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(71) Applicant: **WORLD CLASS TECHNOLOGY CORPORATION** [US/US]; 1300 NE Alpha Drive, McMinnville, OR 97128 (US).

(72) Inventors: **HAGELGANZ, Rolf**; 375 SW Viewmont Drive, Dudee, OR 97115 (US). **BATHEN, Juergen**; 19225 SW Meadow View Drive, McMinnville, OR 97128 (US). **KABBANI, Robert**; Salzweg 35, 30455 Hannover (DE).

(74) Agents: **ROHLFS, Kurt, A.** et al.; Chernoff, Vilhauer, McClung & Stenzel, LLP, 601 SW Second Avenue, Suite 1600, Portland, OR 97204 (US).

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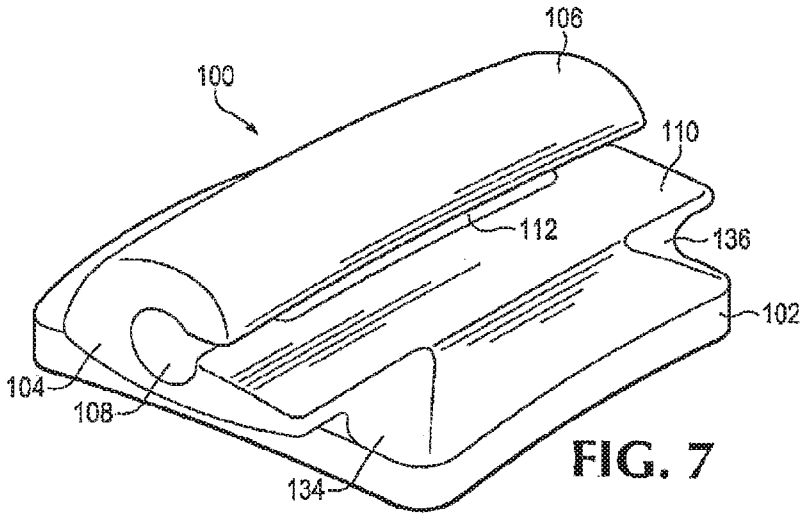

FIG. 7

(57) Abstract: An orthodontic appliance comprises a base portion adapted to be affixed to a patient's tooth and an upper portion including a flexible and resilient hook for forming a tubular channel for receiving an archwire. The upper portion includes a flange affixed to the hook, and is sized and shaped to connect to loops of an elastomeric power chain.

WO 2017/164916 A1

ORTHODONTIC APPLIANCE WITH ELASTOMERIC CHAIN

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to orthodontic appliances and in particular, to orthodontic brackets having a curved archwire slot that is round in cross section and has a flange for engaging an elastomeric chain.

BACKGROUND ART

[0002] Orthodontic treatments for the repositioning of teeth employ a combination of appliances that are affixed to the teeth and archwires, which are coupled to the appliances. By placing the correct amount of tension on the archwires, the orthodontist is able to manipulate the position and orientation of a patient's teeth.

[0003] Orthodontic appliances, also known as "brackets" each possess an archwire slot, which accommodates an archwire. The archwire is a piece of stiff wire that has a curve that approximates the arc of the teeth in a human mouth. That is, from the rear molars of the left side of the mouth to the rear molars on the right side of the mouth, there is a natural curve that forms an arc of about 180 degrees. The arc is not circular but U-shaped. At the distal ends, the arc barely has any curve at all and is mostly straight. As the arc approaches the front teeth however, its curve becomes more pronounced.

[0004] To properly adjust the tension of the archwire, it is necessary that the interaction of the archwire in each archwire slot be as free from extraneous forces as possible. The torque that a properly adjusted archwire places on teeth acts in an inward/outward direction, normal to the surface of the tooth. Forces that act in a side-to-side direction, that is, along the arc of the archwire itself, are undesirable. Such forces can be present, however, because the ends of the archwire slots have edges that contact the archwire and act as a resistance to the movement of the archwire in the slot. This can be the case in locations in the mouth where the curve of the archwire is most pronounced. In some cases, the archwire rests almost entirely across opposite edges of the slot, which results in an unacceptable amount of friction as those edges dig in to the wire. Tightening the archwire then leads to moments with forces directed in undesirable directions.

[0005] Archwires may be either round or rectangular in cross section. A rectangular archwire gives more control to the orthodontist, but also presents problems. Rectangular archwires in rectangular slots produce friction. Each surface in the slot is a bearing surface that can produce friction and retard desired application of forces. In certain phases of the treatment, it may be advantageous to use one type versus the other. For example, the end phases of treatment frequently call for the use of a round archwire. Round archwires are chosen for

this phase because there is less friction between a round wire and an archwire slot. However, archwire slots are made rectangular to accommodate rectangular or square archwires. Round archwires are commonly used in rectangular or square slots but this arrangement is less desirable than it could be. There is still friction produced by the round archwire engaging the straight walls of the slot. Additionally, round archwires do not torque well in rectangular slots because of the lack of contact between the wire and the walls of the slot.

[0006] Typically, orthodontic brackets have profiles that cause irritation of the inner lip surfaces of a patient because the bracket is rectangular in cross section and its edges protrude too far above the top of the tooth. Typical orthodontic bracket designs are shown in various U.S. patents such as Wildman *et al.* (No. 5,613,850), Damon (No. 5,466,151), and in published application no. US2004/0072117 to Farzin-Nia *et al.* (now U.S. Patent No. 7,419,375).

