicates atrophy of the ingrown nerve **194** due to prolonged compression of the staple fastener **286**.

Figure 82 shows a staple fastener **286** with inwardly curved legs **124**.

Figure 83 shows a staple fastener **286** with overlapping legs **124**.

10 Figure 84 depicts trocars **103** insertion by sliding the semiconic tips **278** against the external walls of the inwardly curved legs **124** of the staple fastener **286**.

Figure 85 shows resilient straightening of the inwardly curving legs **124** by the rigid trocars **103**.

Figure 86 depicts repair of a broken bone **118** with the inwardly curved legs **124** of the staple fastener **286**.

15 Figure 87 shows a one-piece elastically curved counter-gripping fastener **285** with a trough **104**, trocar retainers **106** and gripping elements **113**.

Figure 88 depicts the one-piece elastic fastener **285** being resiliently straightened by a trocar **103**, deliverable by a compressive sleeve **109**.

20 Figure 89 shows a side view of a three-piece resilient fastener **144**, similar to the one in Figure 1, containing a suture **122** through suture openings **235**.

Figure 90 shows the assembled fastener **144** containing the suture **122**.

Figure 91 shows a trocar **103** linking both trocar retainers **106** of the left and the right pieces to resiliently straighten the legs **124** of the fastener **144**.

25 Figure 92 depicts the leading trocar **103** and compression of the compressive sleeve **109** delivering the suture fastener **144** into a bleeding cancellous bone **118**.

Figure 93 depicts components of a suture counter-gripping fastener **285** containing four elastically curved legs **124** similar to the components shown in Figure 35.

Figure 94 depicts resilient straightening of the legs **124** of the suture fastener **285** by inserting a trocar **103** through the retainers **106** in preparation for delivery.

Figure 95 depicts a needle **103** leading the suture counter-gripping fastener **285** puncturing and bridging a meniscal tear **139**.

Figure 96 shows distal anchoring of the suture fastener **285** within the torn tissue by partial withdrawal of the needle **103** while the compressive sleeve **109** is held stationary
5 behind the suture fastener **285**.

Figure 97 depicts rejoining or approximating the torn portion with the main body of the meniscus **135** by pulling the suture **122**.

Figure 98 shows complete withdrawal of the needle **103** to open and fasten the proximal legs **124**. The compressive sleeve **109** is then also withdrawn to tightly fasten
10 the tear **139**. Excess suture **122** is then cut.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Although molding, casting or machining the expandable fastener as a single piece is possible, the expandable fasteners are assembled from individual parts to clarify the
15 mechanisms and functions. In addition, the parts can be made with different materials to enhance performances of the expandable fasteners. Figure 1 depicts a side view of the three components of the expandable tack fastener **144**. Two curved pieces or sections are made with elastic material containing generally semi-circular heads **101**, necks **116** and legs **124** with outward facing gripping elements **113** and longitudinal troughs **104** or
20 grooves in the interior sides. Figure 1 also shows pegs **117** protruding from the interior side of the right piece at the head **101** and neck **116** regions. In the interior side of the left piece, peg holes **110** are positioned, sized, and configured to fit the pegs **117**. On both interior sides of the right and left legs **124**, semi-cylindrical trocar retainers **106** or passages arch over the troughs **104**. Adjacent to the retainers **106**, indentations **112** or
25 recesses are sunken into the trough **104**. The indentation **112** on the right elastic piece is positioned, sized and configured to fit or house the retainer **106** on the left elastic piece and vice versa.

The inner dimension of a ring **107** or assembly retainer, as shown in Figure 1, is sized and configured to fit around the neck **116** region of the elastic pieces. Figure 2 depicts
30 the interior sides of the components with trocar retainers **106** arching over the

longitudinal troughs **104** adjacent to indentations **112** in the troughs **104**. The arching retainers **106** enclose over portions of the troughs **104** to fit a trocar **103**. The peg holes **110** on the left elastic piece are positioned, sized and configured to fit or house the pegs **117** on the right elastic piece.

Figure 3 shows assembly of the pegs **117** into the holes **110** by placing the interior sides of the left and right pieces together. Connection between the pegs **117** and holes **110** prevents slippage between the pieces and aligns the retainers **106** over the indentations **112**. By compressing or closing the elastic legs **124** with an external force, the trocar retainer **106** of the right piece fits into the indentation **112** of the left piece and vice versa. In the closed position, the legs **124** are resiliently joined or straightened; the two semi-cylindrical troughs **104** are also joined together to form a cylindrical lumen **104**. Furthermore in the closed position, the ring **107** can slide over the gripping elements **113** onto the neck **116**, as shown in Figure 4. Working in conjunction with the planted pegs **117**, the tightly fitted ring **107** on the neck **116** prevents separation between the left and right pieces and retains the pegs **117** within the holes **110** to secure the assembled tack fastener **144**. The head **101** and neck **116** regions can also be welded or glued together, without using the ring **107**. If the external force were released, the elastic legs **124** would spread out, reestablishing the open, curved, deployed or predisposed position, as shown in Figure 5.

With the external force still straightening the legs **124**, a trocar or a needle **103** is inserted into the lumen **104** from the head **101** and threaded through both retainers **106** and out past the distal ends of the legs **124**, as shown in Figures 6 and 7. Figure 7 shows a side view of the trocar **103** inserted into the lumen **104** through both trocar retainers **106** to restrict the elastically curved legs **124** from spreading open. In essence, the trocar **103** serves as a removable linkage holding or latching the trocar retainers **106** of the expandable tack fastener **144** in a closed, delivery or straightened position. To optimize resilient closure or straightening of the legs **124**, both retainers **106** are preferred to be located near the distal ends of the legs **124**, as shown in Figure 7. The retainers **106** are also preferred to be positioned adjacent to each other to minimize bending of the trocar **103** by the opening forces of the elastic legs **124**. Friction between the restrained

retainers **106** and trocar **103** keeps the tack fastener **144** from sliding off the trocar **103**. Beyond the distal ends of the closed legs **124**, the protruding sharp tip of the trocar **103** spearheads tissue puncturing. A compressive sleeve **109** is loosely fitted over the trocar **103** as part of the delivery device for pressing the expandable tack fastener **144** into
 5 tissue. For a small surgical field and uneven surgical surface, the underside of the head **101** of the expandable fastener **144** can be contoured to fit over the tissue to be fastened. To avoid rotation of the tack fastener **144** around the trocar **103** during delivery, the lumen **104** of the tack fastener **144** and cross section of the trocar **103** can also be made non-round to improve control and precision for delivery. Figure 7 also shows a torn and
 10 detached ligament **138** over a burred or decorticated cancellous bone **118**.

Figure 8 shows an initial trocar **103** puncture through a torn ligament **138** into bleeding cancellous bone **118**, followed by compression of the sleeve **109** to deliver the straightened legs **124** of the expandable tack fastener **144** through the ligament **138** into the cancellous bone **118**. Figure 9 shows tacking of the torn ligament **138** with the head
 15 **101** and securing of the legs **124** with gripping elements **113** into the bleeding cancellous bone **118**. As the trocar **103** is withdrawn while compression of the sleeve **109** continues, the trocar restrainers **106** are no longer linked or bound together. Thus the legs **124** resiliently or elastically open, pressing the gripping elements **113** outwardly to fasten onto the porous cancellous bone **118**, as shown in Figure 10. To prevent jamming between the
 20 retainer **106** and the indentation **112** or between the retainers **106**, which would hinder the legs **124** from opening after withdrawal of the trocar **103**, both distal and proximal ends of the retainers **106** are tapered, as shown in Figures 5 and 10. The compressive sleeve **109** is then withdrawn from the expanded tack fastener **144**. The outward anchoring of the gripping elements **113** is elastic and continuously embeds and fastens into the tissue.

25 The interface between the reattached ligament **138** and the bleeding bone **118** will likely formed an adhesion, thus favoring permanent ligament reattachment to bone **118**. Therefore, the expandable tack fastener **144** can be made with biodegradable material, which slowly degrades after the healing is complete. Figure 11 shows a tack fastener **144** with tack grips **108** at the underside of the head **101** to minimize movement of the tacked

tissue, perhaps improving the healing rate of the tacked ligament **138** or tissue. The shape of the head **101** can also be modified to fit over the fastened tissue.

Outward anchoring is most intense at the distal ends of the legs **124**, gradually decreasing toward the proximal ends to provide anchoring strength along the entire length of the legs **124** of the expandable tack fastener **144**. The anchoring or fastening space created in the tissue between the curved legs **124** of the tack fastener **144** is cone-shaped, large at the base and small toward the surface, as indicated in Figure 10. In essence, the legs **124** of the deployed tack fastener **144** elastically flare open to establish a cone-shaped anchoring space within the tissue. The formation of the conical space alone within tissue would oppose pull out. Combined with the fastening of the outward pressing gripping elements **113** against the tissue within the conical space, the anchoring strength is expected to be exceptionally high. The outwardly opening legs **124** of the expandable tack fastener **144** may be sufficient to anchor within osteoporotic bone or mushy tissue, whereas other anchors or suture may fail.

The tack fastener **144** may be able to be delivered without the sliding compressive sleeve **109**. When the resiliently straightened legs **124** are inserted into the tissue, the tightness of the insertion provides some restriction upon the straightened legs **124**, keeping the legs **124** together, as indicated in Figure 9. As a result, the friction between the trocar **103** and the retainers **106** substantially decreases, while the legs **124** are bound and surrounded by tissue. Furthermore, the gripping elements **113** of the legs **124** snag onto the tissue, allowing the trocar **103** to withdraw and dislodge the tack fastener **144**, possibly without holding the compressive sleeve **109** against the head **101**. The trocar **103** can be modified by adding a step with a larger diameter to prevent the fastener **144** from sliding up and provide compression against the head **101** of the tack fastener **144** during delivery. The trocar **103** can also contain markers to indicate depth of insertion or penetration.

The expandable tack fastener **144** can be shaped to function as an expandable screw. Figure 12 shows another assembled three-piece screw fastener **284** with self-tapping threading as gripping elements **113**. The screw fastener **284** also contains a lumen **104**, trocar retainers **106** and indentations **112** in the elastically curved legs **124**. The top of the head **101** contains a Phillips cross slot **228**. The interior surfaces of the separated

pieces have tongues **168** and grooves **169**, as shown in the top view in Figure 13, which prevent twisting between the pieces during tightening of the screw fastener **284**. Other types of slots **228** for advancing the screw fastener **284** are possible. Figure 14 shows the fit between the tongues **168** and grooves **169** held together by the ring **107**, as shown in

5 Figure 12. The lumen **104** extends from the bottom of the Phillips slot **228** to the distal end of the screw fastener **284**. Figure 15 shows a trocar **103** protruding from the tip of a Phillips screw driver **133**. The proximal end of the Phillips screw driver **133** contains screw thread **236** for tightening into a removable handle **174**. In Figure 16, the elastically curved legs **124** of the screw fastener **284** are straightened into a closed position. The

10 trocar **103** is inserted from the head **101** into the lumen **104**, through both trocar retainers **106** to restrict the legs **124** from elastically opening, then out through the distal end of the screw fastener **284**. Insertion of the trocar **103** also helps to guide and position the driver **133** into the Phillips slot **228** to advance the screw fastener **284**.

Figure 17 depicts a common nerve **194** impingement at the neuroforamen around the

15 facet joint **129**. Figure 18 shows the screw fastener **284** inserted through an elongated opening **165** of a disc compressor **111** and advanced into the bulging disc **100**. The disc compressor **111** is designed to allow lateral adjustment with the elongated opening **165** for the screw fastener **284**. For the comfort of the patient, the opening direction of the legs **124** is preferred to be in the plane of the disc **100**, rather than opening and pressing

20 toward the end plates **105** of vertebral bodies **159**. A marker **153** on the driver **133** is aligned with the opening gap of the screw fastener **284** to identify the direction of leg **124** expansion. Figure 19 shows advancement of the screw fastener **284** through the nucleus pulposus **128** into the distal annulus of the disc **100** to compress the bulge with the

compressor **111**. The bulge compression opens up the neuroforamen to allow lateral to

25 medial manipulation, positioning of the disc compressor **111** toward the neuroforamen, as shown in Figure 20. The screw fastener **284** is further advanced into the disc **100** to free the nerve **194** impingement by pressing in a large section of the bulging annulus, as shown in Figure 21. The trocar **103** with Phillips driver **133** is then withdrawn, allowing the

unrestricted legs **124** of the screw fastener **284** to resume their curvatures, pressing and

30 anchoring the gripping elements **113** into the relatively healthy and secured distal annulus,

as shown in Figure 22. As a result, the bulging annulus is compressed and fastened to alleviate nerve **194** impingement. The compression and fastening of the bulging annulus may also collapse and seal leaking channels of the viscous nucleus pulposus **128** that cause neural irritation. The disc compressor **111** and the screw fastener **284** can be made with biodegradable material to treat nerve **194** impingement. As the degenerated annulus is compressed and metabolized, concurrently new annulus is shaped and formed under the compressor **111**. After the disc **100** is healed, both the compressor **111** and screw fastener **284** then degrade to avoid possible device migration with time.

Figure 23 shows another screw fastener **284** having two elastically curved pieces with lumens **104**, retainers **106**, indentations **112**, gripping elements **113** and semicylindrical threaded proximal portions **161**. As the curved pieces join together, the threaded proximal portions **161** form a cylindrical threaded portion **161**. A nut with internal thread, sized to engage the cylindrical threaded portion **161**, is used as head **101** of the screw fastener **284**. Figure 24 shows the assembled screw fastener **284** tightened by the nut-like head **101** over the cylindrical threaded portion **161**. Figure 25 shows a socket **189** and a trocar **103** protruding from the tip of a socket driver **133**. The elastically curved legs **124** are resiliently straightened, prepared for trocar **103** insertion. Sequentially, the trocar **103** enters through the socket **189**, into the lumen **104** of the straightened fastener **284** and through the retainers **106** to bind the legs **124** in a straightened or closed position, and then protrudes out the distal end of the assembled fastener **284**. The trocar **103** insertion also guides the driver **133** to the socket **189** and the socket **189** over the nut-like head **101**, as shown in Figure 26.

The screw fastener **284** with the threaded proximal portion **161** attachment and round contour of the nut-like head **101** is designed to be used as a pedicle screw. In a closed position, the expandable screw fastener **284** is advanced into the vertebral body **159** with the socket **189** and driver **133**. The trocar **103**, socket **189** and driver **133** are then withdrawn to allow the legs **124** to resume the open position, pressing and fastening the gripping elements **113** into the vertebral body **159**, as shown in Figure 27. Additional instrumentation for spinal fusion will be attached to the threaded proximal portion **161**, then fastened with another nut, which will further secure the assembly of the screw

fastener **284** within the vertebral body **159**. Expandable fastening can be particularly useful in poor quality bone.

To prevent lateral slippage between the legs **124** of the screw fasteners **284**, as shown in Figures 12 and 24, during rotational tightening of the fastener **284** in the tissue, tongues **168** and grooves **169** can be incorporated longitudinally along both legs **124**. The longitudinally oriented tongues **168** and grooves **169** along the adjoining surfaces of the legs **124** are shown in cross-sectional view in Figure 28. In the closed position, the tongues **168** are entrenched in the grooves **169**, as shown in a cross-sectional view in Figure 29.

Expansion of the screw fastener **284** or spreading of the legs **124** can be controlled without the trocar **103**, lumen **103**, retainers **106** and indentations **112**. The interior sides or adjoining surfaces of the elastically curved legs **124**, as well as the heads **101** and necks **116**, contain matching tongues **168** and grooves **169**, as shown in Figure 30. The adjoining surfaces of the curved pieces are glued and bound with a water degradable or soluble adhesive, while the ring **107** retains the tongue **168** in the groove **169** at the head **101** and neck **116** regions to hold the screw fastener **284** together, as shown in Figure 31. Welding or gluing with a water insensitive adhesive can also join the heads **101** and necks **116** of the elastic pieces without using the ring **107**. After the screw fastener **284** is installed in tissue, the adhesive slowly degrades by blood serum, allowing the legs **124** of the fastener **284** to spread open and further fasten into tissue. The curved legs **124** can also be tied or bound together with degradable sutures **122**, as shown in Figure 32, or with other degradable material.

Expandable fastener can also approximate and repair torn tissue by counter fastening. Figure 33 depicts an elastic counter fastener **285** with four legs **124** resiliently straightened by a trocar **103** with a compressive sleeve **109**. Similar to the expandable tack fasteners **144** mentioned, each leg **124** contains an indentation **112** adjacent to a retainer **106** for linking onto the trocar **103**, as shown in a mid-longitudinal view in Figure 34. Figure 35 shows two major pieces forming four elastically curved legs **124** with the trocar retainers **106** positioned, sized and configured to fit and match the indentations **112** on the adjoining piece. Both the indentation **112** and retainer **106** are

preferred to be near the tip of each leg **124** to ensure adequate closure of the legs **124**.

The direction of the gripping elements **113** at the distal halves oppose the direction of the

elements **113** at the proximal halves of the counter-gripping fastener **285**. The gripping

elements **113** at the distal halves of the fastener **285** oppose pulling, while the gripping

5 elements **113** at the proximal halves oppose pushing. The distal and proximal groups of

gripping elements **113** are separated by a counter junction **120**. Within the counter

junction **120**, a retainer **106** is embedded in an indentation **112** like tongue and groove, as

shown in Figures 34 to 36. The two-piece elastic fastener **285** is then tied and fastened by

a ring **107** or a restricting member over the counter junction **120**, as shown in Figure 33,

10 to keep the retainer **106** in the indentation **112** and hold the mid-section of the counter-gripping fastener **285**.

The needle **103** and compressive sleeve **109** are used in conjunction to deliver and

deploy the counter-gripping fastener **285**. The needle **103** carrying the fastener **285**, as

shown in Figure 33, punctures into a torn tissue to deliver the distal half of the fastener

15 **285** through the tear **139**, and places the counter junction **120** at the tear **139**. In essence,

the counter-gripping fastener **285** is bridging the torn tissue, over the tear **139**. To deploy

the counter-gripping fastener **285**, the compressive sleeve **109** proximal to the fastener

285 is held stationary while the needle **103** is withdrawn. This allows the legs **124** to

curve outwardly, as shown in Figure 36, pressing the gripping elements **113** into tissue at

20 both distal and proximal sides of the tear **139**. Figure 37 depicts a portion of a meniscus

135 with a tear **139**. The fasteners **285** are delivered with counter junctions **120**

positioned at or near the tear **139** of the meniscus **135**. The needle **103** is then withdrawn

from the puncture site **121** to allow both the distal and proximal legs **124** to counter-

fasten the torn tissue, as shown in Figure 38. The counter-gripping fastener **285** is totally

25 hidden within the repaired meniscus **135** with no protrusion to scrape, scratch or damage

the delicate articular surface of the joint. Counter-fastening of the expandable fastener

285 is made possible by the opposing directions of the gripping elements **113** at the distal

and proximal portions of the fastener **285** to rejoin or approximate the torn tissue for

healing.

The counter fastener **285** may be able to be delivered without the sliding compressive sleeve **109**. As the resiliently straightened legs **124** are inserted into tissue, tightness of the insertion provides restriction upon the straightened legs **124**, keeping the legs **124** together. While the legs **124** are bound and surrounded by tissue, friction between the
 5 needle **103** and the retainers **106** substantially decreases. Furthermore, the gripping elements **113** of the legs **124** snag onto tissue, allowing the needle **103** to withdraw and dislodge the fastener **285** perhaps without holding the compressive sleeve **109** over the proximal end of the fastener **285** during needle **103** withdrawal. The needle **103** can be modified with a step, formed by an enlarged diameter, to provide compression onto the
 10 fastener **285** during delivery without the compressive sleeve **109**. The needle **103** can also contain markers to indicate depth of penetration.

During tissue puncturing, the proximal gripping elements **113** of the counter-gripping fastener **285** may snag onto the tissue. Therefore, a sleeve **279** can be used to cover the proximal legs **124**, shielding the gripping elements **113** from tissue snagging during
 15 insertion. The sleeve **279** can be an extension from the distal end **280** of the compressive sleeve **109**, as shown in Figure 39. To ease tissue insertion, the proximal legs **124** of the counter-gripping fastener **285** are housed within the sleeve **279** above the distal end **280** of the compressive sleeve **109**, as shown in Figure 40.

The counter-gripping fastener **285** can be used to repair a bulging disc **100**. The
 20 sleeve **279** covered fastener **285**, as shown in Figure 40, is spearheaded by the trocar **103** as it punctures into the bulging annulus of the disc **100**, as indicated in Figure 41. The trocar **103** is partially withdrawn, allowing the distal legs **124** of the fastener **285** to open and anchor into the distal portion of the disc **100**, as shown in Figure 42. The bulging annulus is pressed inward by an outer sleeve **279** with an enlarged distal surface **287**, as
 25 shown in Figure 43, or with another instrument. While the outer sleeve **279** continues to press against the bulge, the compressive sleeve **109** then trocar **103** are withdrawn, allowing the proximal legs **124** to open, pressing the gripping elements **113** into layers of the compressed annulus, as indicated in Figure 44. The compressed annulus is fastened or anchored by a series of gripping elements **113**, holding the annulus in a non-impinging
 30 position even after compression of the outer sleeve **279** is withdrawn, as shown in Figure

45. The counter-gripping fastener **285** is totally hidden within the repaired disc **100** with no protrusion to impinge the nerve **194**. Migration of the fastener **285** is expected to be greatly minimized by the counter-gripping mechanism of the elements **113** and opening of both distal and proximal legs **124**. Furthermore, the counter-gripping elements can be made with degradable material, which lasts long enough to repair the disc **100**, then degrades.

The distal and proximal gripping elements **113** of a counter-gripping fastener **285** can be operated independently. The counter-gripping fastener **285** is also made with elastic material. The distal legs **124** of the fastener **285** are operated by a trocar **103** similar to that of the counter-gripping fastener **285** mentioned in Figure 34. The proximal gripping elements **113** are elastically flared outward at an angle less than ninety degrees to trap, snag, hook, snatch or grab the surrounding tissue, as shown in Figure 46. The proximal gripping elements **133** are also designed to be resiliently pressed inwardly into adjacent recesses **281**. A stepped trocar **103** is inserted through a lumen **104** to restrict or bind the elastic distal legs **124** from opening, as shown in Figure 47. The step **165** of the trocar **103** is for pushing and advancing the counter-gripping fastener **285**. A compressive sleeve **109** is positioned to slide over the stepped trocar **103**. A sleeve **279** with penetration markers is used to restrict or maintain the proximal-gripping elements **113** in closed positions, as shown in Figure 48. Spearheaded by the stepped trocar **103**, the counter-gripping fastener **285** is punctured into a bulging disc **100** with the sleeve **279** restricting and covering the proximal-gripping elements **113**, as shown in Figure 49. When a proper depth into the disc **100** has been reached, the sleeve **279** is withdrawn while the stepped trocar **103** is held stationary to open the proximal-gripping elements **113**. The first set of the elements **113** open between layers of the bulging anulus; and the second set of the gripping elements **113** open external to the bulging disc **100**, as shown in Figure 50. The counter-gripping fastener **285** is further advanced into the disc **100** by pushing the stepped trocar **103**. The first set of the opened elements **113** push against the inner layers of the bulging anulus toward the nucleus pulposus **128**, as shown in Figure 51. The second set of the gripping elements **113** push the outer layers of the bulging anulus inward, as the distal legs **124** advance toward the distal edge of the disc **100**. The

stepped trocar **103** is withdrawn while holding the proximal end of the counter-gripping fastener **285** stationary with the compressive sleeve **109**. The distal legs **124** elastically open, pressing the gripping elements **113** into the distal annulus of the disc **100** to counter fasten the inwardly compressed annulus with the proximal-gripping elements **113**, as
 5 shown in Figure 52. Then, the compressive sleeve **109** is withdrawn from holding the proximal end of the fastener **285**. As a result, nerve impingement is alleviated. The counter-gripping fastener **285**, delivery device and method can be used endoscopically for a minimally invasive repair.

It may be possible to withdraw the stepped trocar **103** without using the compressive
 10 sleeve **109**. When the resiliently straightened legs **124** of the counter-gripping fastener **285** are inserted into tissue, tightness of the insertion provides some restriction upon the straightened legs **124**, keeping the legs **124** together, as indicated in Figure 51. As a result, the friction between the trocar **103** and the retainers **106** is substantially decreased, while the legs **124** are bound and surrounded by the annulus. Furthermore, the gripping
 15 elements **113** of the legs **124** snag onto the tissue, which may allow the trocar **103** to withdraw and dislodge the fastener **285**.

The expandable fastener **286** can also be made like a staple with elastically curved legs **124** containing lumens **104** inside and gripping elements **113** outside, as shown in Figure 53. The rectangular gripping elements **113** are designed to embed and fasten into
 20 tissue by elastic compression of the legs **124** to maximize the anchoring strength. The legs **124** are joined proximally by a bridge **175** with lumens **104** open from the bridge **175** leading to the distal ends of the legs **124**. The bridge **175** contains tissue ingrowth openings **160** for securing or incorporating the staple fastener **286** into the fastened tissue. The inner surface **288** of the bridge **175** can be made smooth with a round contour to
 25 compress or with spikes to anchor the fastened tissue. The inner surface **288** can also contain ridges to fortify the bridge **175** and legs **124** of the staple fastener **286**, as shown in Figure 54. Figure 55 depicts a double trocar **103**, sized and configured for insertion into the lumens **104** of the staple fastener **286**, as shown in Figure 53. To facilitate insertion and straightening of the elastically curved legs **124**, the double trocar **103** is
 30 generally semicylindrical, tapered to semiconical **278** distal tips. During double trocar

103 insertion, the semicones **278** slide and glide along the inner walls of the legs **124** to avoid puncturing and snagging within the elastically curved legs **124** of the staple fastener **286**, as shown in Figure 56. The inner walls of the curved legs **124** serve as trocar retainers **289** to restrain the elastic legs **124** from bending outwardly. In essence, the rounded sides of the distal ends of the trocars **103** facilitate insertion into the lumens **104** and straightening of the elastically curved legs **124**. Figure 57 shows lumen **104** insertion of the rigid double trocar **103** to straighten the elastic legs **124** from a curved to a generally parallel or straightened position. A compressive sleeve **109** is designed to fit and slide over the shaft of the double trocar **103**, also shown in Figures 55 and 57. The trocars **103** protrude beyond the distal tips of the legs **124** with the flat portion of the semicylindrical trocars **103** supporting the gripping elements **113** from beneath, as shown in Figure 58. The legs **124** of the staple fastener **286** are fortified by the double trocar **103** from within to prevent buckling or breakage during tissue insertion. The base **277** of the double trocar **103** and the distal end of the compressive sleeve **109** are sized and configured to fit and press against the bridge **175** of the staple fastener **286**. Figures 58 and 59 show the tapered distal end and retainer **289** of the leg **124** with the protruding semiconical **278** tip of the trocar **103** to facilitate or spearhead tissue insertion. The tapered ends and semi-circular cross section of the legs **124** and trocars **103** are designed to ease tissue puncture and reduce tissue trauma during delivery of the staple fastener **286**. Figure 60 shows a cross-sectional view of the leg **124** with a generally semi-circular lumen **104** forming a half-ring like trocar retainer **289** and a flat support for the rectangular gripping elements **113** at the outer surface.

The double trocar **103** and the staple fastener **286** fit like a hand in a glove to straighten, protect, puncture and deliver the staple fastener **286**. In summary, the double trocar **103** and the staple fastener **286** function as follows: (1) The semiconical **278** tips slide through the curved lumens **104**. (2) The rigid trocars **103** straighten the elastically curved legs **124**. (3) The trocars **103** fortify the legs **124** to prevent buckling or breakage during tissue insertion. (4) The exposed tips of the trocars **103** spearhead tissue insertion. (5) The base **277** of the double trocar **103** is positioned to press against the bridge **175** during tissue insertion.

The staple fastener **286** can be used to repair a bulging intervertebral disc **100**. Figure 61 shows a herniated disc **100** impinging upon a nerve **194**. Figure 62 shows a leaking channel of nucleus pulposus **128** within the bulging disc **100**. Figure 63 shows the double trocar **103** spearheading penetration with the resiliently straightened legs **124** of the staple fastener **286** into the bulging disc **100**. The curved base **277** of the double trocar **103**, as shown in Figures 55 and 57, are sized and configured to fit and press the bridge **175** against the bulging annulus, as shown in Figure 63. Due to major blood vessels located antero-lateral to the spine, the trocar **103** protrusion through the disc **100** can potentially rupture the blood vessels. Therefore, under fluoroscopic view or other imaging, advancement of the trocars **103** stops prior to exiting the disc **100**, as shown in Figure 64. The annular tissue distal to the distal ends of the legs **124** has already been punctured or carved open by the protruding tips of the sharp trocars **103** to allow further penetration by the tapered legs **124** of the staple fastener **286**. Similar to the base **277** of the double trocar **103**, the distal end of the compressive sleeve **109** is also sized and configured to conform to the shape of the bridge **175** for pressing against the staple fastener **286**. As the bridge **175** is pushed by the compressive sleeve **109**, the remaining bulging annulus is pressed into the disc **100**; and the legs **124** of the staple fastener **286** slide further along the double trocar **103** into the disc **100**, as shown in Figure 65. Since the distal ends of the legs **124** are relatively blunt, the risk of blood vessel puncturing beyond the disc **100** is avoided. While the compressive sleeve **109** continues to press against the bridge **175** and the bulge, the double trocar **103** is withdrawn to allow the legs **124** to resume the elastic curvatures, as shown in Figure 66. The degenerated annulus of the disc **100** is compressed and compacted. As a result, the leaking channel of the viscous nucleus pulposus **128** may also being compressed, narrowed or even sealed by the disc **100** fastening, as indicated in Figure 66. The curvatures are greatest at the distal halves of the legs **124**, pressing the gripping elements **113** into the relatively healthy and solid distal annular tissue to anchor and fasten the bulge, as shown in Figure 66. Due to the central location of the gel-like nucleus pulposus **128**, the legs **124** of the staple fastener **286** might be able to straddle the nucleus pulposus **128** to grip the sturdy annular tissue. Regardless, the outward curvatures of the legs **124** will press and anchor onto annulus

surrounding the nucleus pulposus **128**, as shown in Figure 66. The length, size and/or curvature of the legs **124** can be varied with complementing trocars **103** to fit the anchoring sites and maximize the fastening strength of the staple fastener **286**. Figure 67 depicts the result of the fastened disc **100** after withdrawal of the compressive sleeve **109**.

5 In Figure 68, the nerve **194** is lifted with a retractor **196** to show bulge compression by the bridge **175** of the staple fastener **286**, which alleviates neural impingement and/or seals herniation.

Intervertebral disc **100** fastening with the staple fastener **286** may interfere with lateral bending, extension and/or flexion movements of the vertebral segment. During the initial
10 two to six months after disc **100** fastening with the staple fastener **286**, the patients can be fitted with a wide belt **282** fastened by VELCRO™ **283** or a buckle to limit vertebral motion, as shown in Figure 69. Limiting vertebral motion can prevent possible damage to the anulus or the staple fastener **286**. After healing of the disc **100** and degradation of the staple fastener **286**, normal range of motion and activity can then be resumed. The
15 wide belt **282** can also be used by patients with other disc **100** fastening devices, such as the screw fastener **284** shown in Figure 22 or counter-gripping fasteners **285** shown in Figures 44 and 52.

For disc **100** bulging within the central zone behind the lamina of the vertebral body **159**, laminotomy is commonly performed to access the bulge, as shown in Figure 70.
20 Instead of performing a discectomy following the laminotomy, the bulging anulus is compressed and fastened by the bridge **175** of the staple fastener **286** to alleviate nerve **194** impingement, as shown in Figure 71.

Concurrent with metabolism of the degenerated anulus, healthy and non-bulging anulus is shaped and formed under the bridge **175** of the staple fastener **286**. The purpose
25 of the staple fastener **286** is to (1) fasten the bulge to alleviate nerve **194** impingement, (2) seal the leakage of nucleus pulposus **128**, (3) shape the newly forming anulus, and/or (4) degrade after healing of the disc **100**.

The rate of degradation of various parts of the staple fastener **286** may be quite different and significant in terms of safety and efficacy of the staple fastener **286**. Within
30 the generally avascular disc **100**, fluid exchange between the nucleus pulposus **128** and

the end plates **105** of the sandwiching vertebral bodies **159**, as shown in Figures 68 and 71, is quite limited. Therefore, the rate of hydrolysis/degradation of the legs **124** within the disc **100** is expected to be slower, perhaps much slower, than the rate of degradation of the bridge **175** located at the periphery of the disc **100**. In essence, bulge anchoring with the compressive gripping elements **113** on the legs **124** is expected to outlast the compression of the bridge **175** of the staple fastener **286**. It is unlikely to have erosion/degradation on both anchoring legs **124** causing the bridge **175** to break off and migrate into a nerve **194**. Even if both anchoring legs **124** degrade before the bridge **175**, the tissue ingrowth openings **160** on the bridge **175** are designed to trap or bind anular tissue, preventing detachment of the bridge **175** from the disc **100**. The legs **124** of the biodegradable fastener **144**, **284** or **286** can be coated with a water-repellent compound to reduce the rate of hydrolysis/degradation, thereby providing a durable anchoring support to the bridge **175** or head **101** of the fastener **144**, **284** or **286**.

The normal intervertebral disc **100** is designed to bulge slightly and resiliently to absorb the load upon the spine, as shown in Figure 72. Figure 73 indicates a mid-longitudinal view of the normal vertebral segment, responding to the weight from above by flexing the layers of anulus outward, resulting in normal bulging of the disc **100**. However, as the disc **100** degenerates, the internal support of the anular layers decreases, possibly corresponding to the diminishing water content of the nucleus pulposus **128**. Recent research confirms the possibility of anular defects due to dehydration of nucleus pulposus **128**. Studies show that anular unity is lost within cadaveric discs **100** with depleting nucleus pulposus **128**. In fact, the anular layers of degenerated discs **100** delaminate or separate from each other, as shown in Figure 74.

Unlike patients with identifiable nerve **194** impingement, most low back pain patients show no radiographic evidence of disc **100** bulging or bone impairment, but continuously have unidentifiable and nonspecific pain. Experts believe that some of these patients may suffer from unstable motion segments (vertebral body-disc-vertebral body) caused by degenerated discs **100**. The unstable movement is called segmental instability. Segmental instability resembles an out-of-control car riding on a flat or partially deflated tire with unsupported sidewalls. The disc **100** with partially dried nucleus pulposus **128**

is similar to the partially deflated tire. A routine vertebral motion could start swaying of the degenerative segment, as shown in Figure 75. The excessive movement from swaying of the motion segment causes irritation, inflammation, strain and pain in surrounding ligaments and facet joints **129**, as indicated in Figure 76. Treatment
 5 recommended for segmental instability is mostly rest and drug therapy, including analgesics, anti-inflammatory agents, oral steroids, muscle relaxants and/or antidepressants.

Expandable fasteners **284**, **285** and/or **286** and methods used to fasten bulges, as shown in Figures 22, 45, 52, 67 and/or 71 can also be used to minimize segmental
 10 instability of the degenerated disc **100**. Bulge fastening using the expandable fasteners **284**, **285** and/or **286** is accomplished by compressing or restricting the anular layers of the degenerated disc **100**. Compression of the bridge **175** provides side support to the disc **100**, as shown in Figures 67 and 77. Similarly, the disc compressor **111** also provides side support to the disc **100**, as shown in Figure 22. Layers of anulus are linked, fastened,
 15 tied and/or unified by the anchoring legs **124** of the expandable fasteners **284**, **285** and/or **286** to promote rigidity and stability within the degenerated disc **100**, as shown in Figures 22, 45, 52, 67, 71, 77 and/or 78. Furthermore, insertion of the legs **124** of the expandable fasteners **284**, **285** and/or **286** also provides bulk and cushion within the disc **100** to reduce compressibility and instability of the degenerated disc **100**.

20 By adding bulk within the discs **100** and consolidating the bulging anulus, the expandable fasteners **284**, **285** and/or **286** in Figures 22, 45, 52, 67 and/or 71 may also thicken the degenerated discs **100** to alleviate nerve **194** impingement from spinal stenosis.

Chronically degenerated discs **100** can induce ingrowth of sinuvertebral nerves **194**
 25 into the anulus, emitting pain signals within the disc **100** during swaying, as shown in Figure 79, and bulging, as shown in Figure 80. Sinuvertebral nerves, which normally grow only on the surface, extend well into the disc **100** when it is degenerating. The staple fastener **286** in Figure 78, or the compressor **111** in Figure 22 can compress the sinuvertebral nerves **194** at the surface of the disc **100** causing the nerve **194** to atrophy,

thus ceasing or interrupting the signals of pain transmitted within the degenerated disc **100**.

The legs **124** of the staple fastener **286** can also be elastically and inwardly curved with lumens **104** opened into and through the curved legs **124**, as shown in Figure 82.

5 The inward curvature can be further intensified by overlapping the legs **124** and placing the legs **124** in different planes, as shown in Figure 83. The outwardly facing semicones **278** of the double trocar **103** straighten the inwardly curved legs **124**, as shown in Figure 84. During insertion of the trocars **103**, the semicones **278** slide and glide along the outer wall of the legs **124** to avoid puncturing and snagging within the elastically curved legs

10 **124** of the staple fastener **286**, as shown in Figure 84. The outer walls of the curved legs **124** serve as trocar retainers **289**, to restrain the elastic legs **124** from bending inwardly. Figure 85 shows straightening of the elastic legs **124** by the rigid trocars **103**, from a curved to a generally parallel position for delivery. In essence, the round or blunt sides of the tips of the double trocar **103** facilitate insertion into the lumens **104** and straightening

15 of the elastically curved legs **124**. The base **277** of the double trocar **103** is sized, shaped and configured to fit and compress the bridge **175** of the staple fastener **286**. Similar to the outwardly opening staple fastener **286**, the double trocar **103** protects, strengthens and delivers the inwardly opening staple fastener **286**. The sharp distal tips spearhead tissue puncturing, and the base **277** presses against the bridge **175** to drive the legs **124** of the

20 staple fastener **286** into tissue, such as broken bone **119**. As the resiliently straightened legs **124** insert into tissue, tightness of the insertion provides restriction upon the straightened legs **124**, keeping the legs **124** in a parallel position. As a result, the friction between the double trocar **103** and the retainers **289** substantially decreases, while the legs **124** are bound and surrounded by the tissue. Furthermore, the gripping elements **113**

25 of the legs **124** snag onto the tissue, allowing the double trocar **103** to withdraw and dislodge the staple fastener **286**. Therefore, the staple fastener **286** may be able to be delivered with or possibly without the compressive sleeve **109**. Figure 86 shows fastening of the broken bone **119** with the bridge **175** anchored externally and the gripping elements **113** internally onto cancellous bone **118** to hold the broken **139**

30 junction closed.

Elastic fastening provides superior anchoring strength to approximate torn **139** tissue. The legs **124** of the staple fastener **286** are delivered straight into the tissue with the bridge **175** pressing against the surface. As the double trocar **103** is withdrawn from the staple fastener **286**, the legs **124** resume the predisposed elastic curvatures to (1) press the gripping elements **113** into tissue, and (2) approximate the torn tissue **139** through elastic closure. As a result, the elastically fastened tissue is likely to provide no gap at the torn junction for proper and quick healing.

Multiple staple fasteners **286** can be made connected to each other, separated by perforations. The connected staple fasteners **286** form a strip, as the staples for papers, loading into a stapler equipped with double trocar. The strip of staple fasteners **286** is compressed by a spring in the stapler, positioning one staple fastener **286** at a time under the double trocar for delivery. In one downward stroke, the double trocar inserts into the lumens **104**, straightens the elastically curved legs **124**, breaks off the positioned staple fastener **286** from the strip, punctures into tissue and compresses the bridge **175** with the base to deliver the staple fastener **286**. As the resiliently straightened legs **124** insert into tissue, tightness of the insertion provides restriction upon the straightened legs **124**, keeping the legs **124** in a parallel position. While the parallel legs **124** are bound and surrounded by the tissue, the friction between the double trocar and the retainers **289** substantially decreases. Furthermore, the gripping elements **113** of the legs **124** snag onto tissue, allowing the double trocar to withdraw and dislodge the staple fastener **286**. The returned double trocar is ready to deliver another staple fastener **286** advanced by the spring in the stapler. To ensure proper dislodging of the fastener **286**, a compressive sleeve can also be used to hold the bridge **175** of the staple fastener **286** while the double trocar withdraws. The compressive sleeve can slide over the base of the double trocar. It is also possible to compress the staple fastener **286** with a plunger extending from the base of the double trocar. Operation of the double trocar, compressive sleeve or the plunger can be motorized, air-driven or manual.

The staple fasteners **286** can also be used to repair soft tissue. The degradable staple fastener **286**, as shown in Figures 83, 82 and/or 53, may be effective in treating pneumothorax of the punctured lung by sealing air leak into the pleural space.

Counter tissue fastening can also be accomplished with a one-piece elastically curved fastener **285** with a trough **104**, trocar retainers **106** and gripping elements **113**, as shown in Figure 87. In Figure 88, the one-piece elastic fastener **285** is resiliently straightened by a trocar **103** and ready to be delivered by a compressive sleeve **109**. The delivery of the one-piece fastener **285** is similar to the procedure used for the counter fastener **285** depicted in Figure 33.

The expandable tack fastener **144** can also be used as a suture fastener **144**. Components of a suture fastener **144** depicted in Figure 89 are slightly modified from the components of the tack fastener **144** mentioned in Figure 1. The modified tack fastener **144** contains openings **235** for passing a suture **122** and a small head **101**. The assembled suture fastener **144**, as shown in Figure 90, is in an open position with the elastic legs **124** spread apart. To deliver the suture fastener **144**, the elastically curved legs **124** are resiliently straightened with the retainers **106** positioned within the indentations **112**. The legs **124** are then held in the closed position by linking the retainers **106** with the trocar **103**, as shown in Figure 91. The suture fastener **144** is delivered into cancellous bone **118** by the trocar **103** and compressive sleeve **109**, as shown in Figure 92, to reattach a torn ligament **138**. The trocar **103** and compressive sleeve **109** are then withdrawn, allowing the elastic legs **124** to open and fasten within the bone **118**. The suture **122** is used to fasten and reattach the ligament on the cancellous bone **118**. The suture fastener **144** can also anchor in soft tissue, especially for minimally invasive or endoscopic surgery.

The counter fastener **285**, as shown in Figure 33, can also become a suture fastener **285** by attaching a suture **122**. Figure 93 depicts the components of a suture fastener **285**, similar to the one shown in Figure 35. A suture **122** is threaded through suture openings **235** of the counter fastener **285**. Joining of retainer **106** to indentation **112** serves as tongue and groove at the midsection of the suture counter fastener **285**. In the open position, the distal legs **124** compress and anchor the gripping elements **113** into tissue to resist pull out. The proximal legs **124** wedge open, trapping and anchoring tissue between the interior sides of the proximal legs **124**. Unlike tissue counter fastening, the gripping elements **113** on the proximal legs **124** are not crucial for suture **122** fastening.

The anchoring strength of the suture **122** is from the gripping elements **113** on the distal legs **124** and tissue wedged between the proximal legs **124**. A ring **107** or other restrictive means can be used to fasten the midsection of the elastic components. The tension of the suture **122** also holds the elastic pieces of the fastener **285** together. Figure

5 94 depicts resilient straightening of the elastic legs **124** of the suture fastener **285** by inserting a trocar **103** through the retainers **106** in preparation for delivery. Delivery of the suture fastener **285** is similar to that of the counter fastener **285**. Spearheaded by the trocar **103**, the suture fastener **285** punctures and enters into the tissue. Markers on the compressive sleeve **109**, as shown in Figure 94, indicate depth of tissue penetration.

10 When the proper depth is reached, the trocar **103** is withdrawn while the compressive sleeve **109** is held stationary to deploy the suture fastener **285** into tissue. The elastic and unrestricted legs **124** open and fasten within tissue, anchoring the suture **122** for various repairs.

Closure and healing of meniscal tears **139** are challenged by the pressure between

15 bones and lack of blood supply within most of the meniscus **135**. The meniscus **135** is the cartilaginous cushion between constantly rubbing condyles of the femur and tibia. Only the outer quarter to one-third of the meniscus **135** is vascularized with significant possibility of healing. After surgical repair, if a gap is created at the supposed closure by rubbing and/or pressure between the condyles, healing is unlikely and pain persists. Due

20 to the elastic curvatures of the counter-fastening legs **124**, the gripping elements **113** are pressed into the meniscal tissue **135** to provide superior fastening strength to secure and maintain the closure of the tear **139**. Unlike repair with suture or prior art devices, the counter-gripping fasteners **285** are totally concealed within the meniscus **135** to prevent scraping or scratching of the delicate articular cartilage of the condyles, which can lead to

25 irreversible damage to the joint. The counter-gripping fasteners **285** can be made with degradable material to approximate and heal the tear **139**, then degrade to avoid migration or potential exposure at the joint.

The attached suture **122** on the counter-gripping fastener **285** can also manipulate, reposition or tighten a repair. A counter-gripping fastener **285** with an attached suture

30 **122**, similar to the one in Figure 94, is used to puncture and bridge a meniscal tear **139**.

The counter junction **120** is positioned at the tear **139**, as shown in Figure 95. To anchor the distal legs **124** of the counter-gripping fastener **285**, the needle/trocar **103** is partially withdrawn while the compressive sleeve **109** is held stationary, as shown in Figure 96.

The distal legs **124** and the gripping elements **113** act as hooks anchoring into the torn portion of the meniscus **135**. By pulling the suture **122**, the torn portion anchored by the distal legs **124** of the fastener **285** rejoins the main body of the meniscus **135**, as shown in Figure 97. With constant tension on the suture **122**, the needle **103** then compressive sleeve **109** are withdrawn to anchor the proximal legs **124** within the main body of the meniscus **135** for a tight meniscal **135** repair, as shown in Figure 98. The suture **122** is preferred to be biodegradable and excess suture **122** is cut off.

In summary, the elastic legs **124** of the expandable fastener **144**, **284**, **285** or **286** are resiliently straightened by the trocars **103** during tissue insertion. The legs **124** are then allowed to curve after the withdrawal of the trocar **103**, pressing the gripping elements **113** laterally into the tissue for fastening. In the curved position, the elastic leg **124** can have more than one curvature. Location and degree of the curvature of the legs **124** of the fastener **144**, **284**, **285** or **286** can vary. Curvatures of the legs **124** can also be asymmetrical or not in mirror image to each other.

The curved position can also be called the predisposed, deployed or relaxed position of the fastener **144**, **284**, **285** or **286**. The straightened position can also be called the generally parallel, inserting, delivery, or installing position of the fastener **144**, **284**, **285** or **286**.

A wide range of materials can be used to fabricate the expandable fastener **144**, **284**, **285** or **286**. Biocompatible polymers, such as polypropylene, polyethylene, poly-ether-ether-ketone, acetal resin, polysulfone or polycarbonate are possible candidates. For biodegradable capability, the expandable fastener **144**, **284**, **285** or **286** can be made with polylactate, polyglycolic, poly(lactide-co-glycolide), polycaprolactone, trimethylene carbonate or combinations of these materials. Many of these degradable polymers are US FDA approved products. Other degradable polymers, such as polydioxanone, polyanhydride, trimethylene carbonate, poly-beta-hydroxybutyrate, polyhydroxyvalerate, poly-gama-ethyl-glutamate, poly(DTH iminocarbonate), poly(bisphenol A

iminocarbonate), poly-ortho-ester, polycyanoacrylate or polyphosphazene can also be used. For strength, durability and elasticity, nickel-titanium alloy or spring-tempered stainless steel can be used.

