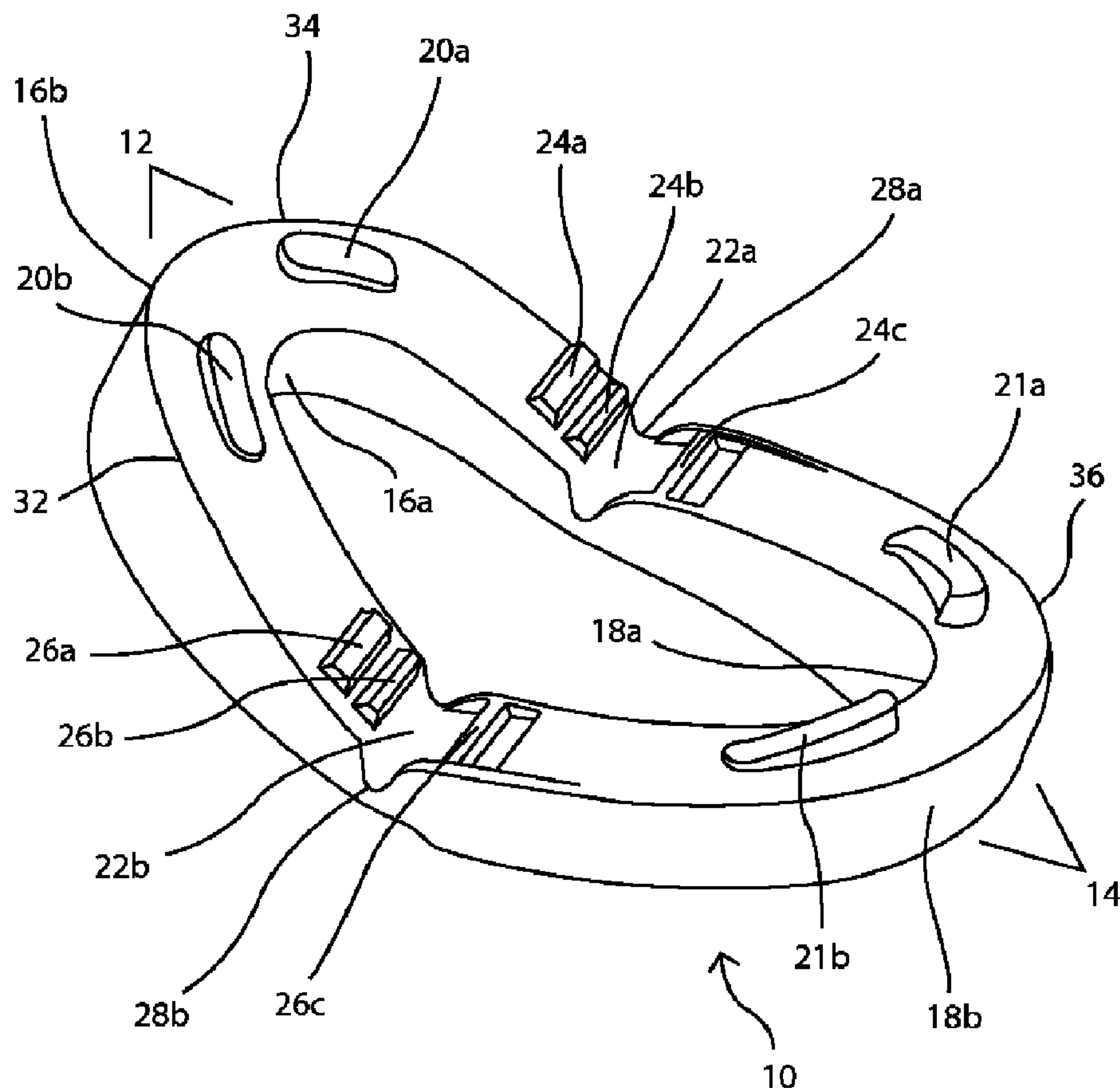




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(54) **Titre : DISPOSITIF D'AVANCEMENT MANDIBULAIRE A CHARNIERE DE POSITIONNEMENT POSITIF**  
(54) **Title: MANDIBULAR ADVANCEMENT DEVICE WITH POSITIVE POSITIONING HINGE**



(57) **Abrégé/Abstract:**

The invention is an oral appliance for prevention of sleeping problems including snoring, sleep apnea and bruxism. Specifically, the appliance alters the position of the user's mandible, which is known as a method for reducing the restriction of the flow of air

**(57) Abrégé(suite)/Abstract(continued):**

through the pharyngeal passageway. The appliance is a one-piece device molded from a flexible polymer such as Kraton ®. It includes an upper maxillary tray and a lower mandibular tray. Both upper and lower trays include inner and outer walls which increase contact area with the teeth.. The hinge mechanism of the device includes a positive positioning system comprised of opposed interlocking ridges. The ridges serve to create offset between the position of the upper tray and lower tray relative to each other, therefore advancing the user's mandible. Additional features include airflow posts to keep the mouthpiece from sealing completely, a cleft contour, and a tooth retention tab.

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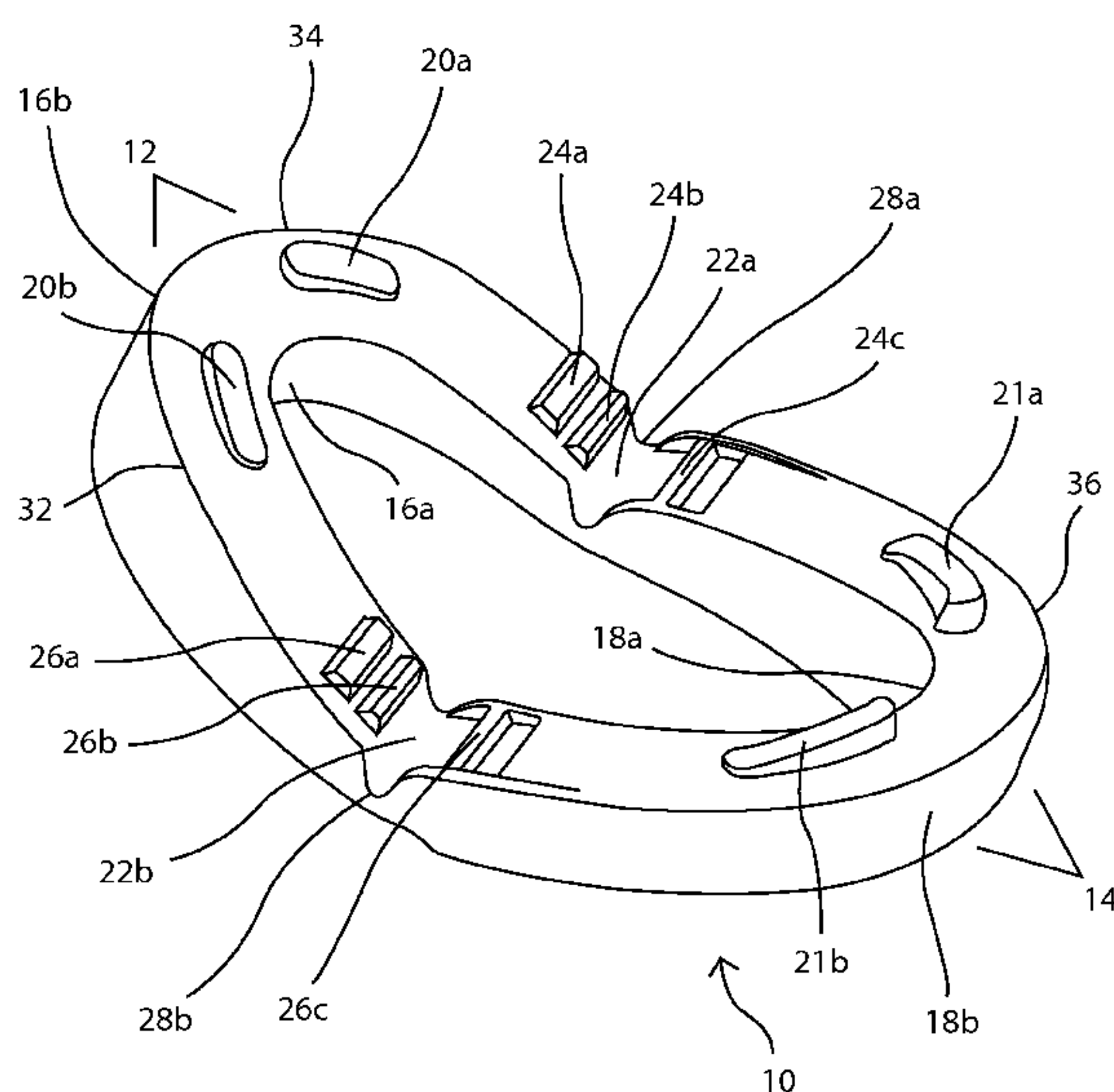


Figure 1

(57) Abstract: The invention is an oral appliance for pre-  
vention of sleeping problems including snoring, sleep ap-  
nea and bruxism. Specifically, the appliance alters the posi-  
tion of the user's mandible, which is known as a method for  
reducing the restriction of the flow of air through the pha-  
ryngeal passageway. The appliance is a one-piece device  
molded from a flexible polymer such as Kraton®. It in-  
cludes an upper maxillary tray and a lower mandibular  
tray. Both upper and lower trays include inner and outer  
walls which increase contact area with the teeth.. The hinge  
mechanism of the device includes a positive positioning  
system comprised of opposed interlocking ridges. The  
ridges serve to create offset between the position of the up-  
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pletely, a cleft contour, and a tooth retention tab.