SUMMARY OF THE INVENTION

[0007] An orthodontic appliance adapted to be affixed to the top surface of a tooth and includes a base portion and an upper portion, the upper portion having a flexible hook to receive an archwire. The upper portion includes a flange sized to connect to an elastomeric power chain.

[0008] The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a schematic view of a tooth correction means formed of a plurality of tooth top parts and a connecting means.

[0010] Figure 2 is a lateral view of a first embodiment of a tooth top part in a functional position.

[0011] Figure 3 is a perspective view of the tooth top part according to Figure 2.

[0012] Figure 4 is a schematic view of the tooth top part according to Figures 2 and 3.

[0013] Figure 5 is a lateral view of a second embodiment of a tooth top part in a functional position shown as solid lines and in an assembly position shown as dotted lines.

[0014] Figure 6 is a lateral view of a third embodiment of a tooth top part in a functional position.

[0015] Figure 7 is a perspective view of another embodiment of a low profile bracket.

[0016] Figure 8 is a top view of the bracket of Figure 7.

[0017] Figure 9 is a cutaway side view taken along line 9–9 of Figure 9 with an archwire shown in dashed outline.

[0018] Figure 10 is a cutaway view taken along line 10–10 of Figure 8.

[0019] Figure 11 is a top view of the brackets of Figure 8 installed on a patient's teeth in dashed outline and connected by a power chain.

[0020] Figure 12 is a side cutaway view of the brackets of Figure 11.

[0021] Figure 13 is a bottom view of a patient's mouth showing a set of orthodontic brackets attached to teeth and an archwire spanning the bracket set.

[0022] Figure 14 is a top view of a prior art bracket featuring a rectangular archwire slot.

[0023] Figure 14A is a cutaway view taken along line A–A of Figure 14.

[0024] Figure 14B is a cutaway view taken along line B–B of Figure 14.

[0025] Figure 15A is a top view of an orthodontic bracket having a rounded archwire slot and a round archwire.

[0026] Figure15B is a perspective view of the bracket of Figure 15A.

[0027] Figure 16 is a side view of the archwire and bracket of Figure 15A.

[0028] Figure 17 is a cutaway view of the archwire and bracket of Figure 15A taken along line 17–17 of Figure 15.

[0029] Figure 18 is a cutaway view of the archwire and bracket of Figure 15A taken along line 18–18 of Figure 15A.

[0030] Figure 19 is a cutaway view of the bracket of Figure17 attached to a patient's tooth.

[0031] Figure 20 is a top view of a preformed archwire attached to five orthodontic brackets.

[0032] Figure 21 is an enlarged view of the archwire of Figure 20 and two of the attached brackets.

[0033] Figure 22 is a top view of a pair orthodontic appliances to which an elastomeric chain is coupled.

[0034] Figure 23 is a side view along the mesial-distal axis of one of the appliances of Figure 22.

[0035] Figure 24 is a side view of the appliance pair of figure 22 in the gingival-occlusal plane.

[0036] Figure 25 is a top view of an orthodontic appliance with a top flange for engaging loops of an elastomeric chain.

[0037] Figure 26 is a side view of the appliance of Figure 25.

[0038] Figure 27 is a side cutaway view of the appliance of Figure 26.

[0039] Figure 28 is a perspective view of an orthodontic appliance with a top flange for engaging loops of an elastomeric chain.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0040] One aspect of the invention relates to a tooth top part for a tooth correction means, with a base body at which a tooth support surface is formed for being fixed at a tooth surface by bonding, and which is provided with a guide recess which is formed for receiving a connecting means for coupling neighboring tooth top parts and which passes through the base body in spaced relationship to the tooth support surface along a guiding axis.

[0041] A tooth top part of this type, which is also referred to as a bracket, is known from DE 20 2009 008571 U1. The known tooth top part is formed at an outward-facing surface of a tooth for being fixed by bonding, and to that end comprises a tooth support surface which is used as an adhesive surface for adhesively attaching (adhering) the tooth top part to the surface of the tooth. The tooth top part is provided with a groove-type recess extending along a guiding axis and being spaced from the tooth support surface. The known tooth top part comprises a substantially H-shaped cross section in a cross sectional plane normal to the guiding axis. The recess in the tooth top part permits insertion of a connecting means, which couples tooth top parts attached to neighboring teeth and permits transmission of forces between the teeth. The forces and, if applicable, the torques transmitted by the connecting means enable the teeth to move relative to each other and permit correction of false positioning (malocclusion) of teeth.

[0042] The tooth top part known from the prior art has a drawback that the H-shaped cross section, which may be approximated by a rectangular envelope (curve) in the cross sectional plane causes irritations of the mouth mucous membrane (oral mucosa) in particular at the inside of the lips. This results in reduced wearing comfort for a tooth correction means formed by a plurality of such tooth top parts.

[0043] It is an object of the invention to provide a tooth top part that comprises improved adjustment to the anatomical conditions in the mouth region and thus causes less irritation of the mucous membranes.

[0044] This object is achieved in a tooth top part as mentioned in the above introduction using the features of claim 1 which provides that the base body comprises a substantially triangular or circular section shaped cross section in a cross sectional plane normal to the guiding axis.