The expandable fastener **144, 284, 285** or **286** can also be coated with biocompatible
5 polymers, such as polyurethane, polytetrafluoroethylene, silicon, polyethylene or other material. For additional biological and surgical benefits, the expandable fastener **144, 284, 285** or **286** can also be coated with lubricant, growth factor, nutrient, buffering agent, collagen, hydroxyapatite, analgesic, sealant, blood clotting, antibiotic, water repellent, radiopaque or echogenic agents. All materials should be able to withstand
10 sterilization by gamma, electron beam, autoclave, ETO, plasma or UV light to prevent infection.

The trocar/needle **103** and compressive sleeve **109** can be made with stainless steel, titanium, nickel titanium other metal or alloy. The trocar/needle **103** and compressive sleeve **109** can be coated with lubricant, antibiotic, blood clotting, radiopaque or
15 echogenic agents. For hard-to-reach surgical sites, the trocar/needle **103** can be made curved to gain accessibility for the surgeon. To accommodate the curvature of the trocar/needle **103**, the compressive sleeve **109** can also be made with elastic material, such as nickel titanium, polypropylene, polyethylene or other flexible material.

The suture **122** can be permanent or biodegradable, braided or monofilament. The
20 suture **122** can also be metallic for strength and durability.

It is to be understood that the present invention is by no means limited to the particular constructions disclosed herein and/or shown in the drawings, but also includes any other modification, changes or equivalents within the scope of the claims. Many features have been listed with particular configurations, curvatures, options, and
25 embodiments. Any one or more of the features described may be added to or combined with any of the other embodiments or other standard devices to create alternate combinations and embodiments.

It should be clear to one skilled in the art that the current embodiments, materials, constructions, methods, tissues or incision sites are not the only uses for which the
30 invention may be used. It has been foreseen that the expandable fastener **144, 284, 285** or

286 and the trocar/needle **103** can be applied in other surgical and non-surgical purposes.

In fact, the expandable fastener **144**, **284**, **285** or **286** can be used to fasten pictures on walls or machine parts prone to loosening. Different materials, constructions, methods or designs for the expandable fastener **144**, **284**, **285** or **286**, trocar/needle **103** or the

5 compressive sleeve **109** can be substituted and used. Nothing in the preceding description should be taken to limit the scope of the present invention. The full scope of the invention is to be determined by the appended claims.

What is claimed is:

1. An expandable fastener deployable with a trocar, comprising:

a first leg formed of an elastic material and having a first retainer passage extending through at least a portion thereof, said first leg having a curved position and a

5 resiliently straightened position,

a first plurality of tissue gripping elements located on a concave side of said first leg when said first leg is in said curved position,

a second leg formed of an elastic material and having a second retainer passage extending through at least a portion thereof, said second leg having a curved
10 position and a resiliently straightened position,

a second plurality of tissue gripping elements located on a concave side of said second leg when said second leg is in said curved position,

wherein said first and second retainer passages are sized and configured to retain the trocar.

15

2. The expandable fastener of claim 1, further comprising a first head portion attached to a proximal end of said first leg and a second head portion attached to a proximal end of said second leg.

20 3. The expandable fastener of claim 2, wherein said first head portion has at least one alignment opening, and said second head portion has at least one alignment peg that extends into said at least one alignment opening.

4. The expandable fastener of claim 1, 2 or 3, further comprising a first groove in said
25 first leg and a second groove in said second leg, said first retainer passage enclosing a portion of said first groove and said second retainer passage enclosing a portion of said second groove.

5. The expandable fastener of claim 1, 2, 3 or 4, wherein
30 said first and second legs are connected by a bridge,

said first retainer passage extends from a proximal end to a distal end of said first leg,

and said second retainer passage extends from a proximal end to a distal end of said second leg.

5

6. The expandable fastener of any one of claims 1 to 5, wherein the trocar is located in said first and second retainer passages, thereby holding said first and second legs in said resiliently straightened positions.

10 7. The expandable fastener of claim 1, further comprising a retainer ring sized and configured to fit around both of said first and second legs.

8. An expandable fastener, comprising:

15 a first elastically curved section having a first head portion, a first leg portion extending from said first head portion, a first groove indenting along a length of said first head portion and said first leg portion, and a first passage covering a portion of said first groove,

20 a second elastically curved section having a second head portion, a second leg portion extending from said second head portion, a second groove indenting along a length of said second head portion and said second leg portion, and a second passage covering a portion of said second groove,

and a retainer ring sized and configured to fit around said first and second elastically curved sections.

25 9. The expandable fastener of claim 8, further comprising a plurality of tissue gripping elements extending from an outside surface of said first and second elastically curved sections.

30 10. The expandable fastener of claim 9, wherein said plurality of tissue gripping elements form rings around said expandable fastener along said outside surface.

11. The expandable fastener of claim 9 or 10, wherein said plurality of tissue gripping elements form threading along said outside surface.

5 12. The expandable fastener of claim 11, wherein said threading is configured as a self-tapping screw thread.

13. The expandable fastener of claim 11 or 12, wherein said tissue gripping elements are angled.

10

14. The expandable fastener of any one of claims 9 to 13, wherein said tissue gripping elements are barbs.

15 15. The expandable fastener of claim 14, wherein said tissue gripping elements are pointed in more than one direction.

16. The expandable fastener of any one of claims 9 to 13, wherein said tissue gripping elements are semi-circular ridges that extend from said outside surface of said first and second elastically curved sections.

20

17. The expandable fastener of any one of claims 8 to 16, further comprising a needle, said needle sized and configured to fit into said first and second grooves and said first and second passages.

25 18. The expandable fastener of any one of claims 8 to 16, wherein said first and second elastically curved sections may be resiliently straightened such that said first groove aligns with said second groove and a deployment needle may be located through said first and second grooves and said first and second passages, thereby holding said first and second elastically curved sections in straightened positions.

30

19. The expandable fastener of any one of claims 8 to 16, wherein:
a first distance is between a proximal end of said first and second curved sections,
a second distance is between a distal end of said first and second curved sections,
and wherein a curvature of said first curved section is configured such that said
5 second distance is larger than said first distance.
20. The expandable fastener of claim 19, wherein a curvature of said second curved
section is configured such that said second distance is larger than said first distance.
- 10 21. The expandable fastener of any one of claims 1 to 20, further comprising a suture
attached to said expandable fastener.
22. The expandable fastener of any one of claims 8 to 20, wherein said first elastically
curved section has a third groove indenting along said first leg portion and said second
15 elastically curved section has a mating tongue extending from said second leg portion.
23. The expandable fastener of any one of claims 4 to 6, 8 to 22, wherein said first and
second grooves are non semi-cylindrical.
- 20 24. The expandable fastener of any one of claims 1 to 23, wherein said passages are
cylindrical.
25. The expandable fastener of any one of claims 1 to 23, wherein said first and second
passages are D-shaped.
25
26. The expandable fastener of any one of claims 4 to 6, 8 to 25, wherein said first and
second grooves extend to an opening in a tip of said first and second elastically curved
sections such that a needle may extend out from said tip.

27. The expandable fastener of any one of claims 1 to 26, wherein said first and second legs are tapered.

28. The expandable fastener of any one of claims 7 to 27, wherein said retainer ring is tapered.

29. The expandable fastener of any one of claims 1 to 28, wherein said expandable fastener is formed of modular components.

30. The expandable fastener of any one of claims 1 to 29, wherein said expandable fastener is formed of one or more materials chosen from the group of materials consisting of biocompatible polymers, polypropylene, polyethylene, poly-ether-ether-ketone, acetal resin, polysulfone, polycarbonate, biodegradable materials, polylactate, polyglycolic, poly-lactide-co-glycolide, polycaprolactone, trimethylene carbonate, polydioxanone, polyanhydride, trimethylene carbonate, poly-beta-hydroxybutyrate, polyhydroxyvalerate, poly-gama-ethyl-glutamate, poly-DTH iminocarbonate, poly-bisphenol A iminocarbonate, poly-ortho-ester, polycyanoacrylate and polyphosphazene.

31. The expandable fastener of any one of claims 1 to 29, wherein said expandable fastener is formed of a material chosen from the group of materials consisting of nickel-titanium alloy and spring-tempered stainless steel.

32. The expandable fastener of any one of claims 1 to 31, further comprising a coating on an exterior surface of said expandable fastener.

33. The expandable fastener of claim 32, wherein said coating is chosen from the group of coatings consisting of biocompatible polymers, polyurethane, polytetrafluoroethylene, silicon, polyethylene, lubricant, growth factor, nutrient, buffering agent, collagen, hydroxyapatite, analgesic agent, sealant, blood clotting agent, antibiotic agent, water repellent agent, radiopaque agent and echogenic agent.

34. The expandable fastener of claim 2 or 8, wherein said first and second head portions have tissue gripping elements extending therefrom.

5 35. The expandable fastener of claim 2 or 8, wherein said first and second head portions form an opening for a screw driver.

36. The expandable fastener of claim 2 or 8, wherein said first and second head portions form a bolt-head shape.

10

37. The expandable fastener of any one of claims 2, 8, 35 or 36, wherein said first and second head portions further comprise at least one tissue ingrowth opening.

15 38. The expandable fastener of any one of claims 1 to 37, wherein a tissue-contacting surface located proximate said first and second legs is smooth.

39. The expandable fastener of any one of claims 4 to 20, wherein said first and second grooves extend through said first and second head portions.

20 40. The expandable fastener of claim 2 or 8, wherein said first and second head portions have threading and further comprising a nut sized and configured to rotate about said threading.

25 41. The expandable fastener of any one of claims 2 to 20, further comprising a third elastically curved section extending from said first head portion and a fourth elastically curved section extending from said second head portion.

42. The expandable fastener of claim 41, wherein said third and fourth elastically curved sections further comprising plurality of tissue gripping elements.

30

43. The expandable fastener of any one of claims 8 to 20, wherein said retainer ring is located around said first and second curved sections.

5 44. The expandable fastener of any one of claims 8 to 20, wherein said retainer ring is located around said first and second head portions.

45. The expandable fastener of any one of claims 8 to 20, further comprising at least one alignment opening located in said first curved section, and at least one alignment peg extending from said second curved section, said at least one alignment peg sized and
10 configured to fit within said at least one alignment opening.

46. The expandable fastener of claim 45, wherein said at least one alignment opening is located in said first head portion and said at least one alignment peg extends from said second head portion.

15

47. An expandable fastener, comprising:

a first elastically curved section having a first head portion, a first leg portion extending from said first head portion, at least one groove indenting along a length of said first head portion and said first leg portion,

20 a second elastically curved section having a second head portion, a second leg portion extending from said second head portion, at least one tongue extending along a length of said second head portion and said second leg portion, wherein said at least one tongue is sized and configured to fit in said at least one groove,

25 and a retainer ring sized and configured to fit around said first and second elastically curved sections.

48. The expandable fastener of claim 47, wherein said first and second elastically curved sections are held together with a water degradable adhesive.

30

49. The expandable fastener of claim 47, wherein said first and second elastically curved sections are held together with a water degradable band.

50. An expandable fastener for deployment with a needle, said expandable fastener
5 comprising:

a first leg having tissue gripping elements located on a concave surface thereof, said
first leg having a first curved position and a second resiliently straightened
position,

a second leg having tissue gripping elements located on a concave surface thereof,
10 said second leg having a first curved position and a second resiliently
straightened position,

a head portion located at an end of said first and second legs,

at least one passage extending through at least one of said first and second legs, said
at least one passage sized and configured to allow the needle to be located
15 therein,

wherein, when the needle is located within said at least one passage, at least one of
said first and second legs is held in said resiliently straightened position.

51. The expandable fastener of claim 50, wherein said expandable fastener is deployed
20 with a device having two needles, wherein said passage extends through said first leg,
said expandable fastener further comprising a second passage extending through said
second leg, said head portion connecting a proximal end of said first leg and a proximal
end of said second leg.

25 52. The expandable fastener of claim 51, wherein each of said passages has an opening
with a D-shaped cross section.

53. The expandable fastener of claim 52, wherein said first and second curved positions
are configured such that said first and second legs curve apart and rounded edges of said

D-shaped cross sections are located toward convex sides of curvatures of said first and second legs.

54. The expandable fastener of claim 52, wherein said first and second curved positions
5 are configured such that said first and second legs curve together and rounded edges of said D-shaped cross sections are located toward convex sides of curvatures of said first and second legs.

55. The expandable fastener of any one of claims 50 to 54, further comprising a retainer
10 ring located around said first and second legs proximate said head portion.

56. The expandable fastener of claim 55, wherein said retainer ring is tapered.

57. The expandable fastener of any one of claims 50 to 56, wherein said passage forms a
15 portion of a first groove extending the length of said first leg, said expandable fastener further comprising a second passage forming a portion of a second groove extending the length of said second leg, and wherein, when the needle is located within said first and second passages, said first and second legs are held together in said straightened positions.

20 58. The expandable fastener of claim 57, wherein said first groove has a first recess sized and configured to receive said second passage and wherein said second groove has a second recess sized and configured to receive said passage forming said portion of said first groove.

25 59. The expandable fastener of claim 57, wherein, when said first and second legs are in said straightened positions, the tissue gripping elements located on said first and second legs form rings around said legs.

60. The expandable fastener of claim 59, wherein said tissue gripping elements are angled, such that when said first and second legs are in said resiliently straightened positions, said tissue gripping elements simulate threading along an outer surface of said first and second legs.

5

61. The expandable fastener of claim 60, wherein said threading is configured as a self-tapping screw thread.

10

62. The expandable fastener of any one of claims 50 to 61, further comprising a suture attached to said expandable fastener.

63. The expandable fastener of any one of claims 50 to 56, wherein said first leg has a groove indenting along a length thereof and said second leg has a mating tongue extending therefrom.

15

64. The expandable fastener of any one of claims 50 to 56, further comprising at least one alignment opening indenting into said first leg and at least one alignment peg extending from said second leg.

20

65. The expandable fastener of claim 64, wherein said at least one alignment opening is a groove, and said at least one alignment peg is a tongue that extends into said groove.

66. The expandable fastener of any one of claims 50 to 56, wherein said at least one passage is a non-cylindrical shape.

25

67. The expandable fastener of any one of claims 50 to 56, wherein said at least one passage is cylindrical.

68. The expandable fastener of any one of claims 50 to 56, wherein said at least one passage extends to an opening in a tip of said at least one of said first and second legs such that the needle may extend out from said tip.

5 69. The expandable fastener of any one of claims 50 to 68, wherein said first and second legs are tapered.

70. The expandable fastener of any one of claims 50 to 58, wherein said tissue gripping elements are barbs.

10

71. The expandable fastener of claim 70, wherein said tissue gripping elements are pointed in more than one direction.

15 72. The expandable fastener of any one of claims 50 to 71, wherein said expandable fastener is formed of modular components.

73. The expandable fastener of any one of claims 50 to 72, wherein said fastener is formed of one or more materials chosen from the group of materials consisting of biocompatible polymers, polypropylene, polyethylene, poly-ether-ether-ketone, acetal
20 resin, polysulfone, polycarbonate, biodegradable materials, polylactate, polyglycolic, poly-lactide-co-glycolide, polycaprolactone, trimethylene carbonate, polydioxanone, polyanhydride, trimethylene carbonate, poly-beta-hydroxybutyrate, polyhydroxyvalerate, poly-gama-ethyl-glutamate, poly-DTH iminocarbonate, poly-bisphenol A iminocarbonate, poly-ortho-ester, polycyanoacrylate and polyphosphazene.

25

74. The expandable fastener of any one of claims 50 to 72, wherein said fastener is formed of a material chosen from the group of materials consisting of nickel-titanium alloy and spring-tempered stainless steel.

75. The expandable fastener of any one of claims 50 to 74, further comprising a coating on an exterior surface of said expandable fastener.

76. The expandable fastener of claim 75, wherein said coating is chosen from the group of coatings consisting of biocompatible polymers, polyurethane, polytetrafluoroethylene, silicon, polyethylene, lubricant, growth factor, nutrient, buffering agent, collagen, hydroxyapatite, analgesic agent, sealant, blood clotting agent, antibiotic agent, water repellent agent, radiopaque agent and echogenic agent.

77. The expandable fastener of any one of claims 50 to 56, wherein said head portion has tissue gripping elements extending therefrom.

78. The expandable fastener of claim 50, wherein said head portion forms an opening for a screw driver.

79. The expandable fastener of claim 50, wherein said head portion forms a bolt head shape.

80. The expandable fastener of any one of claims 50 to 56, wherein said head portion further comprises at least one tissue ingrowth opening.

81. The expandable fastener of any one of claims 50 to 56, wherein a tissue-contacting surface located proximate said first and second legs is smooth.

82. The expandable fastener of any one of claims 50 to 56, wherein said at least one passage opens through said head portion.

83. The expandable fastener of any one of claims 50 to 56, wherein said head portion has threading and further comprising a nut sized and configured to rotate about said threading.

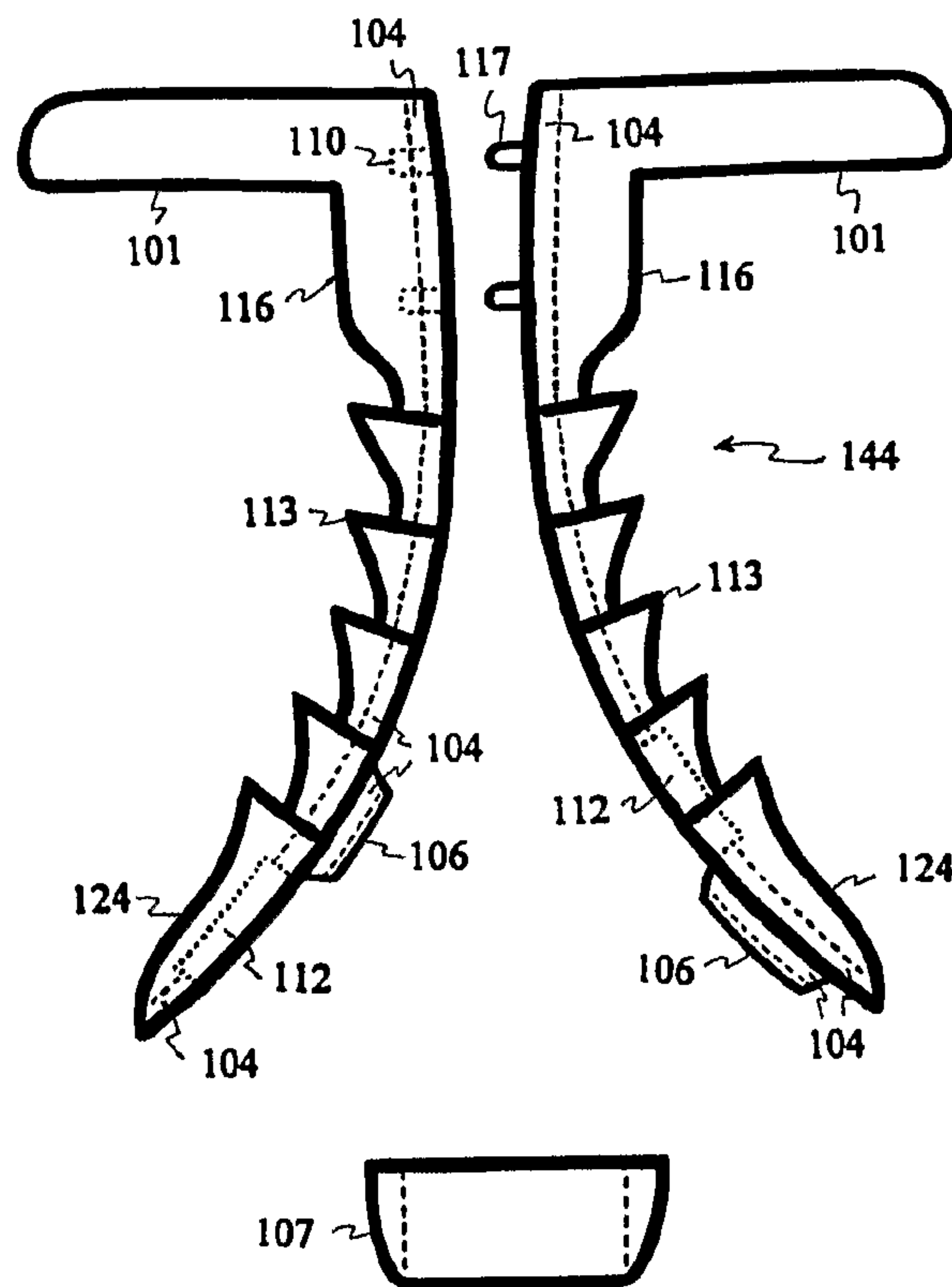


Figure 1

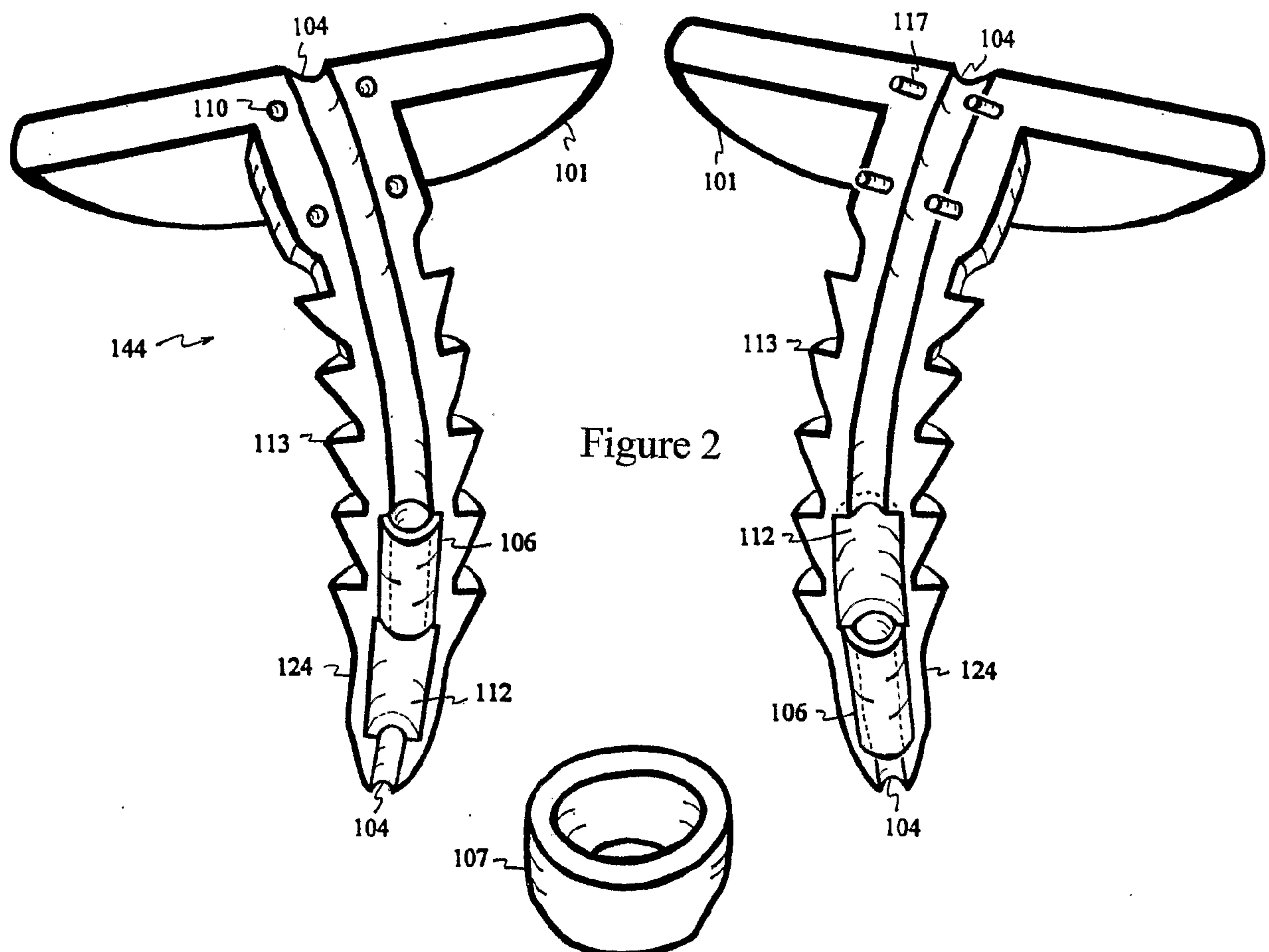


Figure 2

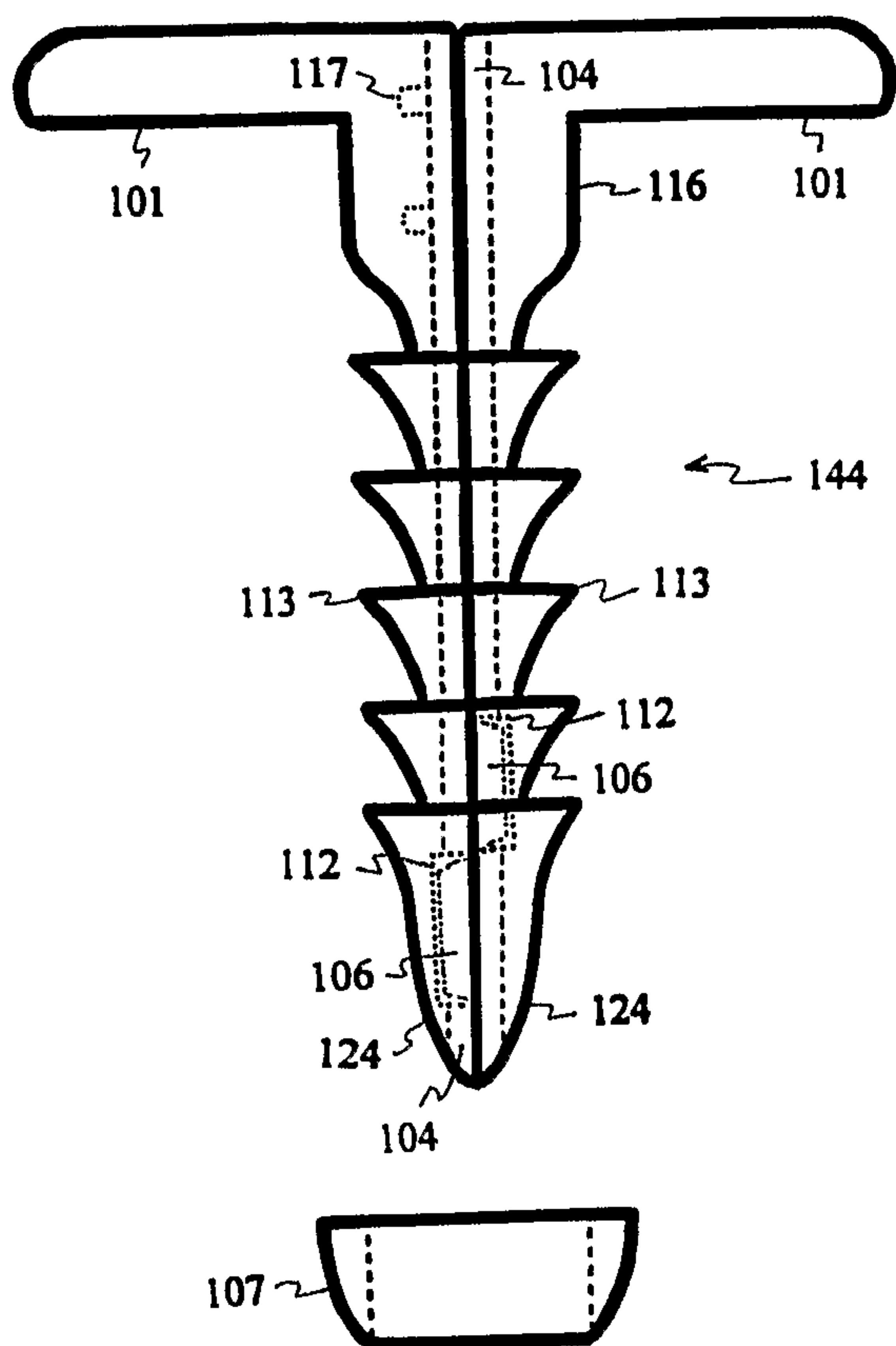


Figure 3

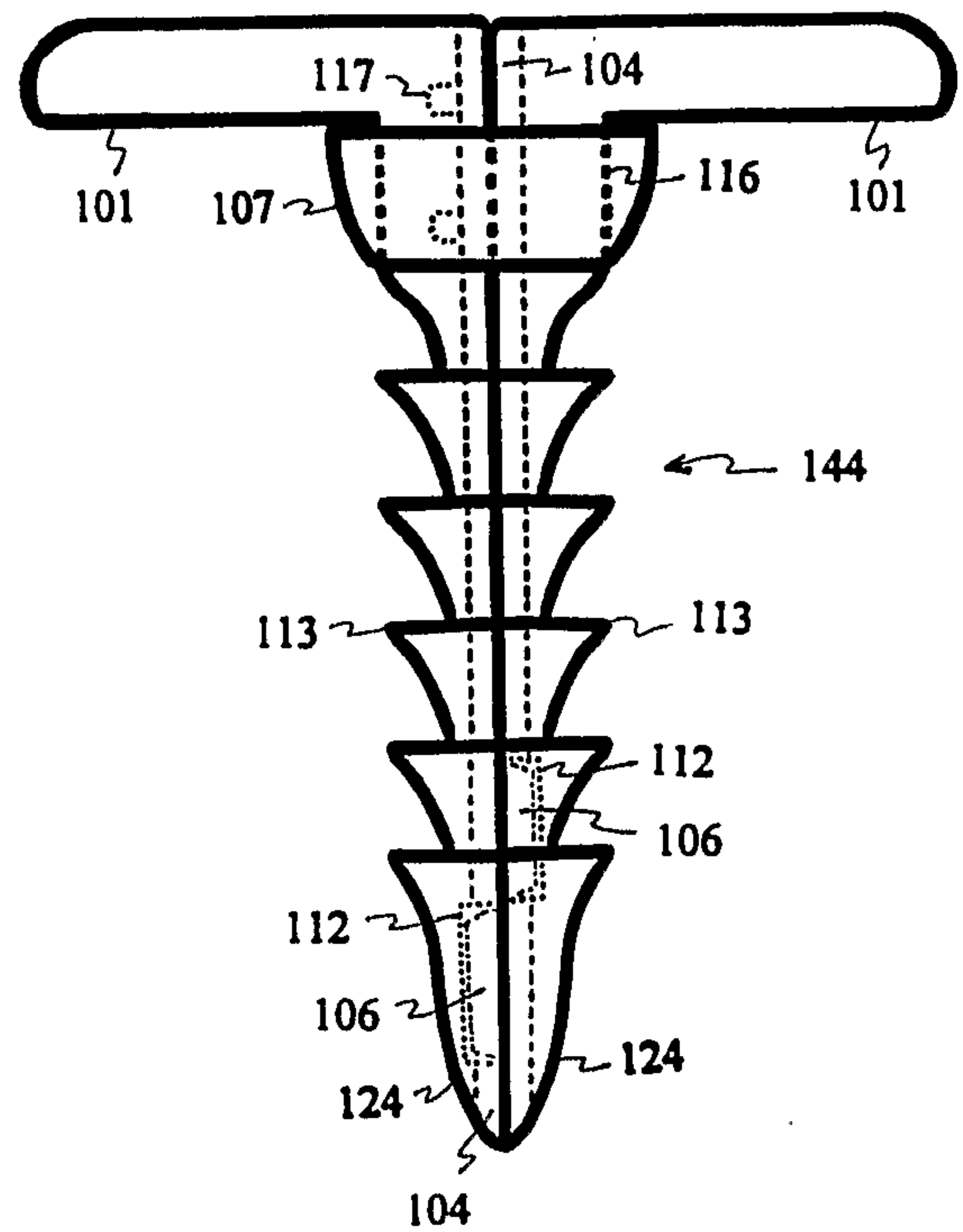
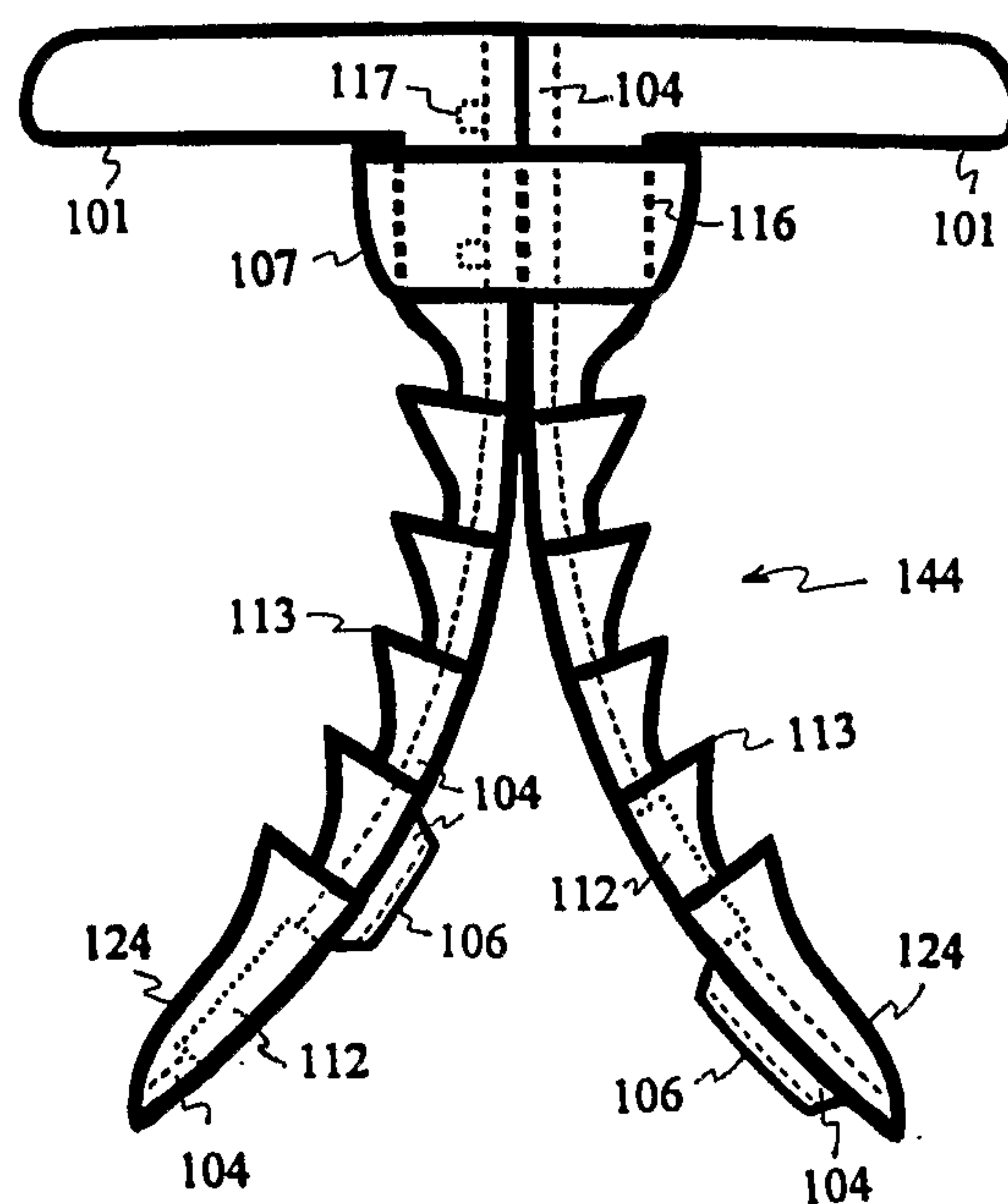


Figure 4

Figure 5



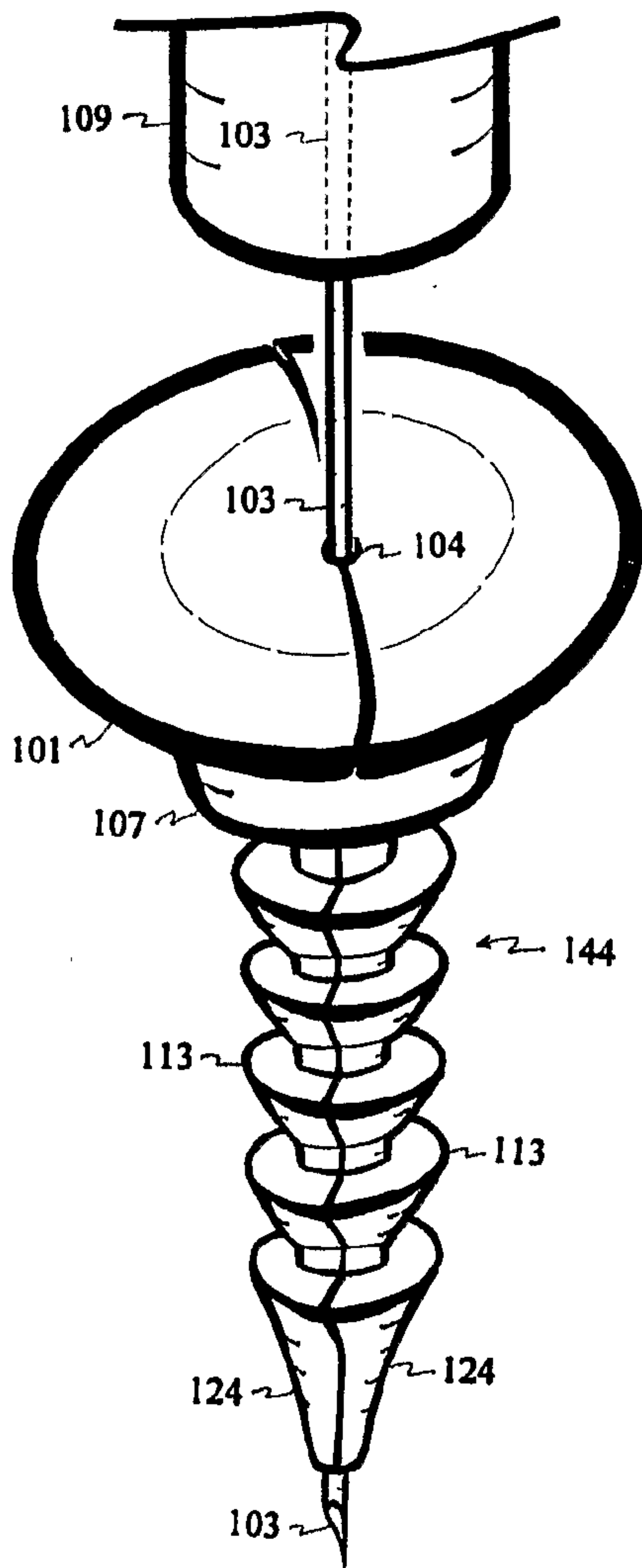


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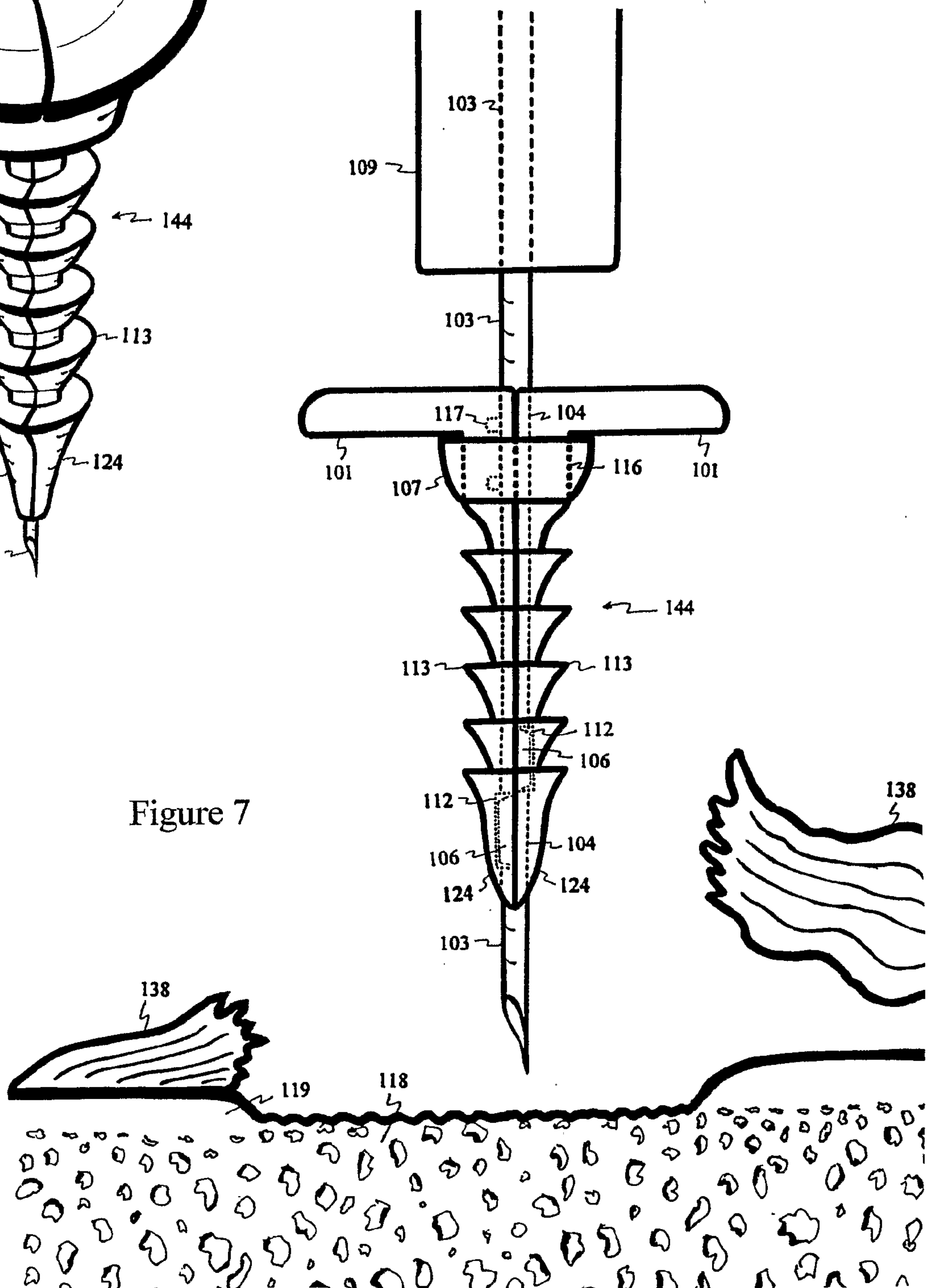
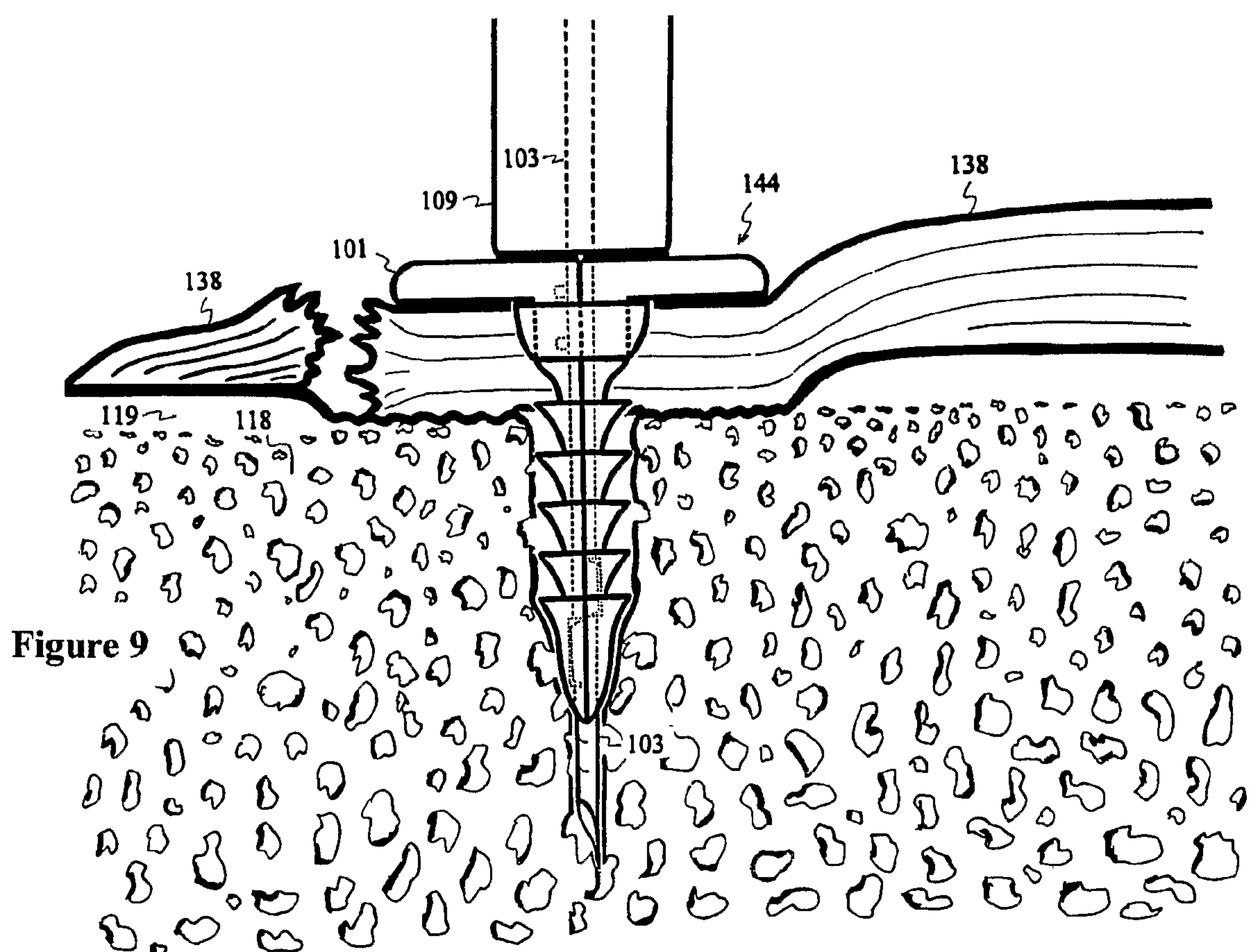
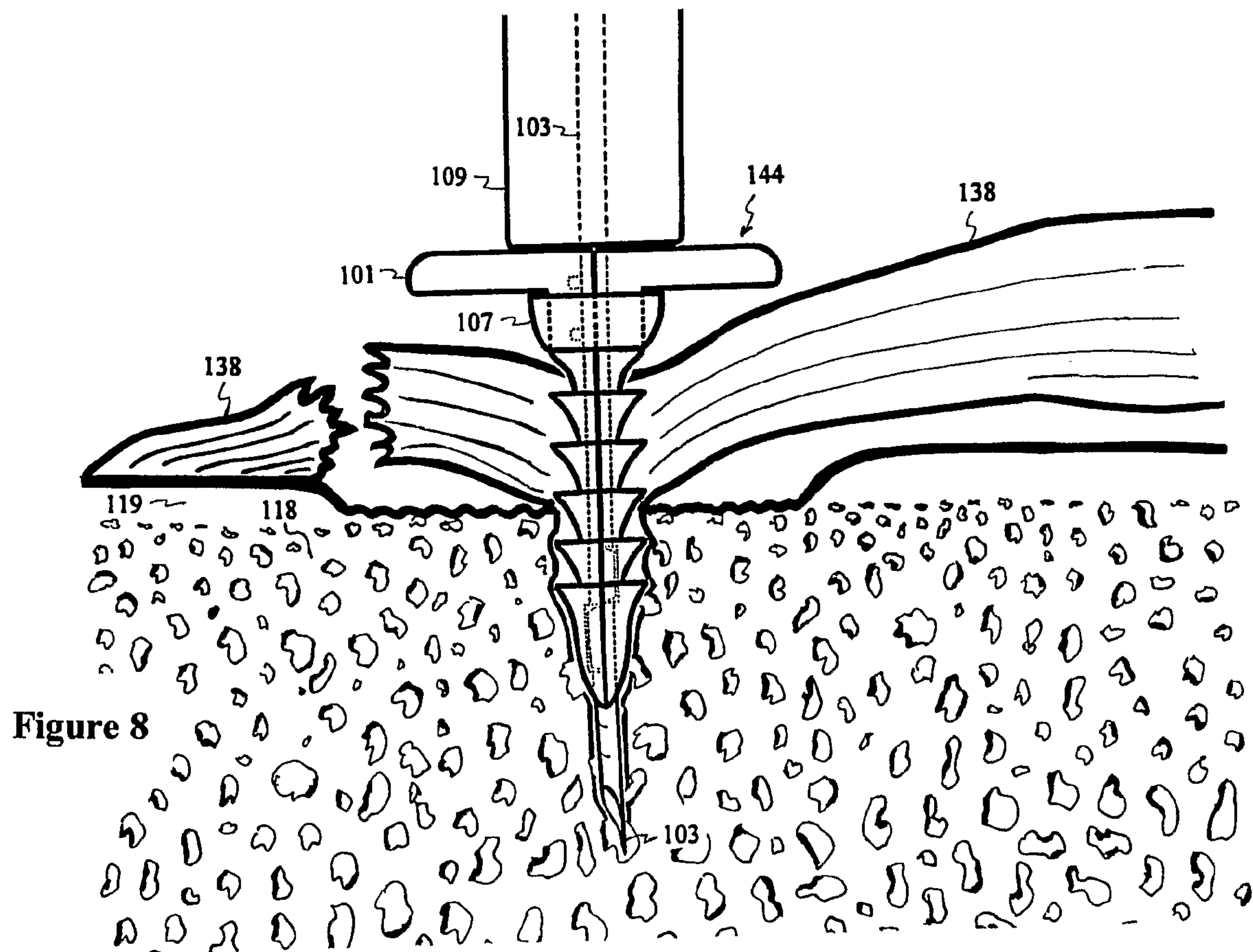