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**MANDIBULAR ADVANCEMENT DEVICE WITH POSITIVE POSITIONING HINGE****FIELD OF THE INVENTION**

5           The present invention relates to devices for prevention of sleeping problems including snoring and sleep apnea. Specifically, the device is an oral appliance which alters the position of the user's mandible. Advancing the position of the mandibular mouth structure relative to the position maxillary mouth structure is known as a method of reducing snoring and sleep apnea by reducing the restriction of the flow of air through the pharyngeal passageway. The decrease in air flow restriction  
10 causes a reduction in the vibration of soft tissue that's a cause of snoring, as well as reducing occlusion that's a cause of sleep apnea.

**BACKGROUND OF THE INVENTION**

          It is well-established that snoring and sleep apnea are sleeping problems that effect the  
15 quality of life of many people. Snoring is generally caused by the vibration of soft tissue and tongue against the back of the throat, which can be caused by restricted airflow through the pharyngeal passageway. Both the person snoring and other persons nearby can be affected by the resulting noise.

          The relaxation of muscles during sleep can allow the structures and tissues of the nose and mouth to  
20 fall backwards against the back wall of the throat. While partial airflow restriction results in snoring, more complete obstruction can result in sleep apnea, also known as obstructive sleep apnea (OSA). OSA can result in the stoppage of breathing for short periods, which causes the sufferer to gasp for air, causing a change in the contraction of muscles and resulting significant disruptions in sleep patterns. With a lower quality of sleep, the sufferer may experience fatigue-induced problems such  
25 daytime sleepiness, depression, and other related problems. More severe complications such as heart attack or stroke can also be associated with decreased airflow and reduced blood-oxygen saturation levels.

          Therefore, opening the pharyngeal passageway for increased airflow while sleeping can  
30 eliminate or significantly reduce snoring and OSA, and the resulting benefits are apparent.

Numerous methods for preventing snoring and/or OSA currently exist. One method is the advancement of the mandibular structure relative to the maxillary structure. It has been established since the 19th century that advancing the mandible results in increased airflow through the pharyngeal passageway. Thus advancement of the mandible while sleeping can  
5 reduce or eliminate snoring and/or OSA.

#### DESCRIPTION OF RELATED ART

Numerous devices exist to advance the position of the mandible, and therefore prevent snoring and OSA. Such devices are in the form of a oral appliance worn by the user while sleeping. However, all such devices previously known face certain limitations. One  
10 common limitation is that custom molding is often required to shape the device to a user's teeth or mouth. This requires the expertise of a medical professional such as a dentist, and is therefore expensive and time-consuming. Additionally, many devices restrict the physiological movement of the user from freely opening and closing their jaw when the device is placed in the mouth. This is uncomfortable and unnatural for many users. The  
15 upper and lower trays of many devices force the jaw in a fixed, nearly closed, or closed position. A device which, by design, is not allowed to close completely would aid in the flow of air through the mouth.

US 6,129,084 (Bergersen) describes an intra-oral device for advancing the user's mandible. The device is comprised of two u-shaped plates joined to form a hinge. The lower  
20 plate includes a channel. This lower plate channel has an inner wall (lingual wall), which faces the user's tongue, and an outer wall (labial-buccal wall), which faces the user's cheek and lips. Thus the user's mandibular teeth are cradled in the lower channel. The upper plate contains an outer wall (labial-buccal wall), but does not include an inner wall (lingual wall). The lack of an inner wall is to position the user's tongue in contact with the lingual side of  
25 the user's maxillary teeth, meaning the inside of the user's upper teeth. The preferred embodiment of this device is molded from pliable material in one piece and uses a simple hinge mechanism. The hinge is comprised simply of a thinning of the cross-section of the molded material, which allows the device to bend. It is described that the hinge may be sufficiently rigid to maintain a substantial gap in an open position, even when the user applies  
30 considerable force.



This '084 device, however, faces numerous limitations. The simple hinge mechanism is subject to wear as the pliable material is bent over many cycles of the user's mouth opening and closing. The mandibular advancement the device provides is created solely by the position of the hinge. Fatigue of the, material, compounded by a lack of mechanical reinforcement, may allow the simple living hinge to become sloppy and loose, rendering the device unable to properly advance the mandible. In addition, there's no mechanical element to prevent the device from completely closing, causing upper surface 24 and lower surface 14 to become co-planar.

US 6,055,986 (Meade) describes a mandibular advancement mouthpiece that includes a hard shell that holds a soft, moldable material. The soft material rests against the teeth. The device is made in two major halves, an upper member and a lower member. One embodiment contains reciprocal surfaces 222 and 224 which fit together to fix the relative forward and backward positions of the upper and lower members to each other. However, with this device the upper and lower members are not connected or hinged to one another. Rather, this device relies on the material being molded to the user's individual teeth and the resulting contact adhesion in order to stay in place in the mouth.

US 6,170,485 (Orrico) also describes system with two halves. It also uses moldable inner trays to interface with the teeth. It further describes tongues 30 and 32 which extend out of person's mouth. One tongue includes a plurality of holes 34, while the other tongue includes a projection 36. The projection aligns with one of the holes to create mandibular advancement, with different holes creating different amounts of advancement. However, with this device the upper and lower members are not connected or hinged to one another. Rather, this device relies on the material being molded to the user's individual teeth and the resulting contact adhesion in order to stay in place in the mouth.

US 5,829,441 (Kidd) also describes system with two halves. It also uses moldable material to interface with the teeth. Means are included for adjustably advancing the user's mandible. However, this device requires the user to sleep with their jaw in a fixed, clenched position. Many people find sleeping with their jaw in a fixed position to be very uncomfortable, potentially even inhibiting sleep.

US 6,516,805 (Thorton), as well as its related parent application, also describes a system with two halves. It also uses moldable material to interface with the teeth. A post 16

extends from the upper arch 12 and contacts the lower arch 14 to extend the user's mandible. However, this two-half design requires the post to be positioned at the front of the upper arch. Thus the post may disengage from the lower arch when the mouth is opened, causing the mandible to no longer be in an advanced position. In addition, there's no mechanical element  
5 to prevent the device from completely closing, causing upper arch and lower arch become coplanar.

US 5,499,633 (Fenton) describes a system with two halves. It includes apertures 40 and projections 36. The projections are received into the apertures, therefore creating mandibular extension. However, with this device the upper and lower members are not  
10 securely connected or hinged to one another. The projections are made from the soft, moldable material of the rest of the device, and as such, may be difficult to engage in the apertures. In addition, the soft material of the projections may allow movement between the upper and lower members, thus not consistently advancing the mandible. In addition, the two members of the device may easily disengage from the teeth through the natural movement of  
15 the jaw. The device also requires boiling and molding.

US 1,146, 264 (Kelly) describes a dental splint. As best understood, this device use two separate trays to hold the jaw in position, with the trays apparently cemented to the user's teeth. This is used to create a static position if the bones of the jaw are fractured and must heal. It recites pillars 18, which hold the trays apart so that food may be inserted into the  
20 user's mouth.

US 4,376,628 (Aardse) describes a tooth-treating mechanism in two halves It includes parallel ridges 9 and 10. The ridges serve to center one device half over the other device half. The orientation of the ridges does not create mandibular advancement, as they are in a direction perpendicular to that required for mandibular advancement.