[0045] The triangular or circular section shaped cross section guarantees reduced friction during relative movements between the tooth top parts and the opposing mucous membrane. Thus, due to the reduced friction, the mucous membranes will be irritated less both during talking and food intake, and discomfort caused by sore spots in the mucous membrane is reduced. Preferably, compared to known tooth top parts, these tooth top parts have a reduced overall height, which may provide a further reduction in mucous membrane irritations. Preferably, the height of the tooth top part in a direction normal to the tooth surface is less than 2.5 times, in particular less than 2 times, the largest edge length (for instance with a rectangular cross section) or the diameter of the connecting means. More preferably, the connecting means comprises a largest edge length or a diameter selected to be less than 0.5 mm, in particular less than 0.4 mm.

[0046] Further advantageous embodiments are presented in the sub-claims.

[0047] Appropriately, a base line of the substantially triangular or circular section shaped cross section is formed by the tooth support surface, and a mean perpendicular to the base line comprises a length less than 50 per cent of the length of the base line. With this shape of the profile of the tooth top parts, an advantageous ratio is achieved between the size of the tooth support surface required for secure immobilization of the tooth top parts at the tooth surfaces and the height of the respective tooth top part. The length of the mean perpendicular corresponding to the maximum height of the tooth top part beyond the tooth surface is small compared to known tooth top parts. As a result, when combined with the triangular or circular section shaped cross section of the tooth top part, a particularly gentle use of the tooth correction means constituted with the tooth top parts according to the invention can be achieved.

[0048] Preferably, each of the outer surfaces of the base body, adjacent to the tooth support surface, include acute angles, preferably less than 45 degrees, more preferably less than 35 degrees, particularly less than 25 degrees, with the tooth support surface. The outer surfaces of the tooth top part are those surfaces at the base body that are in particularly intensive contact with the opposing mucous membranes of the mouth region. The smaller the selected

angle between the outer surface and the tooth support surface, the greater the wearing comfort of the tooth correction means constituted by the tooth top parts. However, since reception of the connecting means is always required, the angles cannot be reduced at will.

[0049] The triangular cross section of the base body may be formed as an isosceles triangle having identical acute angles between the two outer surfaces and the tooth support surface. Alternatively, the triangular cross section may be formed as a triangle at will where the acute angles included between the respective outer surface and the tooth support surface are selected differently. The circular section shaped cross section may be selected as a symmetrical or asymmetrical circular section.

[0050] In a further improvement of the invention, transitional regions between the outer surfaces and/or between an outer surface and the tooth support surface are formed with a rounding-off radius. This avoids sharp edges at the transitions between the outer surfaces or between the outer surface and the tooth support surface which too could give rise to unwanted mucous membrane irritations.

[0051] Appropriately, the, preferably undercut, guide recess is formed as a groove-type indentation starting from one of the outer surfaces of the base body. A groove-type indentation enables comfortable and rapid insertion and, if required, removal of the preferably wire-shaped connecting means into the guide recess and from the guide recess, respectively. This is particularly true if the groove opening of the guide recess extends alongside the guiding axis of the guide recess, thus enabling insertion/removal of the connecting means crosswise/transverse to the direction of its overall extension. Preferably, the guide recess is formed with an undercut that, for instance, allows the connecting means to be locked within the guide recess.

[0052] Advantageously, at least one, preferably sectionally elastic, snap-on nose is formed at the base body, said snap-on nose regionally limiting the groove-type indentation and being formed for lockingly receiving the connecting means in the guide recess. The snap-on nose is meant to immobilize the connecting means at the tooth top part such that, on one hand, the latter is able to transmit the desired forces between adjacent teeth and, on the other hand, can be easily attached at the tooth top part and, if required, removed again therefrom. Preferably, the snap-on nose is formed as an at least sectionally elastic spring nose enabling snap-in of the connecting means and self-locking, in particular positive locking (form-locking), immobilization of the connecting means at the tooth top part. Alternatively, the groove-type recess may also be closed using a separate locking element or a locking element integrally attached to the base body, wherein the locking element may, for instance, be shifted or swung/pivoted between a locked position and an open position.

[0053] In an advantageous improvement of the invention, the snap-on nose is formed for self-locking, in particular positive locking (form-locking), immobilization of the connecting means at the base body. With a self-locking design of the snap-on nose, the connecting means is pushed into the tooth top part while being elastically deformed and, when reaching a predetermined functional position, will be immobilized solely by the resilience (elastic restoration properties) of the snap-on nose without any effort by the user. Preferably, the connecting means, the guide recess in the tooth top part and the snap-on nose are coordinated such that immobilization of the connecting means by positive locking is achieved.

[0054] Preferably, the base body is made of a preferably tooth-colored, clear or translucent synthetic material (plastics material). This enables the tooth top parts to be inconspicuously arranged within the mouth region of a patient. More preferably, the tooth top parts are formed in different colorings and/or degrees of transparency in order to allow for low contrast adaptation to the respective tooth color.

[0055] Appropriately, the groove-type indentation is formed for lockingly receiving a profiled connecting means that is formed for transmitting torsional forces between neighboring tooth top parts. This enhances the versatility of the tooth correction means made of the tooth top parts according to the invention by the possibility of inducing pivoting movements between neighboring teeth. More preferably, the connecting means comprises a square or rectangular cross section, which is at least partially mapped in the recess of the tooth top part in order to allow the transmission of torque between the connecting means and the tooth top part.

[0056] In an advantageous improvement of the invention, the groove-type indentation is adapted to the connecting means such that a, preferably low friction or nearly zero friction, relative movement of the connecting means with respect to the base body, in particular along/alongside the guiding axis of the recess is enabled. This allows particularly rapid correction of false positioning of teeth without requiring frequent readjustment of the connecting means. The mentioned coordination between the recess and the connecting means is also referred to as self-ligating, since the connecting means is free to move in the recesses of the tooth top parts in accordance with the patient's needs without requiring any additional elements such as rubber rings for immobilizing the connecting means at the tooth top parts.