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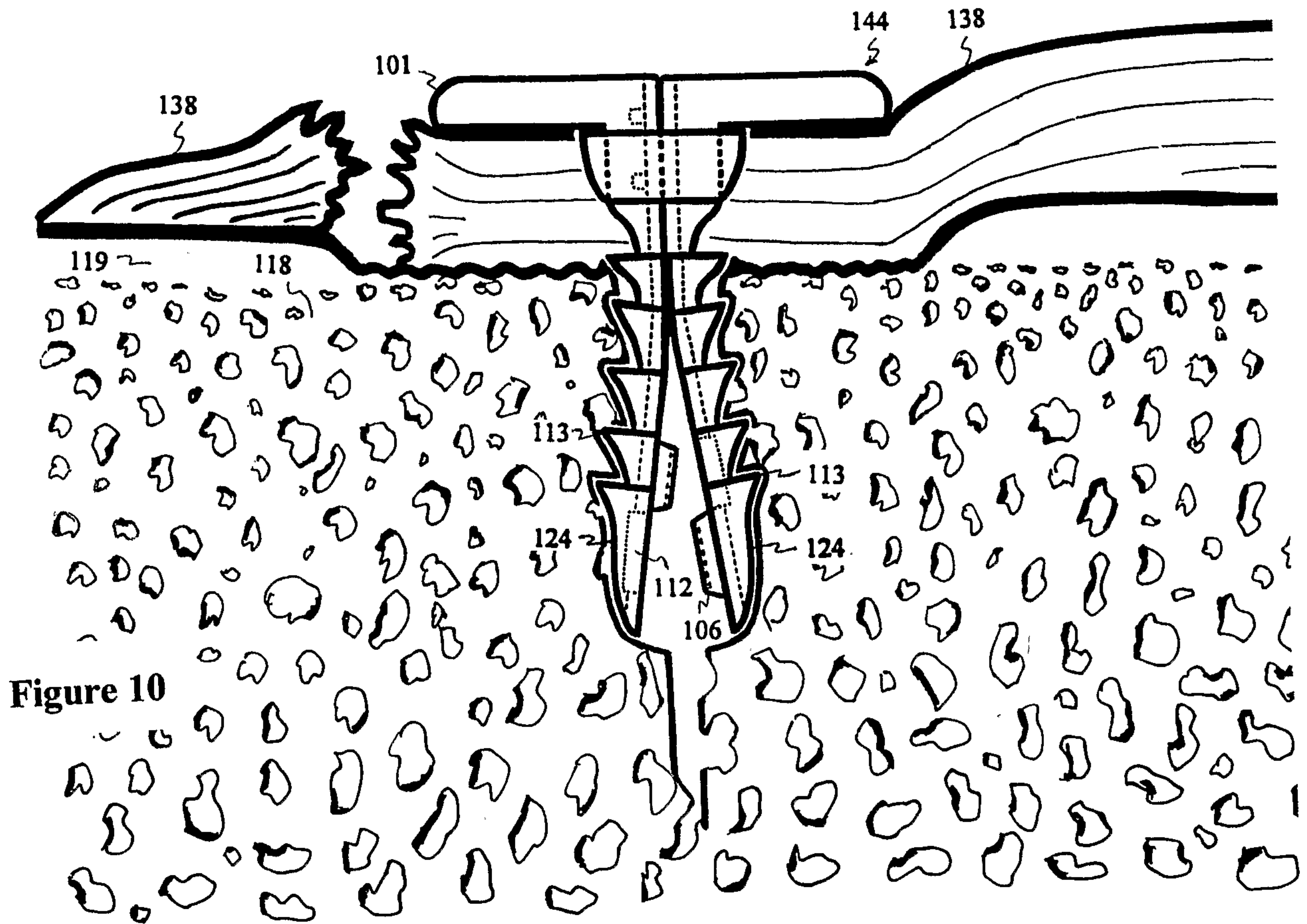


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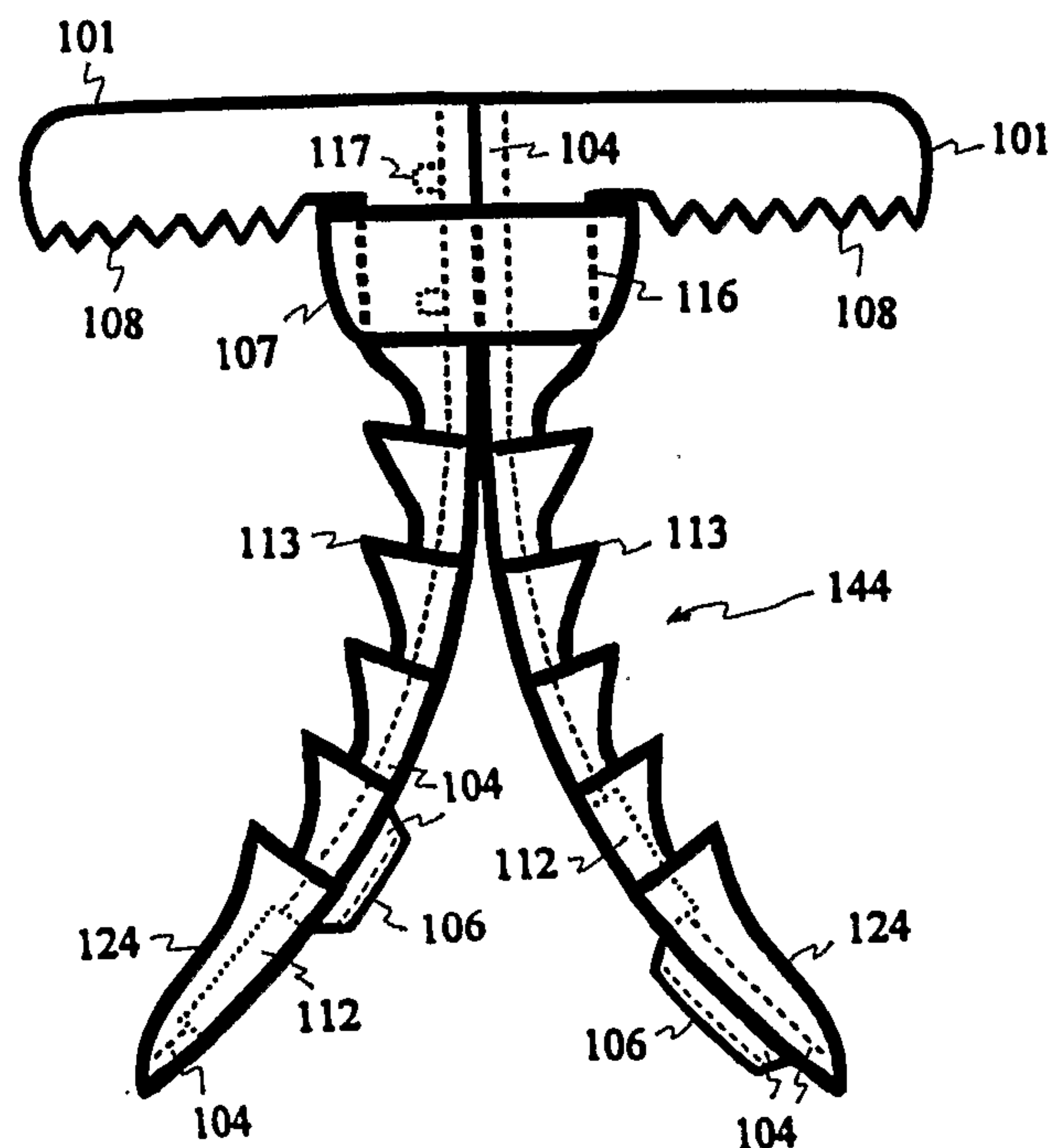


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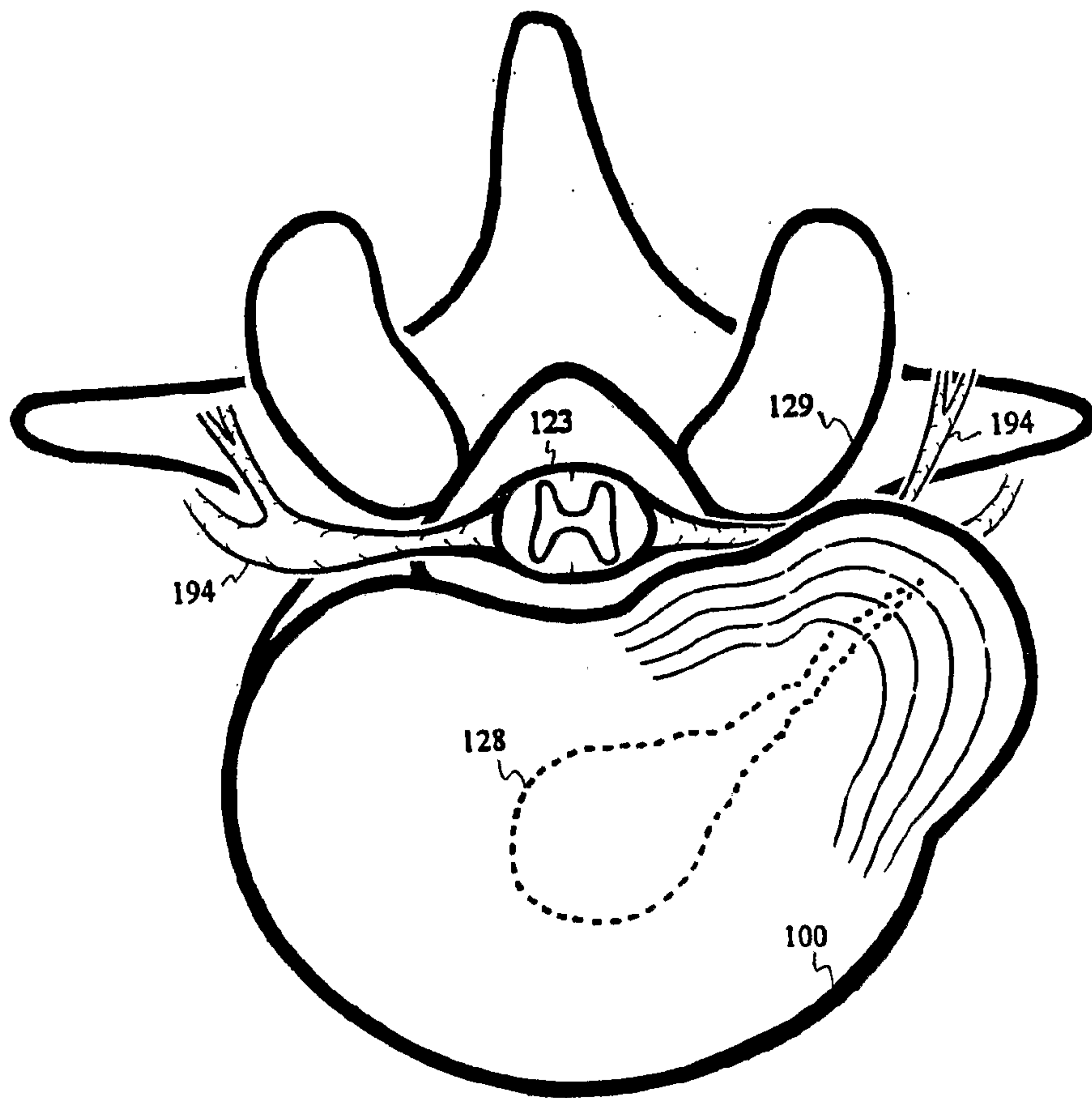


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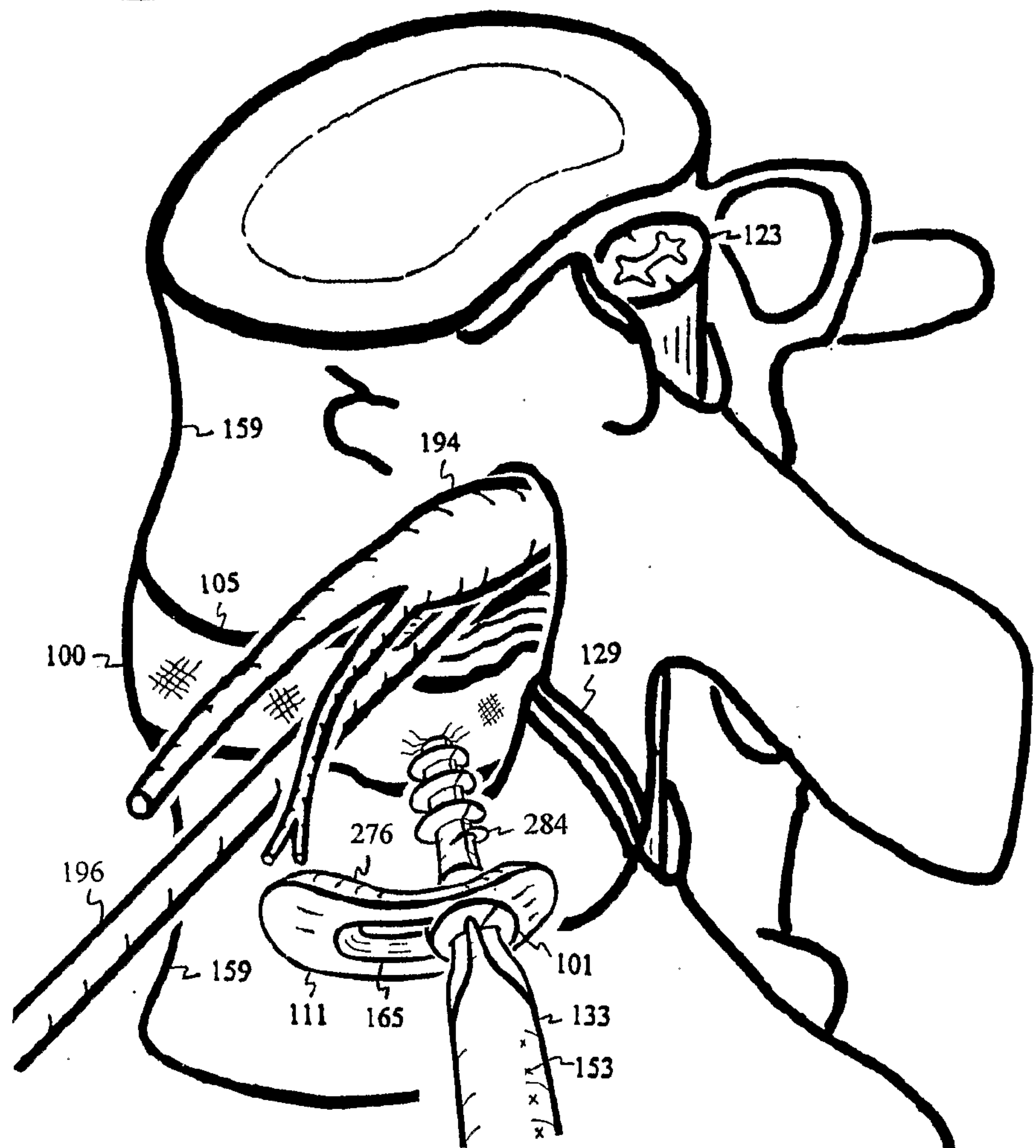


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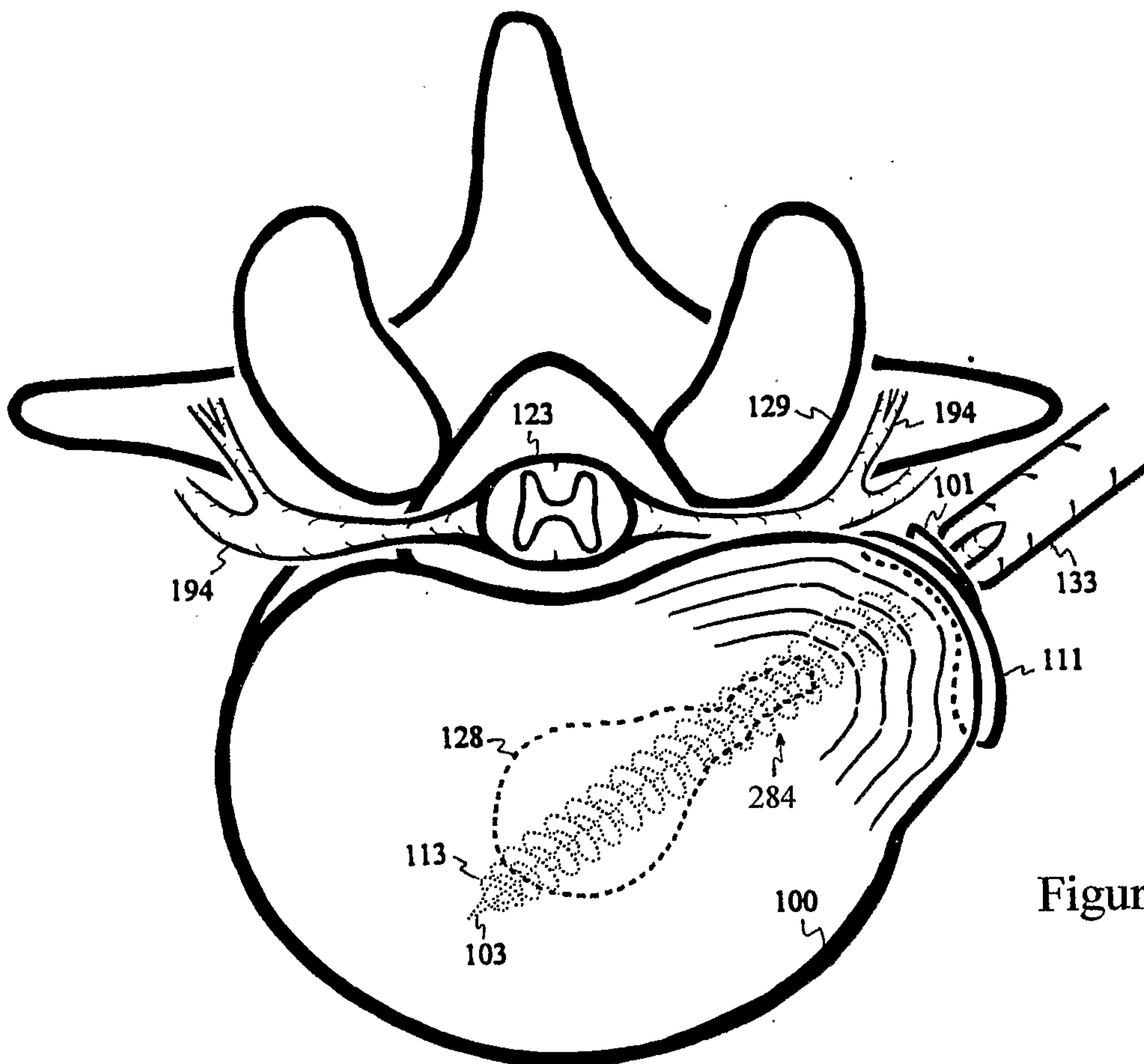


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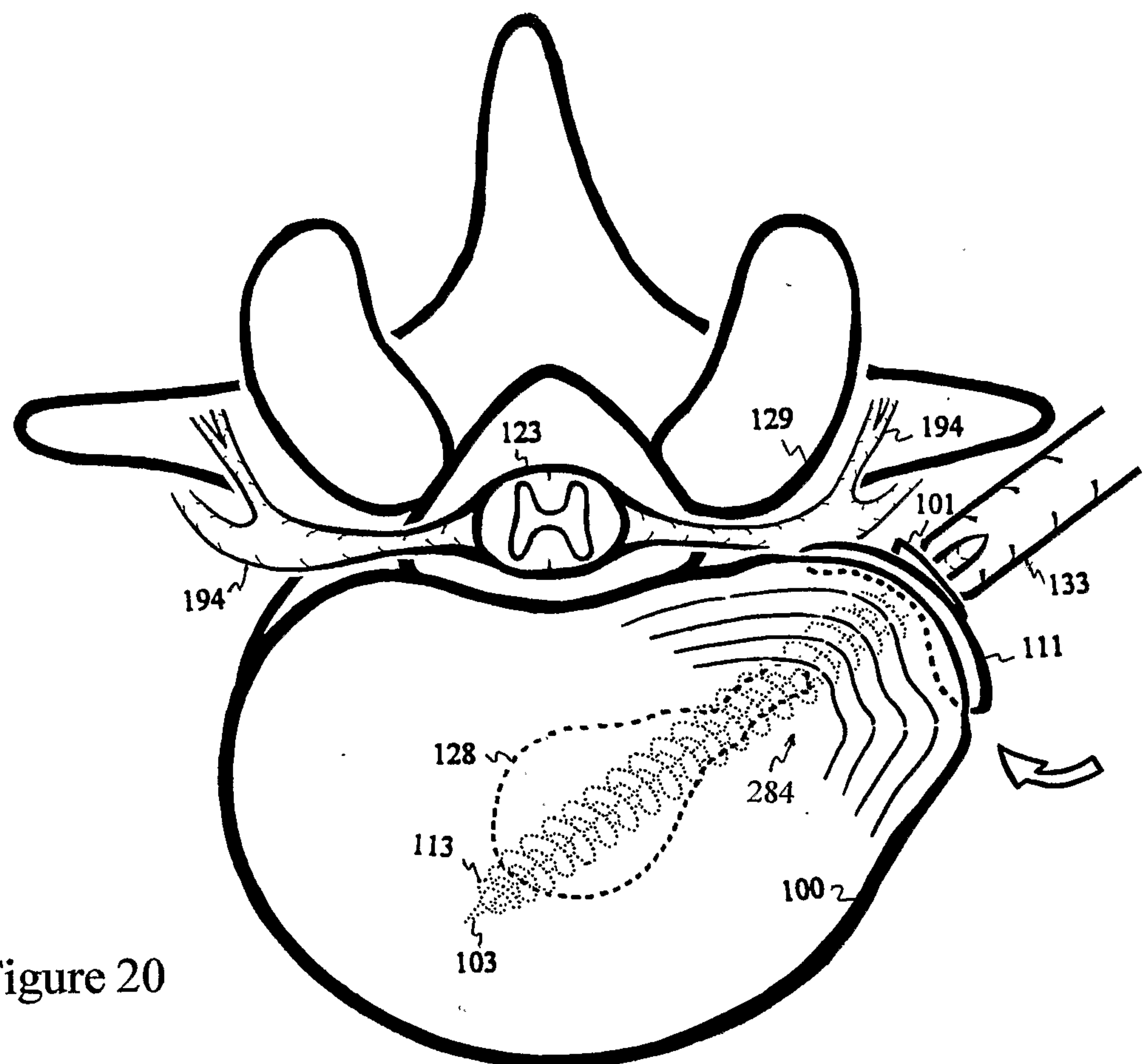
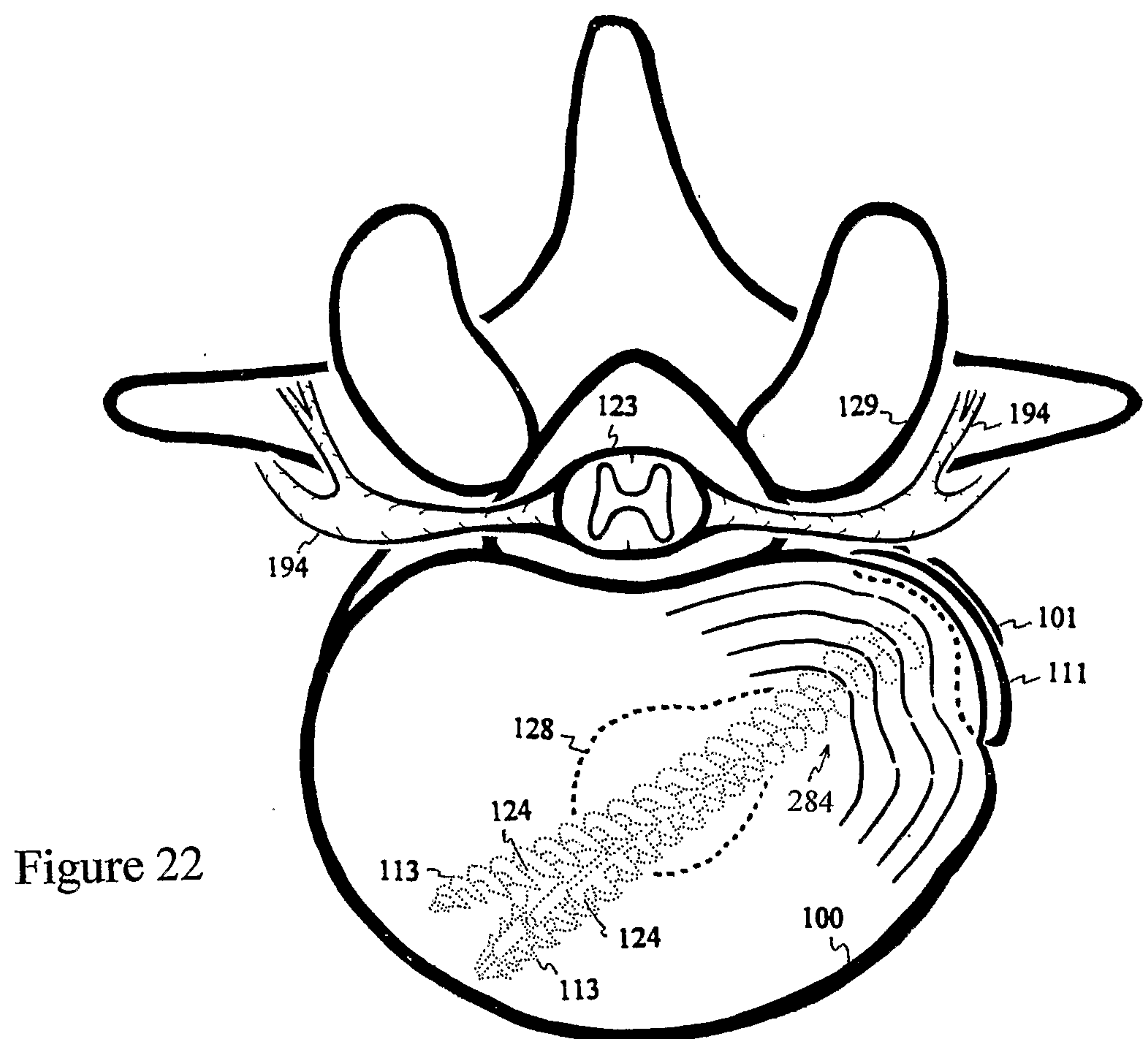
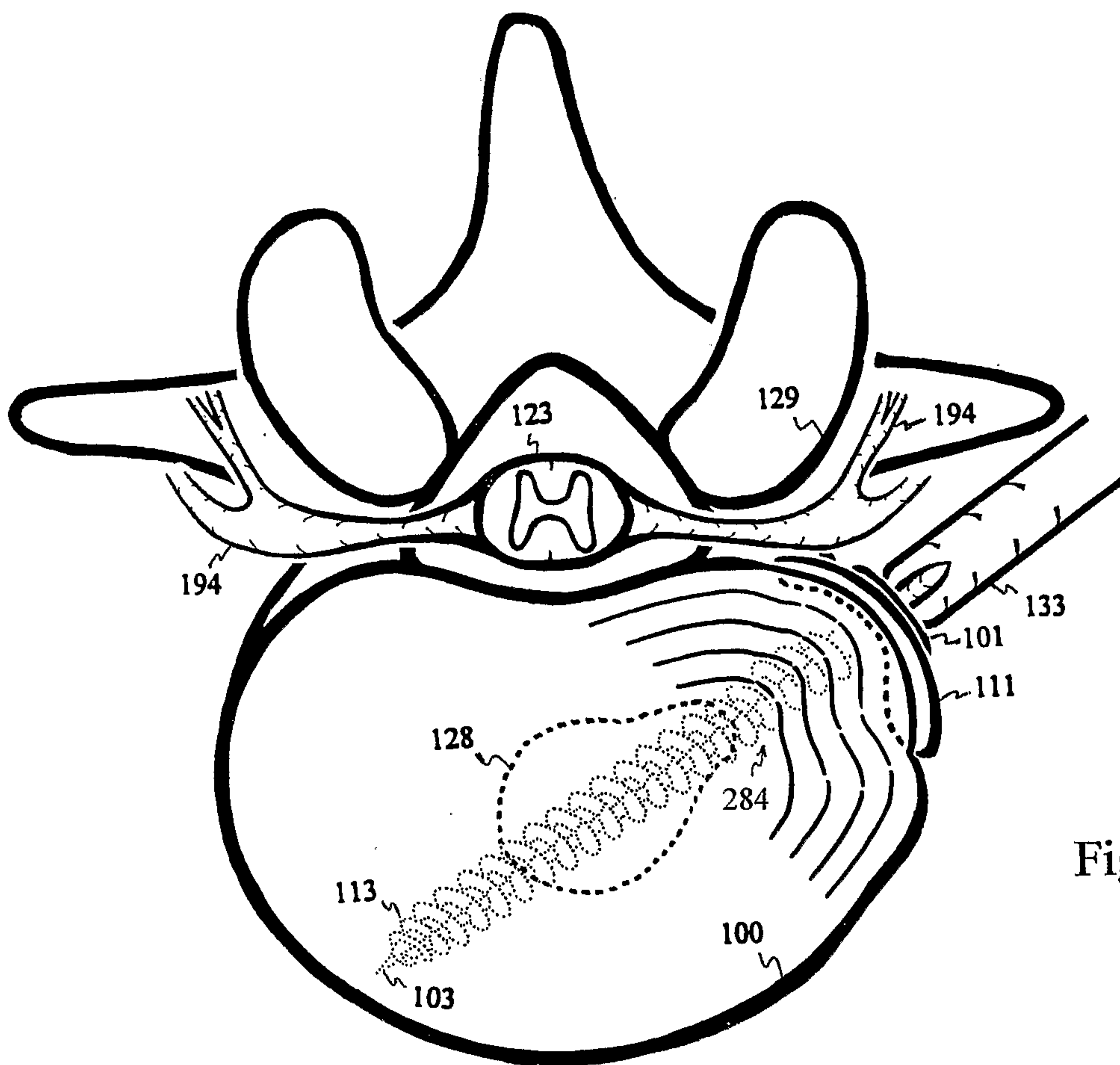


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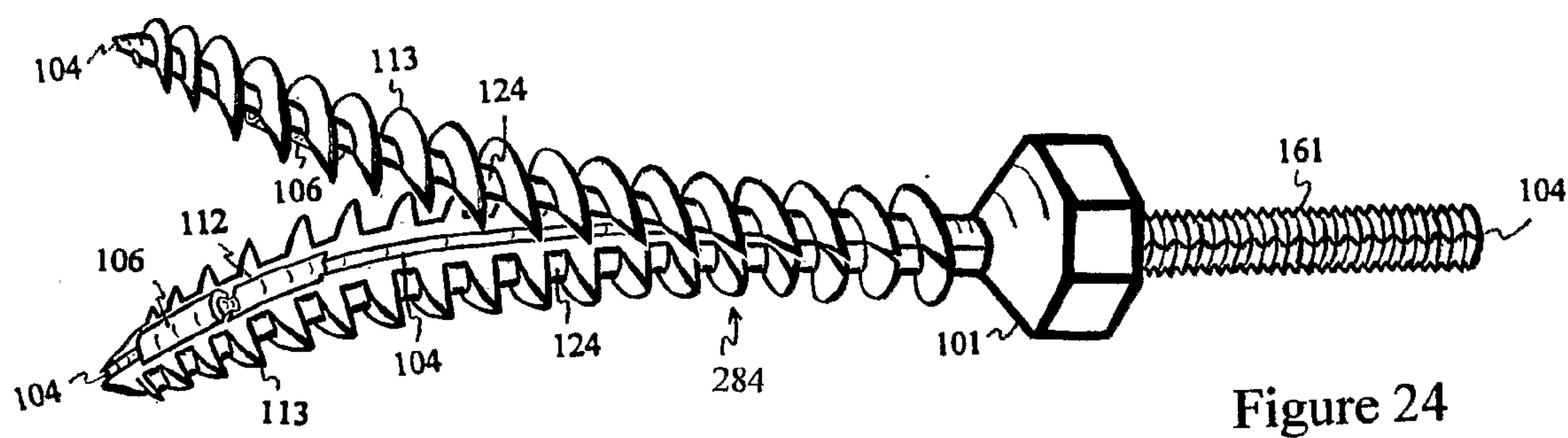
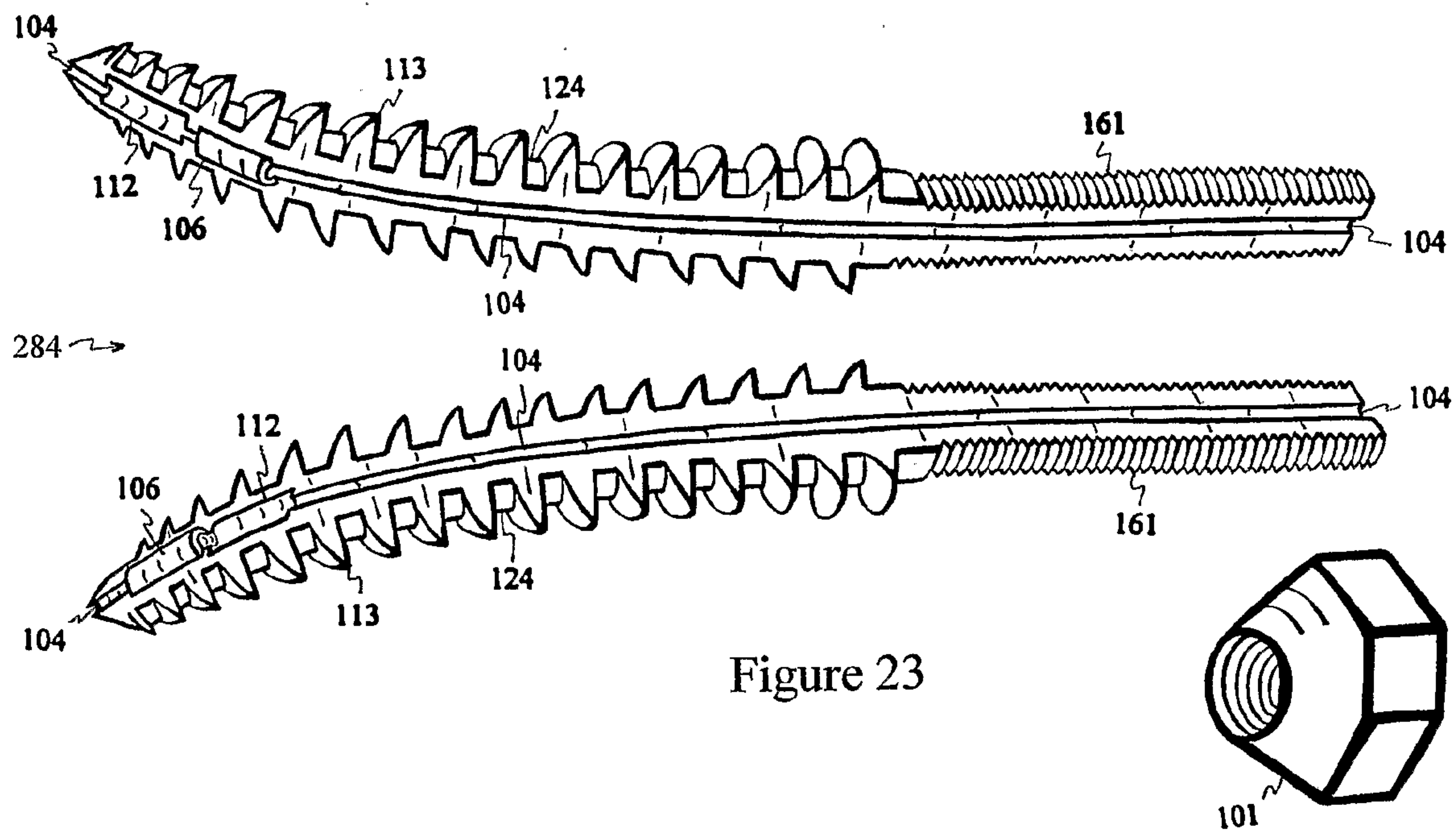


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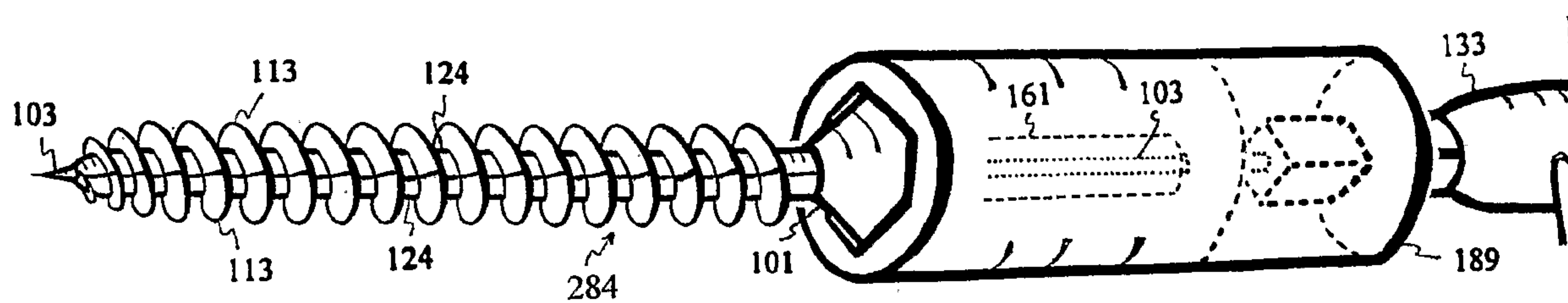
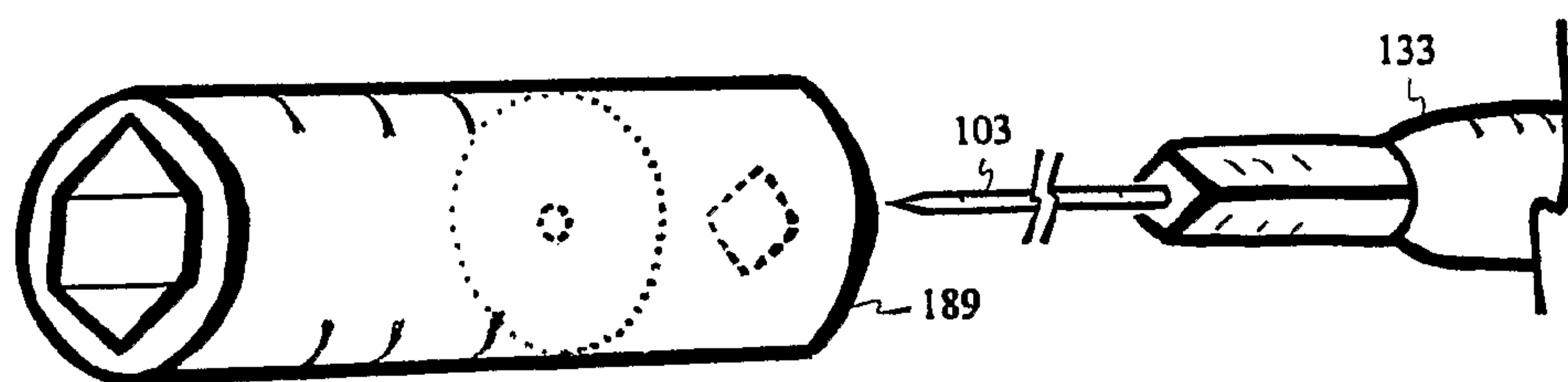


Figure 26

Figure 27

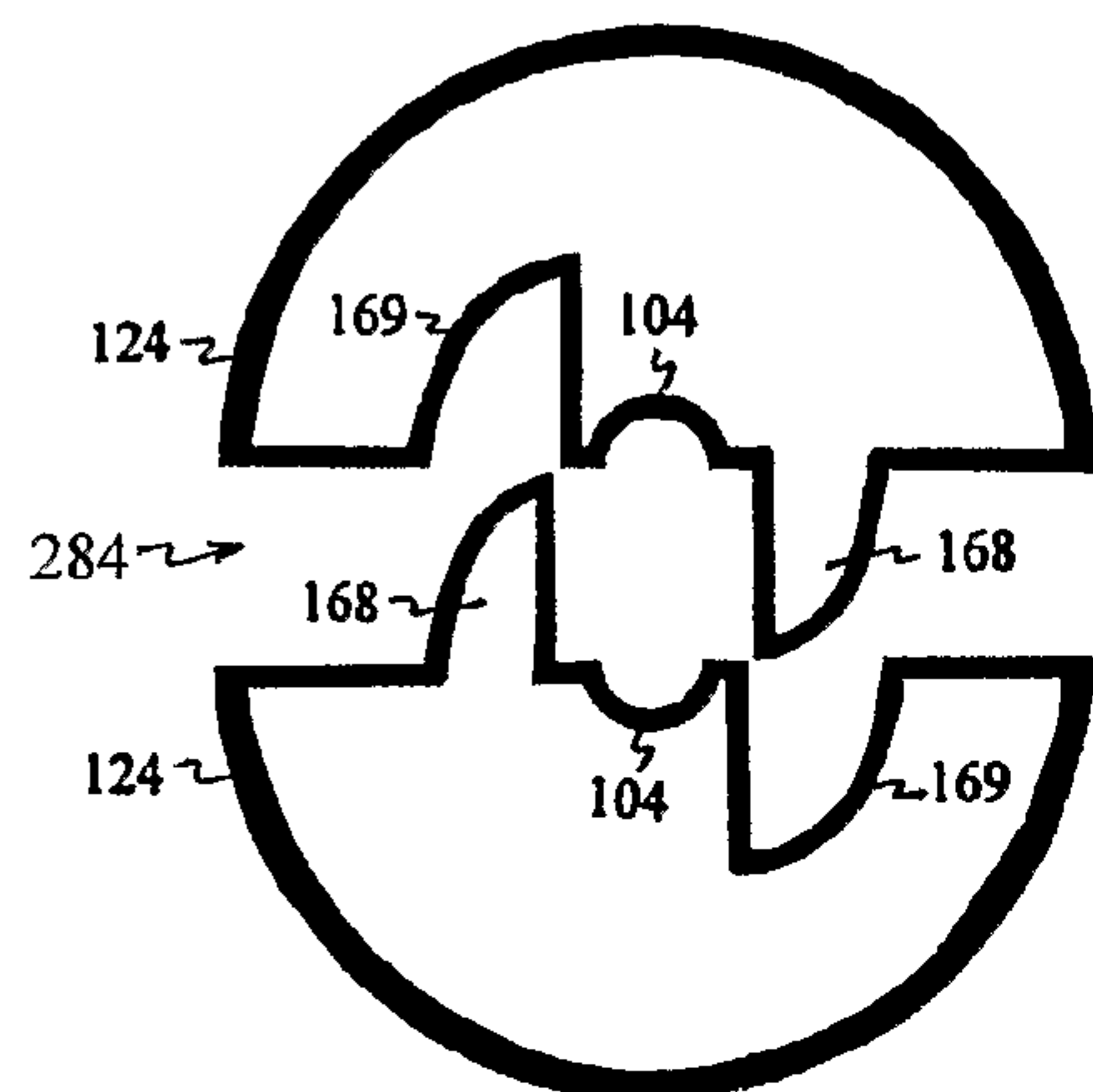
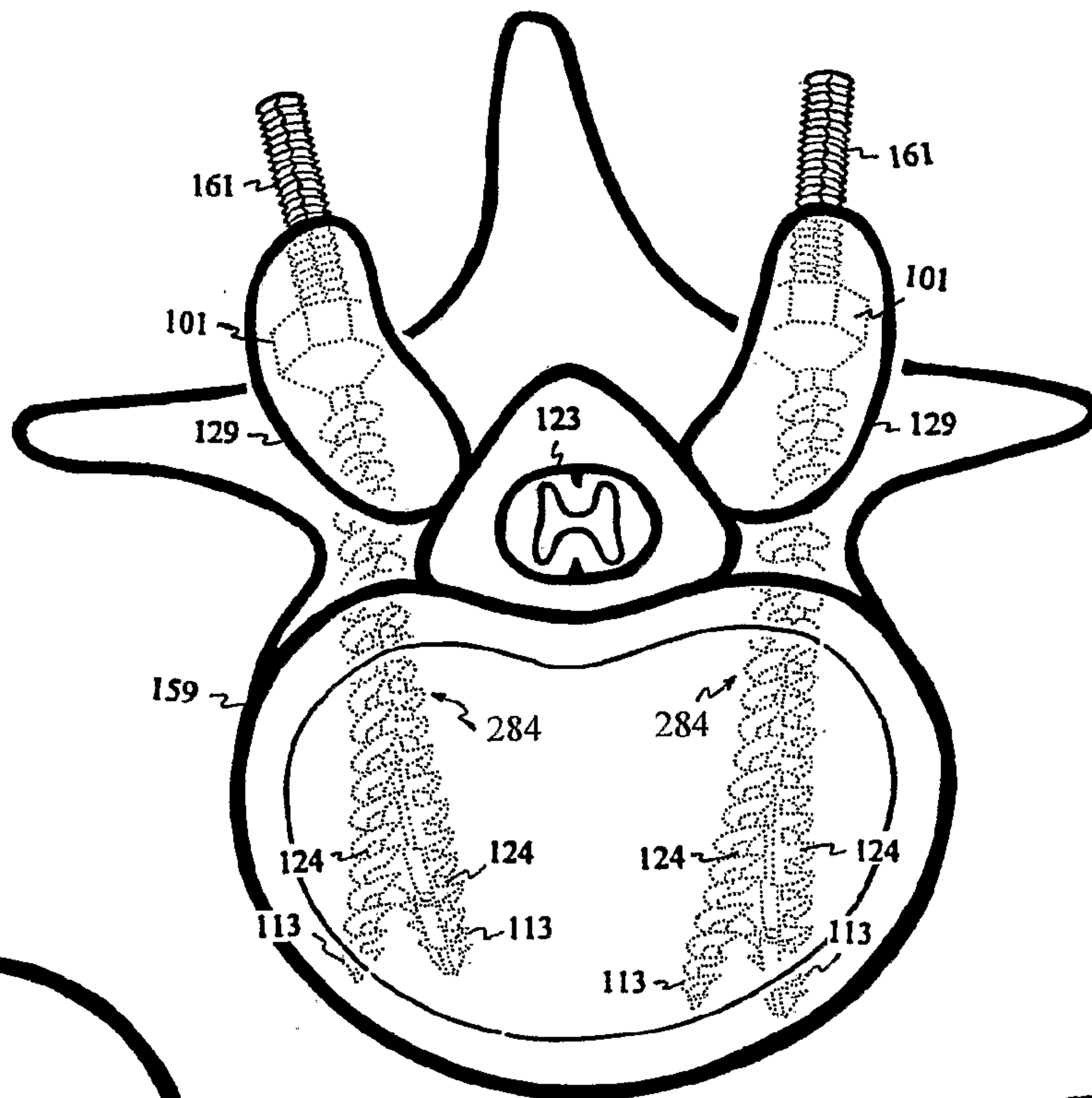