CA 2,177,284 (Voss) describes a one-piece mandibular advancement device. This  
25 device is molded from pliable material in one piece and uses a simple hinge mechanism. The hinges 4 and 4' are comprised of a thinned cross-section of the molded material, in conjunction with half-cylinder 40 and notch 41. This assembly allows the device to bend. This device, however, faces numerous limitations. The simple hinge mechanism is subject to  
30 wear as the pliable material is bent over many cycles of the user's mouth opening and closing. The mandibular advancement the device provides is created solely by the position of



the hinge, and faces similar limitations to the device described in '084 (Bergersen) In addition, there's no mechanical element to prevent the device from completely closing, causing upper surface 24 and lower surface 14 to become co-planar and therefore restricting airflow through the mouth.

5 Other manibular devices are disclosed in patents and in the marketplace as well. However, all face similar limitations as the above described inventions. In summary, many of the above devices require fitting, molding, or adjustment by a dental professional and fabrication laboratory. This process is costly and time-consuming, and prevents by non-skilled persons using the device straight-out-of-the-package. Still other systems use a simple  
10 hinge that quickly wears and may no longer properly advance the mandible. Many of these devices also restrict the user from opening his/her mouth, which many users find undesirable.

#### BRIEF SUMMARY OF THE INVENTION

Several objects and advantages of the present invention will be made clear. What is needed is a mandibular advancement device that does not require fitting, heating, molding, or  
15 adjustment in order to be used. Additionally, a device is needed that's durable, easy to wear, and simple to use. It should be comfortable and allow the user to freely open and close his/her mouth so that natural jaw movement is not inhibited. Further, there's a need for a device that can be used straight-out-of-the-package by non-skilled persons, eliminating the need for costly, time-consuming fitting by a dental professional and fabrication laboratory.

20 In the preferred embodiment of the invention, a one-piece device is molded from a flexible thermoplastic elastomer such as Kraton®. The device includes an upper maxillary tray and a lower mandibular tray connected by a hinging mechanism. Both upper and lower trays include inner and outer walls which increase contact area with the teeth. The lingual surface of the mandibular tray features a flange which extends down into the lingual  
25 vestibule to provide greater contact surface to advance the mandible. The flange is designed to be of a length which extends into the lingual vestibule but does not contact the lingual frenulum.

The hinge mechanism of the preferred embodiment includes a positive positioning system comprised of opposed interlocking ridges. The ridges serve to create and maintain  
30 offset between the position of the upper tray and lower tray relative to each other, therefore advancing the user's mandible. The location of the ridges, close to the hinge points, is also

advantageous because the ridges continue to engage one another and therefore advance the mandible even when the jaw is almost entirely open. Further, the ridges are self-aligning and easily engage with virtually no chance of jamming.

The preferred embodiment also includes posts located near the front of the upper tray and the lower tray. These posts create an air gap that prevents the upper tray and lower tray from completely closing against one another. The preferred embodiment is also contoured and curved to comfortably fit in the mouth and on the teeth. Related to the contouring is a cleft notch on the upper front of the maxillary tray to avoid rubbing and irritation to the connective tissue (maxillary labial frenulum) on the inside of the upper lip.

## 10 DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG 1 is a perspective view of the device in the open position, when not in the user's mouth.

FIG 2a is a top view of the device.

FIG 2b is a bottom view of the device.

15 FIG 3a is a right side view of the device.

FIG 3b is a left side view of the device.

FIG 4a is a back-end view of the device.

FIG 4b is a front-end view of the device.

FIG 5 is a bottom view of the front section of the lower tray of the device.

20 FIG 6 is a perspective view of the front section of the lower tray of the device.

## DESCRIPTION OF THE REFERENCE NUMERALS

- 10 overall device
- 12 upper maxillary tray
- 14 lower mandibular tray
- 25 16a inner wall of upper maxillary tray
- 16b outer wall of upper maxillary tray



	18a	inner wall of lower mandibular tray
	18b	outer wall of lower mandibular tray
	18c	lingual flange portion of inner wall of lower mandibular tray
	20a	right post
5	20b	left post
	21a	right retention post
	21b	left retention post
	22a	overall hinge right
	22b	overall hinge left
10	24a	forward upper interlocking ridge right
	24b	aft upper interlocking ridge right
	24c	lower interlocking ridge right
	26a	forward upper interlocking ridge left
	26b	aft upper interlocking ridge left
15	26c	lower interlocking ridge left
	28a	flexible hinge section right
	28b	flexible hinge section left
	32	outer tray wall chamfer
	34	curved contour of upper maxillary tray
20	36	curved contour of lower mandibular tray
	38	cleft contour
	40	tooth retention tab

## DETAILED DESCRIPTION OF THE INVENTION

In all figures, the device is shown in the open position, when not in the user's mouth.

25 FIG 1 is a perspective view of the preferred embodiment of the invention. As can be seen, the one-piece overall device 10 folds at overall hinge right 22a, and overall hinge left 22b. Upper maxillary tray 12 and lower mandibular tray 14 are both u-shaped, joined together by hinges 22a and 22b. The length of the upper and lower trays are preferably designed so that the device extends back to the centers of the upper first molars when fully  
30 inserted. This allows for ample contact between the trays and the teeth to maintain device positioning, but doesn't extend too far into the mouth so as to create discomfort or promote gagging.



FIG 1 also shows the interlocking ridges of each hinge. Forward upper interlocking ridge right 24a, aft upper interlocking ridge right 24b, lower interlocking ridge right 24c, together form the positive engagement system. The preferred embodiment uses ridges that are trapezoidal in cross-section. This shape creates a chamfered profile that easily lets lower ridge 24c mesh with upper ridges 24a and 24b as the device is closed. This is identical for the left side hinge 22b. The molded material is thinnest in cross-section on the overall device at flexible hinge section right 28a and flexible hinge section left 28b. The thinned cross-section permits the device to flex and bend as a hinge. The hinge also acts as a low-force spring, with the force of the springs aiding to keep the upper tray 12 in contact with the user's maxillary teeth, and lower tray 14 in contact with the user's the mandibular teeth.

FIG 1 also shows right post 20a and left post 20b. These posts prevent upper maxillary tray 12 and lower mandibular tray 14 from closing against each other completely. Of course, said posts could be placed elsewhere on the device, such as an identical location on tray 14. Posts 20a and 20b may be located in different positions on either tray, however the location shown offers advantages of being further ideally located to maintain airflow. Right retention post 21a and left retention post 21b serve similar function to posts 20a and 20b. All posts further serve by: providing additional support for their respective tray, minimizing flex and bending for their respective tray, and correcting overall angulation as each post contacts its opposing tray.

FIG 2a is a top view of the device, further showing the locations of the all of the interlocking ridges, as well as all posts.

FIG 2b is a bottom view of the device, further showing the tooth retention tab 40.

FIG 3a is a right side view of the device, further showing the locations of one side of interlocking ridges, as well as posts. Also seen is the outer wall of upper maxillary tray 16b, inner wall of lower mandibular tray 18a, and outer wall of lower mandibular tray 18b. Outer tray wall chamfer 32, curved contour of upper maxillary tray 34, and curved contour of lower mandibular tray 36 are all also apparent. 18c shows the lingual flange portion of the inner wall of the lower mandibular tray. The flange 18c serves to extend into the user's lingual vestibule to provide greater contact surface for advancing the mandible.

FIG 3b is a left-side view of the device, showing similar features to view 3a.

FIG 4a is a view from the back-end of device.

FIG 4b is a view from the front-end of device. Cleft contour 38 is visible in this view.

FIG 5 is a bottom view of the front section of the lower tray of the device. In this view, tooth retention tab 40 is visible.

5 FIG 6 is a perspective view of the front section of the lower tray of the device. In this view, tooth retention tab 40 is visible.

Overall device 10 readily bends in half at hinges 22a and 22b. It is then inserted into the user's mouth, with the user's maxillary teeth pressing into upper maxillary tray 12 and the user's mandibular teeth pressing into lower mandibular tray 14. The user's maxillary teeth  
10 are cradled by the inner wall of upper maxillary tray 16a and the outer wall of upper maxillary tray 16b. The user's mandibular teeth are contacted by the inner wall 18a of lower mandibular tray 14, and in addition, the outer wall 18b of the tray 14 may contact the maxillary teeth. The opposing forces of the contact with the facial surface of the upper  
15 maxillary dentition and in particular the contact of the inner flange of tray 18a to the lingual surface of the lower lingual dentition maintain the mandible in a forward position relative to the maxilla, whereby the airway passage in the nasopharynx, oropharynx and laryngopharynx are kept substantially free of occlusion, thus reducing or eliminating snoring and/or OSA.