[0057] In another aspect of the invention an orthodontic appliance includes a flange positioned atop a hook portion which resiliently flexes to receive a round arch wire. The flange is sized and shaped to allow engagement by the loops of an elastomeric chain. Such chains are flexible webs of material with loops which may engage tie wings or the like. The

appliance is a low profile appliance so the flanges do not add appreciable height, but provide a more convenient means for attaching elastomeric chains than traditional tie wings.

[0058] Preferred embodiments of the invention are shown in the drawings.

[0059] In a human tooth arrangement schematically shown in Figure 1 and comprising molars, canines and incisors, a tooth correction means 1 according to the prior art is shown in the left-hand region of Figure 1, whereas a tooth correction means according to the invention is shown in the right-hand region of Figure 1. Both tooth correction means are used in order to achieve a desired arrangement of the teeth with respect to each other. The tooth correction means 1 comprises several tooth top parts which, as an example, are attached at tooth surfaces 3 of all teeth and which are coupled to each other by a connecting means 4 for instance having a wire shape. The connecting means 4 enables the transmission of forces and, if required, also torques between the teeth in order to bring the teeth in a predeterminable position during orthodontic therapy. In the prior art tooth correction means, the tooth top parts clearly extend further from the teeth and the wire thickness of the connecting means is clearly selected to be thicker.

[0060] As can be seen from Figure 2, the tooth top part 2 according to the invention, which is identical to the base body in the present embodiment, comprises a tooth support surface 5 by means of which it is bonded to the tooth surface 3 in a known manner. The tooth support surface 5 is flanked by a first outer surface 6 and a second outer surface 7 each of which includes an acute angle 18, 19 (Figure 4) with the tooth support surface 5. Transitional regions between the outer surfaces 6, 7 and the tooth support surface 5 are formed with a rounding-off radii 20, 21.

[0061] In the shown embodiment of the tooth top part 2, end faces 8, 9 of the tooth top part 2 are orthogonal to the outer surfaces 6, 7 and to the tooth support surface 5. Thus, the end faces 8, 9 in the shown embodiment of the tooth top part 2 are parallel to a cross-sectional plane identical to the drawing plane of Figures 2 and 4.

[0062] As can be seen from the schematic view of Figure 4, a cross section of the tooth top part 2 is formed such that it is contained within a triangular envelope 11 or within a circular section shaped envelope 11a. A mean perpendicular 14 of the envelope 11 is orthogonal to a base line 13 of the envelope 11, determined by the tooth support surface 5. A length of the mean perpendicular 14 is less than 50 percent, in the present example about 40 percent, of the length of the base line 13, which results in a low profile for the tooth top part 2, thus causing less irritations of the mouth mucous membrane (not shown).

[0063] In the embodiment of a tooth top part shown in Figures 2 through 4, a recess 12 extending normally to the cross sectional plane 10 is provided with a substantially L-shape profile. For instance, the tooth top part 2 is formed as a geometrically extruded component having a constant cross section normal to the cross sectional plane la throughout its length. Thus, the recess 12 also extends with a constant cross section and thus, determines a guiding axis 17 coinciding with a central axis of the for instance wire-shaped connecting means 4 having a circular cross section.

[0064] Due to the substantially L-shaped profile design, a snap-on nose 15 and a snap-on hook 16 for immobilizing/securing the connecting means are formed in the base body 2 of the tooth top part. The snap-on nose 15 is designed for locking the connecting means 4 in the shown functional position within the snap-on hook 16, thus guaranteeing a safe, positive locking (form locking) immobilization of the connecting means 4 at the tooth top part 2 crosswise/transverse to the extension of the connecting means 4. During an assembly operation (not shown), where the connecting means 4 is pushed transversely to its longitudinal extension into the recess 12, both the snap-on nose 15 and the snap-on hook 16 undergo elastic deformation. During the assembly operation, while the snap-on nose 15 is bent toward the tooth support surface 5, the snap-on hook 16 undergoes deformation in the opposite direction. As a result, the recess 12 opens up a cross section enabling insertion of the connecting means 4. As a result of a preferably exclusively elastic deformation of the snap-on nose 15 and the snap-on hook 16, the tooth top part is self-locking for the connecting means 4.

[0065] As soon as the connecting means 4 arrives at the functional position shown in Figures 2 through 4, the resilience, *i.e.*, elastic restoration forces, of the snap-on nose 15 and the snap-on hook 16 will have a non-positive locking (force locking) and positive locking (form locking) effect for forces occurring within the cross sectional plane la without requiring any additional measures to that end. Both the snap-on nose 15 and the snap-on hook 16 comprise elastic regions formed as solid-state joints enabling elastic pivoting into the assembly position and restoration into the functional position.

[0066] In a variant of the tooth top part 2, the snap-on hook 16 may be reinforced using an insert 22, preferably made of an elastic/resilient metal, as shown in Figure 4.

[0067] In the following description of a second embodiment of a tooth top part 22 shown in Figure 5, components with identical function are given reference numerals increased by 20. The tooth top part 22 is provided for receiving a connecting means 24 having a rectangular cross section in the present case and which enables the transmission of torque between neighboring tooth top parts 22. The recess 32 is adapted to the connecting means 24 such

that the latter engages the snap-on hook 36 via three lateral surfaces and is pressed by the snap-on nose 35 into this region of the recess 32.