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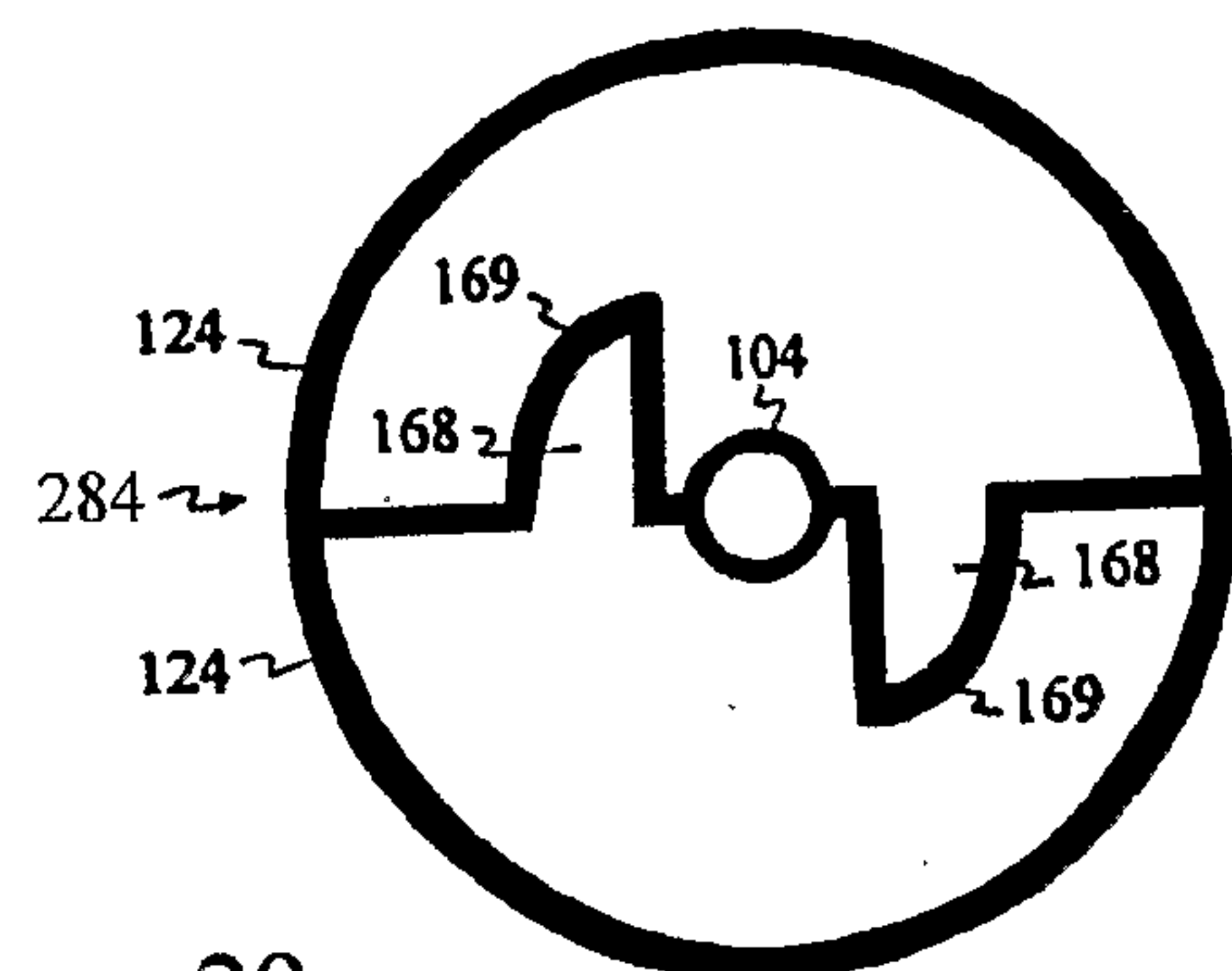


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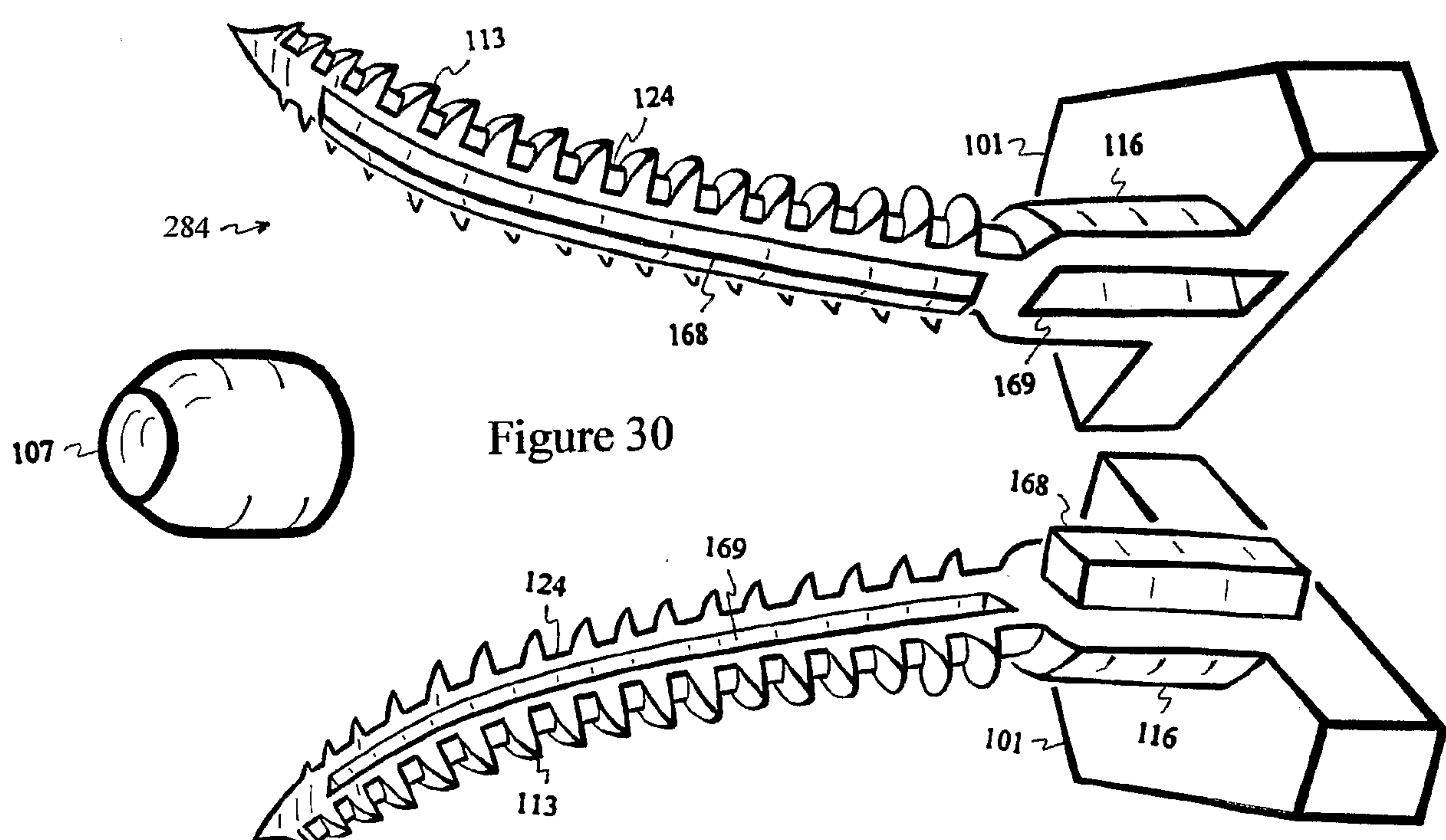


Figure 30

Figure 31

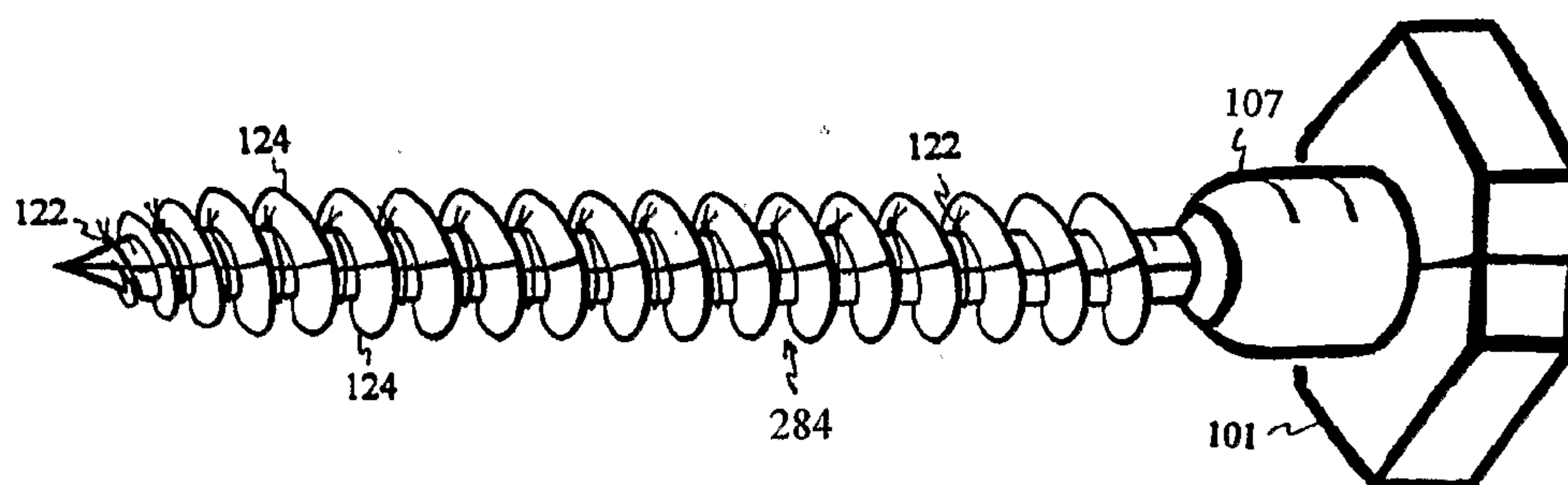
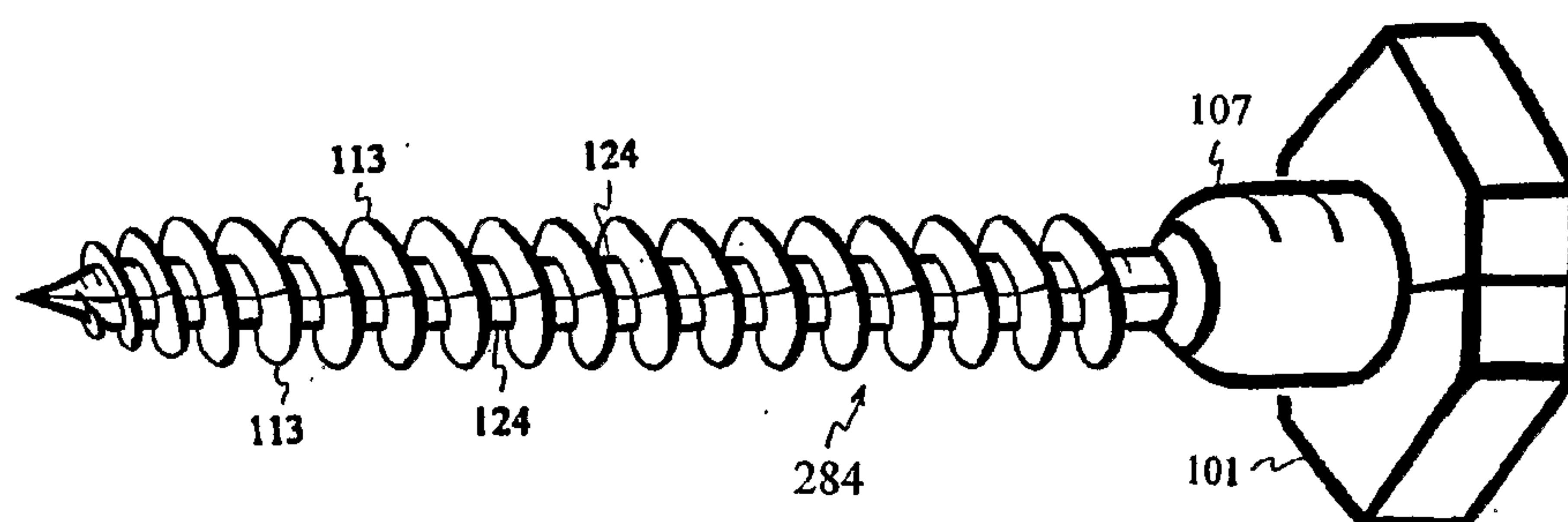


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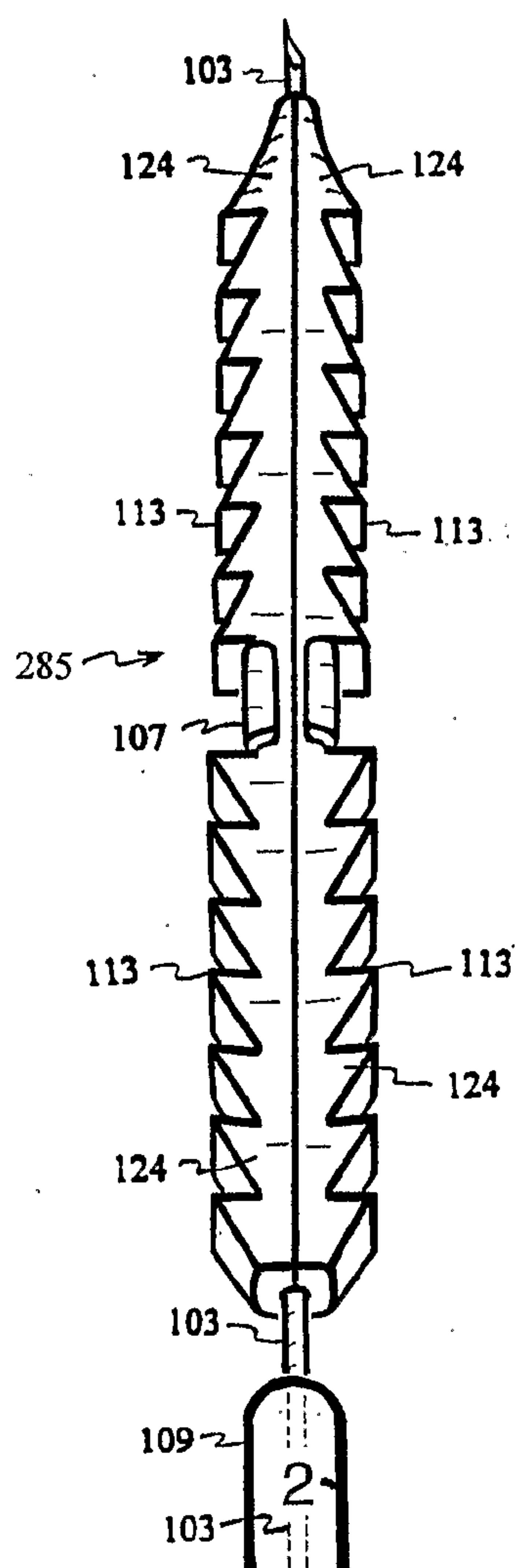


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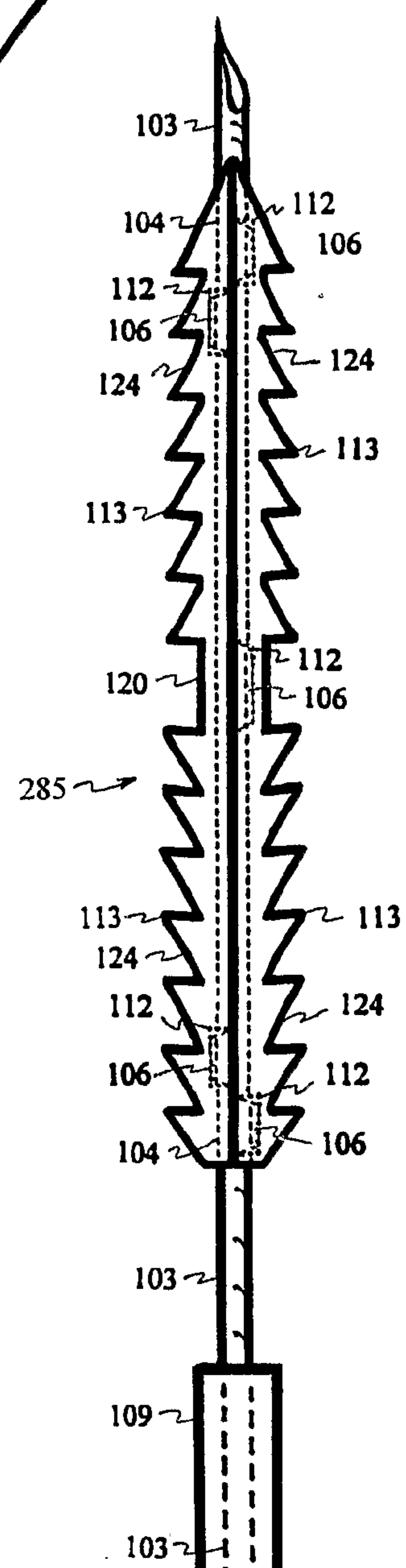


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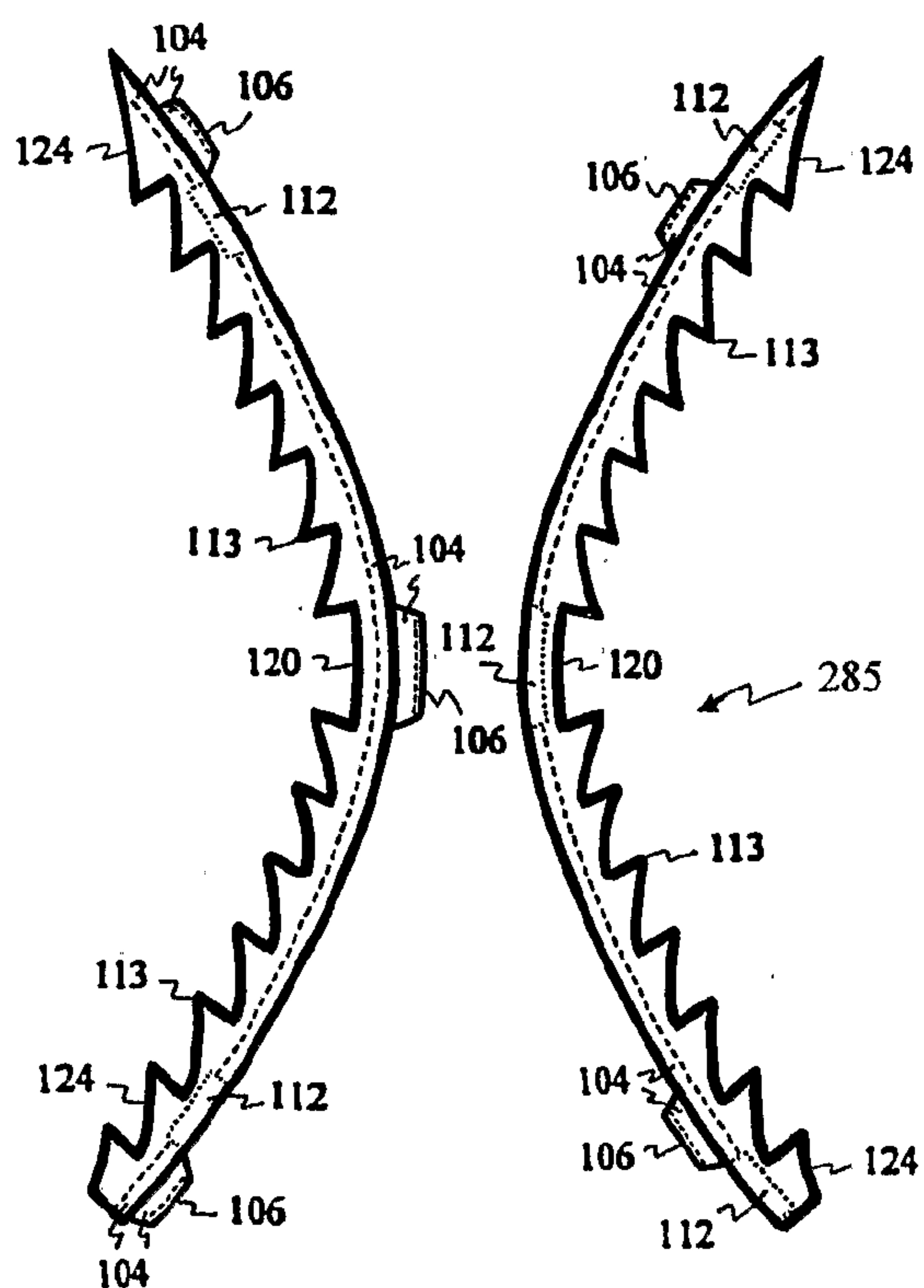


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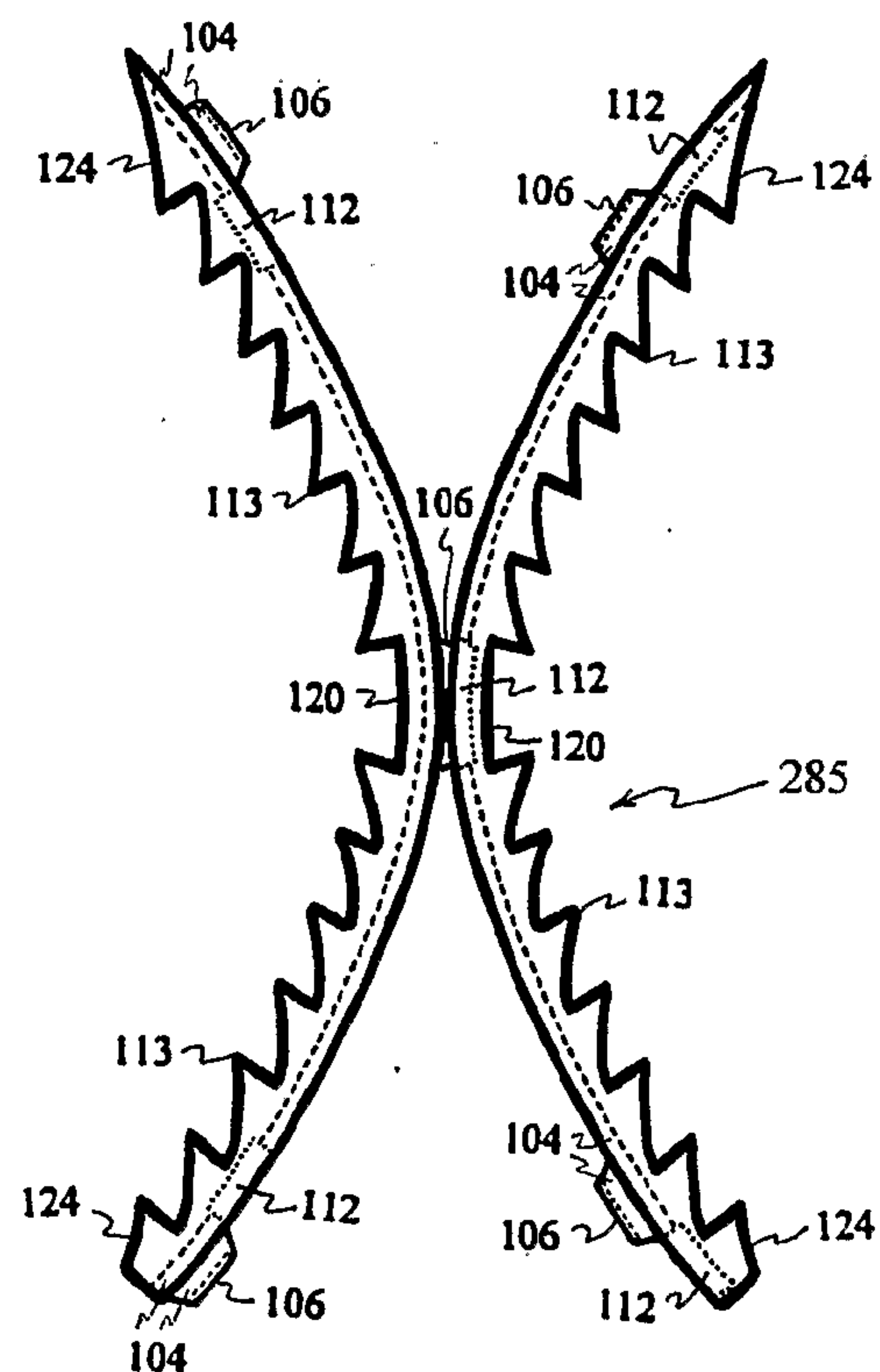


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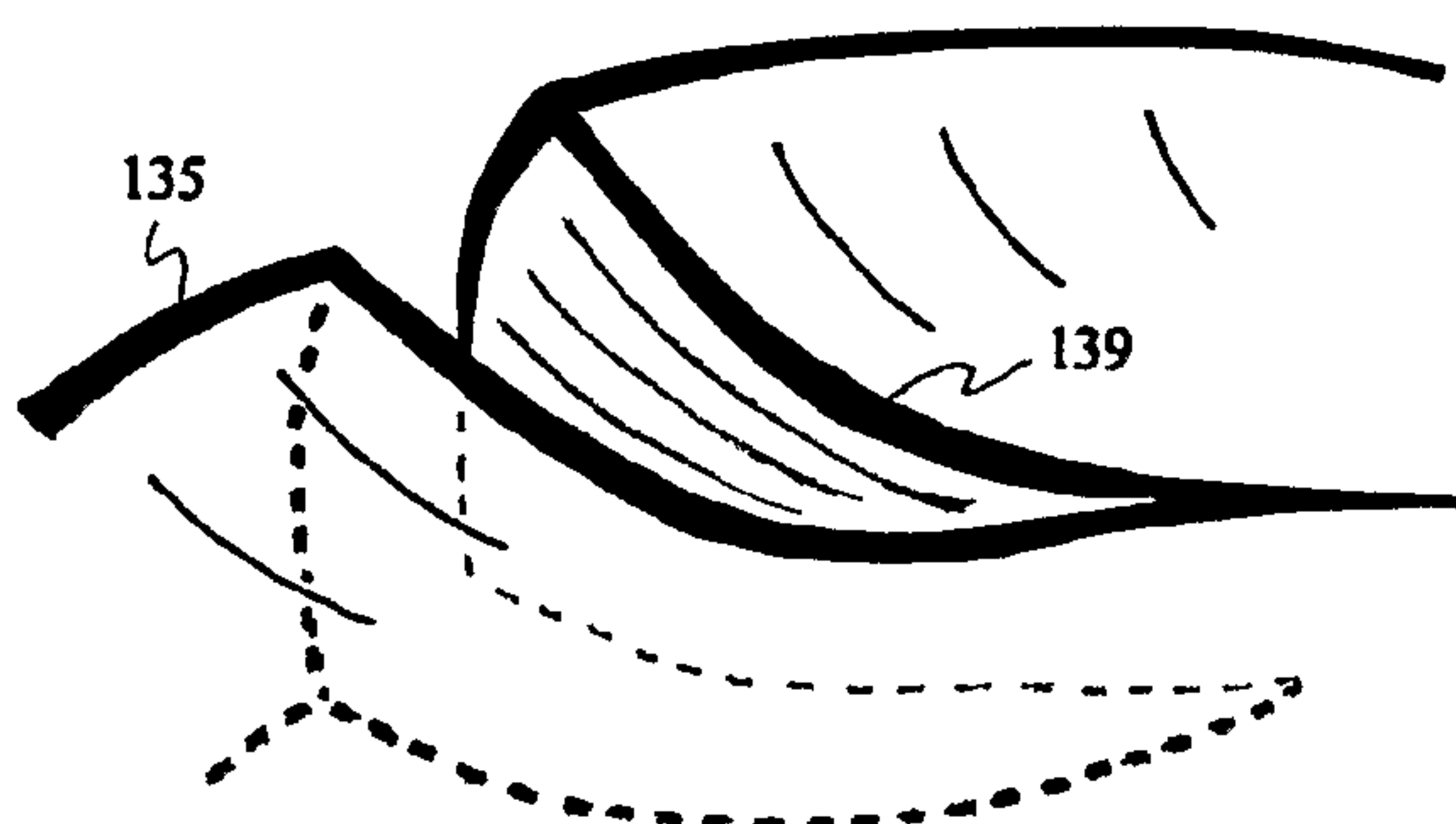
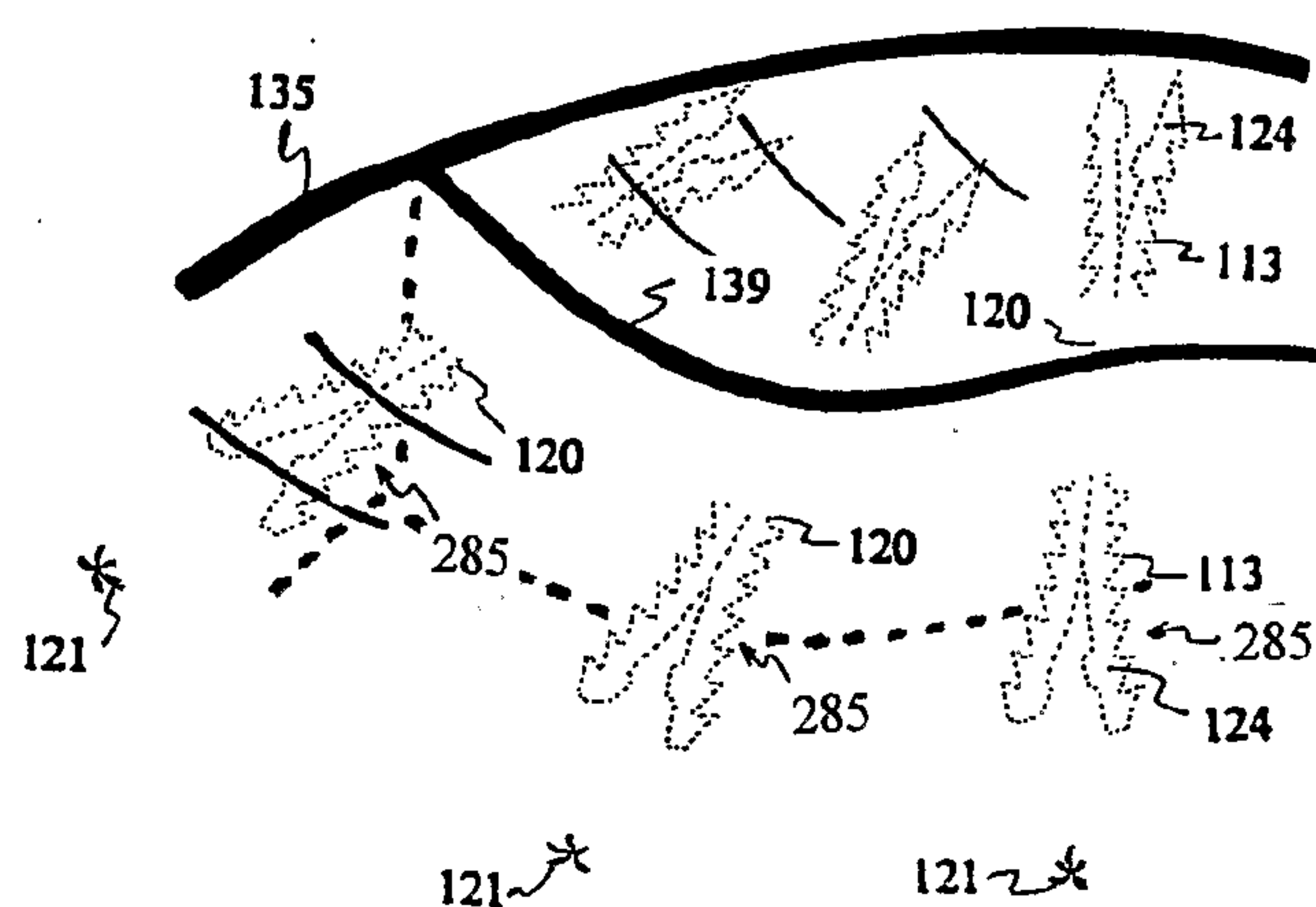


Figure 37

Figure 38



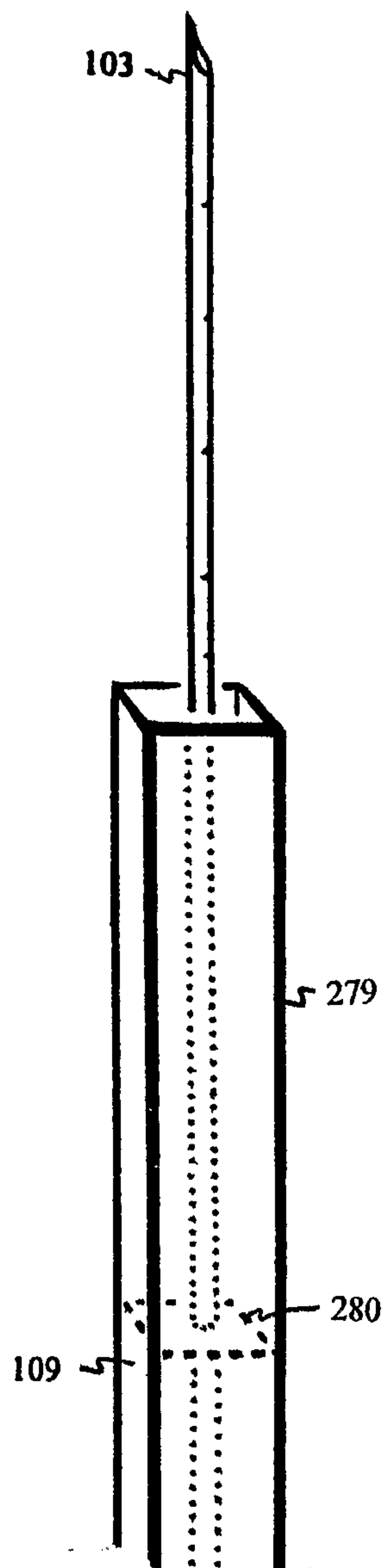


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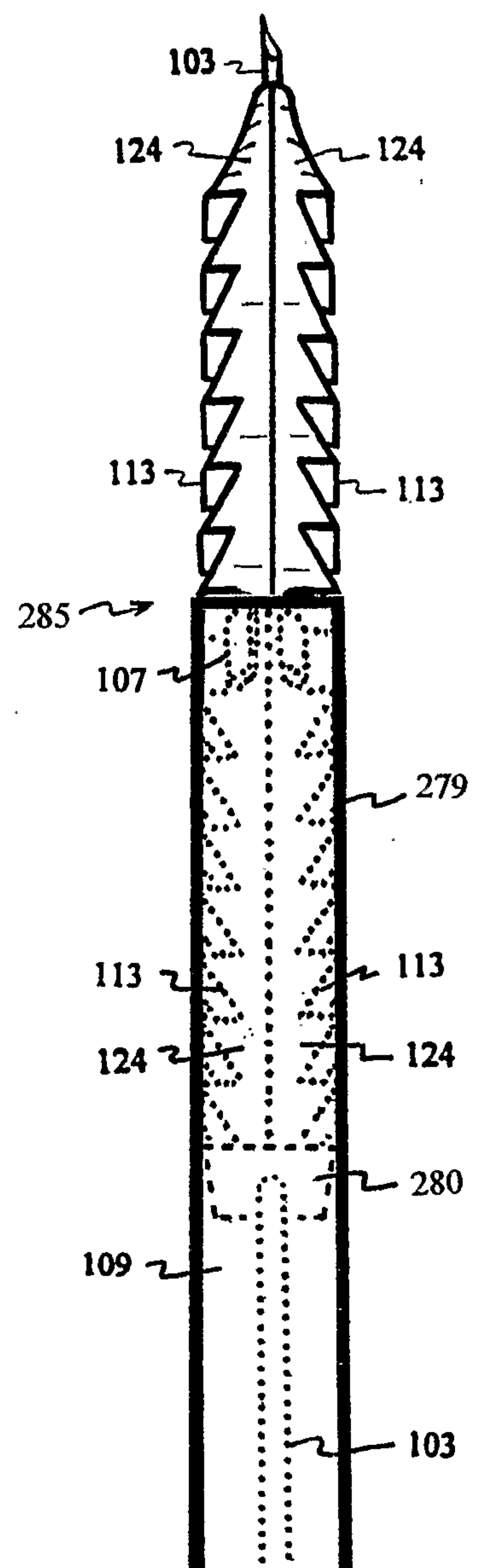


Figure 40

Figure 41

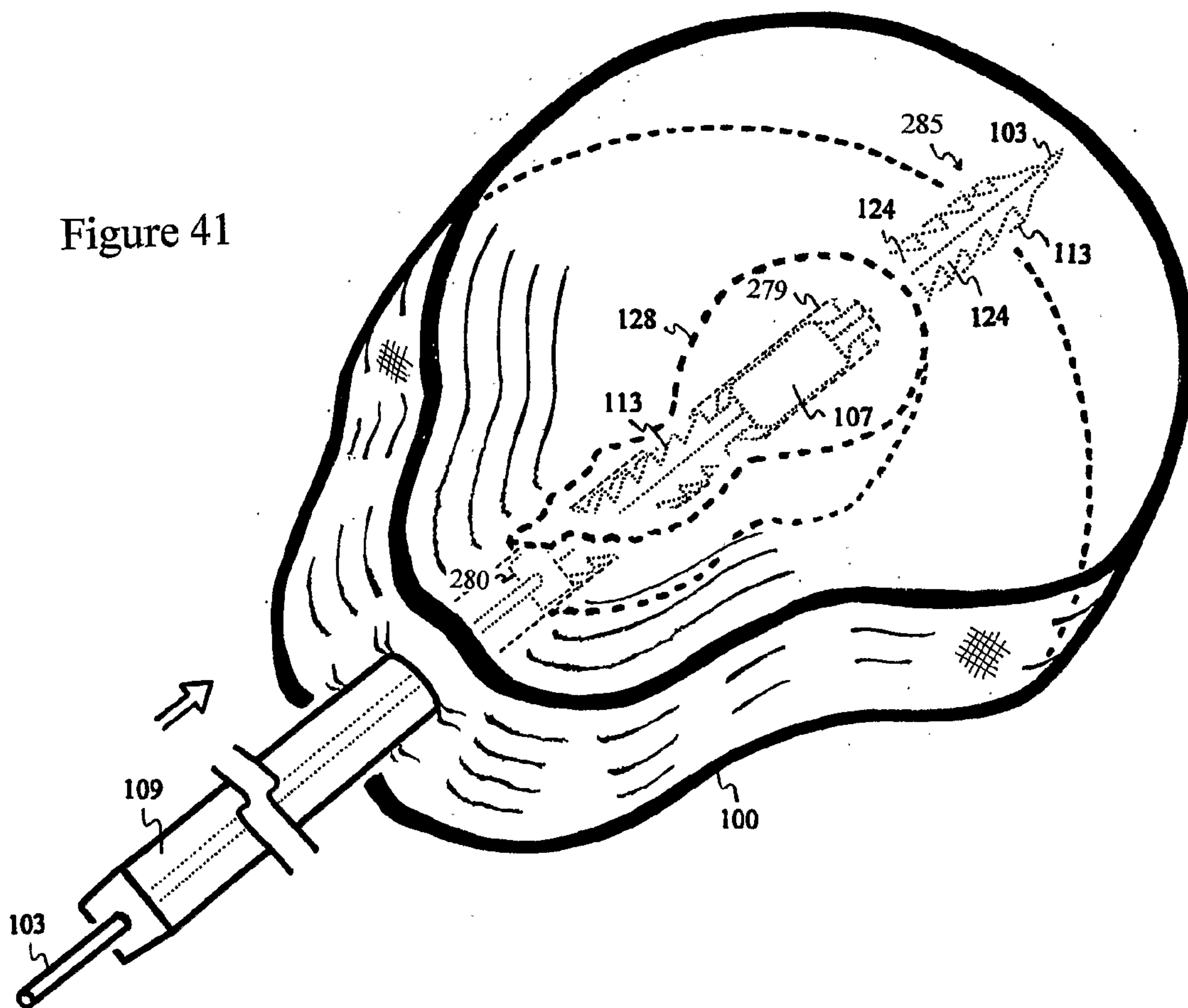


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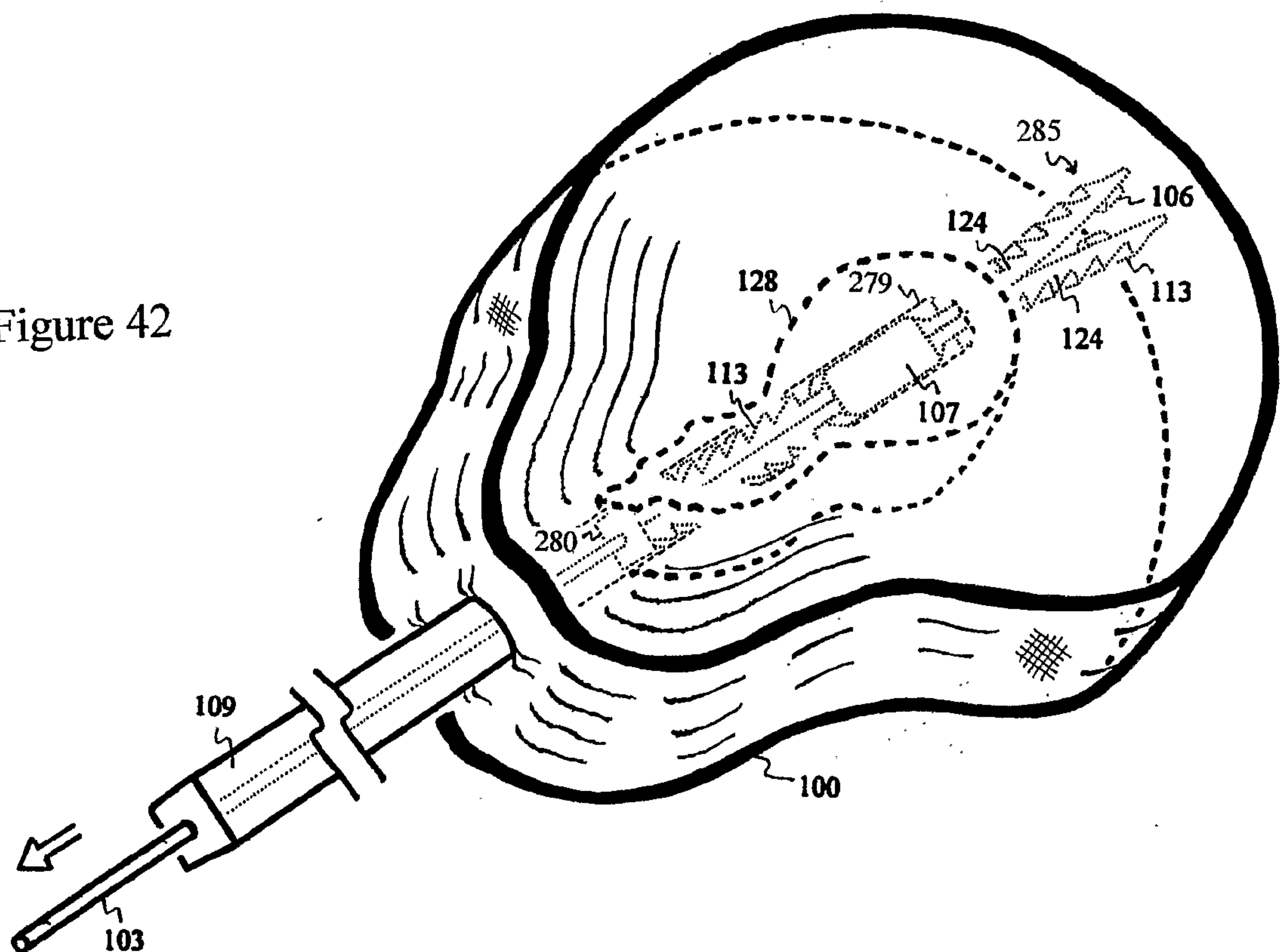