The position of the two trays relative to each other, or offset, is determined by the location of overall hinges 22a and 22b. The offset is further reinforced by the pairs of hinged  
20 ridges, 24a, 24b, 24c, and 26a, 26b, 26c. At the device bends and is placed in the user's mouth, the ridged hinges engage and further reinforce the offset. The ridges continue to engage as a user partially or even fully opens his/her mouth. The location of the ridges, close to the hinge point, allows the ridges to stay engaged over a wider range of mouth motion than if the ridges were located closer to the front of the overall device. It is therefore  
25 advantageous to incorporate the ridges into the hinge portion of the overall device. Further, the interlocking ridges help prevent side to side and rotational motion between the upper and lower trays, thereby maintaining alignment.

In the preferred embodiment, the right and left lower interlocking ridges, 24c and 26c respectively, may be formed such that the highest point of each ridge is co-planar with the



larger planar surface of lower mandibular tray 14. This effectively creates a small recess for each ridge, 22a and 22b, to engage into, thereby creating a more positive engagement which helps insure the desired mandibular advancement is achieved. Alternately, ridges 24c and 26c may be more simply formed such that they are raised above the planer surface of tray 14.

5 While the preferred embodiment shows a one-piece, living-hinge design, other types of hinges designs could be employed as well. In alternate embodiments, the upper and lower trays could be made as separate pieces and joined together by separate hinge pieces. Alternatively the hinging mechanism could be made of the same or completely different type of material including but not limited to alloy, metal, plastic, polyethelene, etc.

10 Another inventive element of the preferred embodiment are the two airflow posts 20a and 20b located near the front of the upper maxillary tray 12. These posts create an air gap that prevents the planar surfaces of the upper tray 12 and lower tray 14 from completely closing against one another. This insures air will flow through the user's mouth, even if the teeth are tightly clenched during sleep.

15 Optionally, right retention post 21a and left retention post 21b may be included. Posts 21a and 21b are shown on lower mandibular tray 14. When the inventive device is placed in the closed position in the user's mouth, posts 21a and 21b help insure that the mandible stays in an advanced position by engaging against posts 20a and 20b and thereby further preventing lower tray 14 from moving backward relative to upper tray 12.

20 Another inventive element which may be optionally included is tooth retention tab 40. This tab is located on the inner wall of the lower mandibular tray 14, in the location seen in FIG 6 and FIG 5. This tab is positioned and shaped such that it interfaces with the lingual surface of the mandibular central incisors. The naturally curved lingual surface of the mandibular central incisors mates with the retention tab, which helps keep the lower  
25 mandibular tray positioned on the teeth and helps prevents the tray from sliding off and disengaging with the teeth.

The preferred embodiment is also contoured and curved to comfortably fit in the mouth and on the teeth. The edge of both the upper and lower trays are chamfered, or otherwise made non-sharp, to be comfortable in the user's mouth. Related to the contouring  
30 is cleft contour 38 on the upper front of the maxillary tray 12 to avoid rubbing and irritation



to the connective tissue on the inside of the upper lip. Likewise, the wall thickness of the device may vary throughout to create an optimal shape for comfort while maintaining durability.

5 In the preferred embodiment, the device is molded from an appropriate material such as Kraton® polymer. Kraton® polymers provide additional comfort and cushion to the user. The rubbery properties of the polymer increase the amount of surface tension and contact adhesion with the teeth and prevent the device from falling out during use. Kraton® polymers will also wear longer and better than the traditional resins currently on the market. Specifically, a Dynaflex® thermoplastic elastomer offers excellent properties for the  
10 invention. Of course, other suitable materials could be employed as well, whether in the form of synthetic polymers or even natural rubber.

While the overall device serves primarily for the purpose of mandibular advancement, with the associated sleep-related benefits, the device also serves to reduce problems associated with bruxism, or the grinding of the teeth. The mechanism for this is readily  
15 apparent, as the upper and lower trays prevent the maxillary and mandibular teeth from making direct contact.

The above described elements combine to create a mandibular advancement device that does not require custom fitting and is easily used off-the-shelf. Although the above specification and related drawings describe a specific embodiment of the invention, this  
20 should not be interpreted as limiting the scope of the invention to these particular elements. The interpretation of the scope of the invention should be determined by the claims and their legal equivalents.

**CLAIMS:**

1. A mandibular advancement device comprising:
  - an upper maxillary tray, said upper tray including an inner wall and an outer wall;
  - a lower mandibular tray, said lower tray including an inner wall and an outer wall;
  - two hinge mechanisms which connect on an axis said upper tray's rearmost portion to said lower tray's rearmost portion, said hinge mechanisms positioned to create offset between said upper tray and said lower tray when said upper tray and said lower tray are folded about said axis; and
  - interlocking ridges in said hinge mechanisms to further engage said lower tray with said upper tray, said interlocking ridges positioned on said upper tray's and said lower tray's rearmost portions immediately in front of said axis.
2. The device of claim 1 in which the interlocking ridges are substantially parallel to said axis that connects said upper tray to said lower tray.
3. The device of claim 1 which further includes a cleft contour on said upper tray.
4. The device of claim 1 which further includes a tooth retention tab on the inner wall of said lower tray.
5. The device of claim 1 which is made from a thermoplastic polymer.
6. The device of claim 1 in which said hinge mechanisms further function as springs, with the force of said springs aiding to keep said upper tray in contact with a user's maxillary teeth and said lower tray in contact with a user's mandibular teeth.
7. The device of claim 1 in which said inner wall of said lower tray includes a flange portion, such that in use said flange extends into a user's lingual vestibule to provide greater contact surface for advancing the mandible.
8. The device of claim 1 in which said upper tray and said lower tray extend to the centers of a user's upper first molars when said device is fully inserted.

9. The device of claim 1 which further serves to reduce any effects of bruxism.

10. A mandibular advancement device comprising:

an upper maxillary tray, said upper tray including an inner wall and an outer wall;

a lower mandibular tray, said lower tray including an inner wall and an outer wall;

two hinge mechanisms which connect on an axis said upper tray's rearmost portion to said lower tray's rearmost portion, said hinge mechanisms positioned to create offset between said upper tray and said lower tray when said upper tray and said lower tray are folded about said axis;

interlocking ridges in said hinge mechanisms to further engage said lower tray with said upper tray, said interlocking ridges positioned on said upper tray's and said lower tray's rearmost portions immediately in front of said axis; and

a plurality of posts to prevent a planar surface of said upper tray from closing completely against a planar surface of said lower tray.

11. The device of claim 10 in which the interlocking ridges are substantially parallel to said axis that connects said upper tray to said lower tray.

12. The device of claim 10 which further includes a cleft contour on said upper tray.

13. The device of claim 10 which further includes a tooth retention tab on the inner wall of said lower tray.

14. The device of claim 10 which is made from a thermoplastic polymer.

15. The device of claim 10 in which said hinge mechanisms further function as springs, with the force of said springs aiding to keep said upper tray in contact with a user's maxillary teeth and said lower tray in contact with the user's mandibular teeth.

16. The device of claim 10 in which said inner wall of said lower tray includes a flange portion, such that in use said flange extends into a user's lingual vestibule to provide greater contact surface for advancing the mandible.



17. The device of claim 10 in which said upper tray and said lower tray extend to the centers of a user's upper first molars when said device is fully inserted.