[0068] As can be seen from the dotted-line representation of Figure 5, when the connecting means 24 is mounted, the snap-on nose 35 is supposed to be bent downward while the snap-on hook is deformed downward toward the tooth support surface 25. This causes the recess 32 to open up a cross section through which the connecting means 24 can be brought into the functional position, as it exists in the solid-line representation of Figure 5. After the connecting means 24 has reached the functional position, the snap-on nose 35 and the snap-on hook 36 will pivot back elastically into the initial position shown with solid lines and thus, will cause positive locking (form locking) of the connecting means.

[0069] Demounting of the connecting means 24 can be effected by holding down the snap-on nose 35 toward the tooth support surface 25 with a tool (not shown) and subsequently pivoting the connecting means 24 out of the recess 32 by performing a pivoting movement while deforming the snap-on hook 36.

[0070] A simplified embodiment of a tooth top part 42 is shown in Figure 6. In this case, the cross section of the recess 52 substantially corresponds to the cross section of the connecting means 44 and is only limited by barbed hooks 57 provided on both sides in the region of the groove opening. These barbed hooks 57 are elastically displaced when the connecting means 44 is inserted into the recess 52, and will move back into the shown position as soon as the connecting means 44 has reached the functional position. The advantage of the embodiment according to Figure 6 can be considered as having no hollow spaces at the tooth top part 42 due to the corresponding cross sections of the connecting means 44 and the recess 52. Demounting of the connecting means 44 is preferably effected by pulling it out laterally toward the guiding axis oriented normally to the drawing plane of Figure 6.

[0071] The tooth top parts 2, 22, 42 shown in Figures 2 through 6 are preferably made of a synthetic material such as a plastics material. Alternatively, the use of ceramics or metal for producing the tooth top parts is possible. In doing so, it may be necessary to modify the geometries of the tooth top parts, in particular in the region of the solid-state joints, in order to guarantee the desired elastic properties. When using synthetic materials such as plastic materials or ceramic materials for the tooth top parts, a regional/sectional reinforcement employing metal inserts may be provided.

[0072] The tooth top part 2, 22, 42 according to the invention enables relative displacement and/or pivoting of neighboring teeth. Given that the tooth top part 2, 22, 42 does not have any hooks and eyelets (no "nooks and crannies"), no additional connecting elements such as rubber bands can be inserted. In order to provide for additional force application to the teeth

to be corrected, additional hooks may be provided in the region of the gum line. These additional hooks, which may be attached in a structurally separated manner from the tooth top parts 2, 22, 42 at selected or all teeth and which are preferably made of synthetic material, enable additional connecting elements to be hooked up which are typically significantly shorter than the tooth top parts 2, 22, 42 and, as they are suited exclusively for hooking up additional connecting elements, can be designed in a very skinny fashion. By providing additional hooks in the region of the gum line, these hooks as well can be placed very inconspicuously and in particular at particularly suitable force application points on the teeth to be moved, since this will favor parallel displacement of the teeth. Due to the decoupling of the different force application systems, which are determined by the tooth top parts 2, 22, 42 on one hand and by the additional hooks on the other hand, not only an optically inconspicuous attachment of the corresponding components for the tooth correction means with little irritation of the mouth mucous membrane, but also a particularly efficient movement of the teeth due to the advantageous selectability of the force application points can be achieved.

[0073] In another aspect of the invention, a bracket 100 as shown in Figures 7–11 includes a base 102 and a top portion 104. The brackets 100 are affixed to teeth 101 (shown in dashed outline). The base 102 has a width in both the gingival-occlusal plane (L1) and a length in the distal-anterior direction (W1). The top portion 104 is made of an elastically deformable hook portion 106 that curls around past the apex to create a substantially cylindrical or tubular archwire channel 108. Note that the interior of this channel could also be rectangular in cross section as shown in the embodiment of Figure 6. In this embodiment, the snap-on nose is eliminated and a shelf 110 is formed underneath the hook portion 106. The shelf and the distal end of the hook portion 106 form an opening 112 that is slightly smaller than the largest diameter of an archwire 114 (dashed outline in Figure 9). When the archwire 114 is press fitted into the opening 112, the hook portion 106 elastically deforms allowing the archwire to enter the channel 112. Once the archwire 114 has reached its functional position, the hook snaps back, securing the archwire 114 therein. The archwire may be removed by prying the hook portion 106 upward with a tool (not shown).

[0074] The archwire 114 for this bracket is thin. Treatment typically begins with an archwire having a diameter of 0.010". It progresses during the treatment to 0.012" and eventually to 0.014". All archwires fit within the bracket 100, which has a nominal channel diameter of 0.016". As shown in Figure 12, the archwire channel is larger in the center portion of the bracket for reducing friction.

[0075] The archwire has a radius of curvature "R" as also shown in Figure 12. The interior shape of the hook portion (and hence, of the archwire channel 108) of the top part in the

distal-anterior direction is curved and has a radius of curvature made to match the radius of curvature "R" of the archwire. This insures that the archwire slides through the channel with the least amount of friction possible.

[0076] The base and the top portion may be configured to provide a tie wing for an elastic power chain 120. An elastic power chain (see Figure 1) is an elastic band with at least two open loops 122 joined by bridge portions 124. The power chain 120 has three loops and can be looped about adjacent brackets so as to exert a compressive force tending to draw them together as shown in Figure 11. The power chain may have any number of loops desired.