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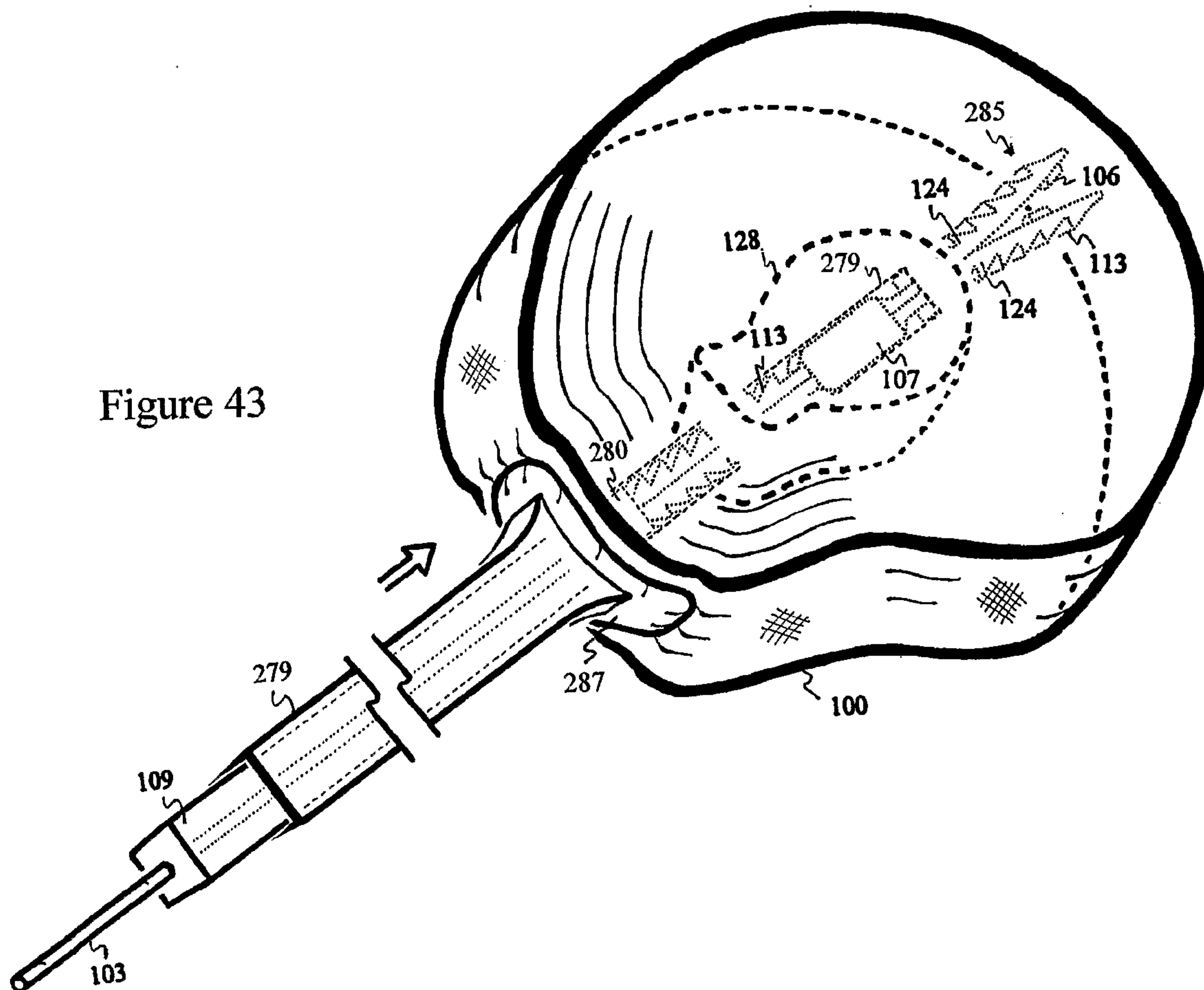
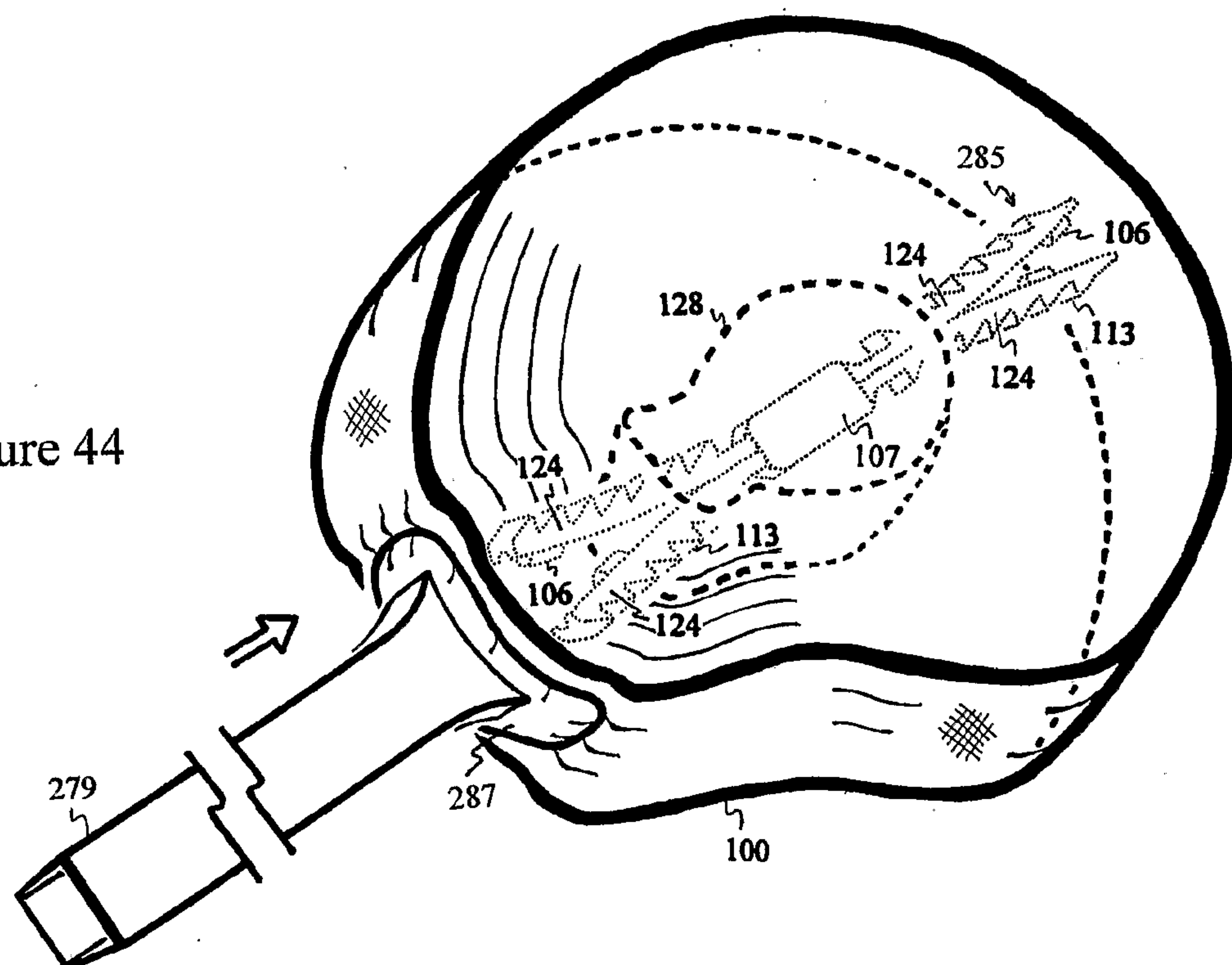


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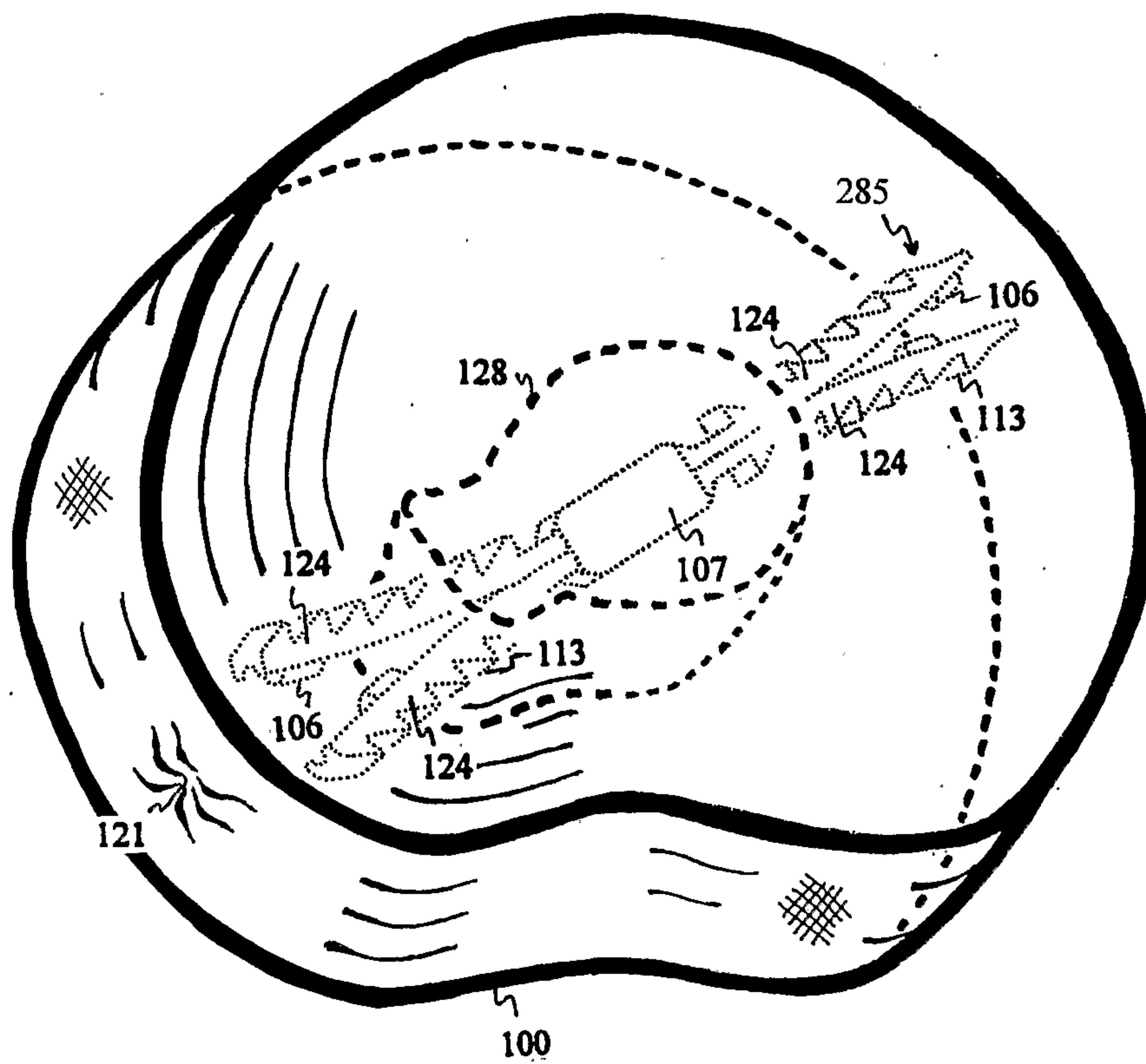


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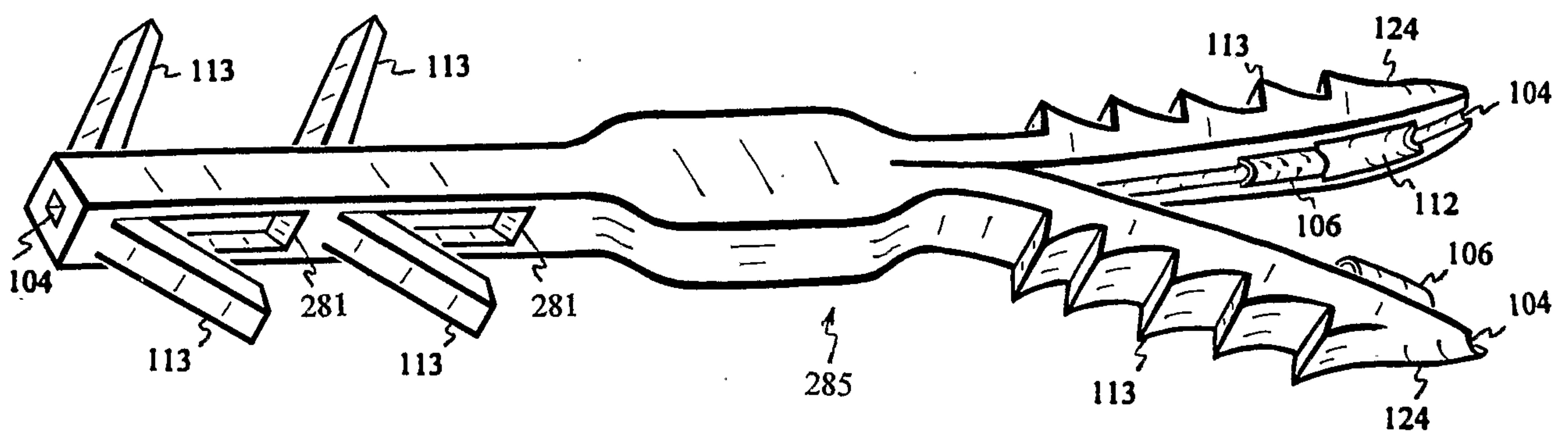


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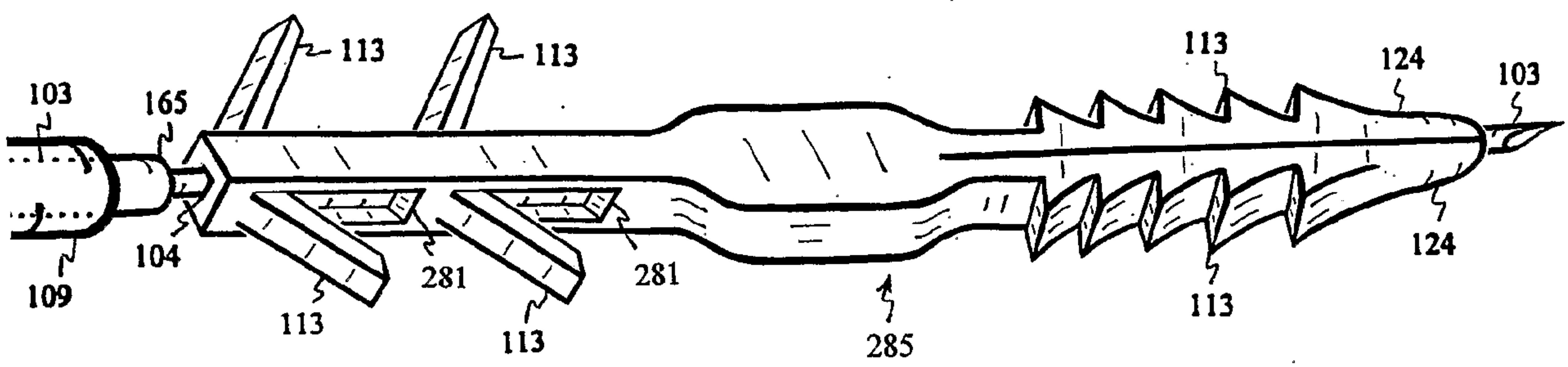


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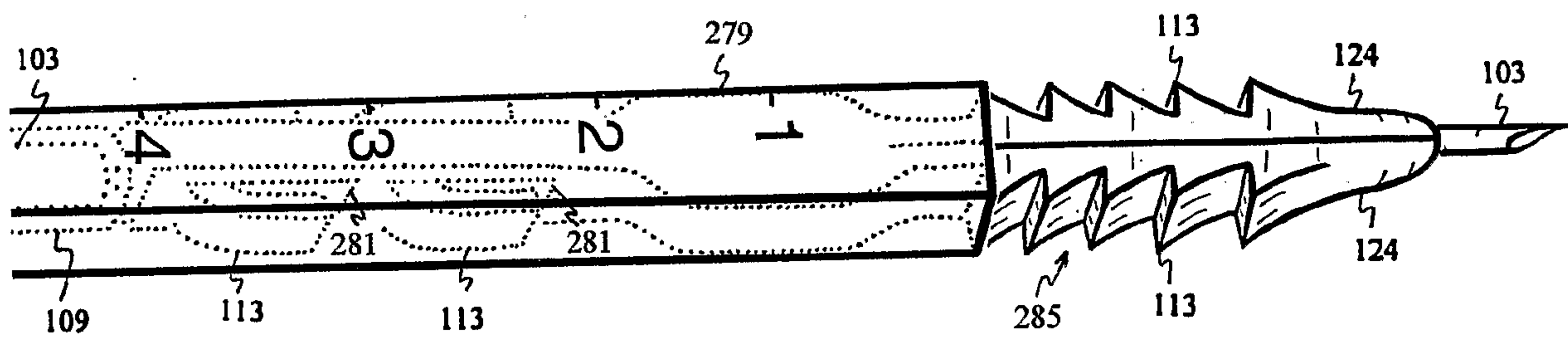


Figure 48

Figure 49

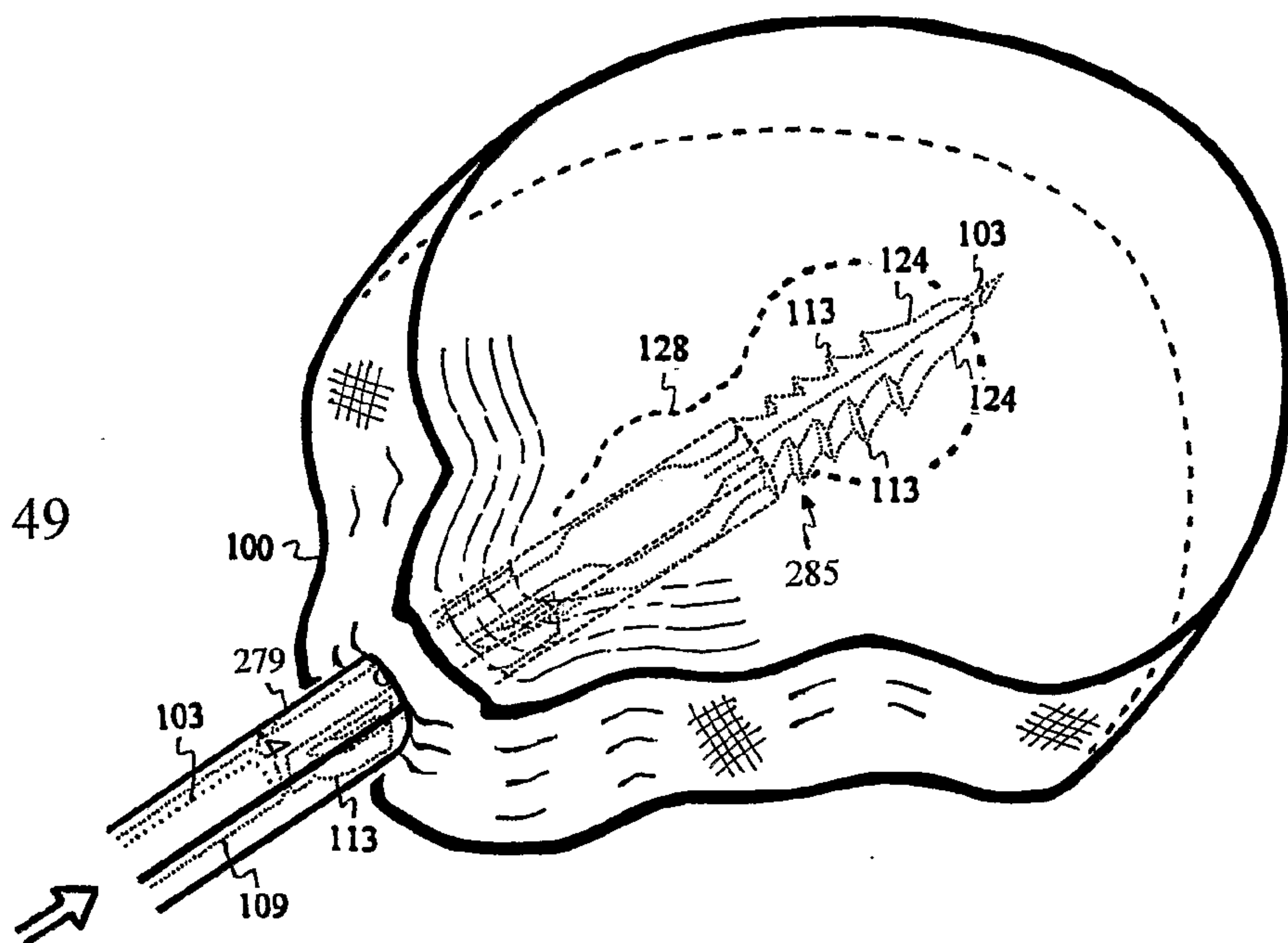


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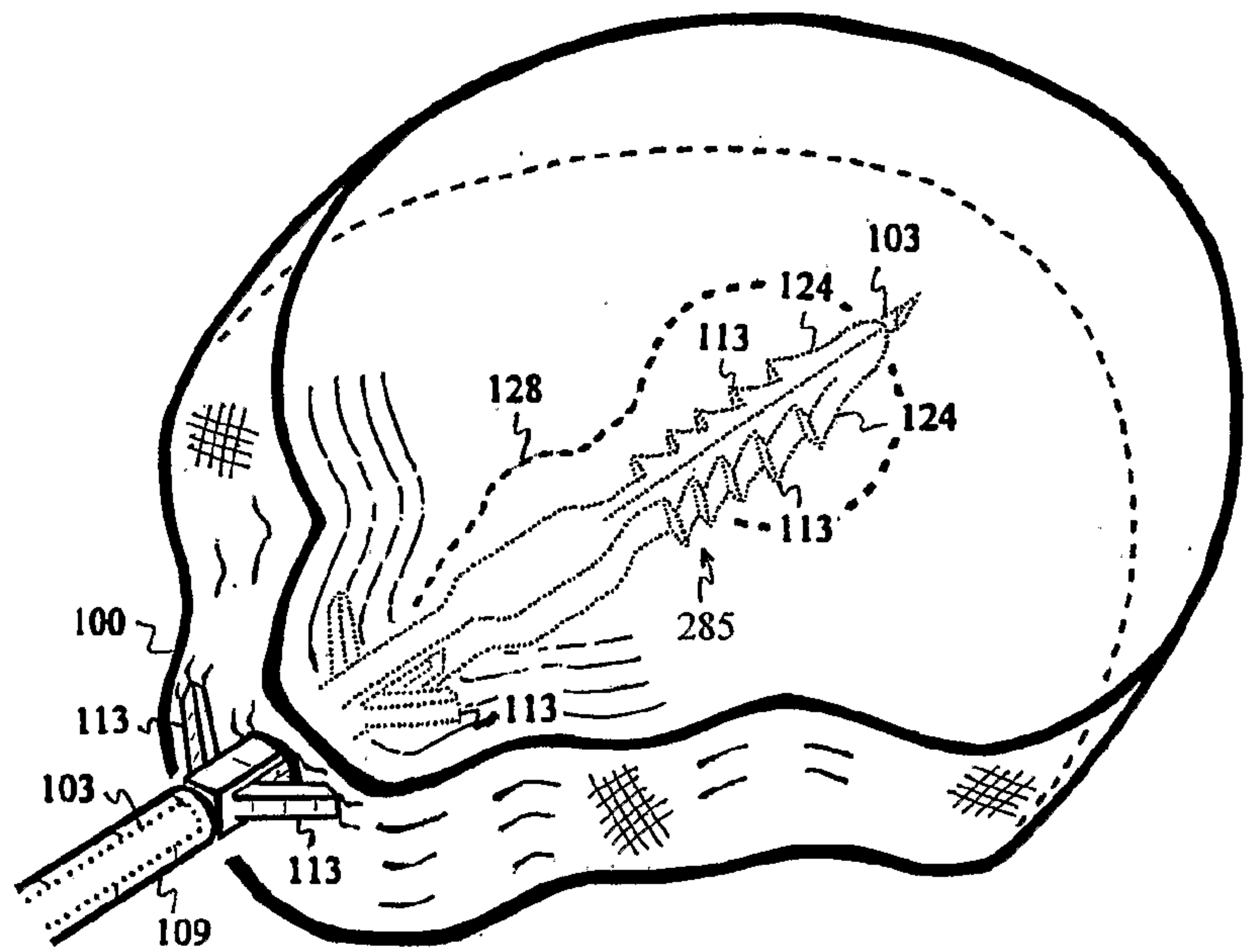


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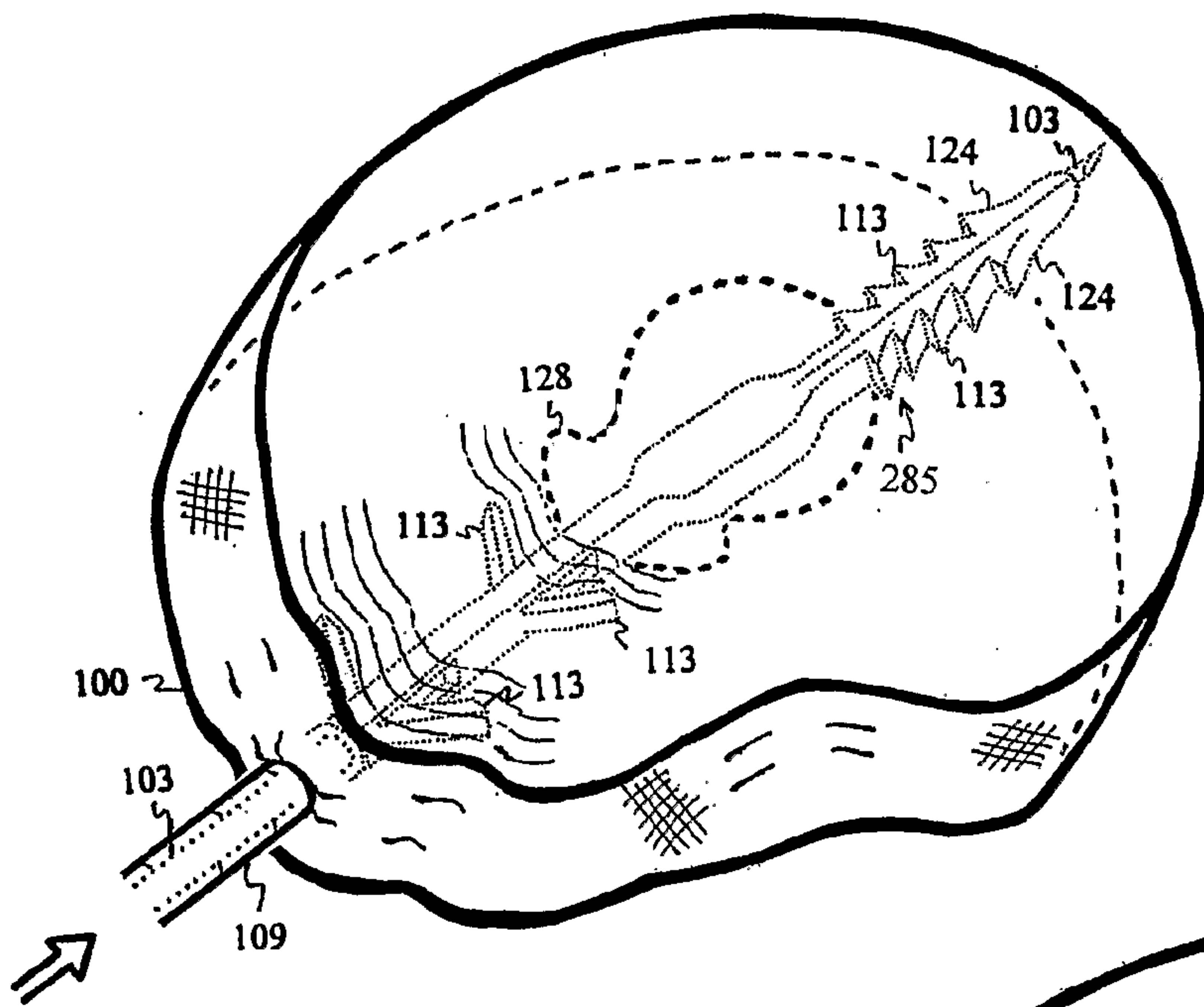
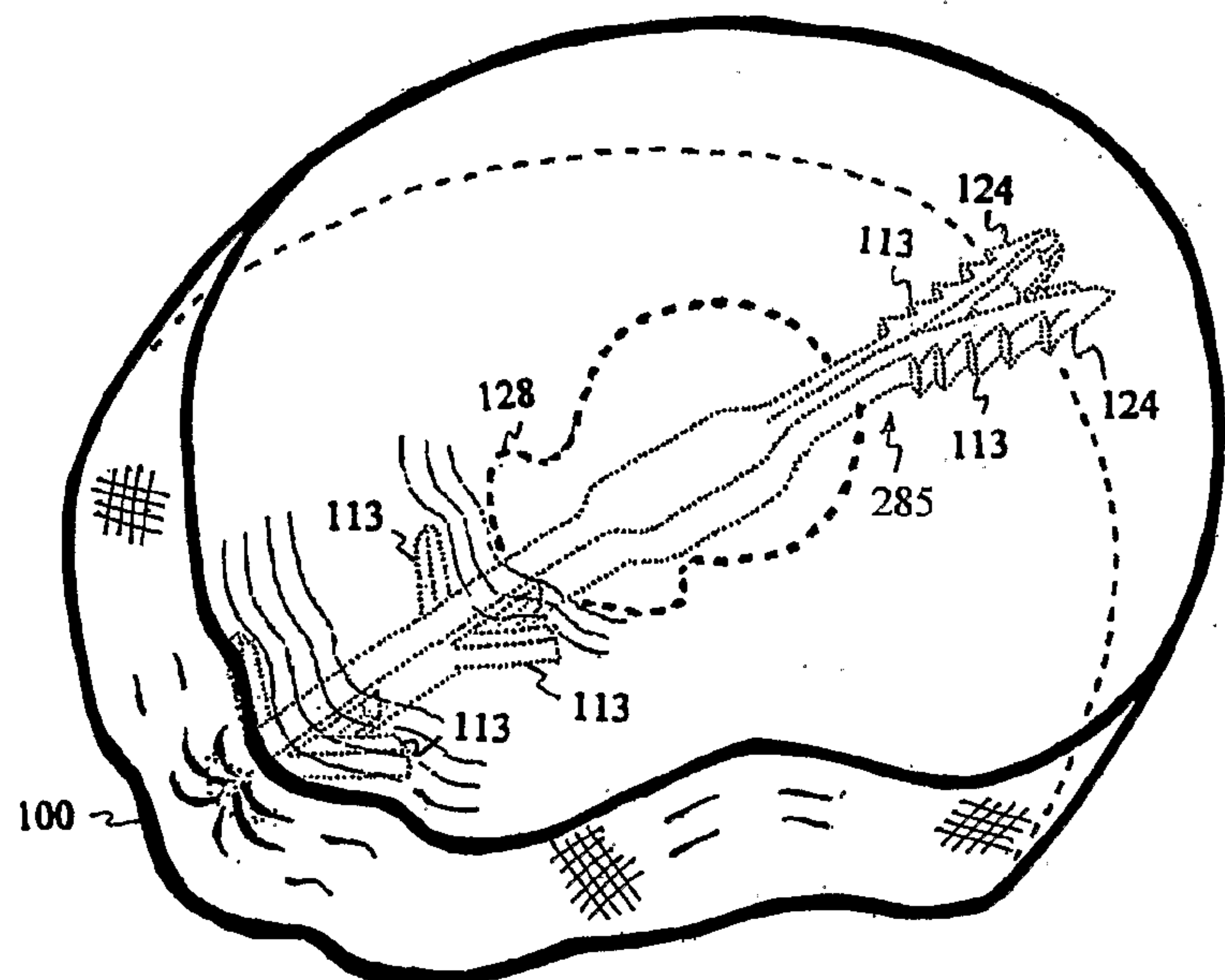


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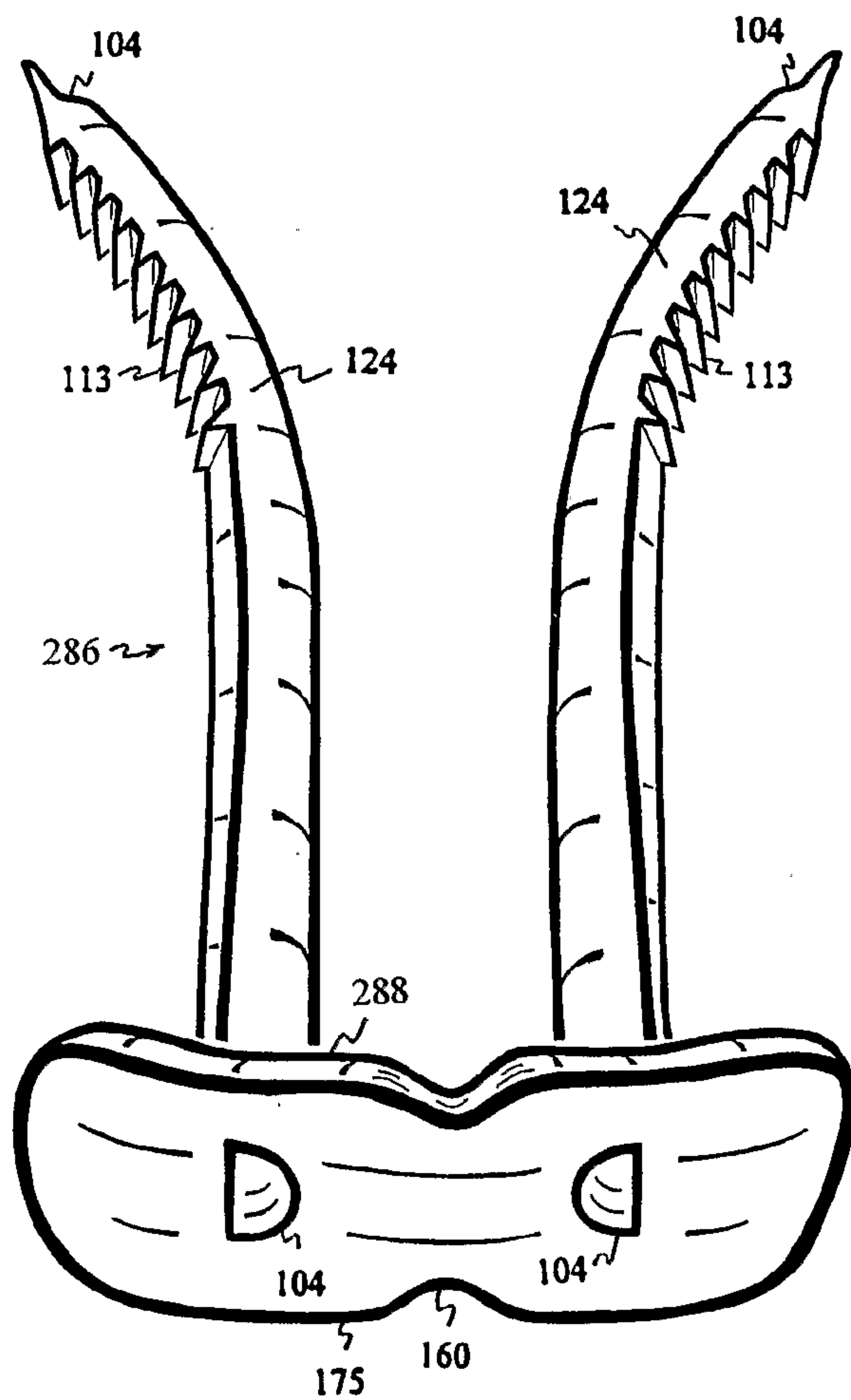


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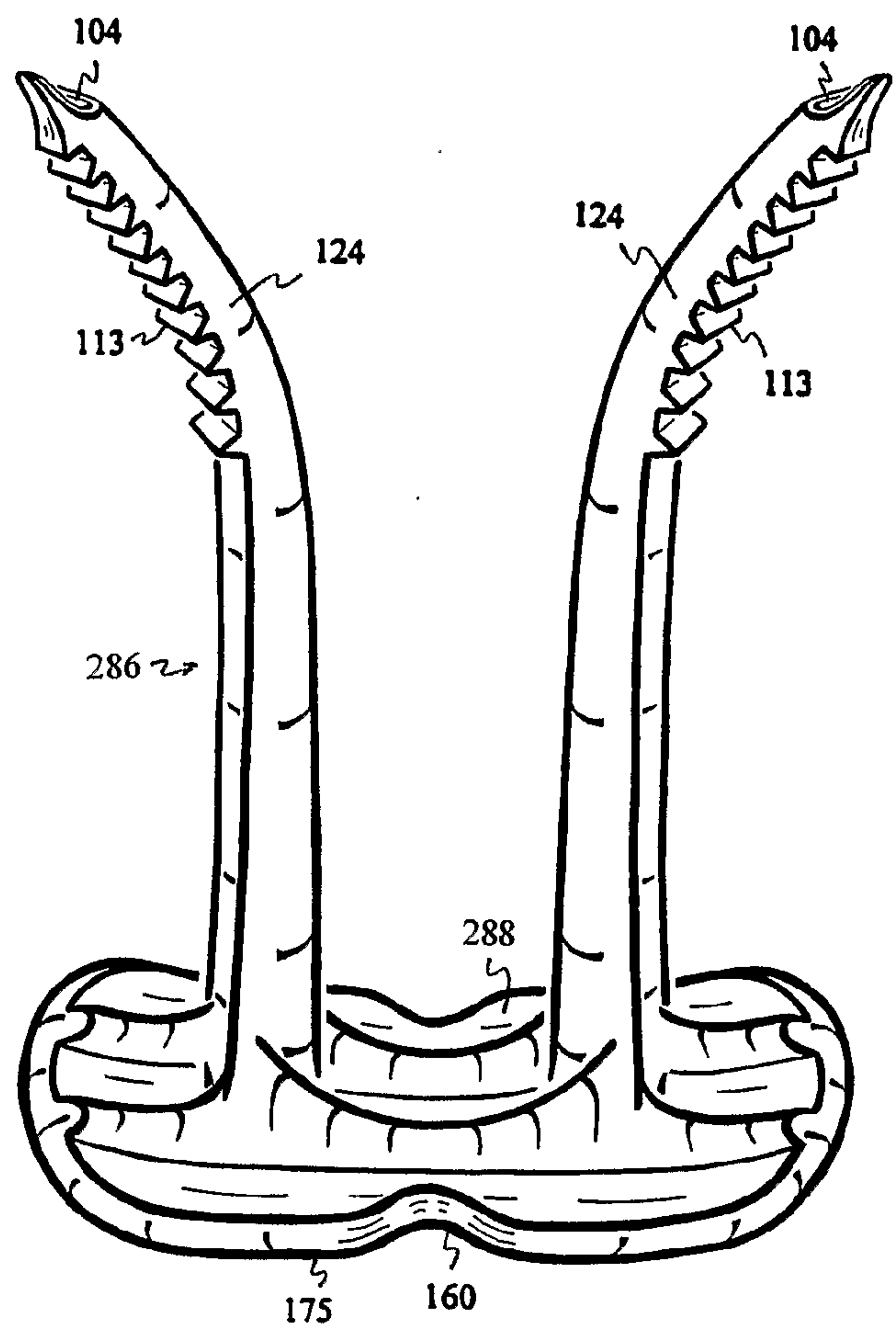


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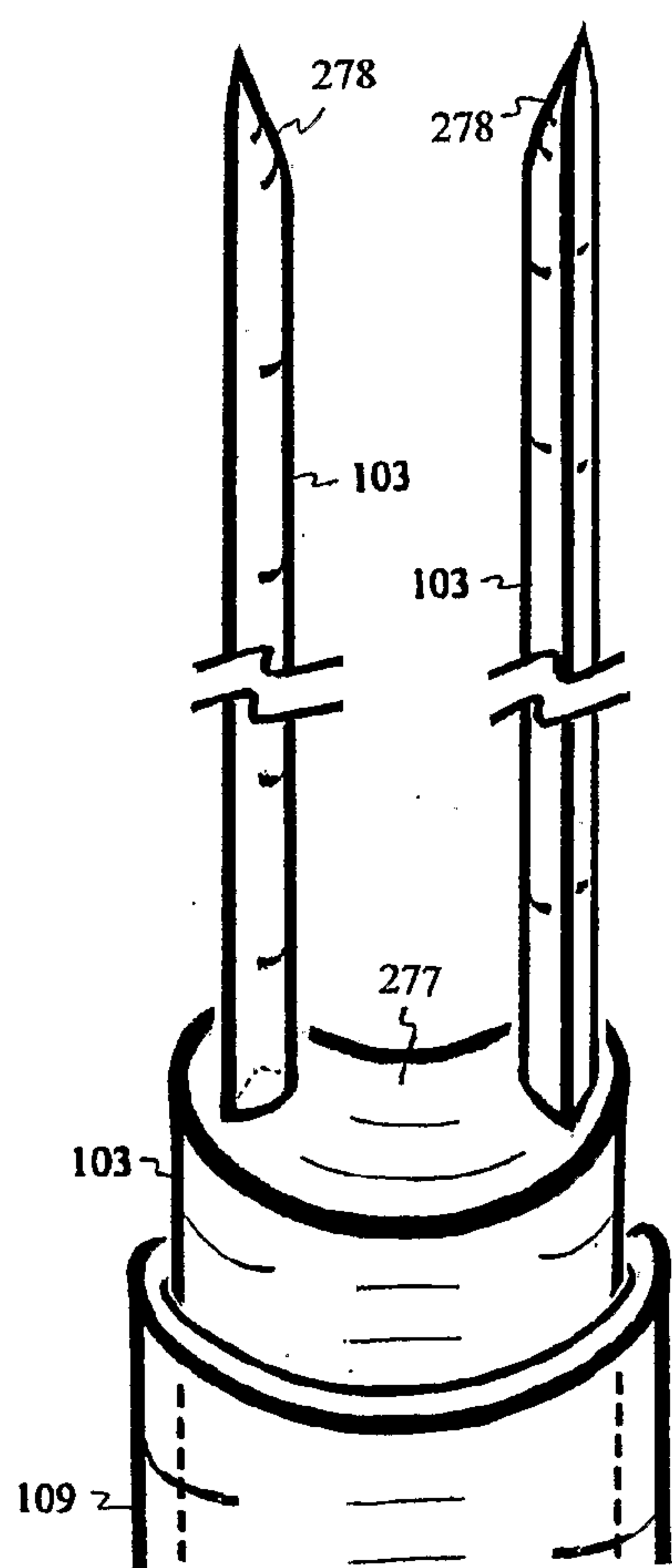


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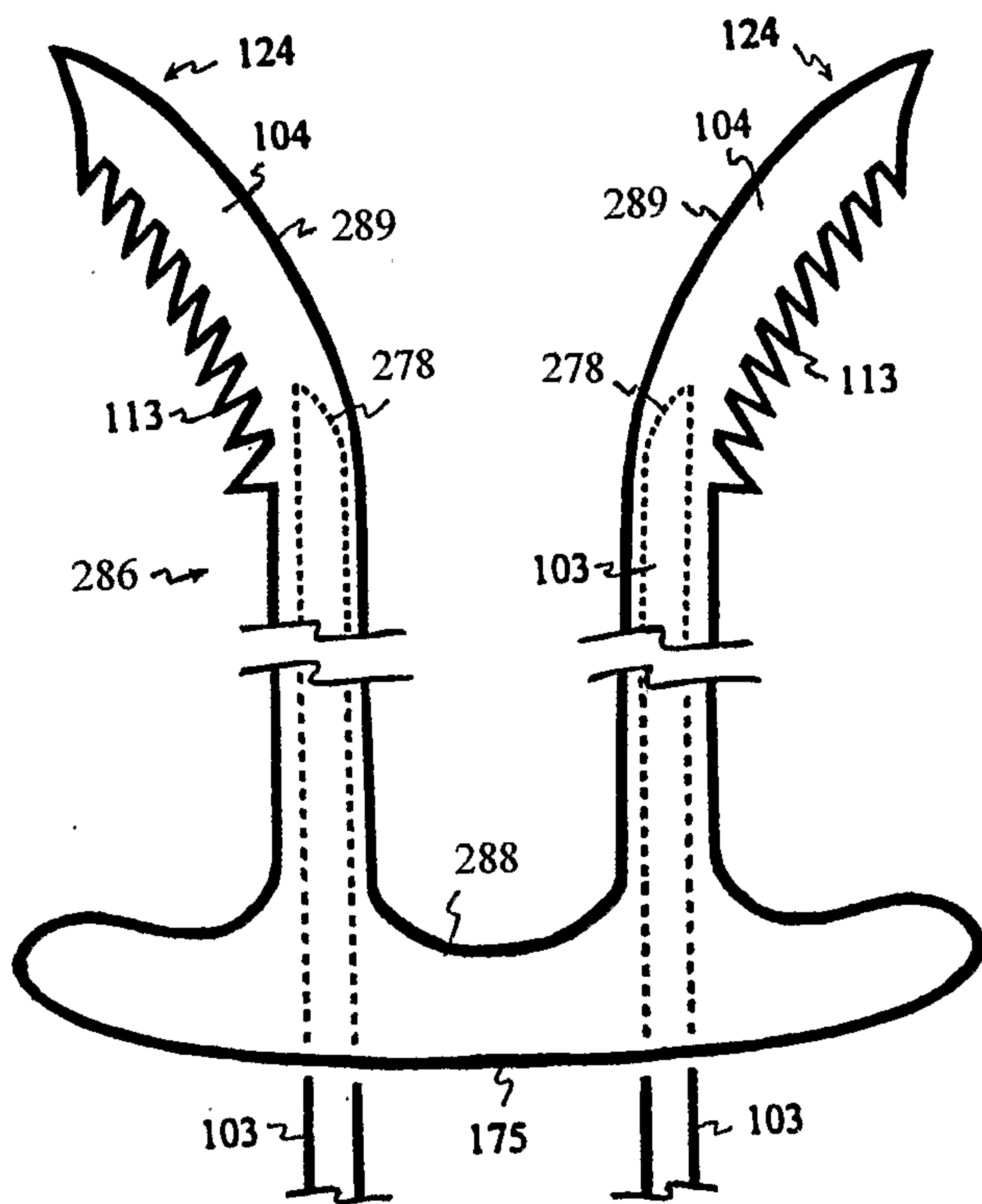