18. The device of claim 10 which further serves to reduce the effects of bruxism.

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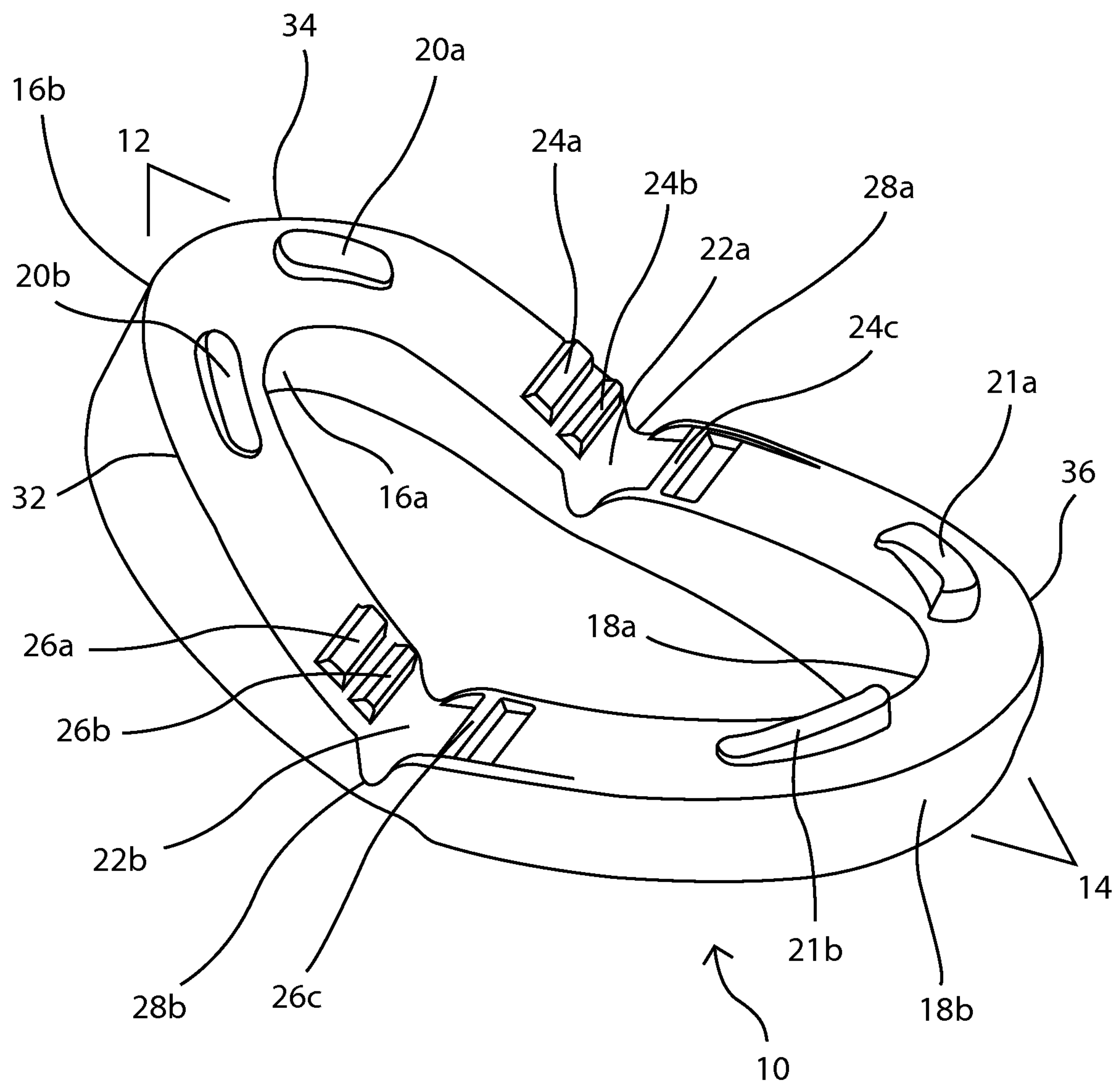