[0077] To form a tie wing, the top portion 104 is made longer in the distal-anterior direction than the width of the base 102 in this same direction as shown in Figure 8 by the arrows designating W1 and W2. In addition, the base 102 may be chamfered at its corners so that the power chain 120 is retained more easily when it is looped over the top of the bracket. The corners 130, 132, 134 and 136 are all chamfered to provide a surface for retaining the power chain loops 122.

[0078] The bracket 100 is a small low-profile bracket in which the mean height "h" is less than half of the length L1 of the base 102 in the gingival-occlusal direction. The low profile insures that the bracket will not irritate the inside of the lips of the patient. Typical dimensions are that the gingival-occlusal length of the base is about 0.135". Thus, the bracket could be 0.140" to 0.130" inches in length. The low profile comes from the height of the bracket, which in a preferred embodiment is about 0.053", but could range, preferably, from about 0.048" to 0.058". The height of the bracket, however, should not exceed half of the gingival-occlusal length. Thus if the length were 0.130", the bracket height should not exceed 0.065". This results in a bracket that is triangular in cross section with a rounded crown at the apex. The triangle is a shallow low-profile shape that makes the bracket comfortable for the patient and is easy to adjust.

[0079] Referring to Figure 13 an archwire 200 is coupled to brackets 202 which are affixed to a patient's teeth. The archwire is curved over its length in a horseshoe shape but the curvature is not constant. At the distal ends at the buccal tubes 204, 205 the archwire 200 is nearly straight along the molars 203. The radius of curvature begins to change fairly abruptly at the bicuspids 206, 207, the cuspid 208 and curves across the lateral 209 and the central 210. There may be different radii of curvature in the archwire at different points along its length.

[0080] In a prior art bracket as shown in Figures 14, 14A,14B, a rectangular archwire 211 spans the archwire slot 212 of a typical bracket 213. As Figure 14A shows, when there is

curvature in the archwire 211, it contacts the ends of the slot 212 and does not lie flat. Thus, the ends of the slot dig into the archwire at these points and resist lateral sliding movement.

[0081] In the embodiment of the bracket of Figures 15A–18, a round archwire 220 occupies an archwire slot 222 in a bracket 224, which has two portions, slot portion 222a and portion 222b. The archwire slot portions are rounded U-shaped channels having straight walls and are curved at the bottom to form a tubular channel having a radius that matches the radius of the archwire at least approximately. The slot portions are formed between each pair of tie wings 219, 218. There is a gap 217 between the tie wings 218, 219 so that the archwire makes contact only with slot portions 222a and 222b. This reduces the amount of lateral sliding friction between the archwire 222 and the archwire slot 222. Over 180 degrees of the outer surface of the archwire are in direct contact with the walls and bottom of the archwire slot portions 222a, 222b. Thus, forces directed inwardly, normal to the tooth, or in the occlusal-gingival directions are well coupled to the bracket 224. This is illustrated in Figure 19, which shows how torque may be coupled to a patient's tooth by way of an archwire 220 in a rounded bottom archwire slot 222.

[0082] This property also exists in the low profile brackets of Figures 7–12. In Figure 9, the archwire slot or channel 108 is round in order to accommodate the round archwire 114. The archwire 114 only contacts the channel 108 at either end of the bracket. Thus, friction is reduced due to the expanded radius in the middle of the bracket where the archwire does not touch.

[0083] Archwires are Nickel-Titanium and are heat treated to retain their shape. They thus have memory and tend to return to their original shape, which has been chosen and fashioned for optimal results. This spring effect generates forces that are applied to the walls of archwire slots. With round archwire slots, forces are coupled in the desired direction more efficiently because for over more than half of the circumference of the archwire the surface is in direct contact with the slot, which efficiently couples the return forces to any contact point within the archwire slot.

[0084] Referring to Figure 18, the archwire slot 222 of the bracket 224 has a radius of curvature in the mesial-distal plane that matches the radius of curvature of the archwire 220 at that position. The floor of the archwire slot 222a, 222b appears nearly flat but is actually formed with a convex curvature that may be different for different brackets, depending upon where along the curve of the archwire 220 they are placed. For example, referring to Figures 20 and 21 the curvature of each respective archwire slot, 231, 233 is different for brackets 230 and 232. The radii of curvature may vary depending upon the size and shape of the

archwire 220. The table below gives ranges of values that are typical for most common shapes and sizes of archwires.

Tooth Position	Radius Range in Inches
Upper 1	0.85 – 2.20
Upper 2	0.75 – 2.00
Upper 3	0.75 – 2.00
Upper 4	3.00 – 7.50
Upper 5	3.00 – 7.50
Lower 1	0.70 – 2.00
Lower 2	0.70 – 2.00
Lower 3	0.50 – 2.00
Lower 4	2.50 – 7.50
Lower 5	2.50 – 7.50

[0085] These values are merely typical and may change depending on the size and shape of the archwire. Moreover, each bracket in a set will have its own contoured archwire slot depending upon its position in the mouth. Thus, a set of values exists for radii of curvature for individual archwire slots in a set of brackets.

[0086] The use of a contoured archwire slot is applicable to any type of orthodontic bracket including the low profile brackets of Figures 1–12 or the generic full size brackets of Figures 13–21. The same is true of the rounded archwire slots. The use of round wires in complementarily rounded archwire slots is advantageous in any type of orthodontic bracket.