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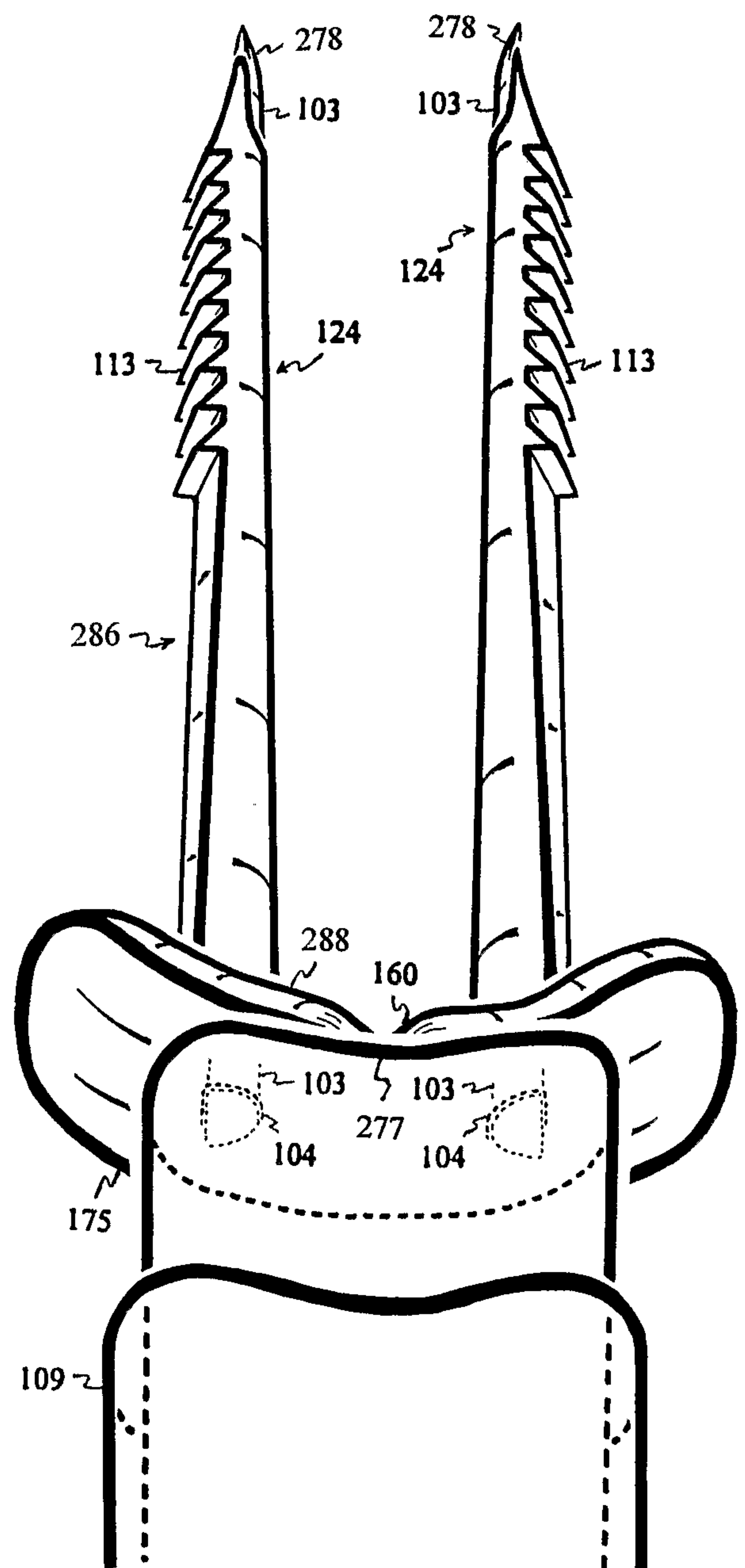


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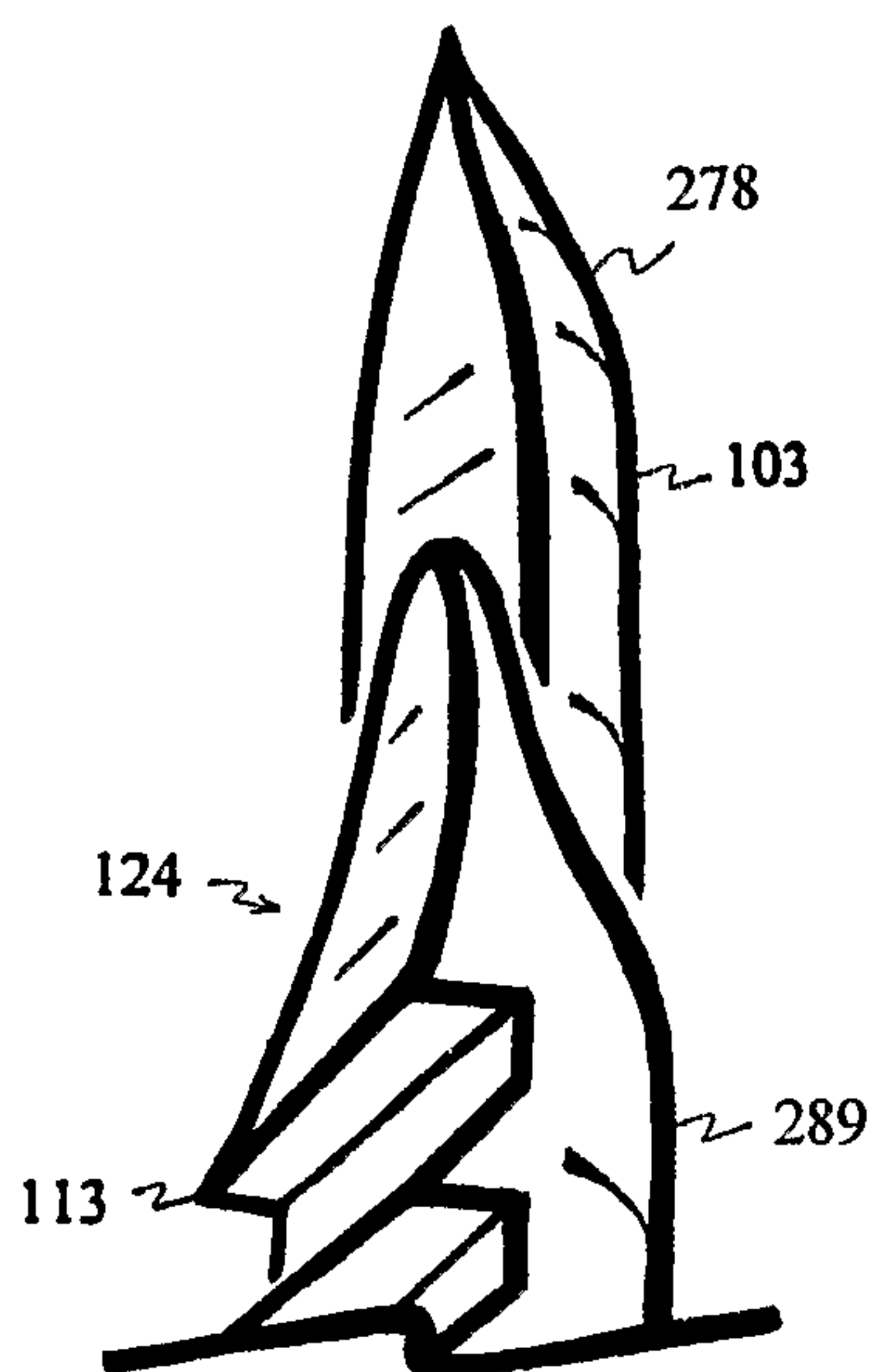


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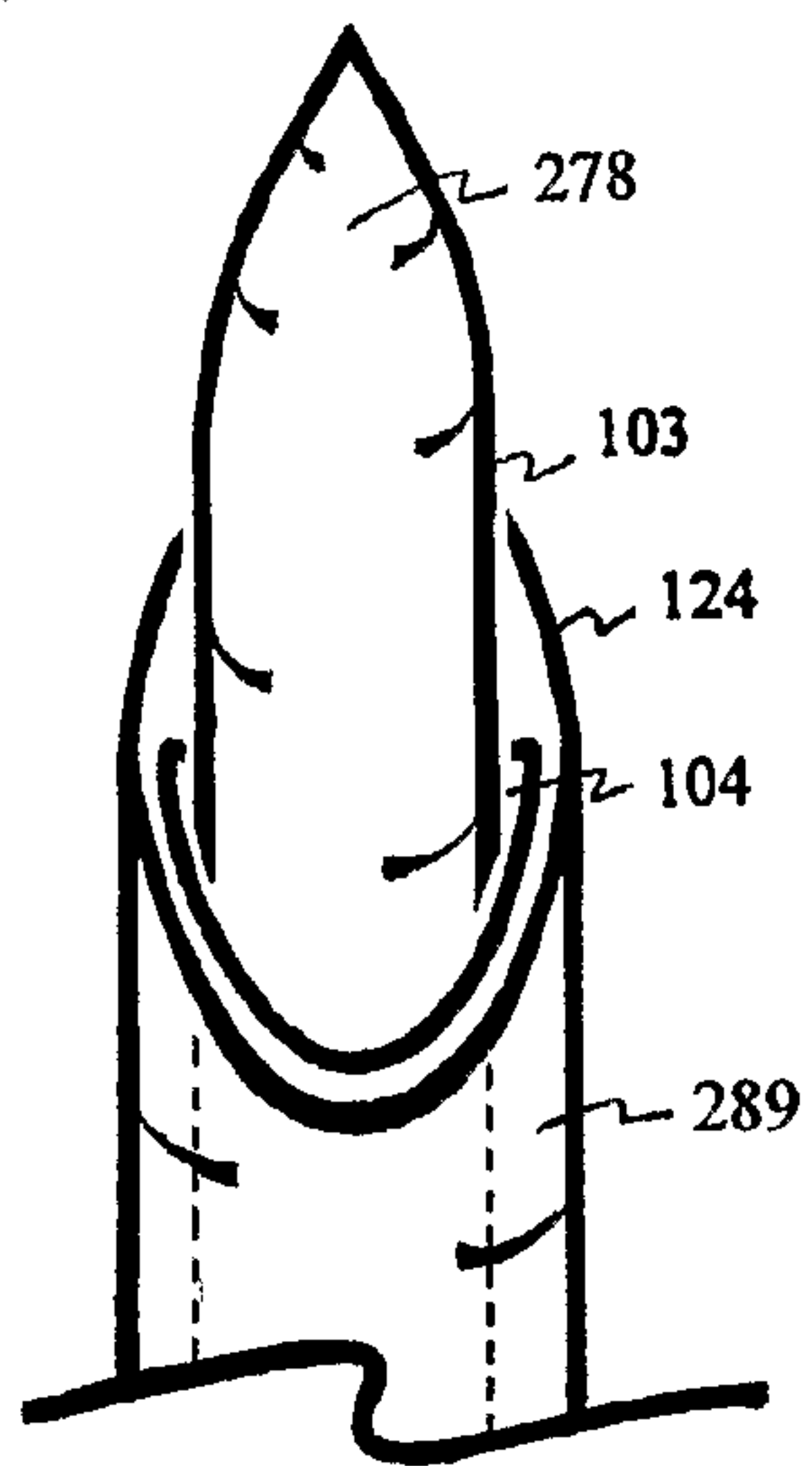


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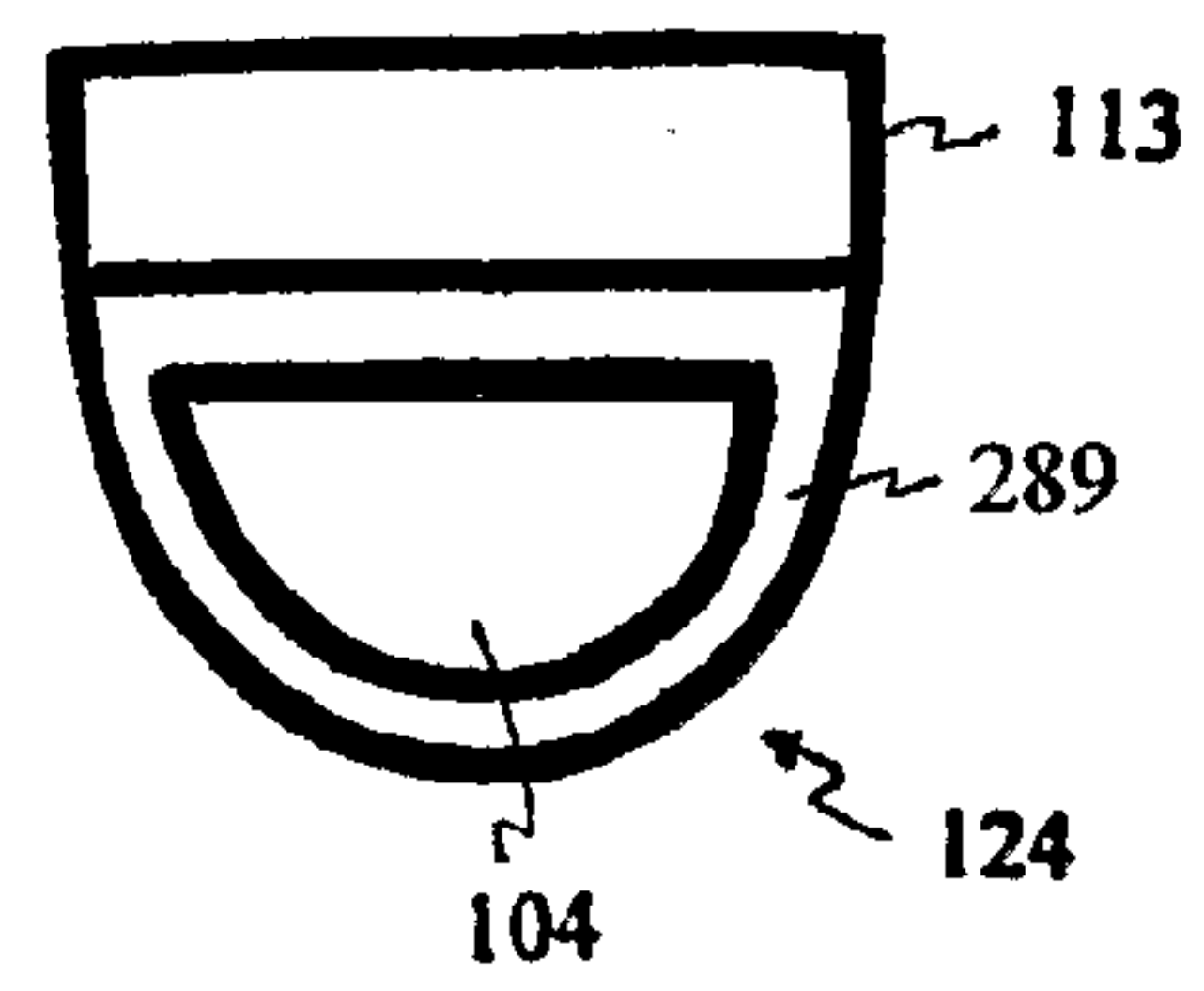


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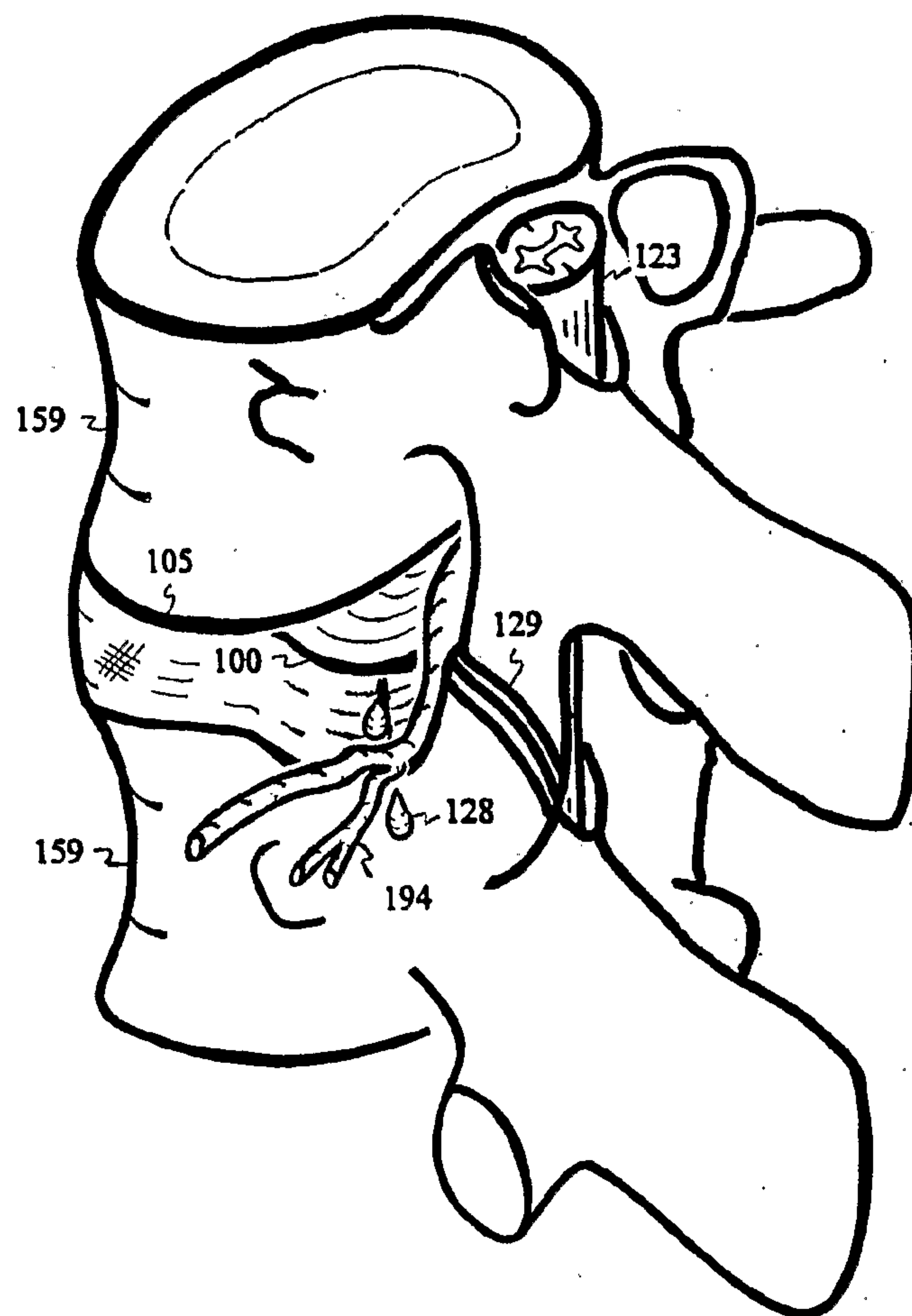


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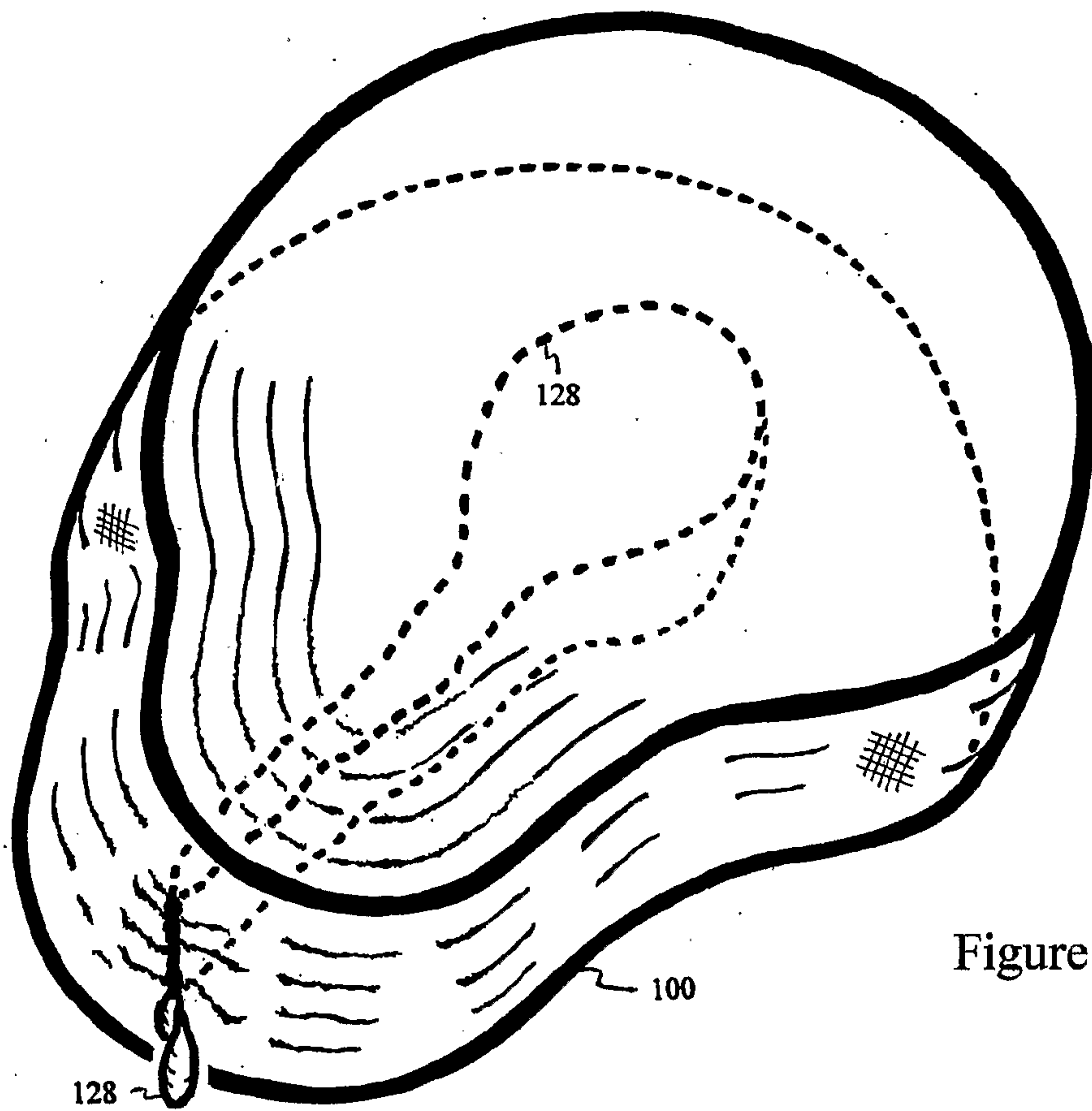


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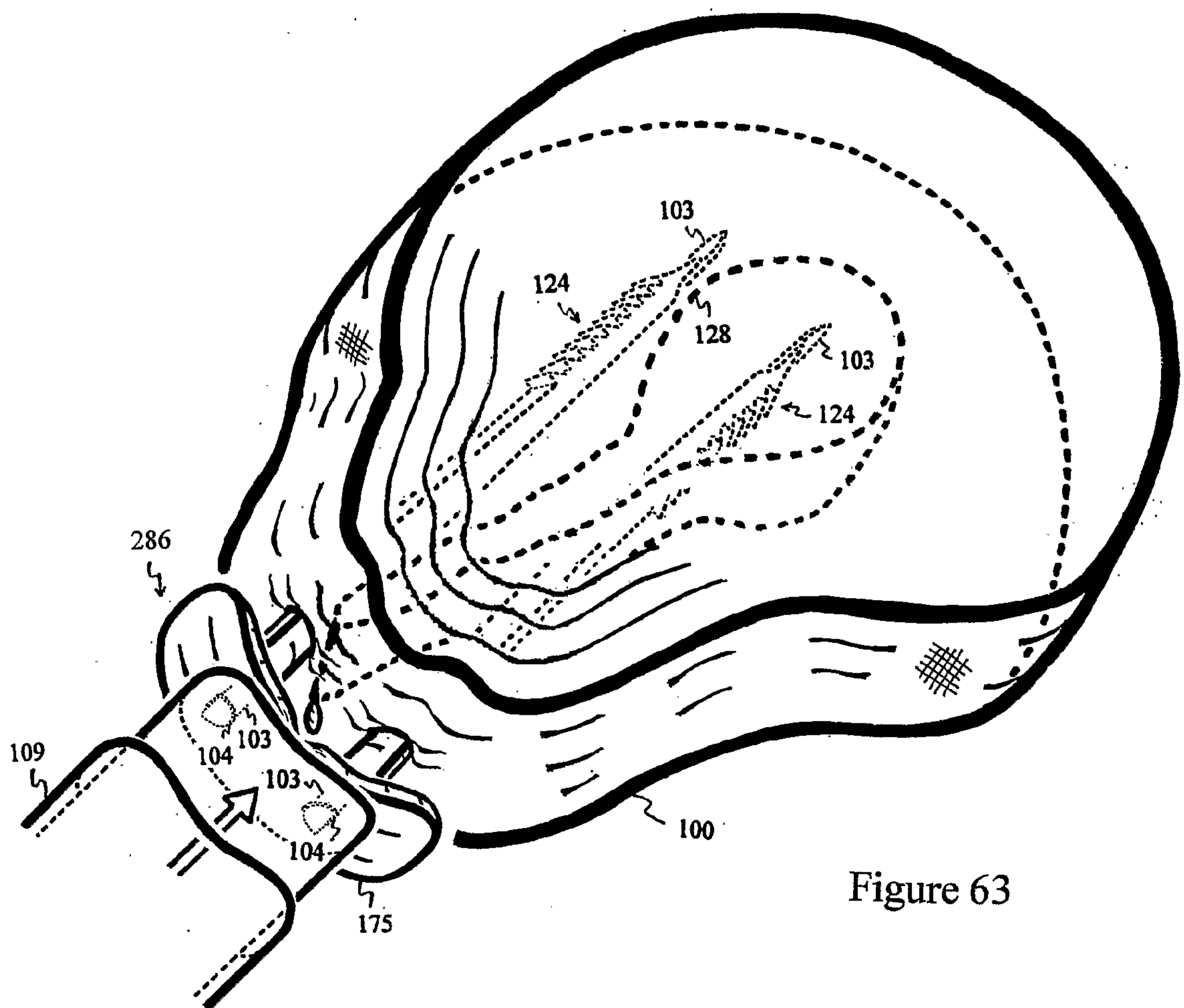


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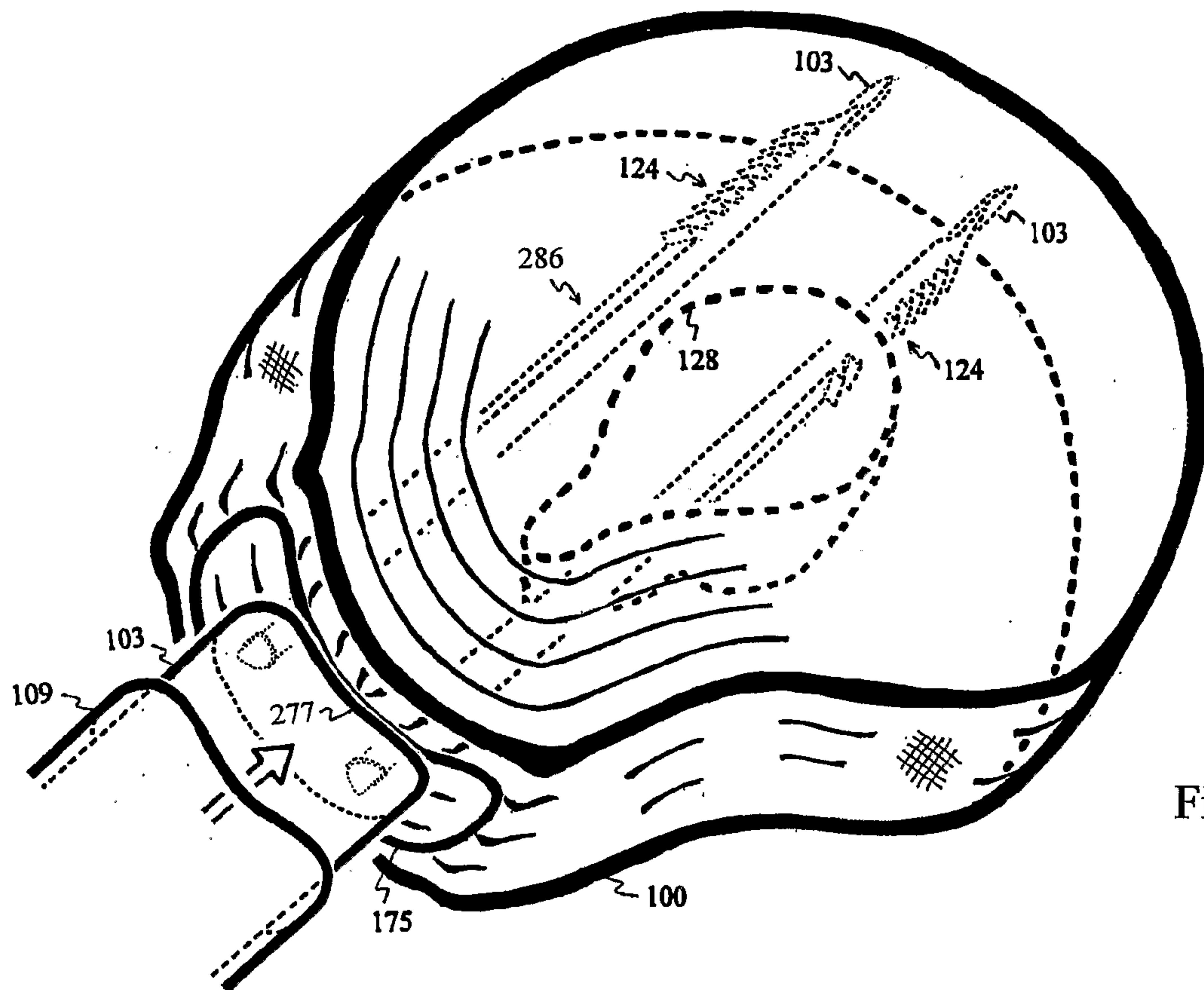
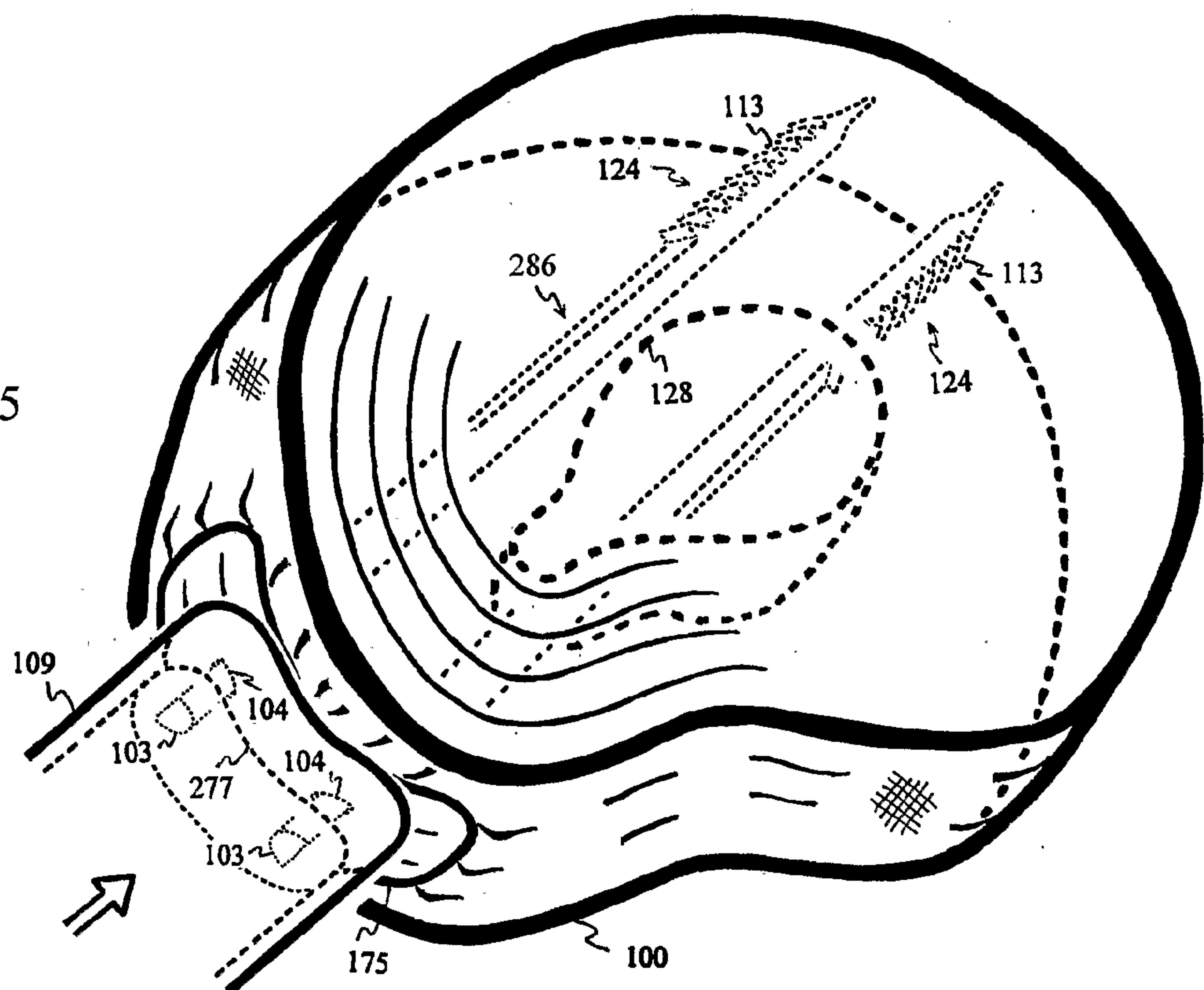


Figure 64

Figure 65



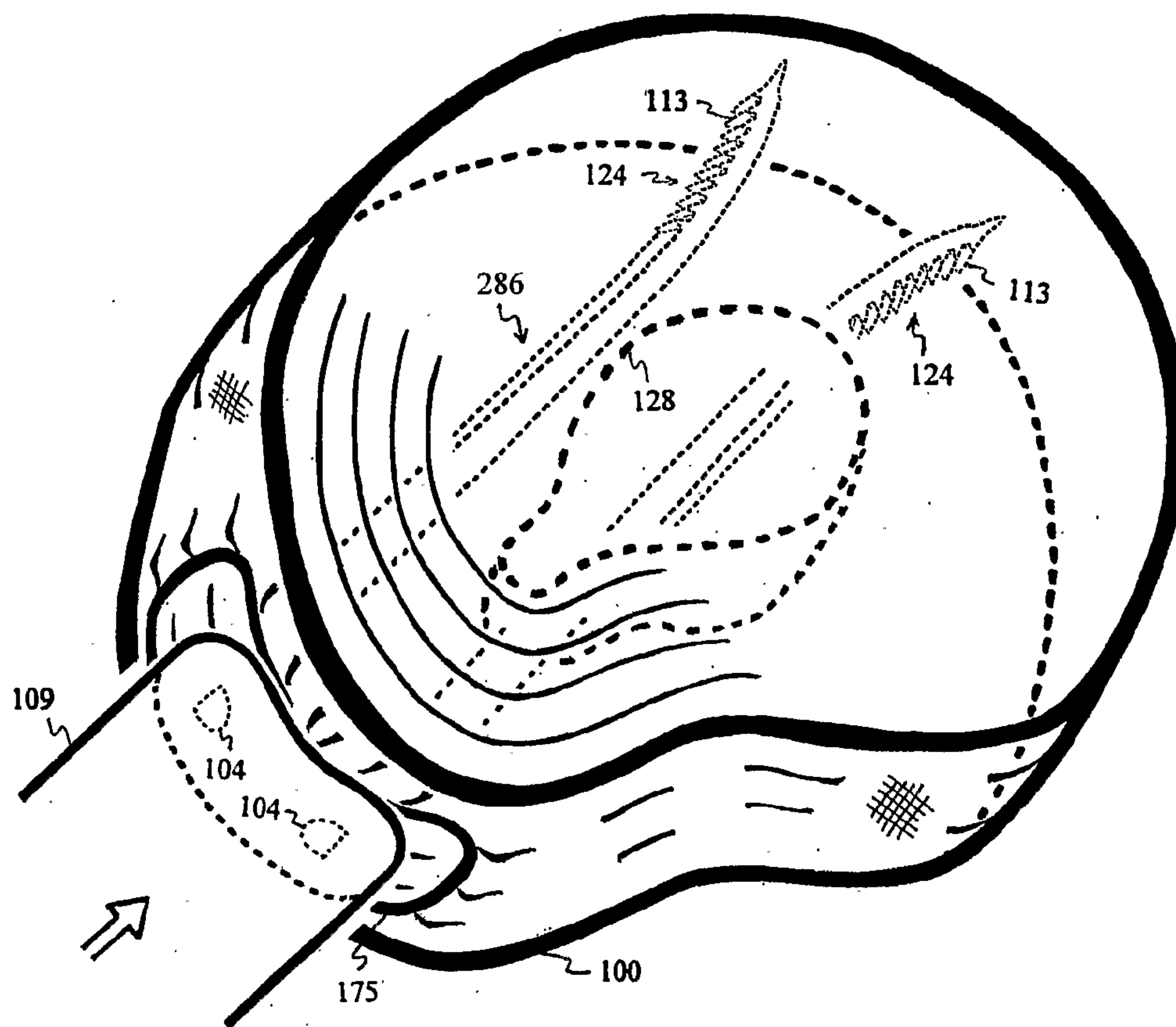
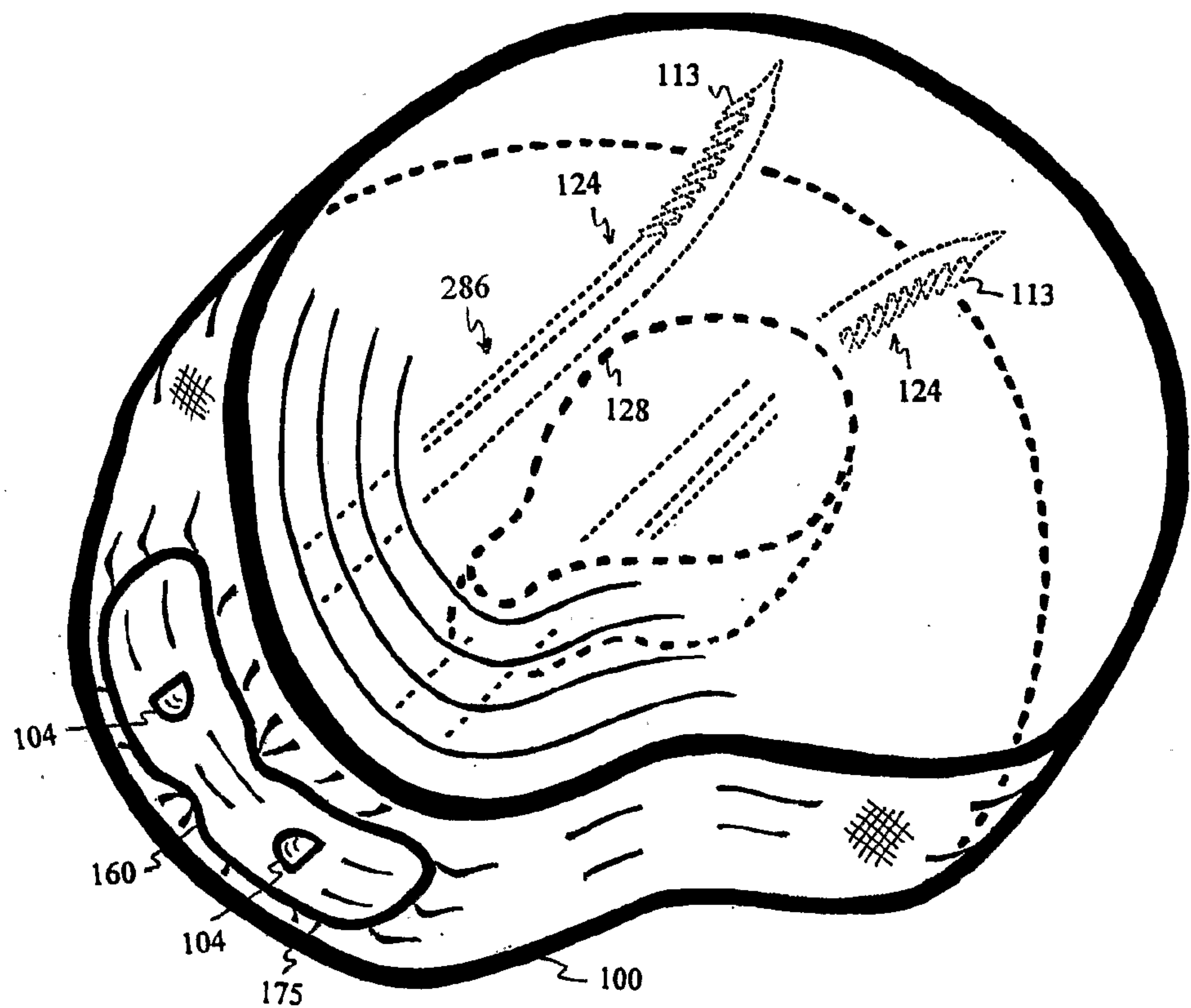


Figure 66

Figure 67



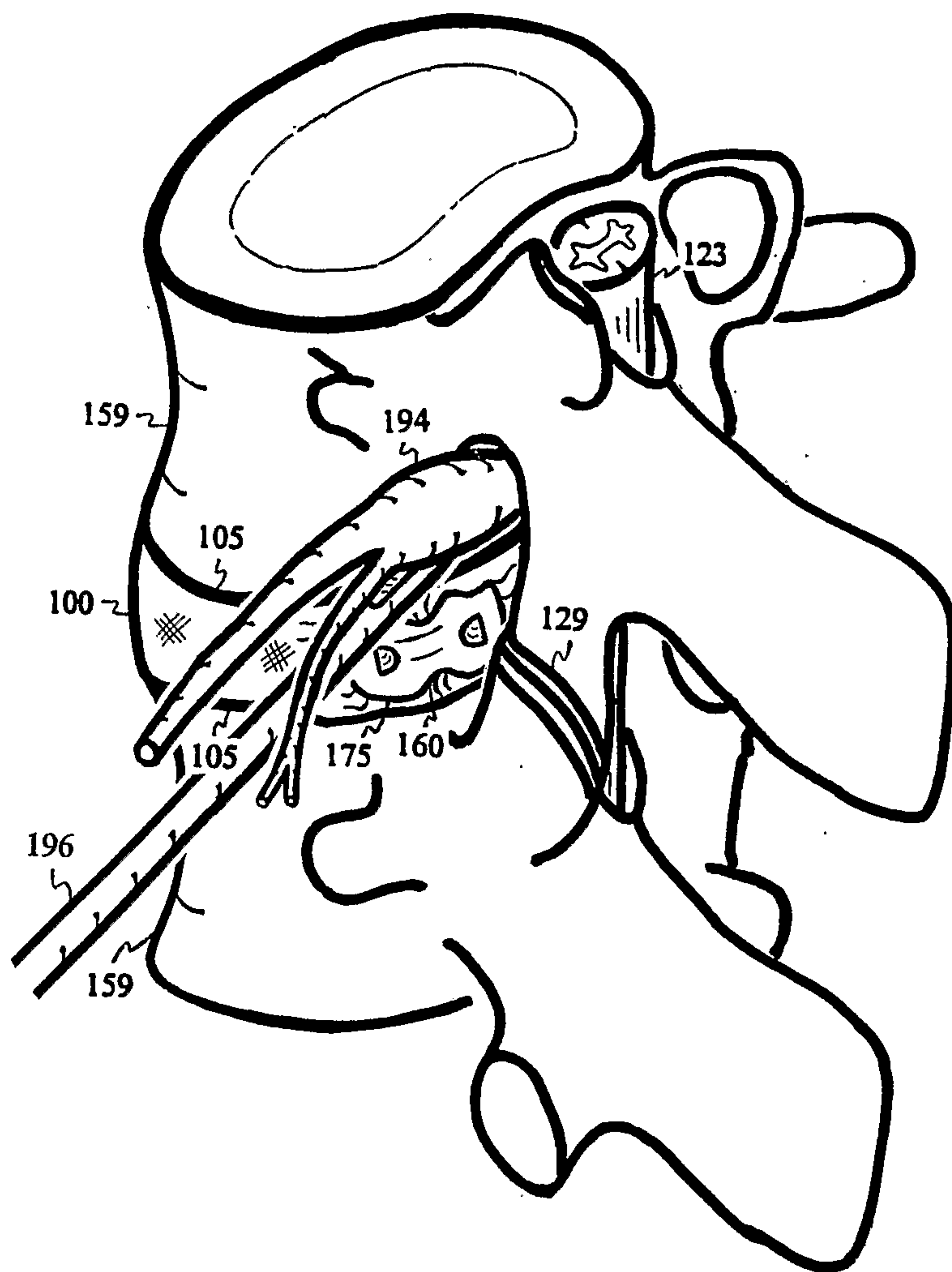
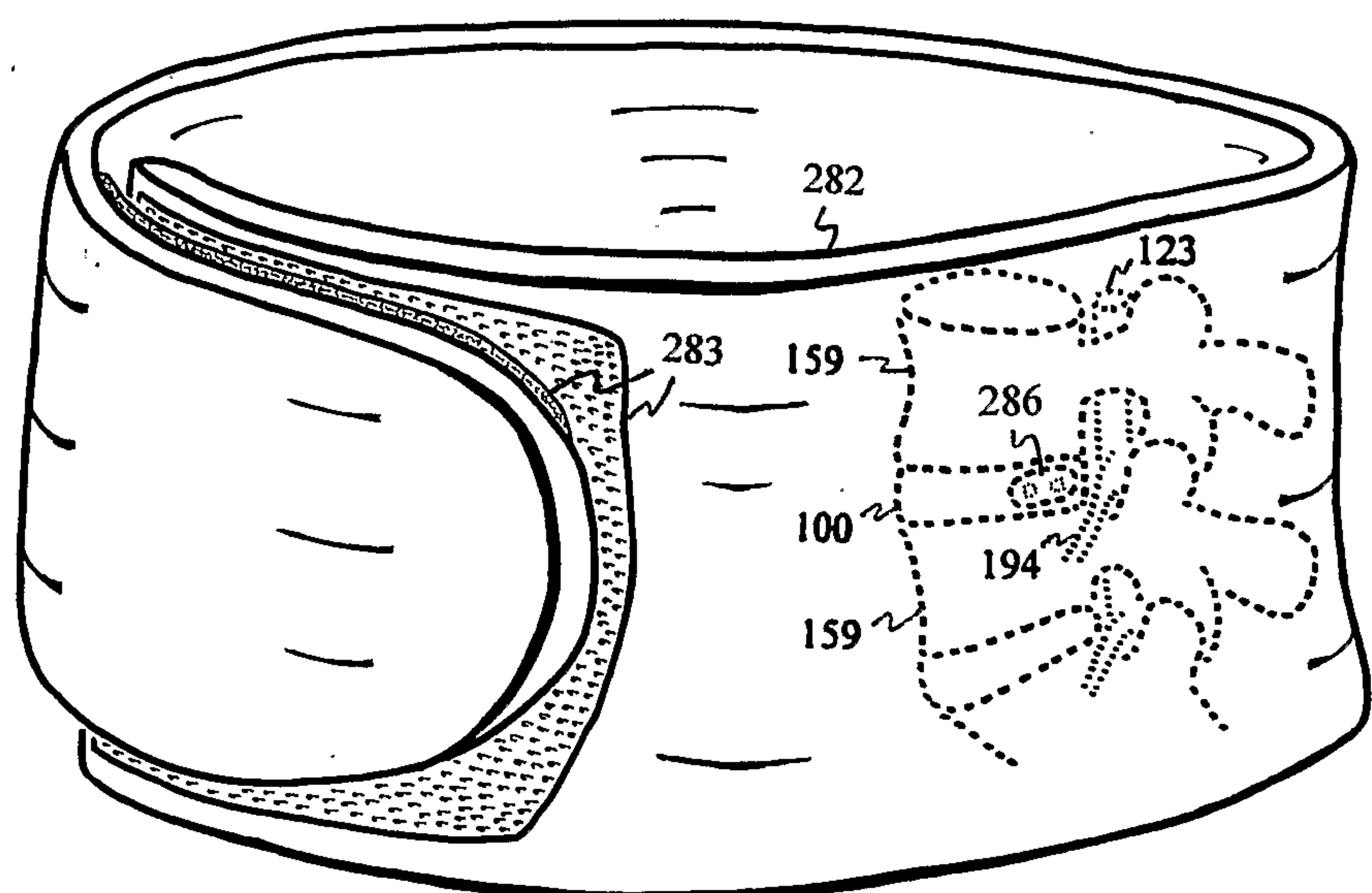