Figure 1

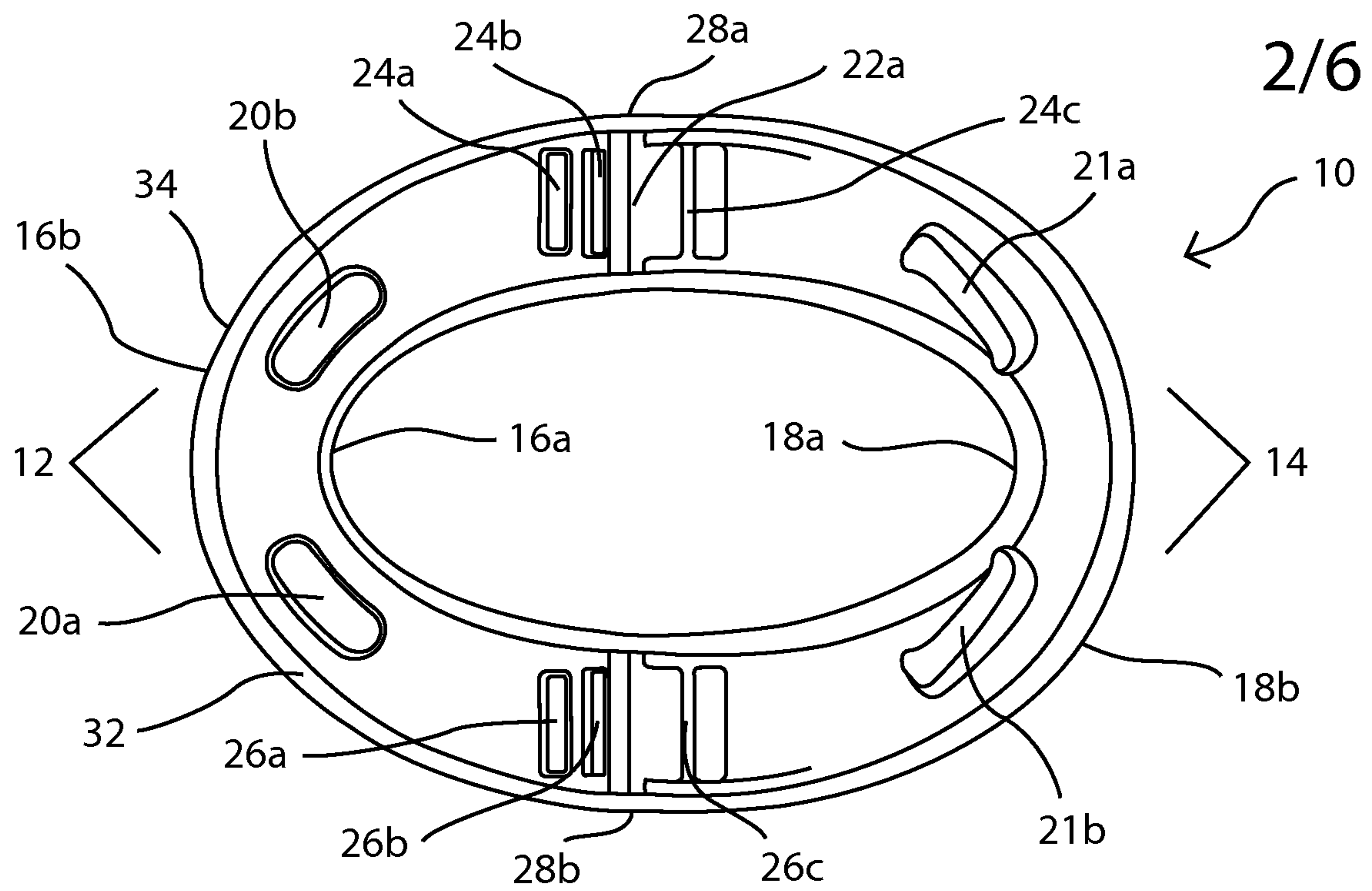


Figure 2a

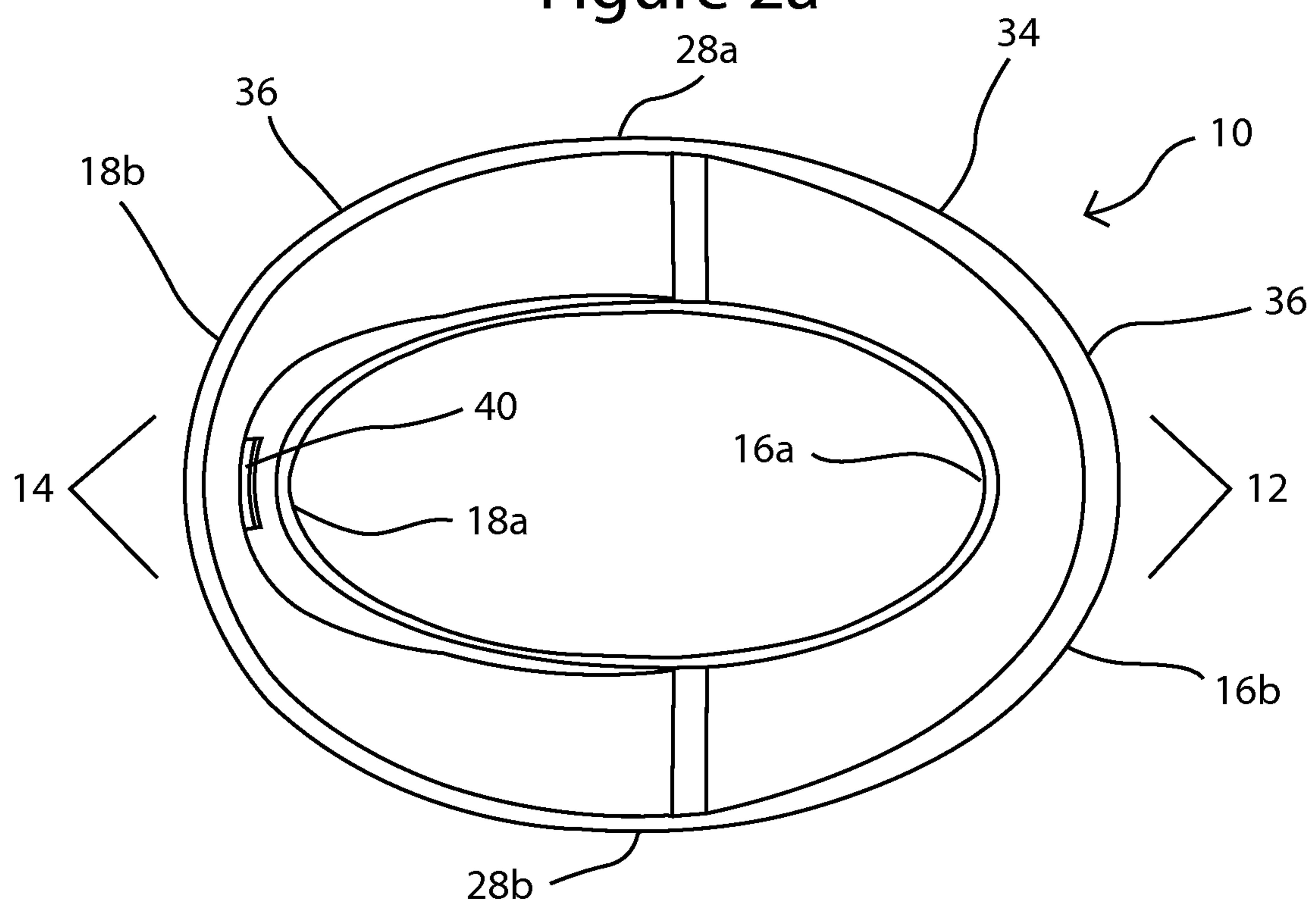
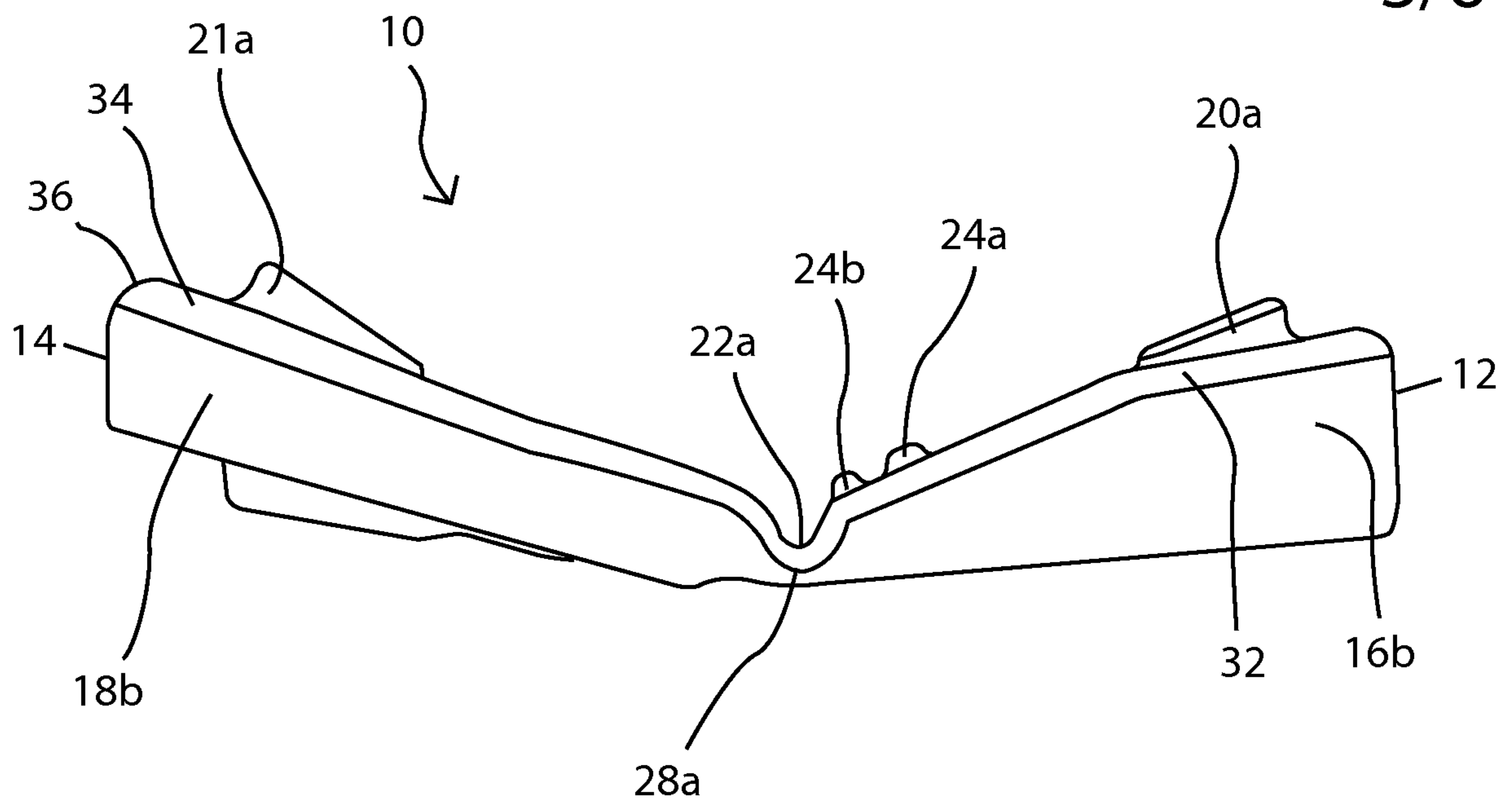
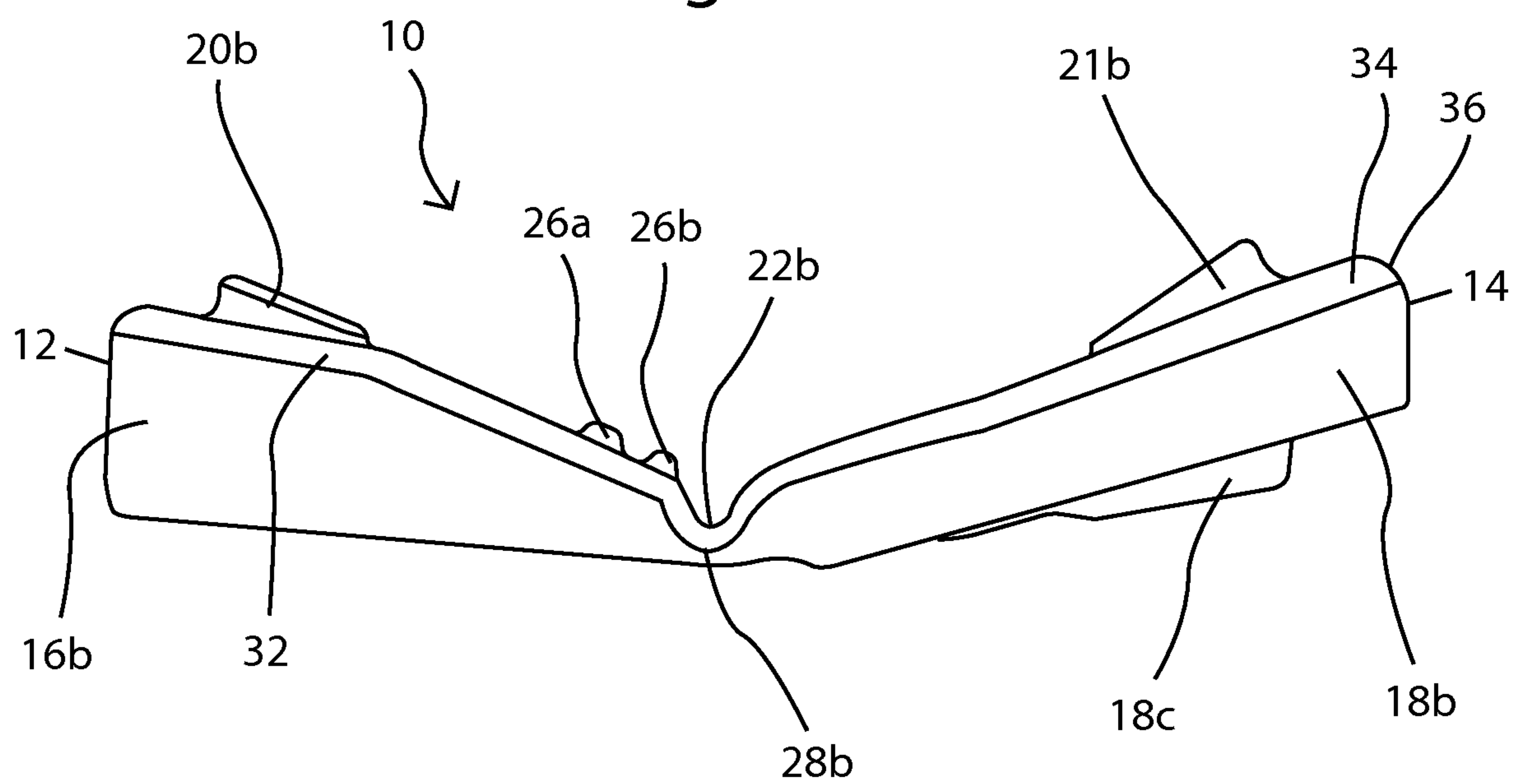