[0087] Alternatively, in another aspect of the invention, a bracket 300 as shown in FIGS. 22-28 may be used. Such a bracket 300 includes a base portion 302, adapted to be affixed to a patient's tooth, and an upper portion 304. As viewable in FIG. 27, the base portion 302 can include bond pads 322 adjacent the bottom surface of the bracket 320. Such bond pads 322 have side walls that form channels in the base portion 302 to be filled with adhesive (not shown). The use of bond pads 322 in conjunction with adhesive help the bracket 300 to remain secured to the surface of a tooth when the bracket is subject to shear forces.

[0088] As best viewed in FIGS. 26-25, the upper portion 304 includes a flexible and resilient hook 306 that curls around past the apex to create a substantially cylindrical or tubular archwire channel or trough 308 having an inner tubular wall. The channel or trough 308 is positioned to extend in a mesial-distal direction. Similar to other embodiments of the present invention, the interior of this channel could also be rectangular in cross section as shown in the embodiment of FIG. 6. The distal end of the hook portion 306 forms an opening 310 that

is slightly smaller than the largest diameter of an archwire 312 (viewable in FIGS. 22-24). Similar to other embodiments of the present invention, the archwire 312 is curved over its length in a horseshoe shape but the curvature is not constant. When the archwire 312 is press-fitted into the opening 310, the hook portion 306 elastically deforms allowing the archwire to enter the channel 308. Once the archwire 312 has reached its functional position within the channel 308, the hook 306 snaps back, securing the archwire 312 therein. The channel 308 may have a radius that approximately matches the radius of the archwire so that the archwire is in contact with over 180 degrees of the surface area of the channel. The archwire may be removed by prying the hook portion 306 upward with a tool (not shown).

[0089] The upper portion 304 also includes a flange 314. The flange 314 may be positioned on top of the hook portion 306. In this embodiment of the invention, the flange is shorter in the distal-anterior direction than in the gingival-occlusal direction. The flange 314 is shaped to be engaged with an elastomeric power chain 316, as shown in FIGS. 22-24. The power chain 316 may be a generally elastic band of material having at least two spaced apart apertures or loops 318. The corners of the flange 314 may be rectangular in shape and chamfered to facilitate engagement of the power chain 316 with the flange 314. The flange 314 may also be positioned in a plane that is substantially parallel to the base or bottom surface of the bracket 320.

[0090] The configuration of the bracket 300, such that the archwire 312 is secured in a position within the bracket 300, and a power strip 316 is engaged over top the archwire aids in the orthodontic use of a power strip 316. Such a power strip is generally used to apply force to close a gap in adjacent teeth. Because the power strip 316 is secured with use of the flanges 314 after the archwire 312 is set in place within the channels 308, a user may easily change the configuration of the power strip 316 based on a patient's needs without disengaging the archwire 312.

[0091] The terms and expressions that have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

CLAIM(S)

1. In combination an elastomeric power chain and an orthodontic bracket, said bracket comprising a base portion adapted to be affixed to a patient's tooth and an upper portion including a resilient hook having an inner tubular wall, said hook overlying a rounded trough, said trough and said wall forming a channel extending in a mesial-distal direction for receiving an archwire, and a flange positioned atop said hook and adapted to engage said elastomeric power chain.

2. The combination of claim 1 wherein said elastomeric power chain comprises a flexible band of material having spaced apart apertures.

3. The combination of claim 1 wherein said flange comprises a substantially rectangular tab lying in a plane substantially parallel to said base portion of said bracket.

4. The combination of claim 1 wherein said tubular channel has a cross sectional radius which approximately matches the cross sectional radius of said archwire such that the archwire is in contact with over 180 degrees of the surface area of said tubular channel.

5. An orthodontic appliance comprising a base portion adapted to be affixed to a patient's tooth and an upper portion including a flexible hook for forming a tubular channel for receiving an archwire, said upper portion further including a flange affixed to said hook.

6. The orthodontic appliance of claim 5 wherein said flange is sized and shaped to connect to an elastomeric power chain.

7. The orthodontic appliance of claim 5 further including an elastomeric power chain wherein said elastomeric power chain includes loops adapted to be engaged by said flange.