Figure 68

Figure 69



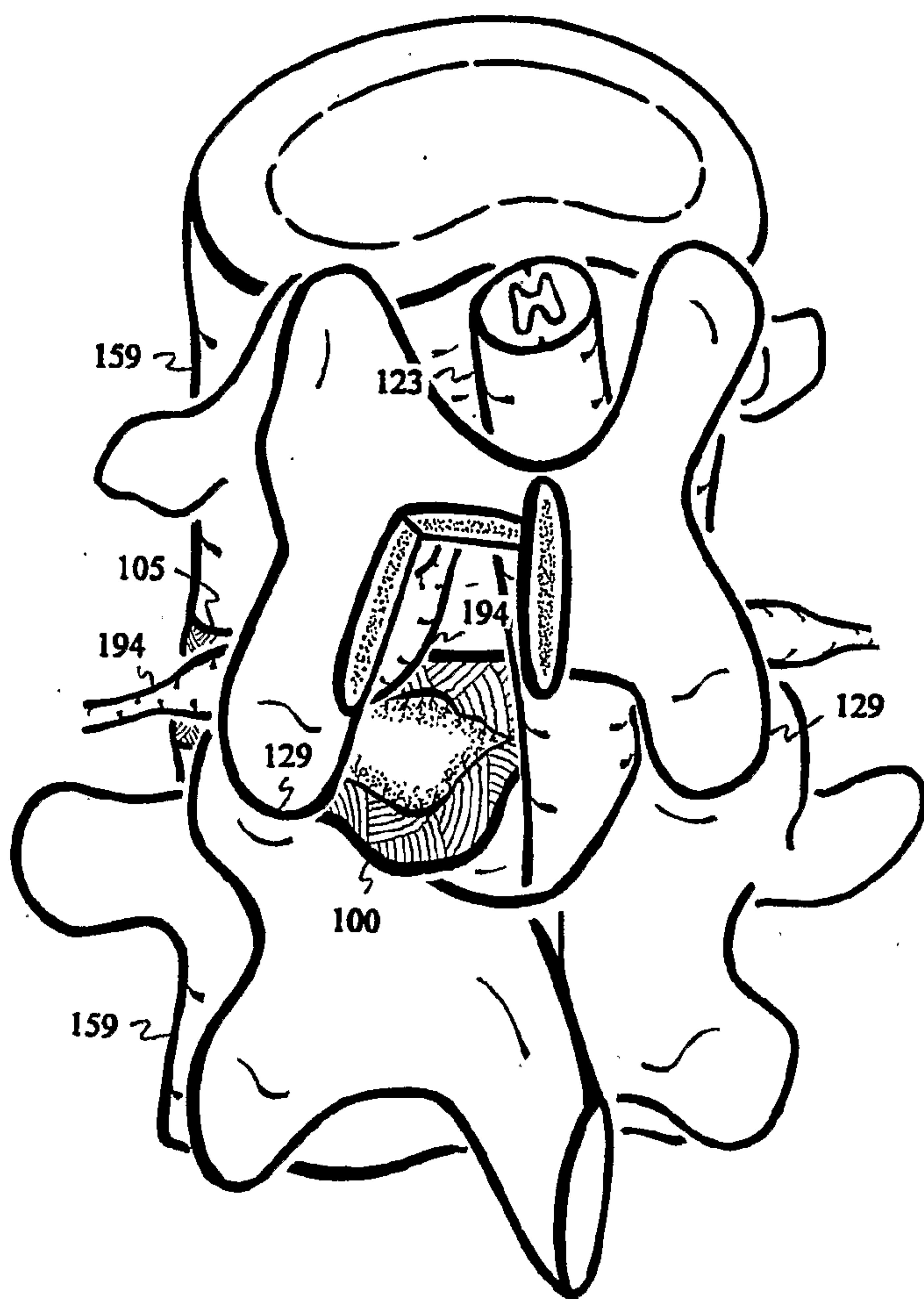


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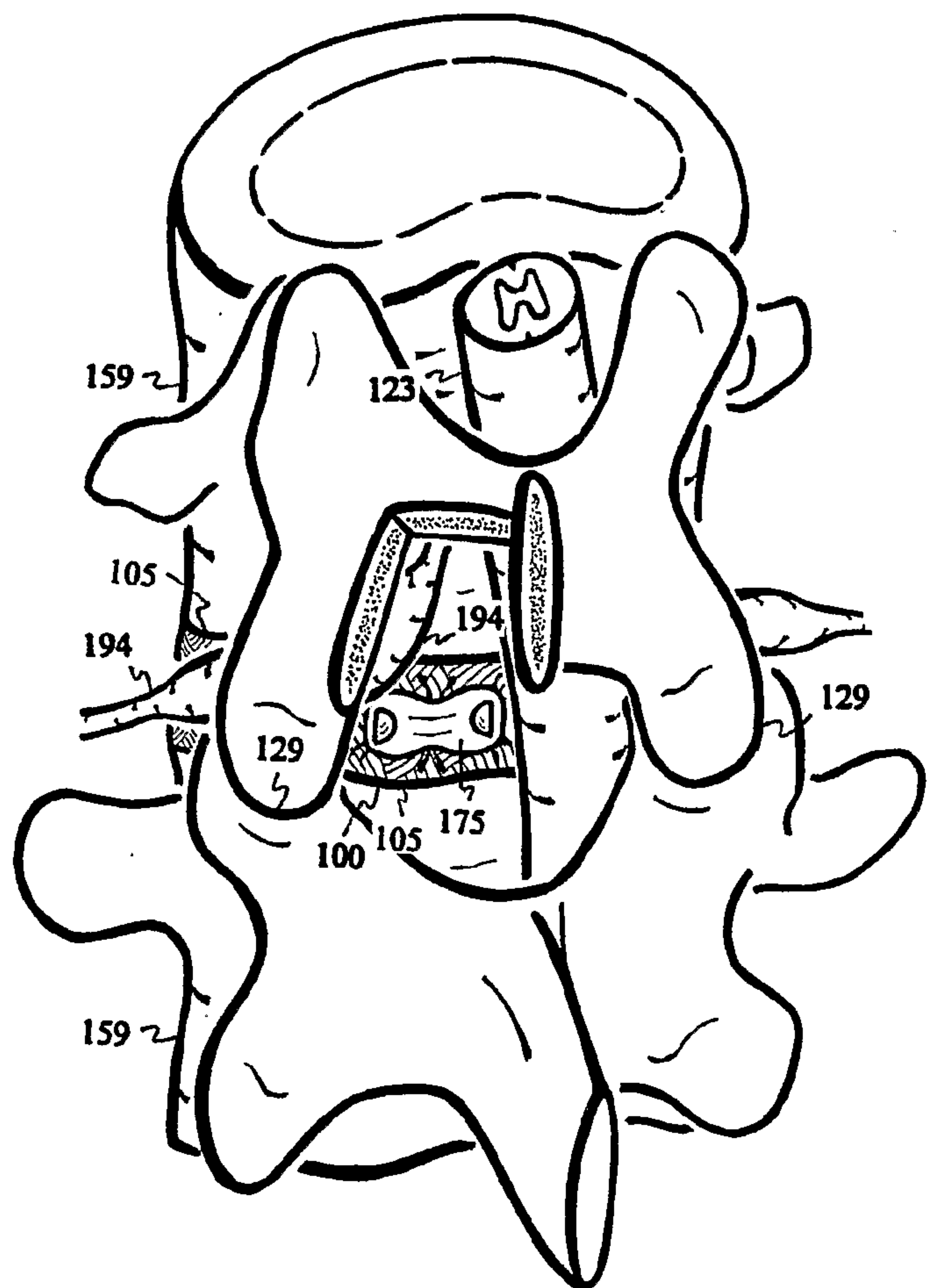


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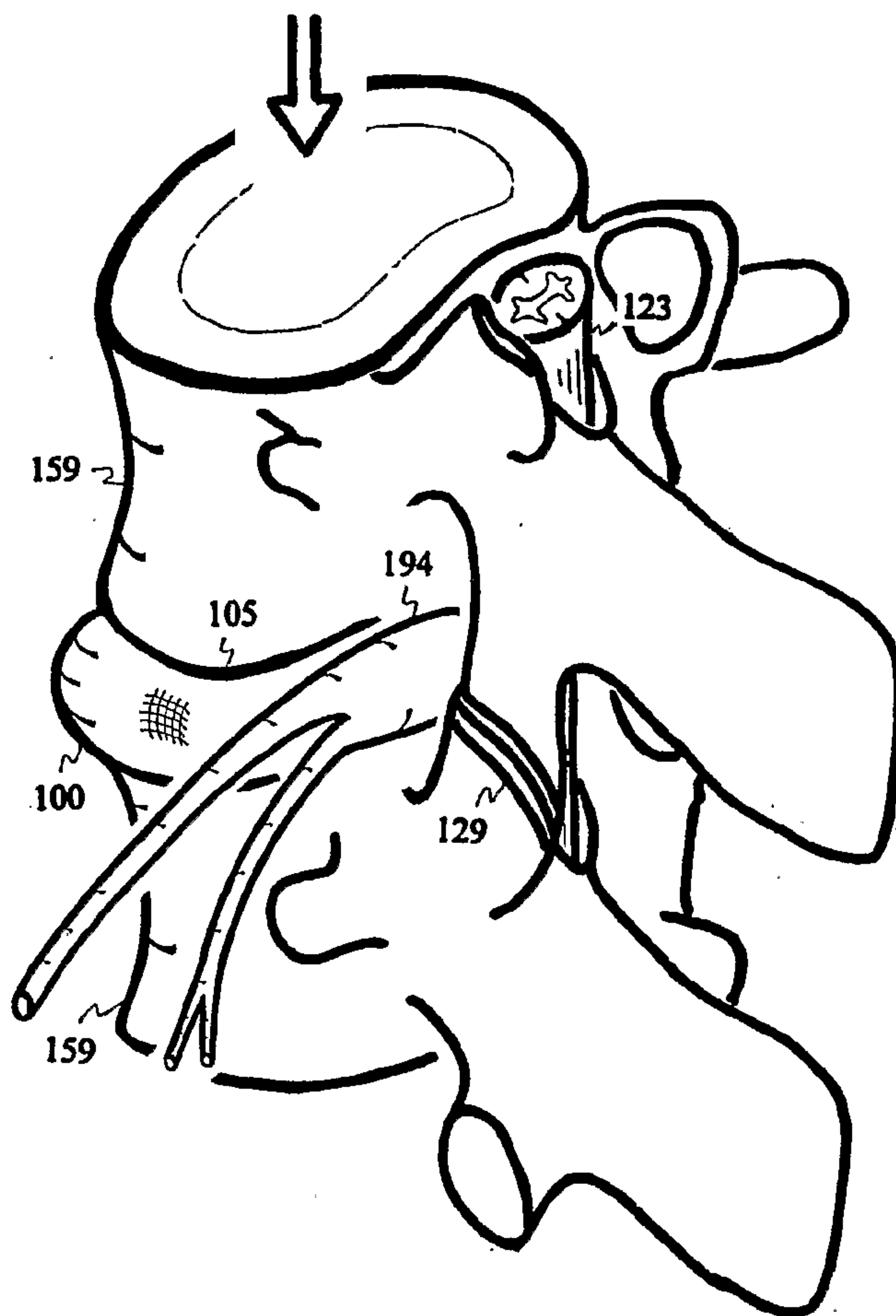


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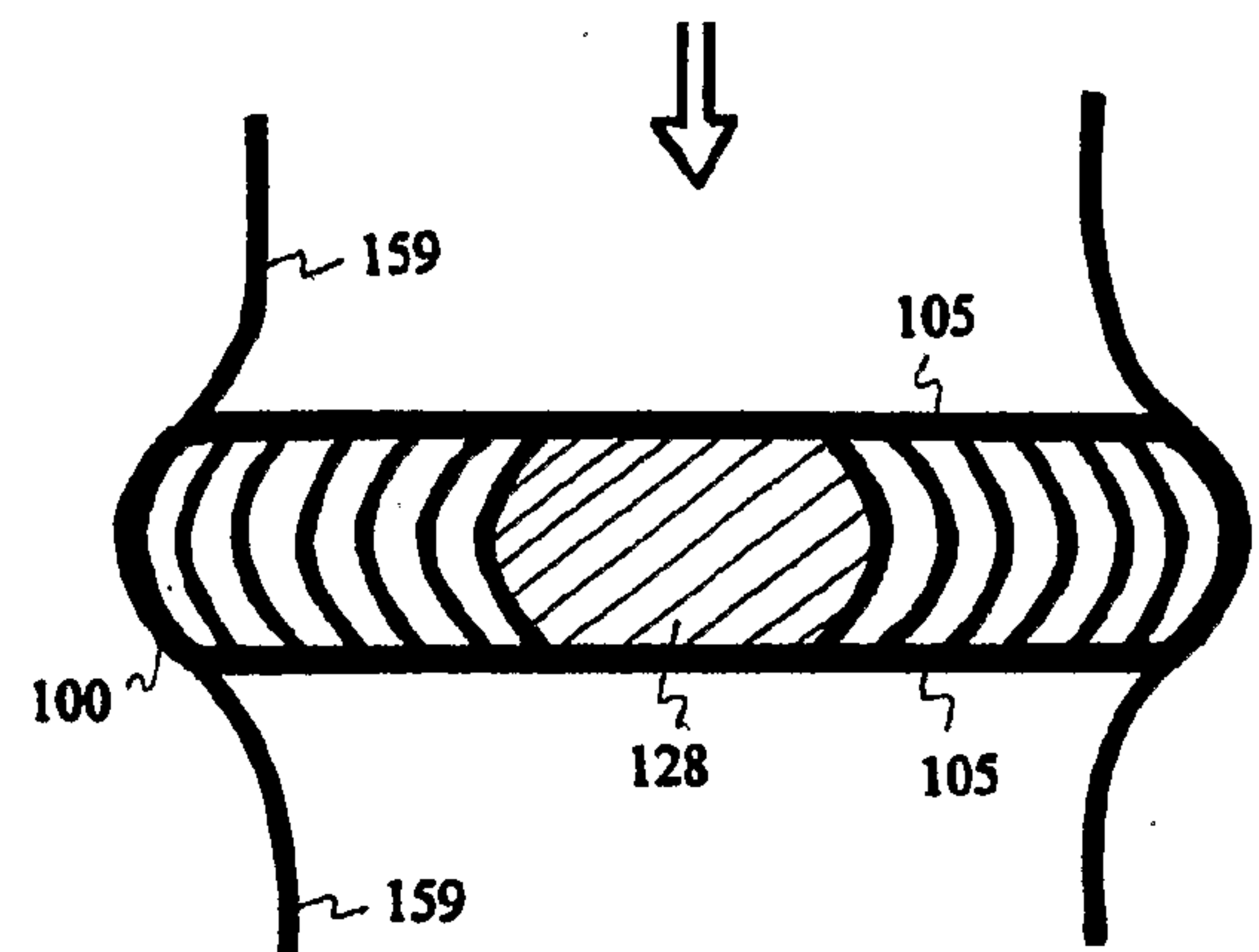


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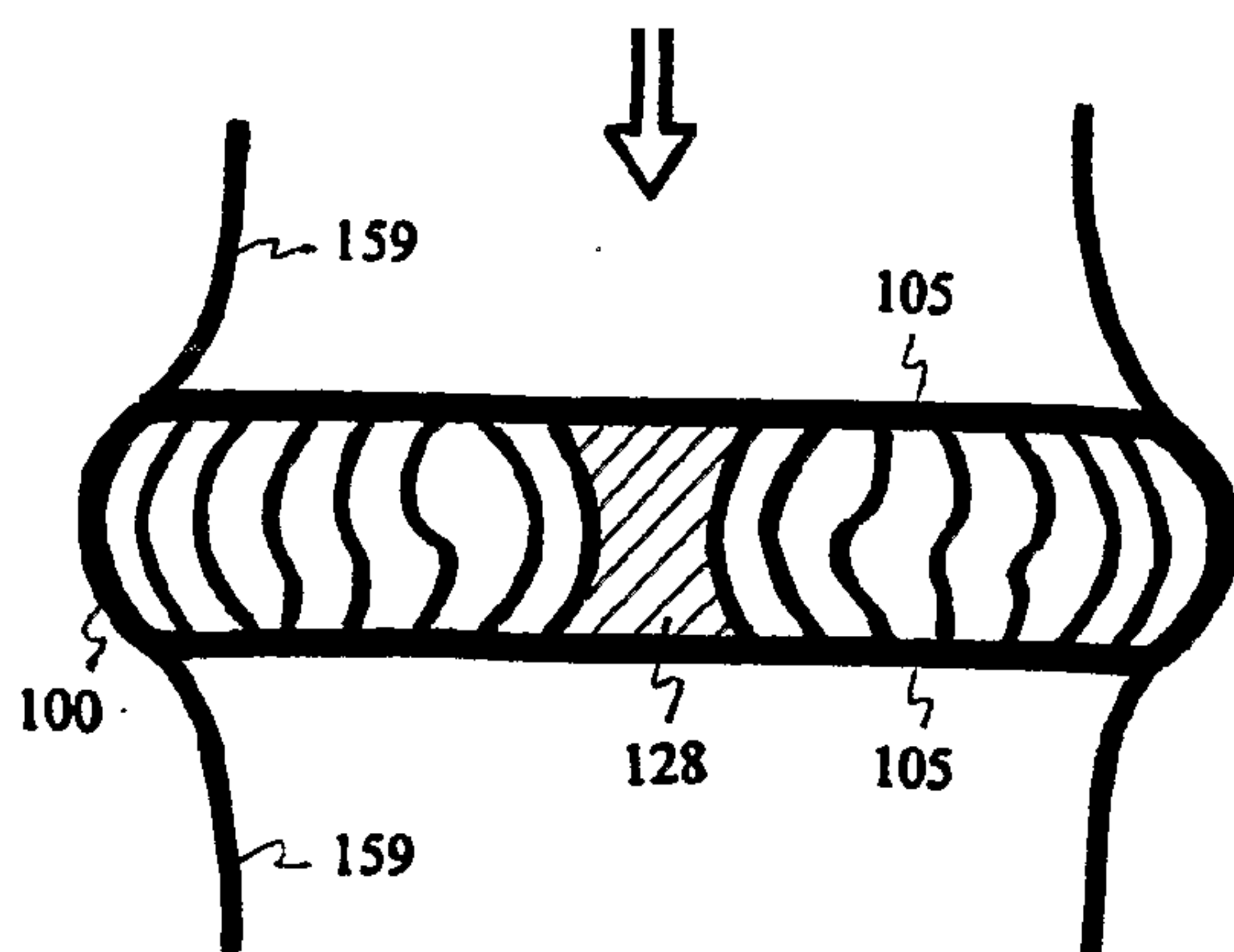


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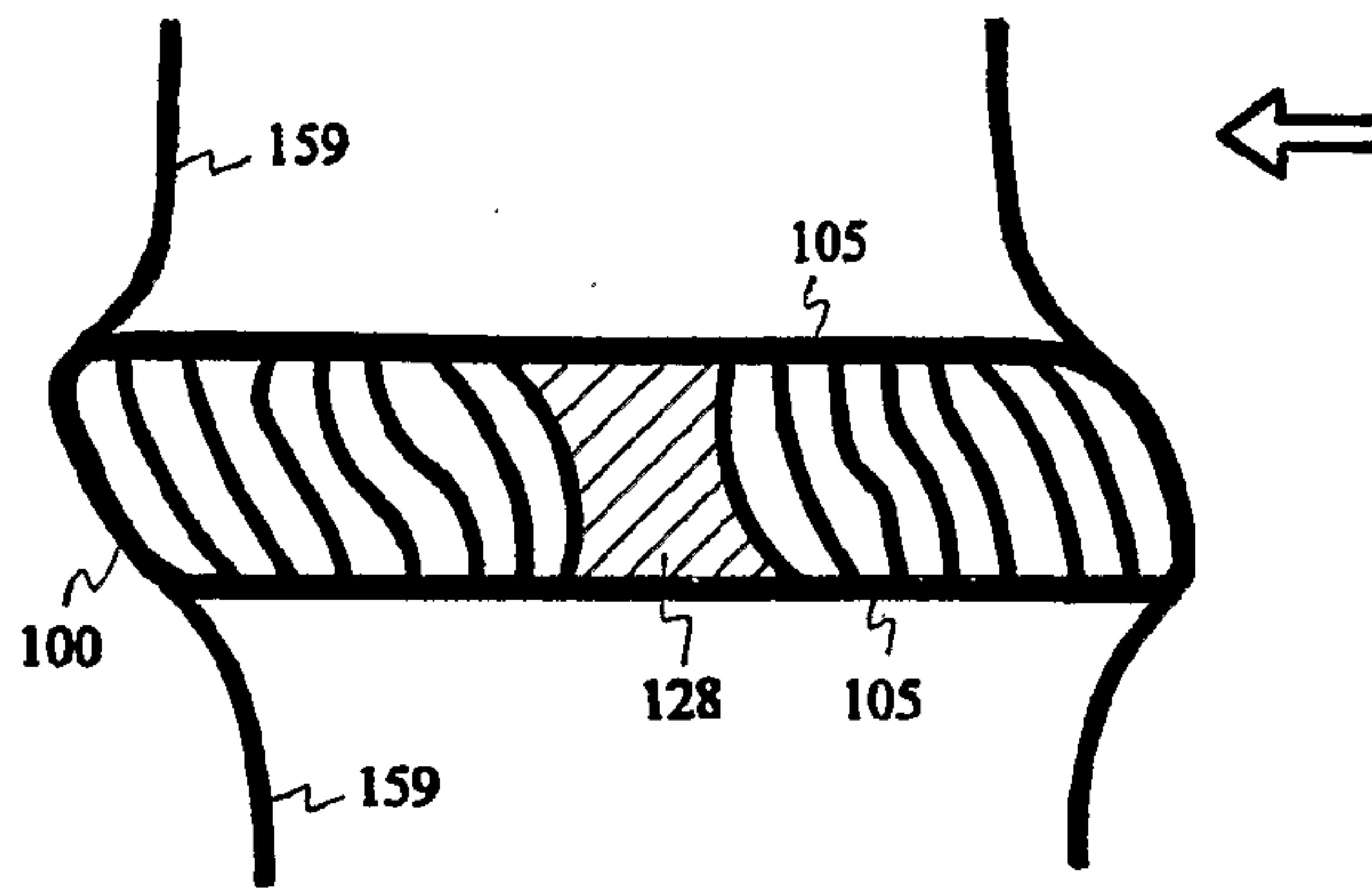


Figure 75

Figure 76

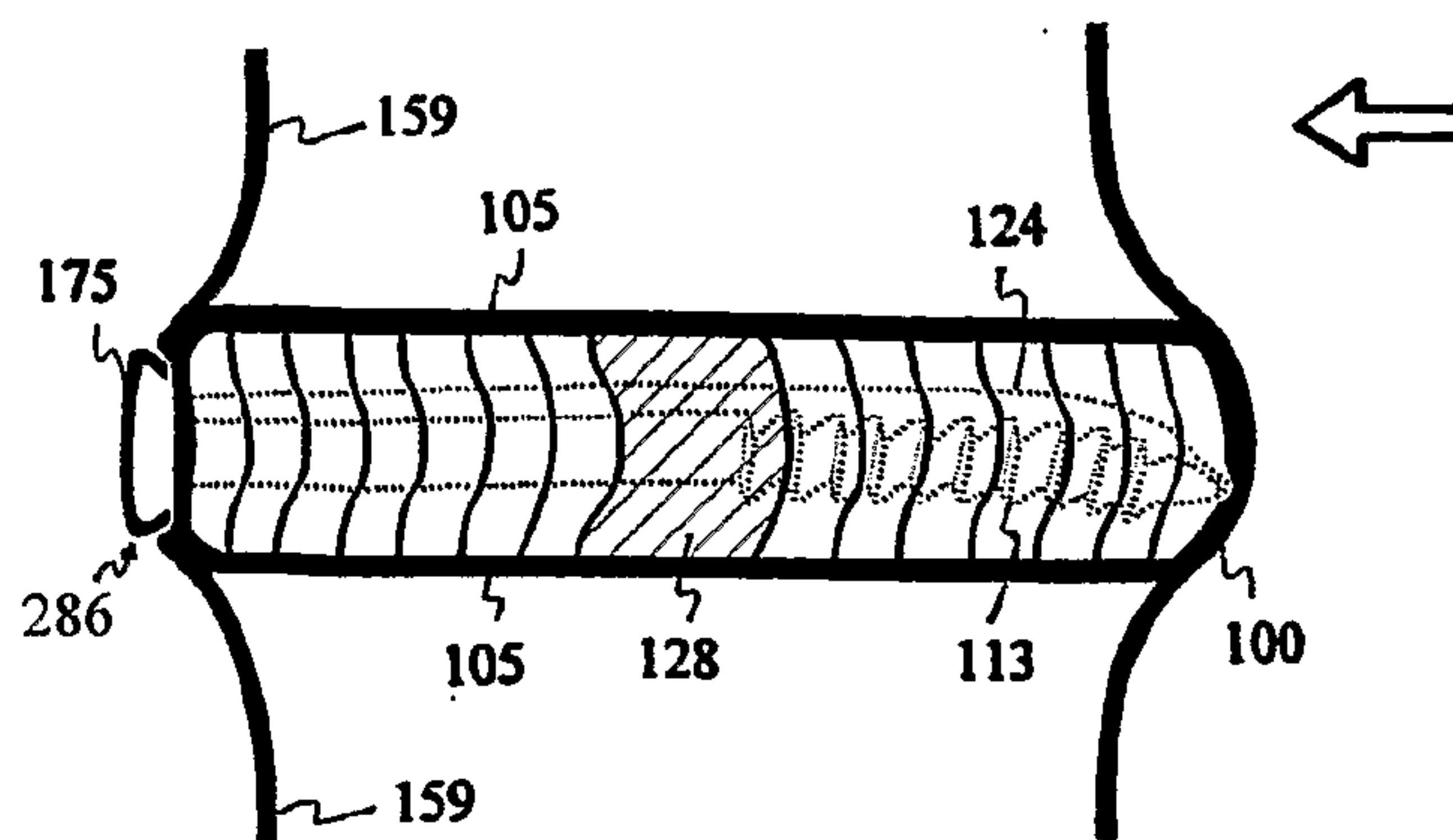
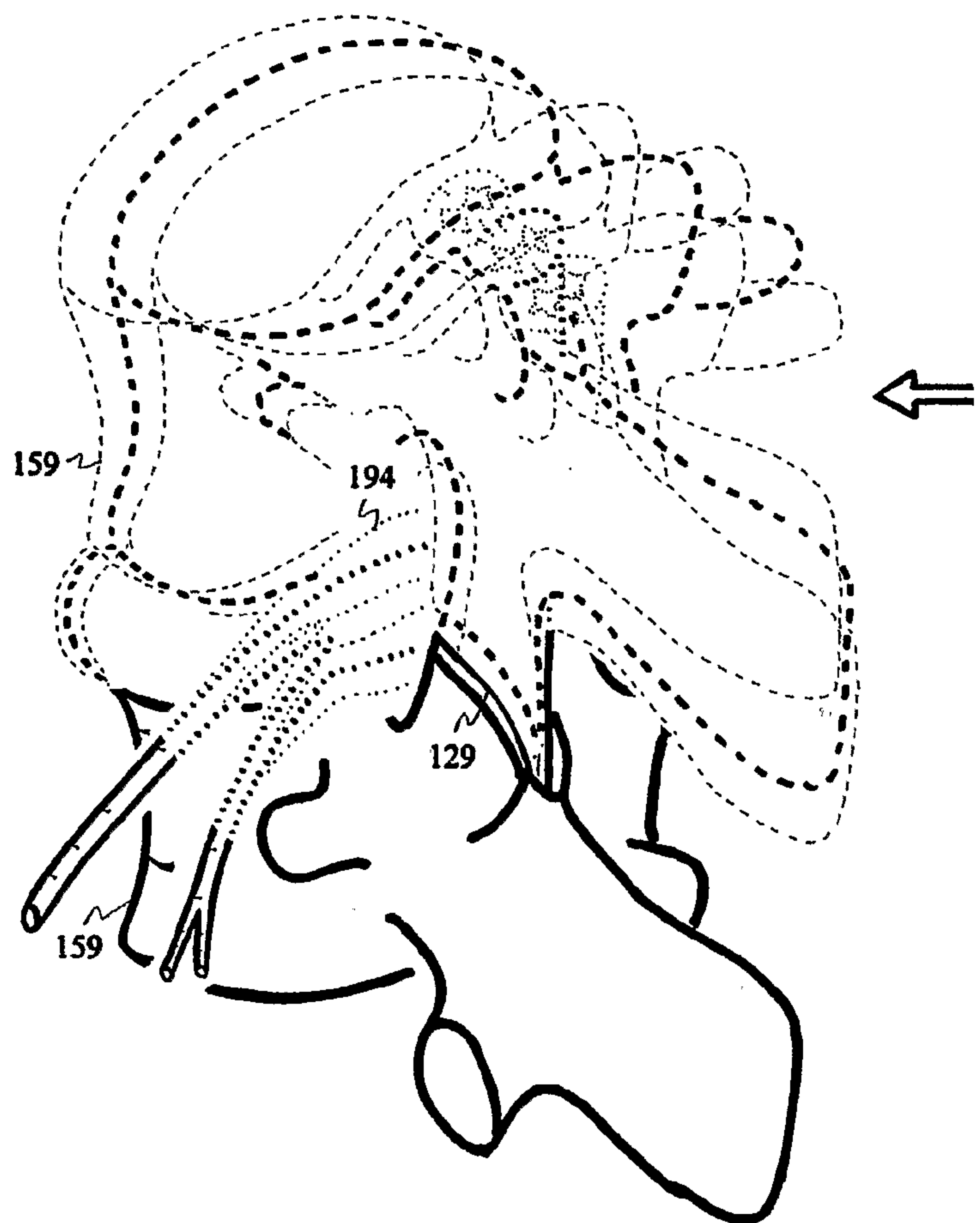


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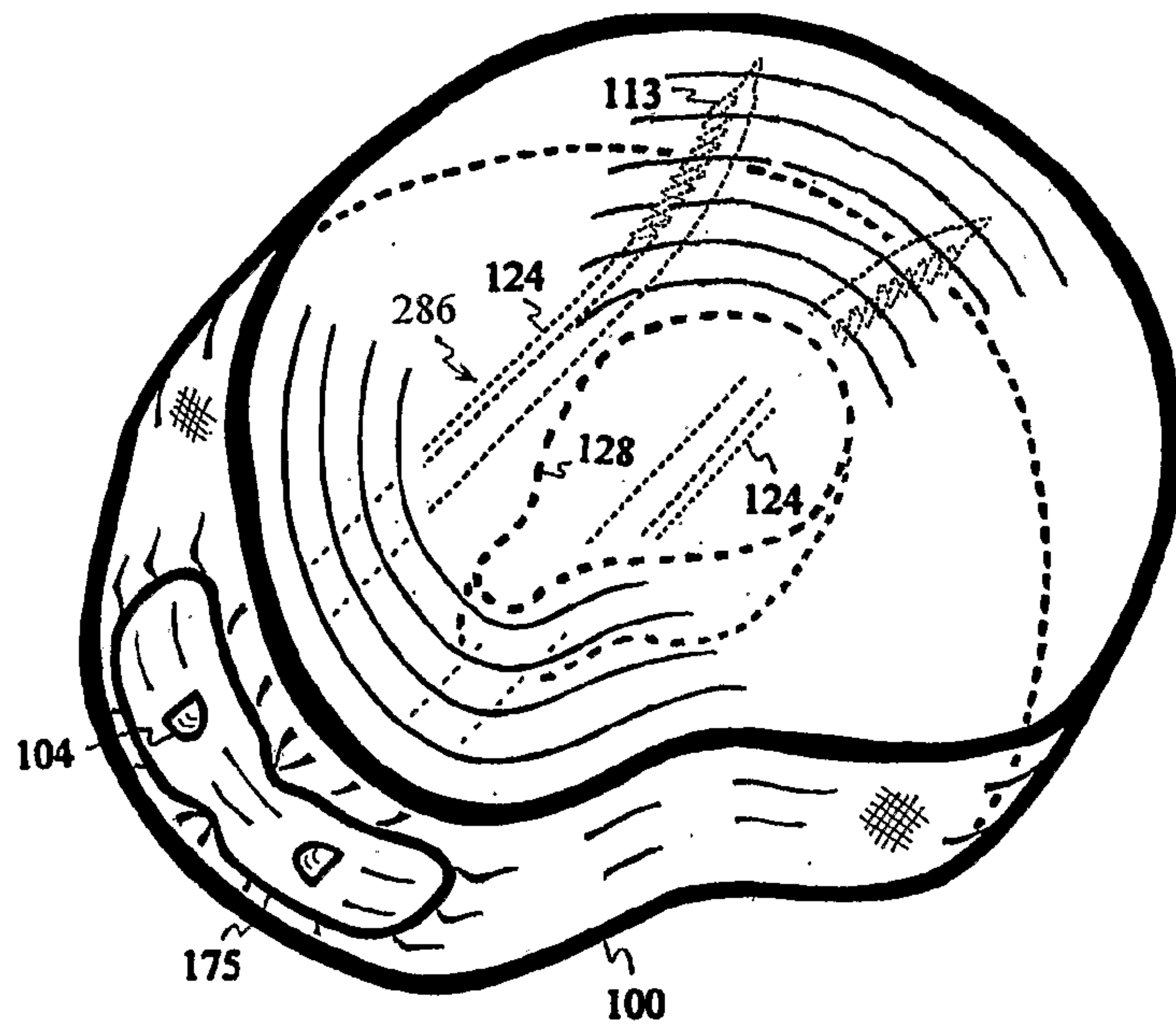


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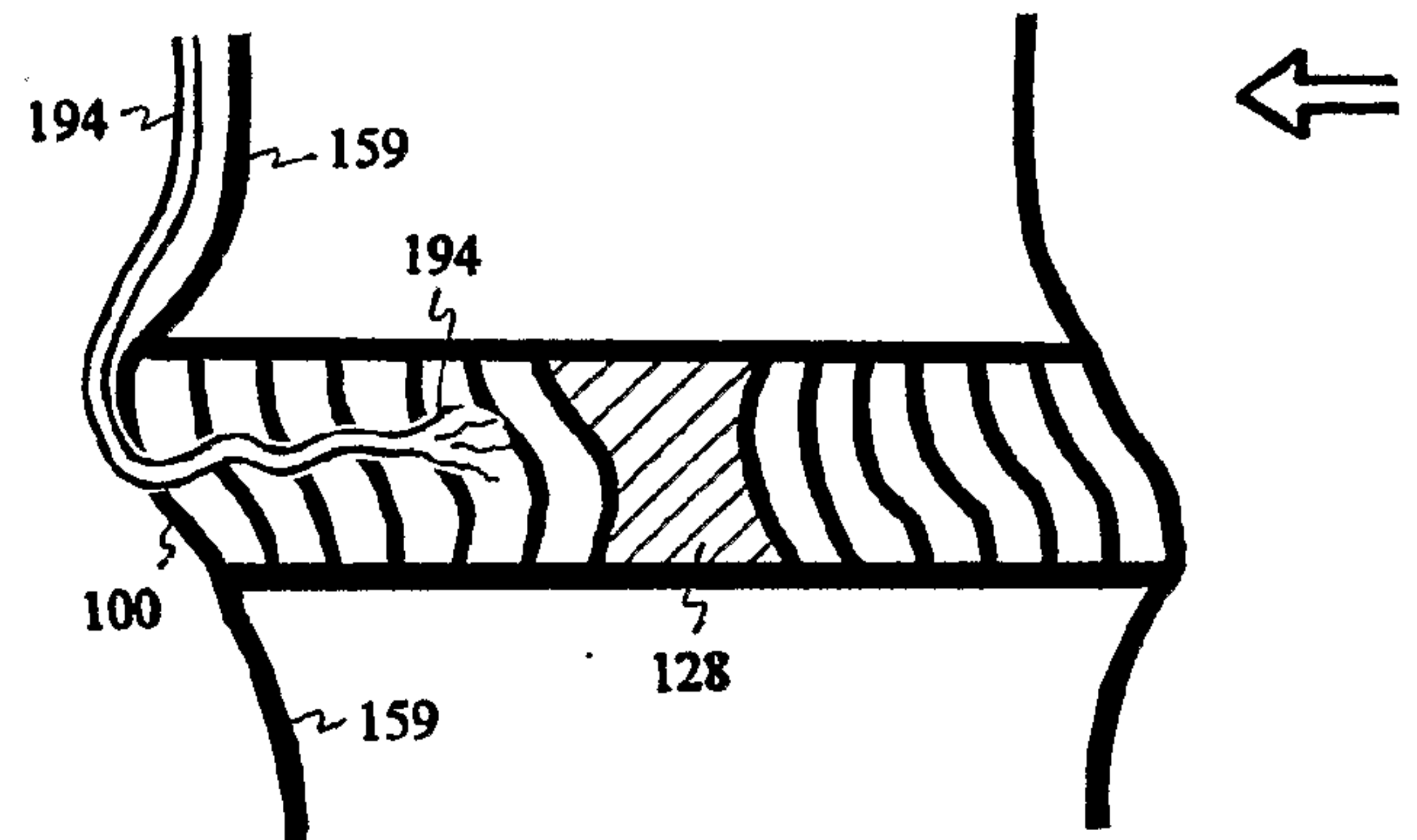


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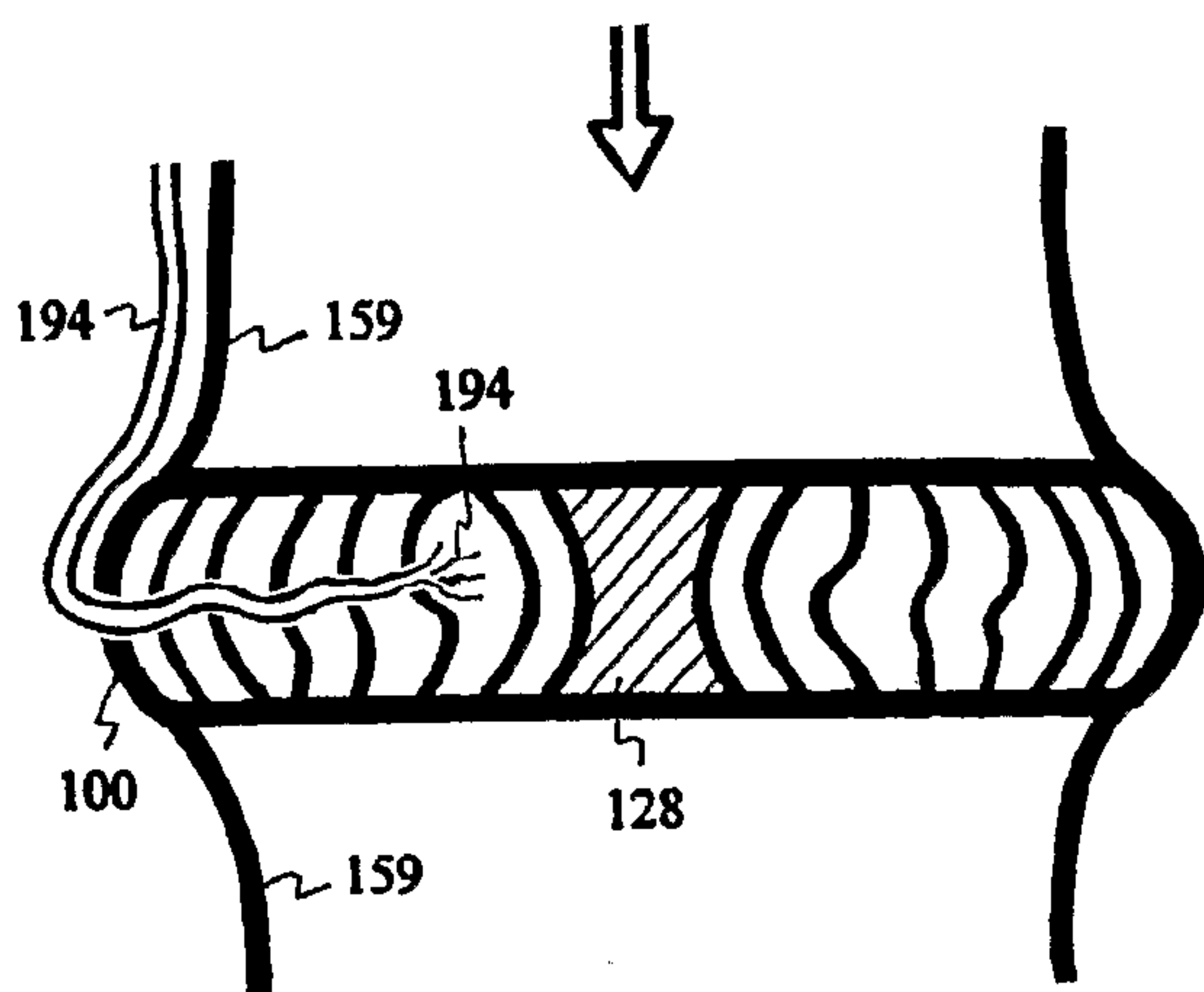
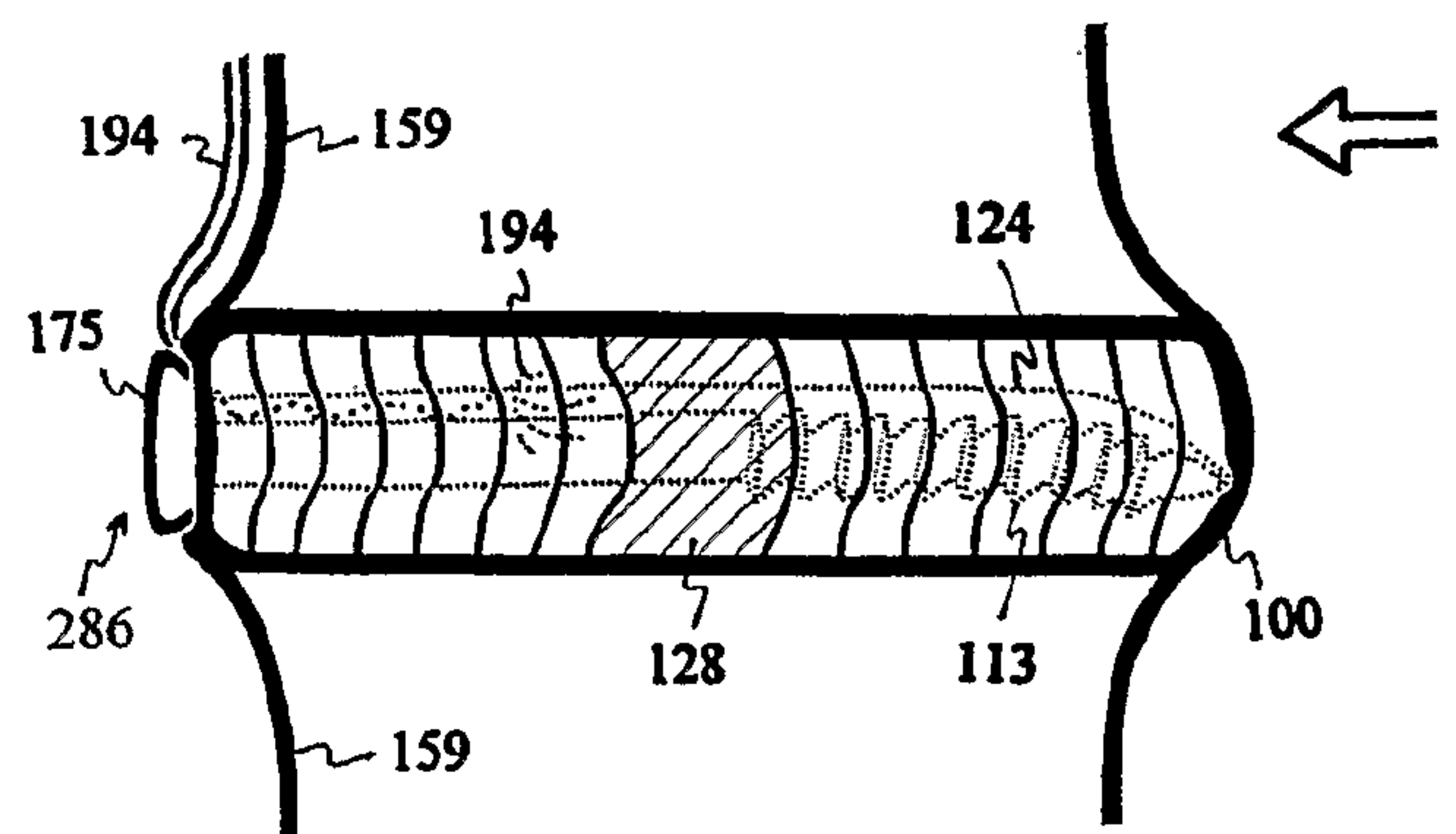