Figure 2b





### Figure 3a



### Figure 3b

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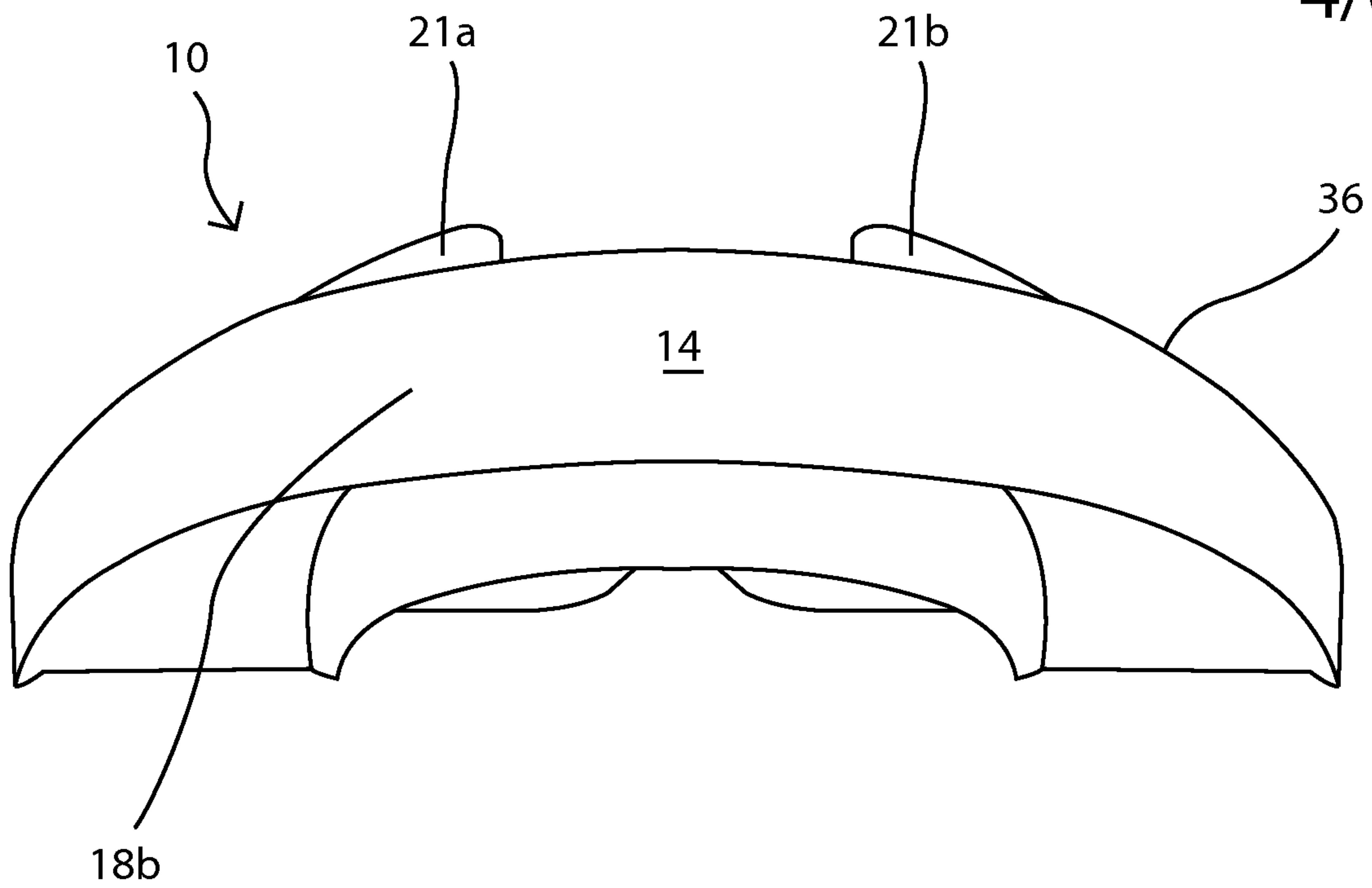


Figure 4a

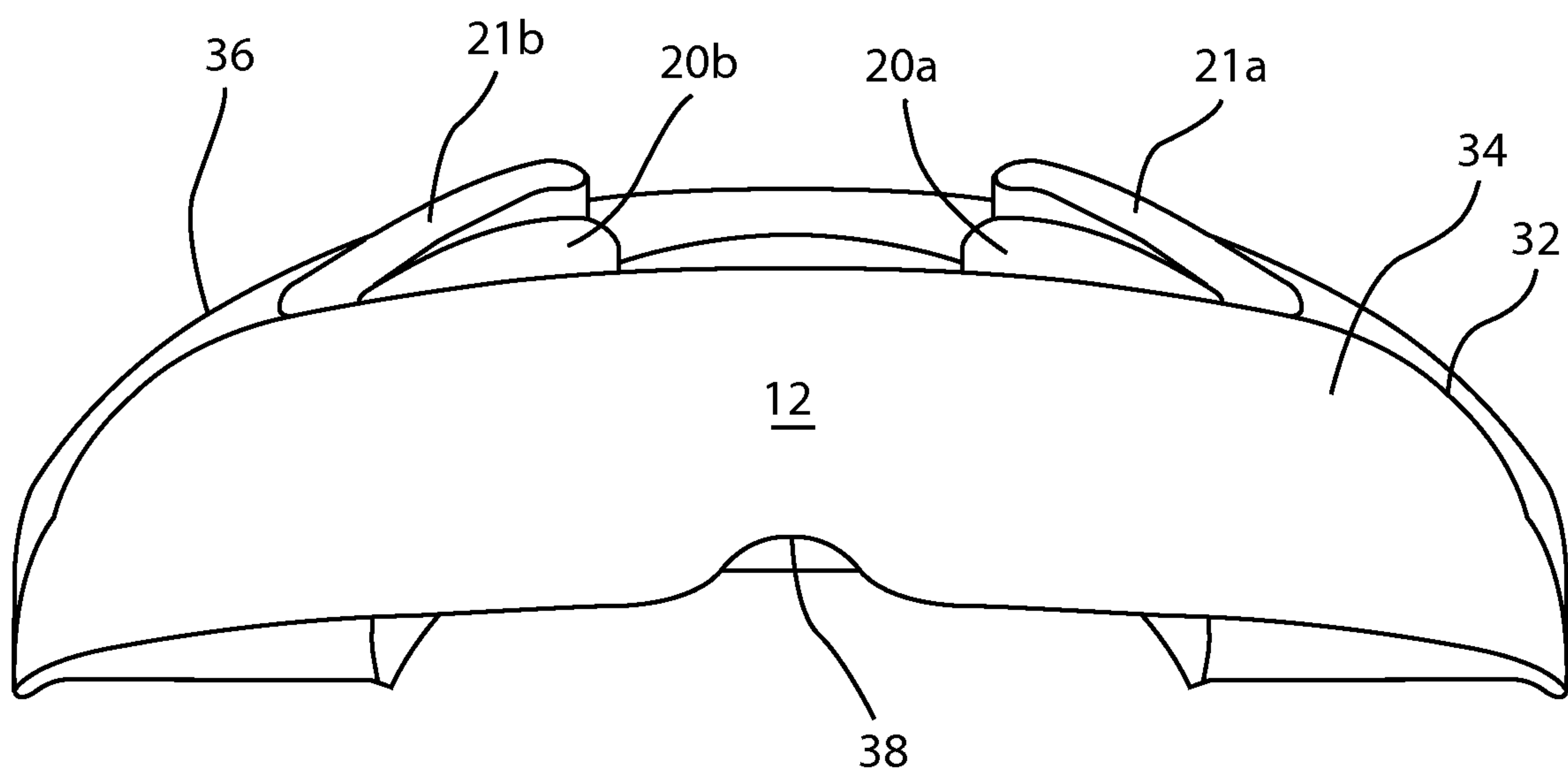


Figure 4b

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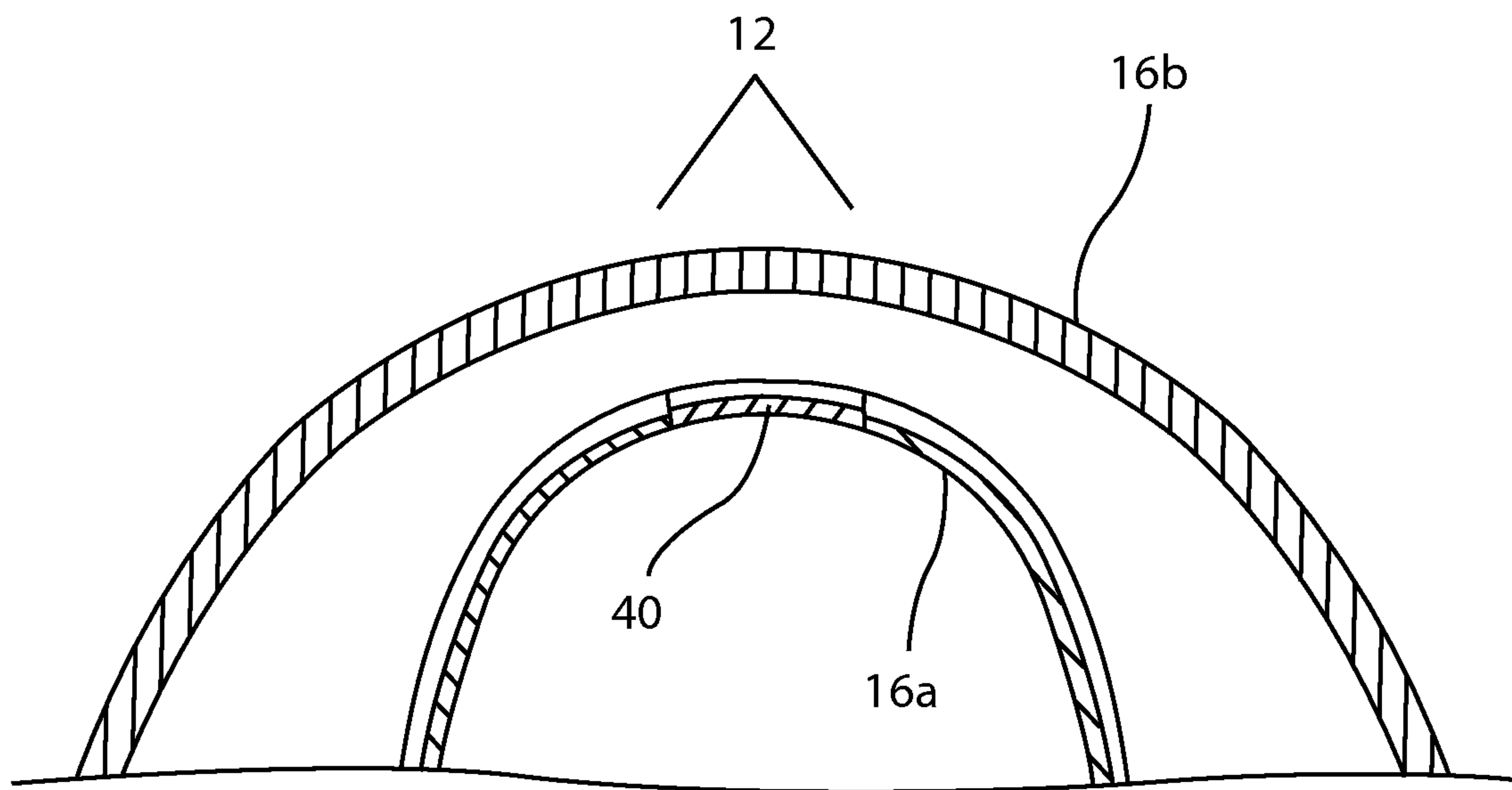


Figure 5



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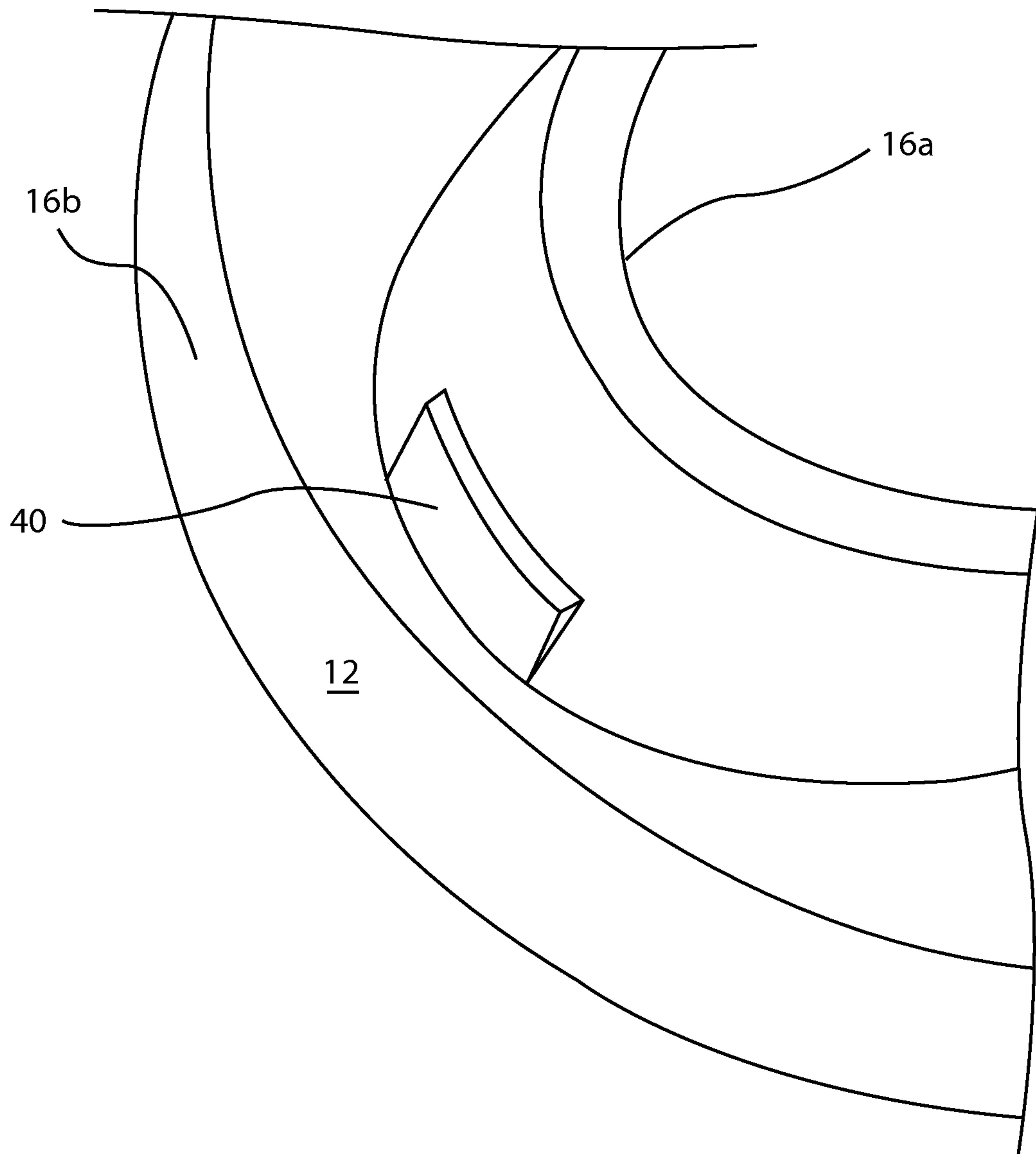


Figure 6