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Figure 81



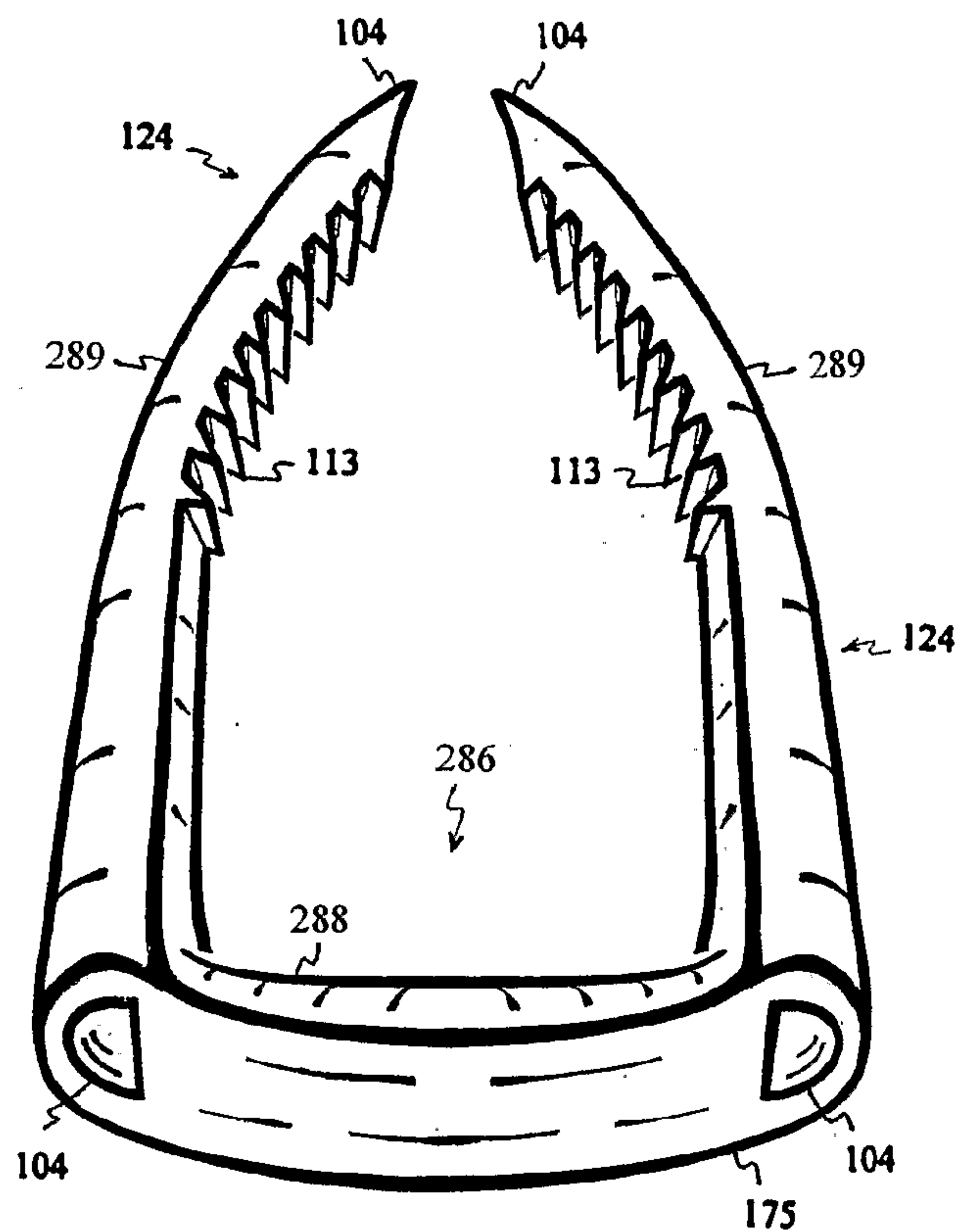


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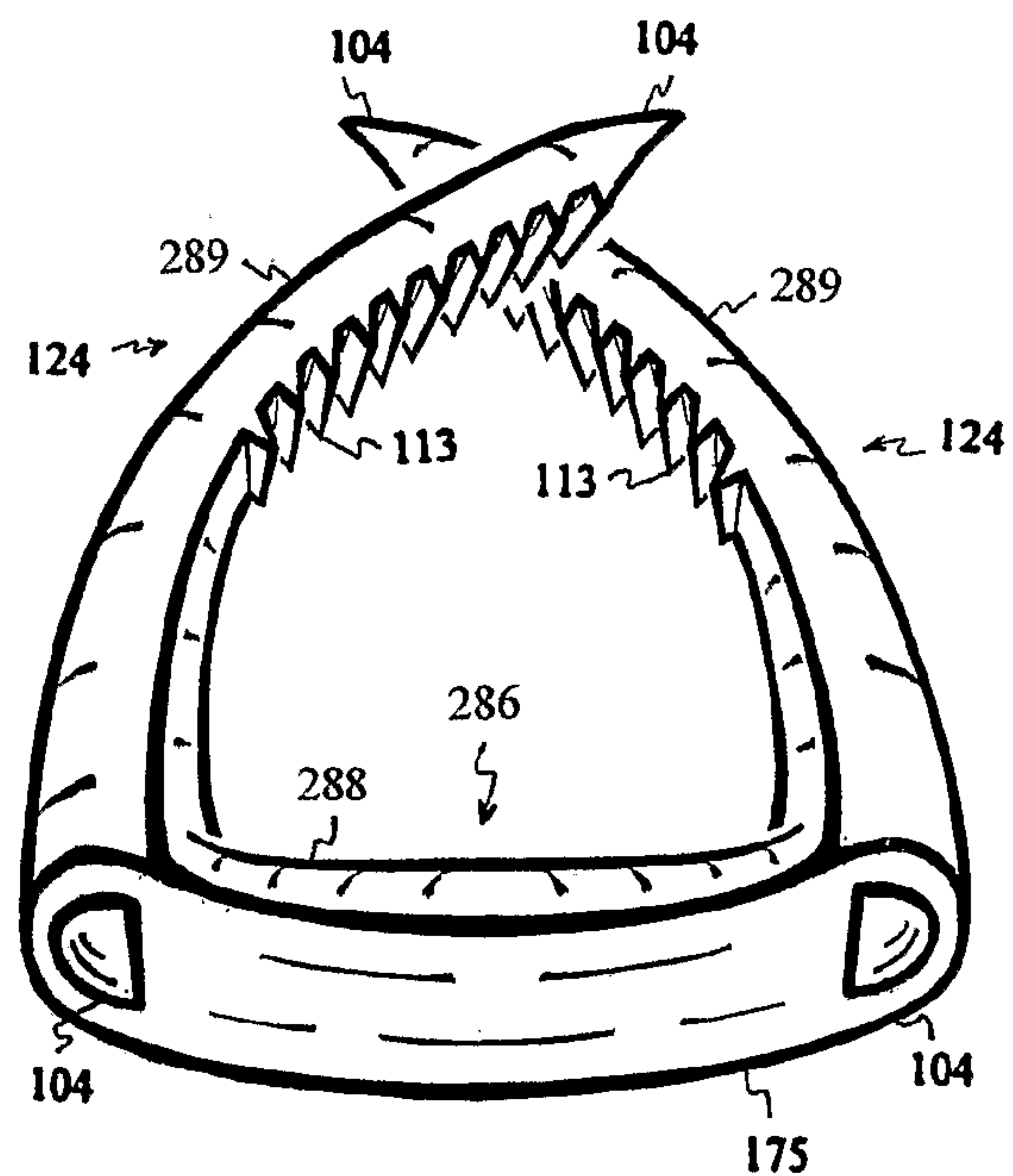


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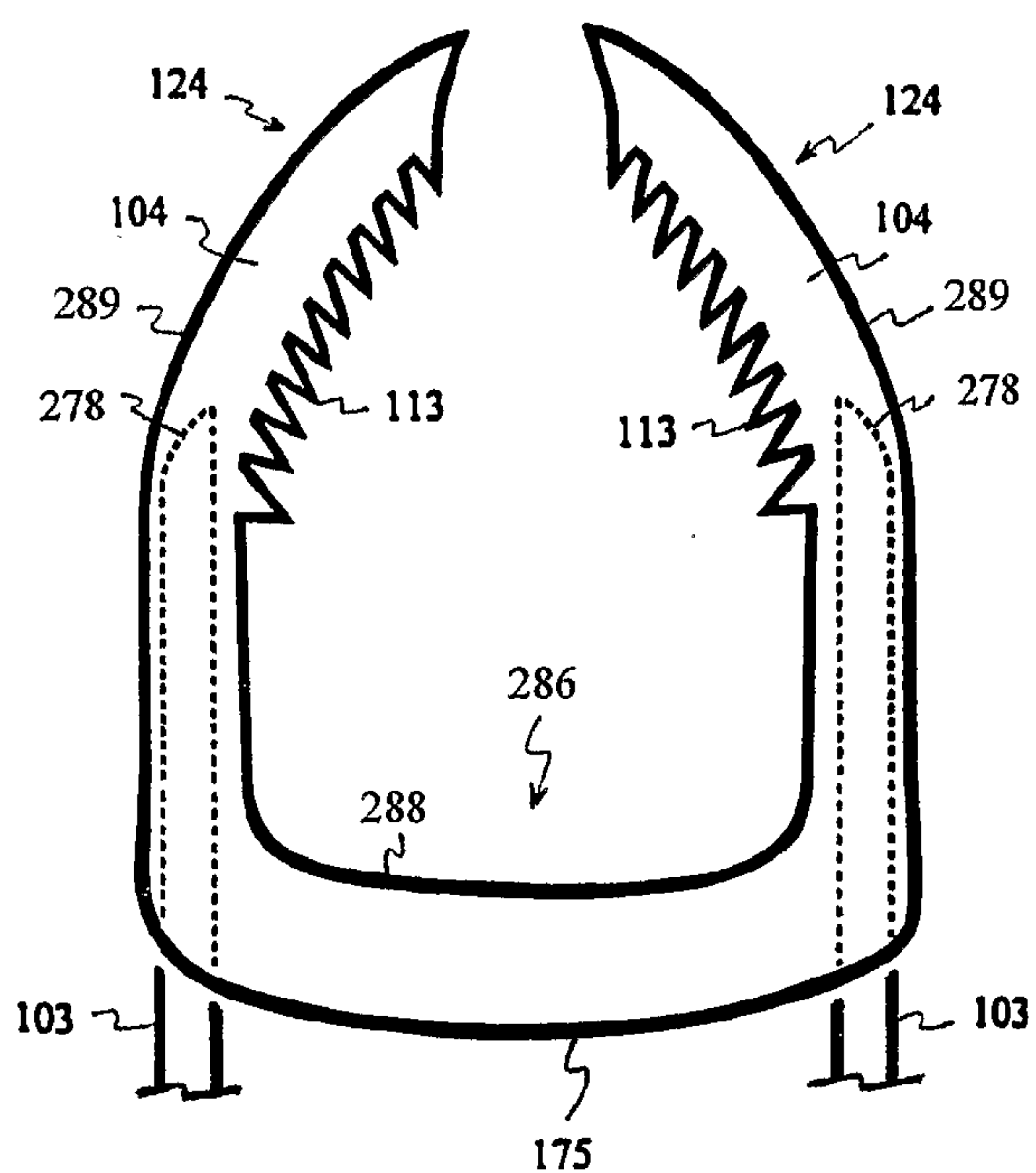


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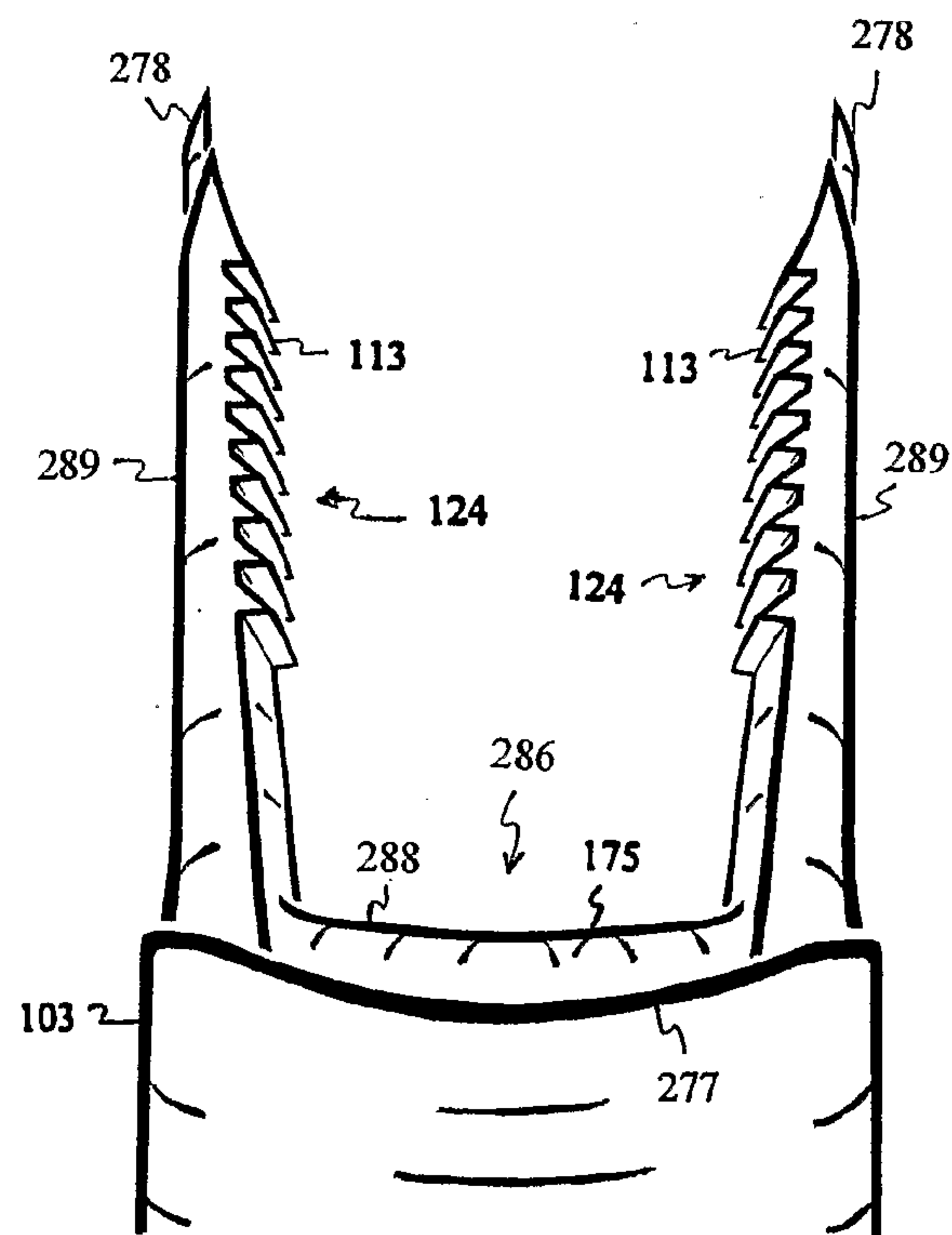


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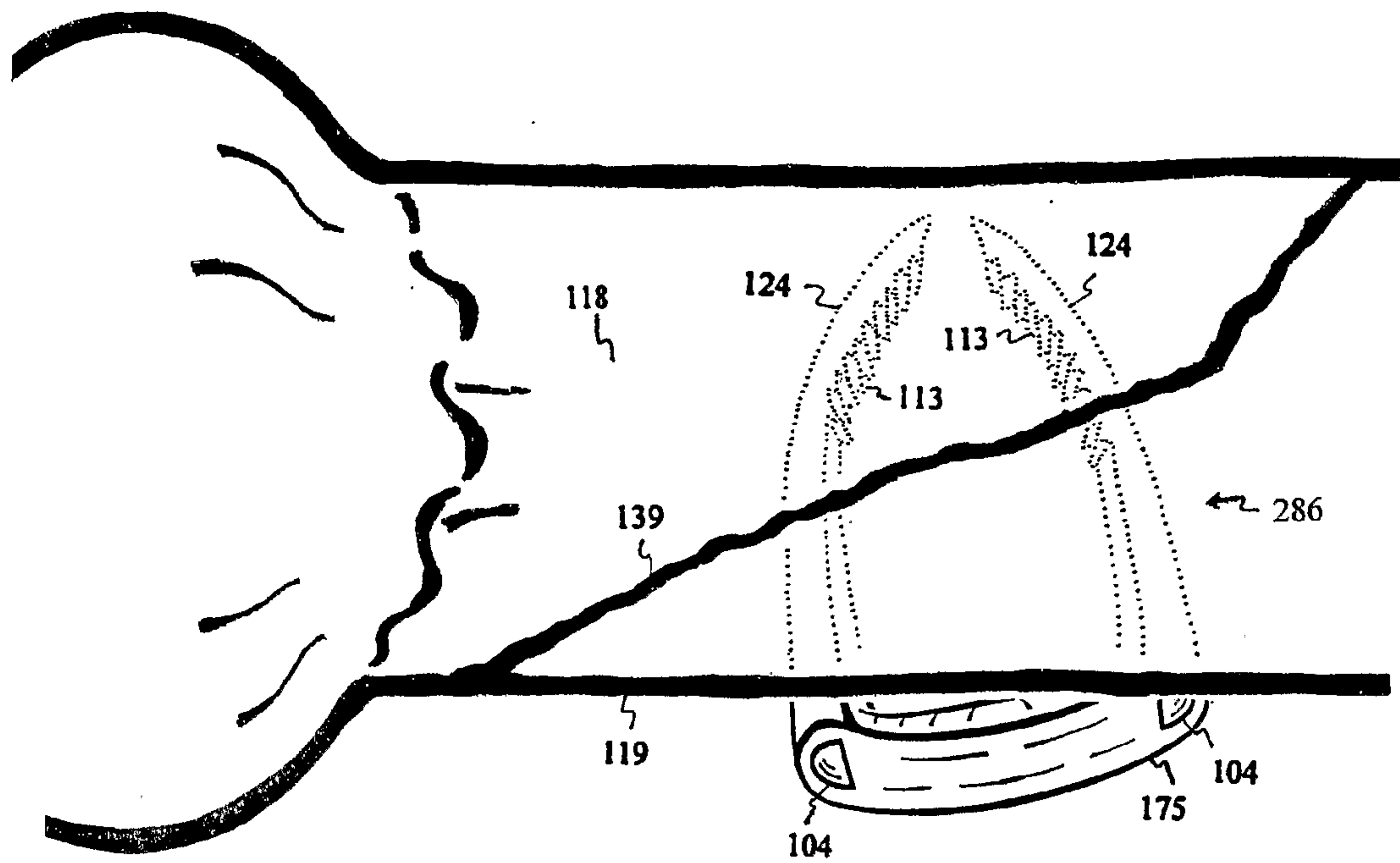


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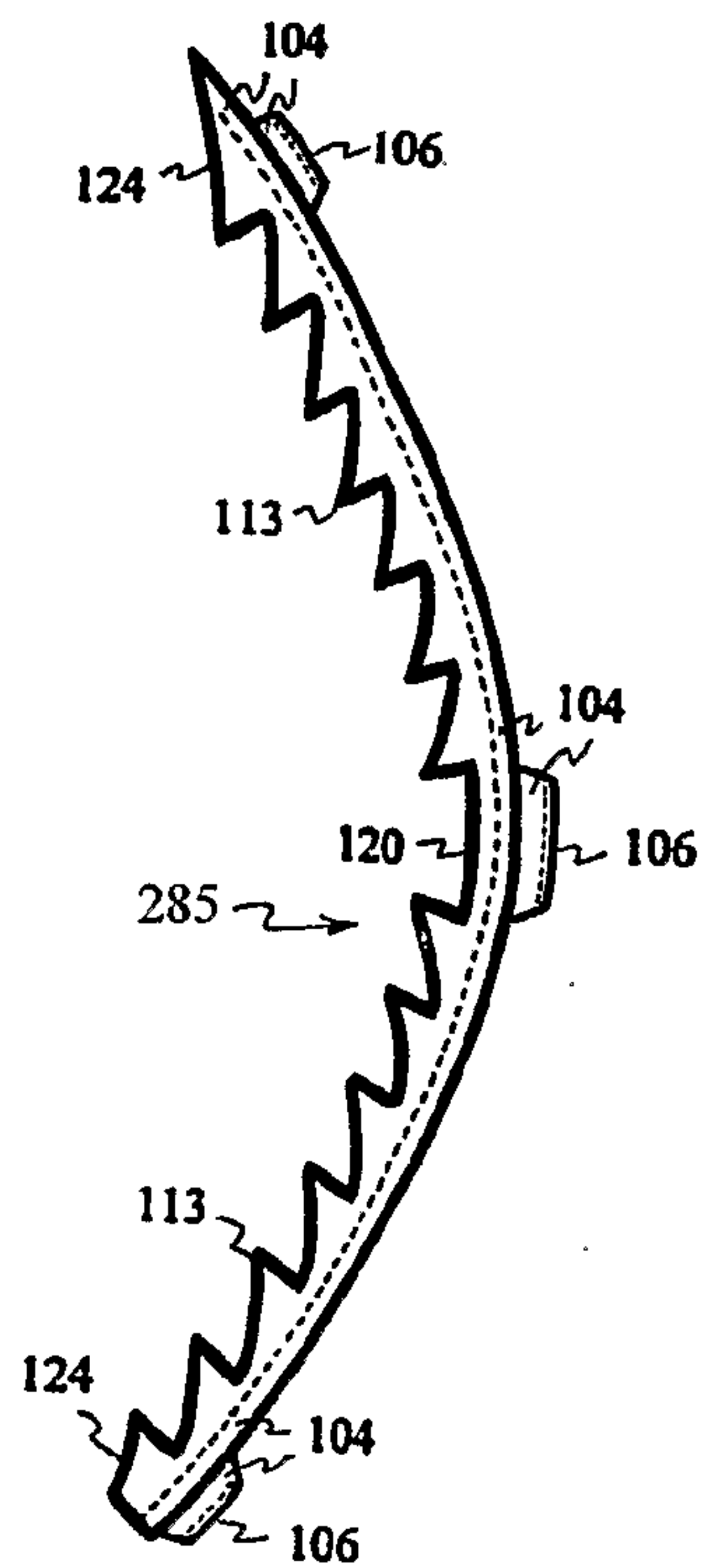


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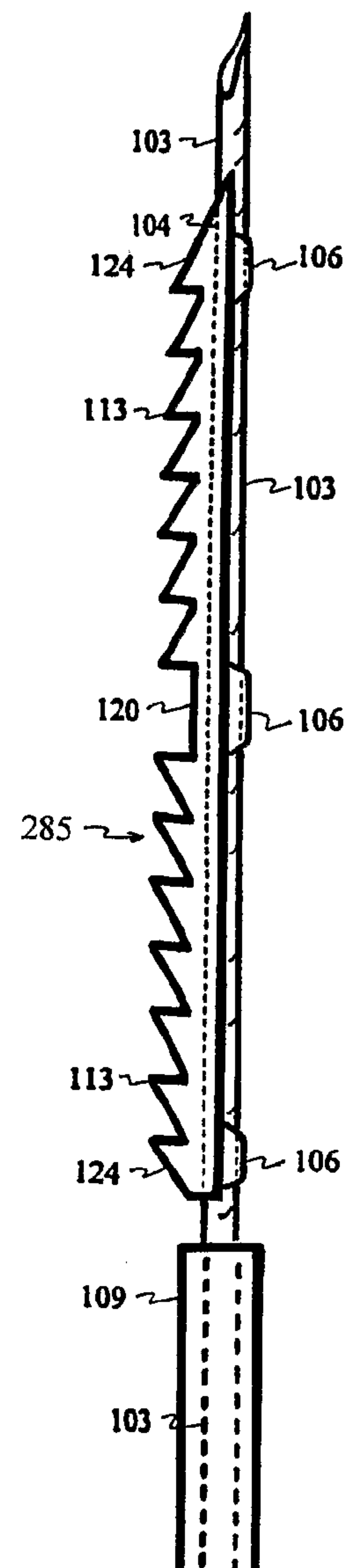


Figure 88

Figure 89

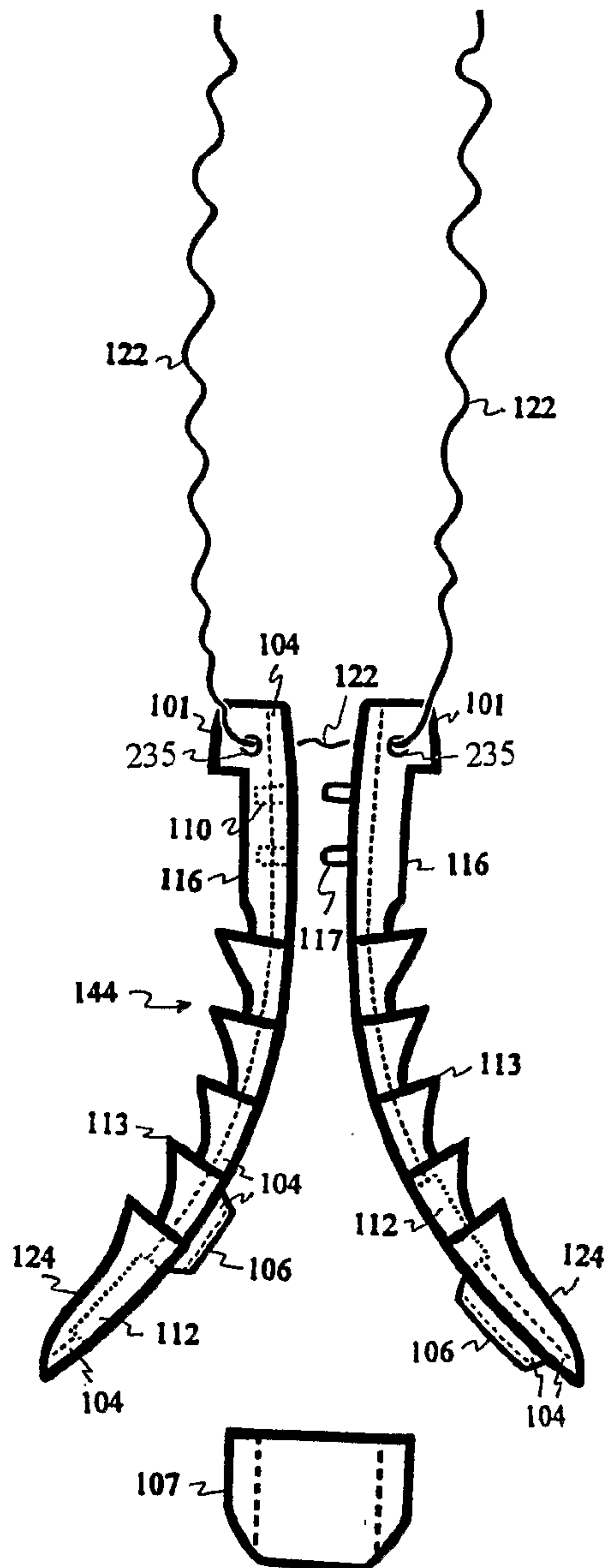


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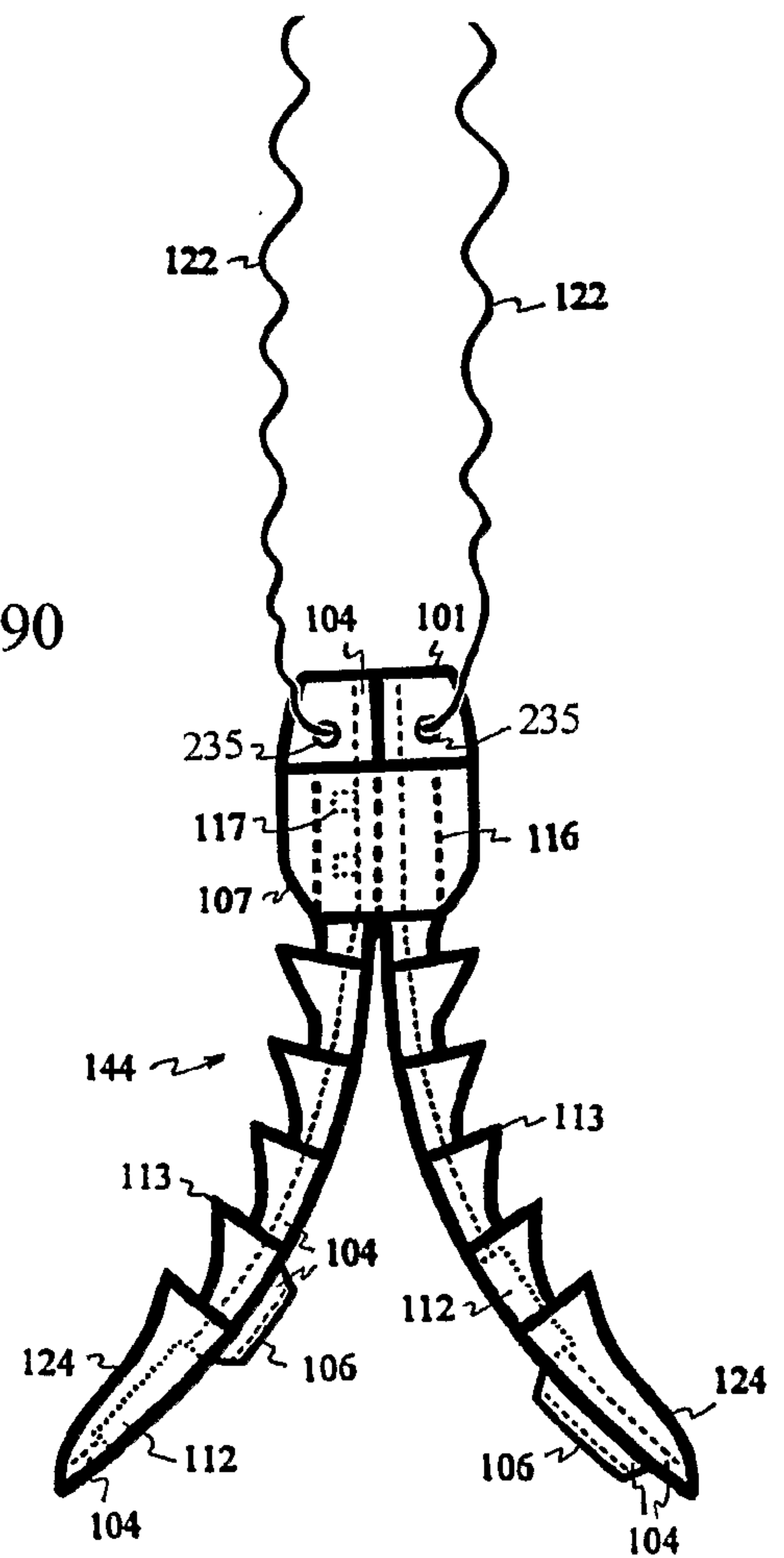
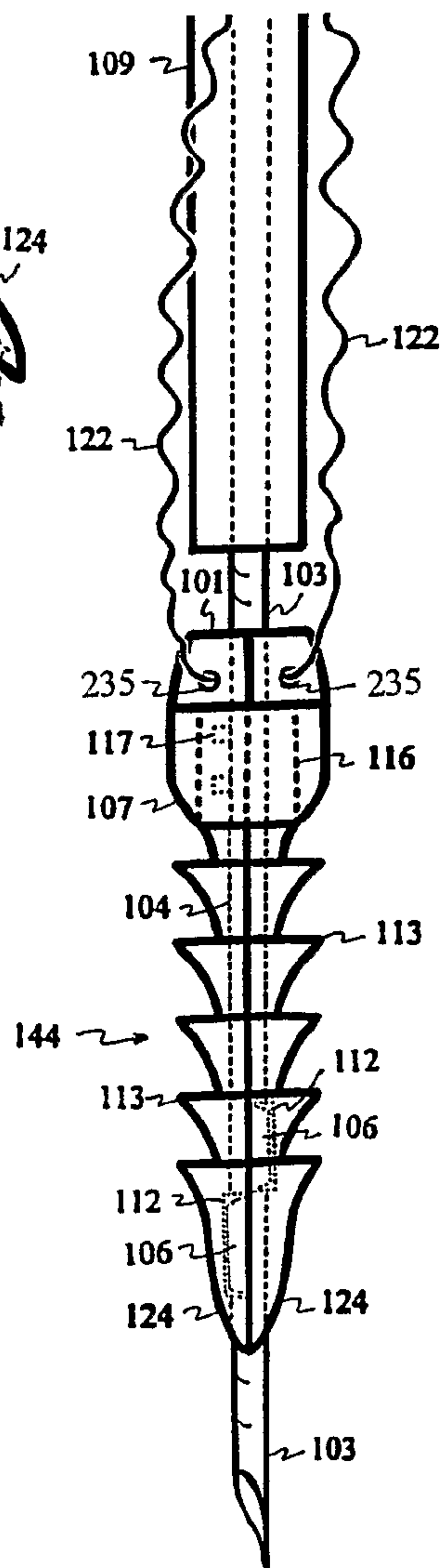


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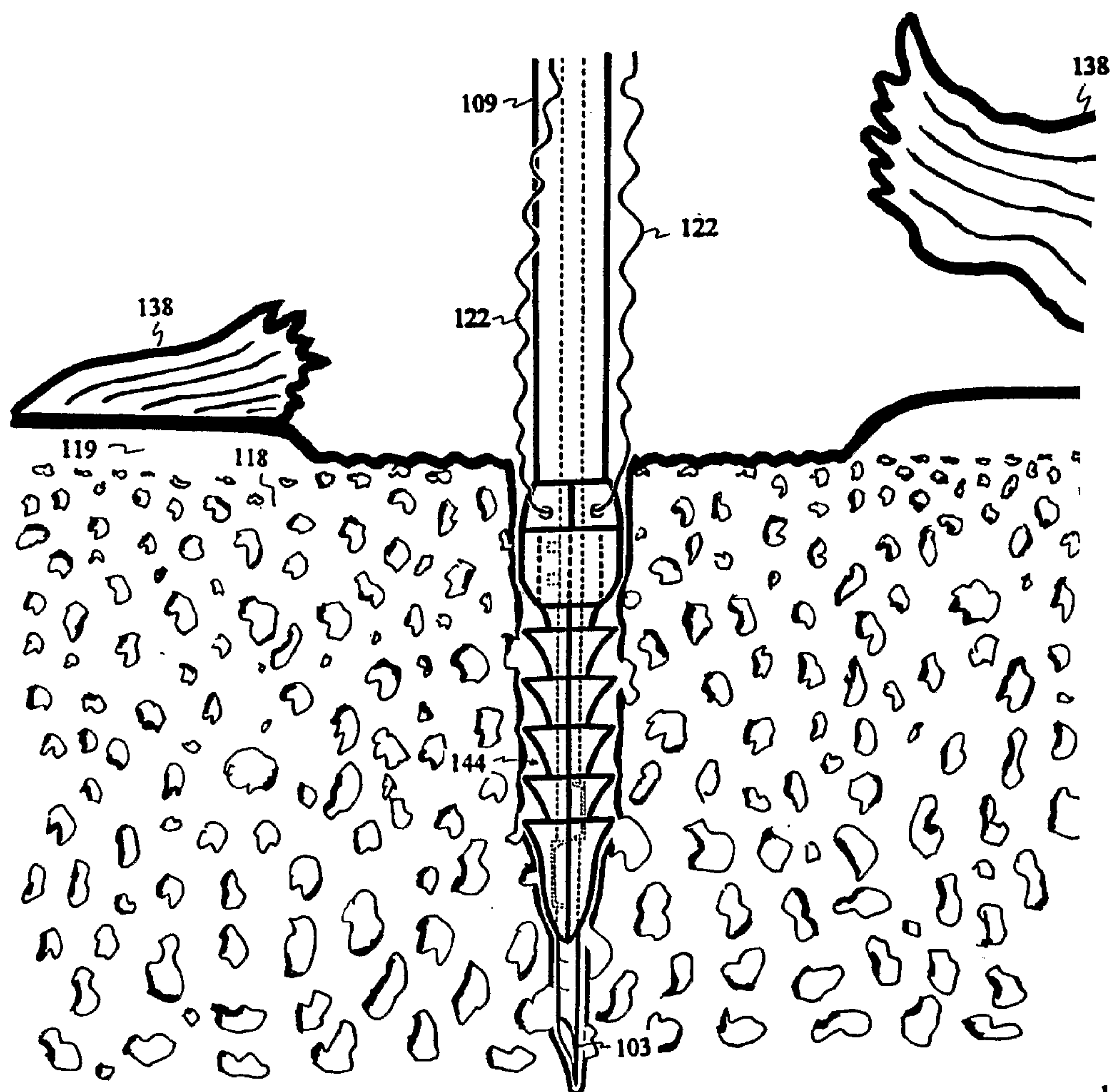


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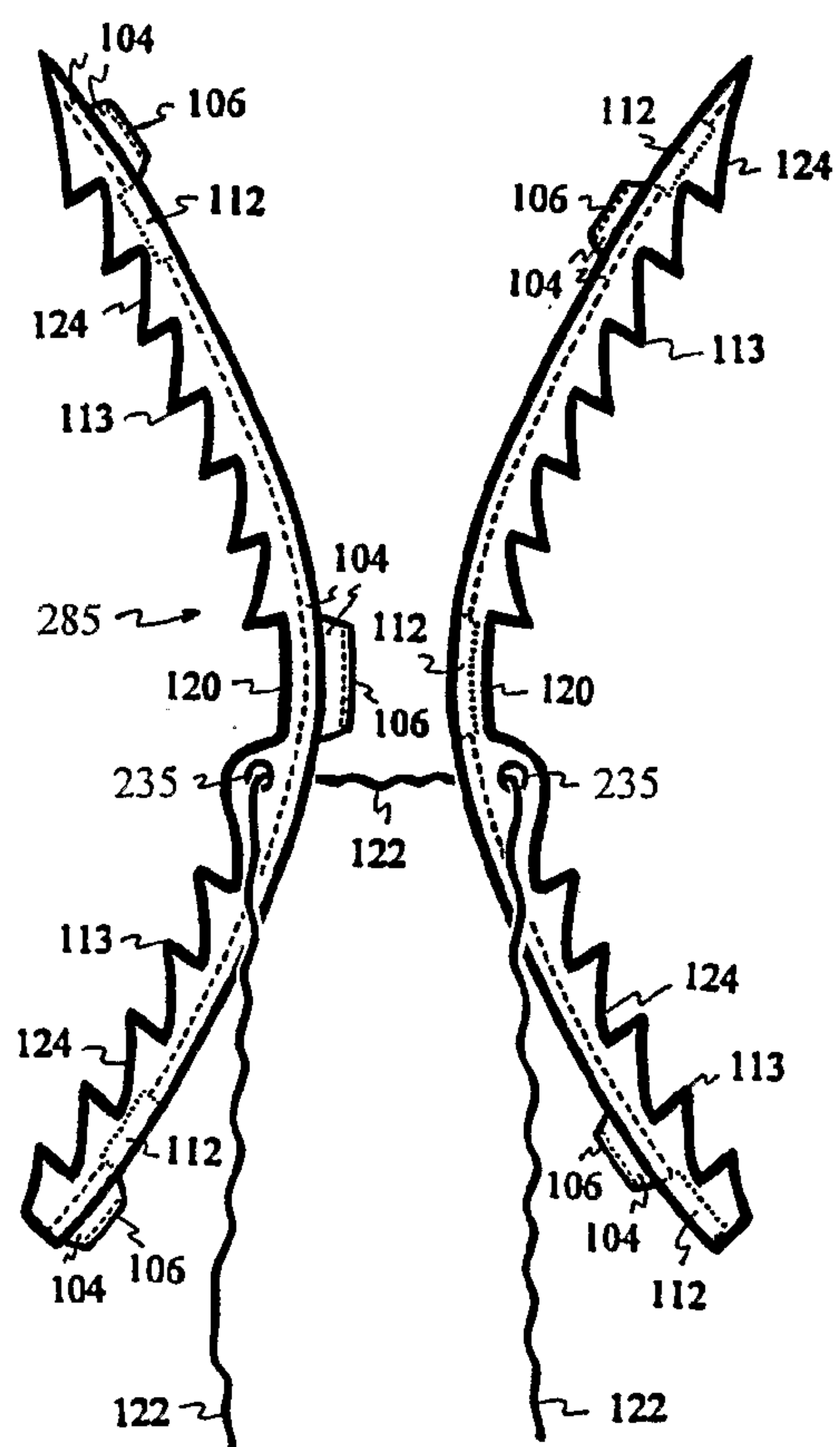


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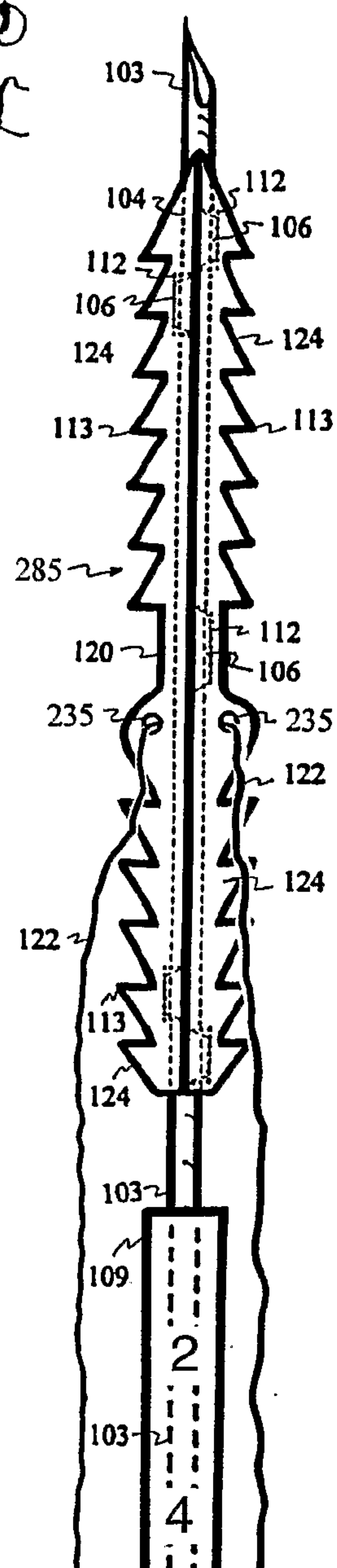


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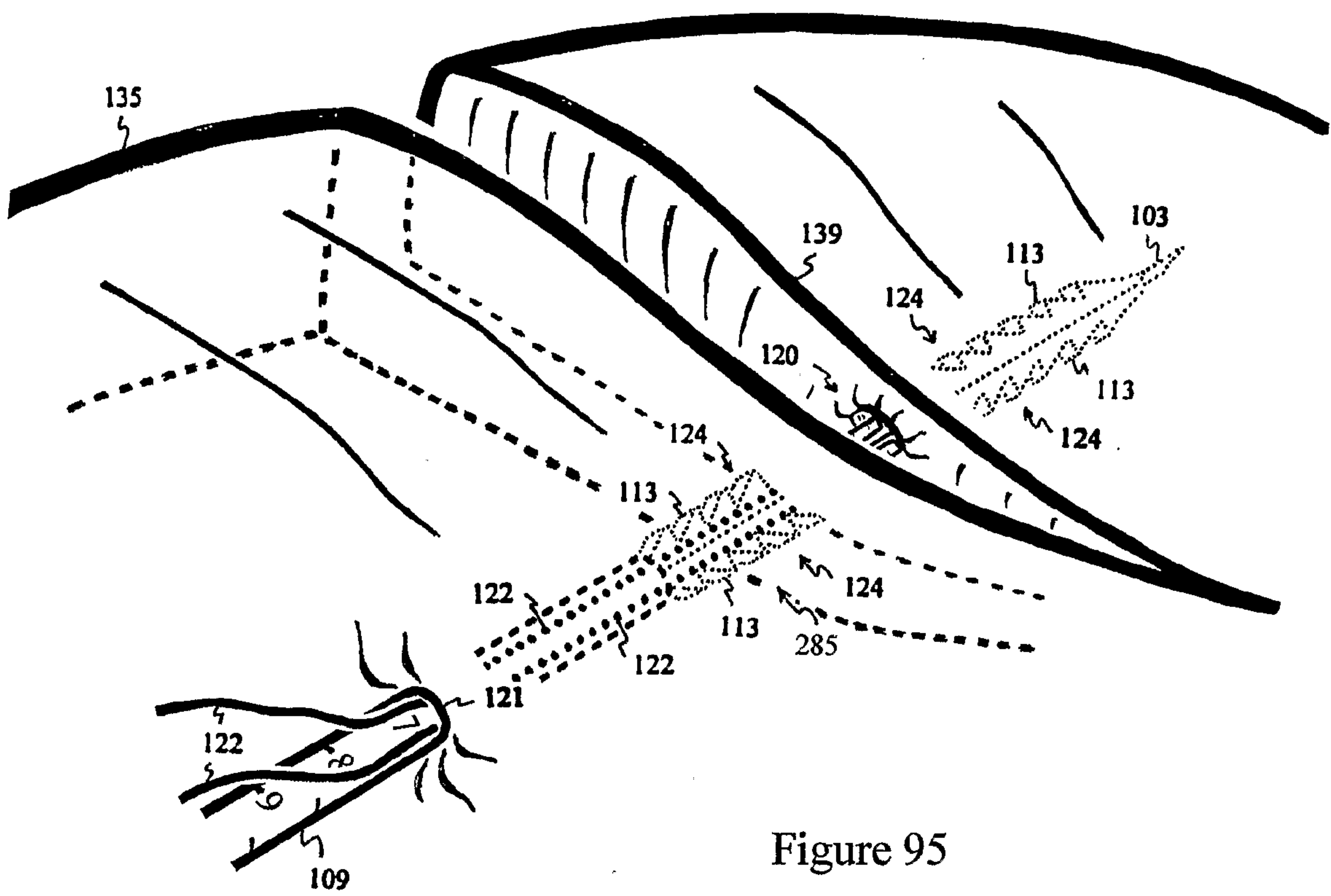


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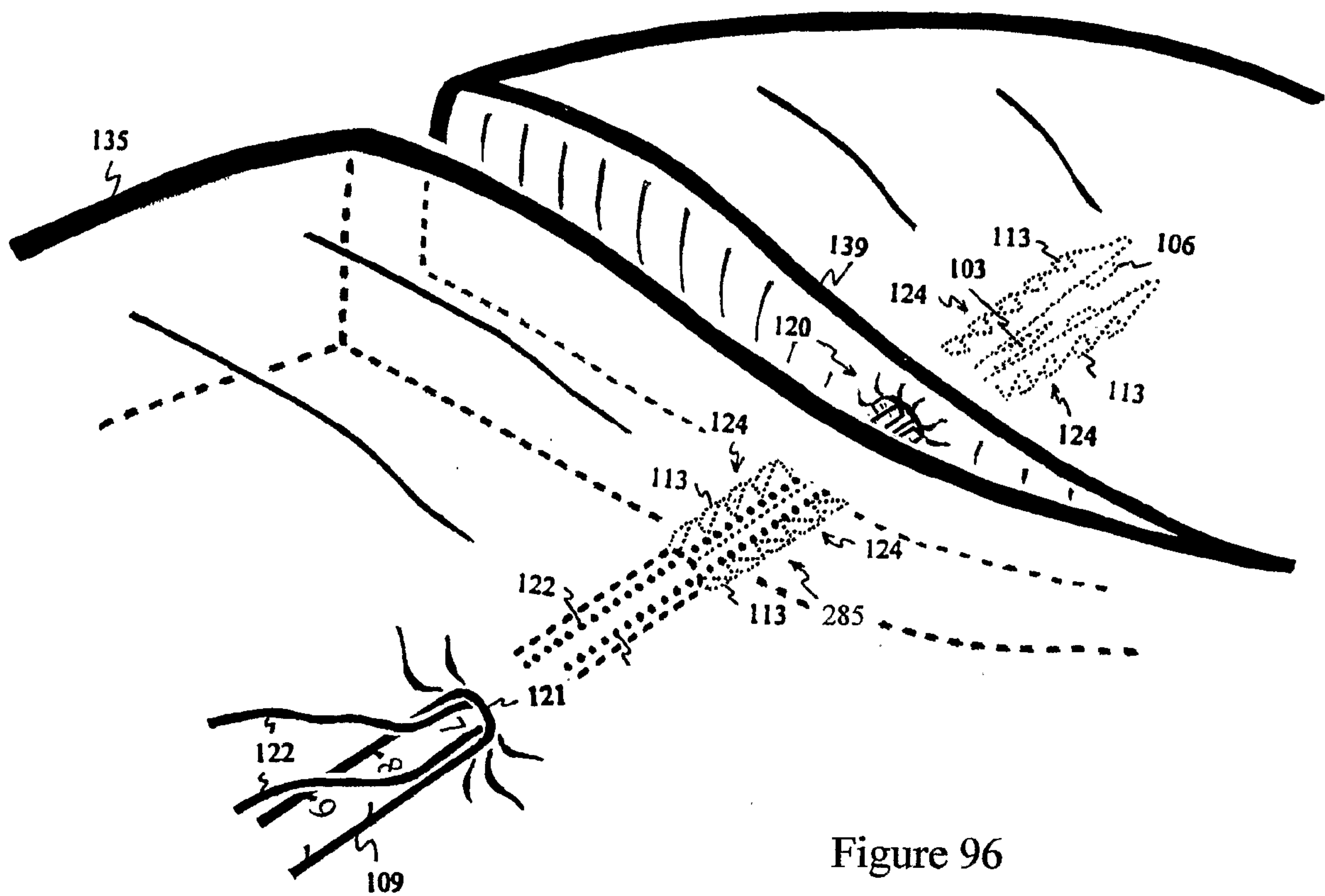


Figure 96