8. The orthodontic appliance of claim 5 further including an archwire adapted to fit snugly within said tubular channel.

9. The orthodontic appliance of claim 5 wherein said flange comprises a flat tab substantially centered atop said hook.

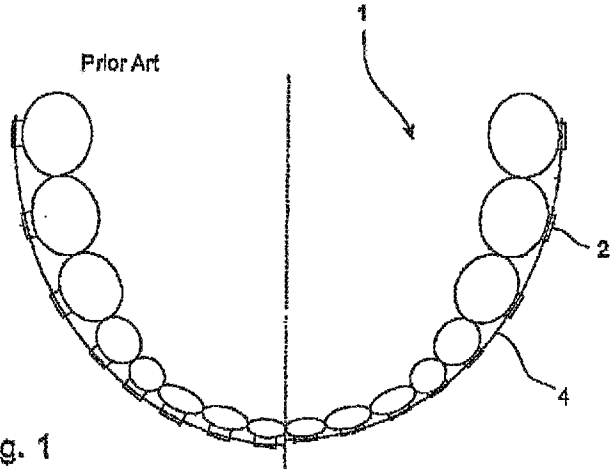

Fig. 1

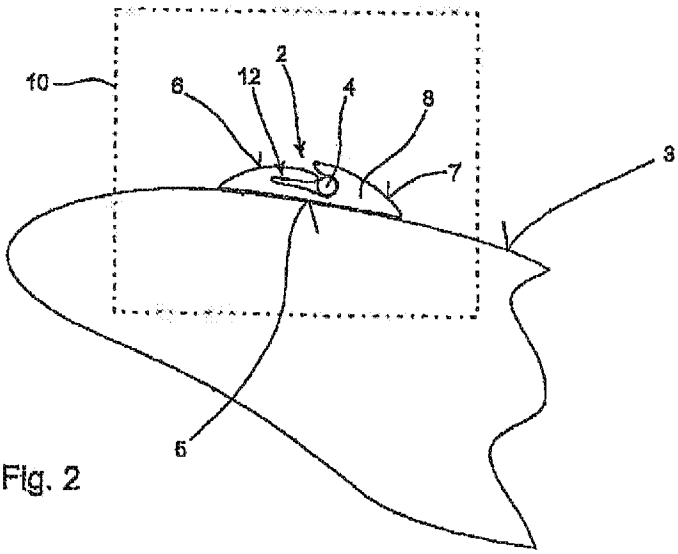

Fig. 2

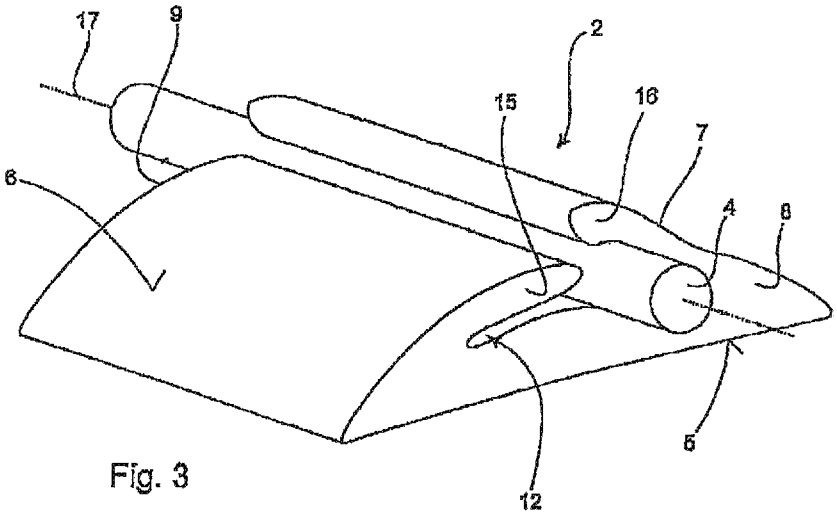

Fig. 3

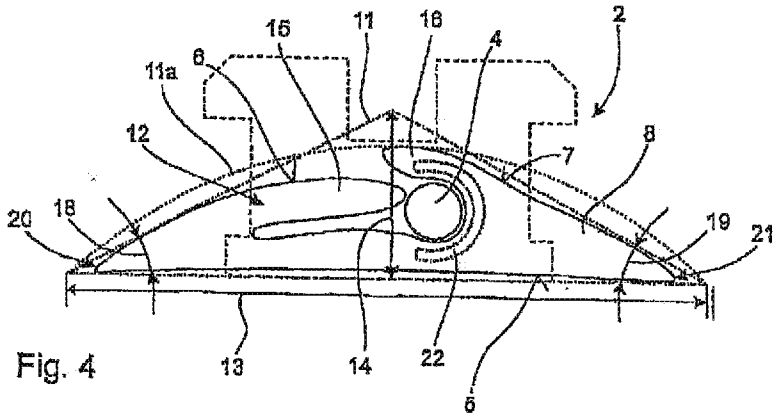

Fig. 4

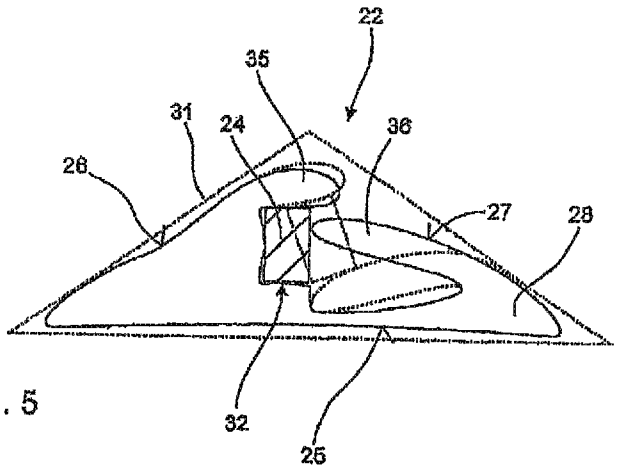

Fig. 5

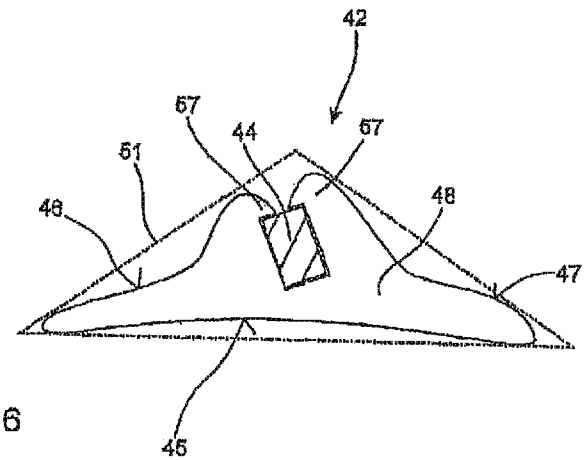

Fig. 6

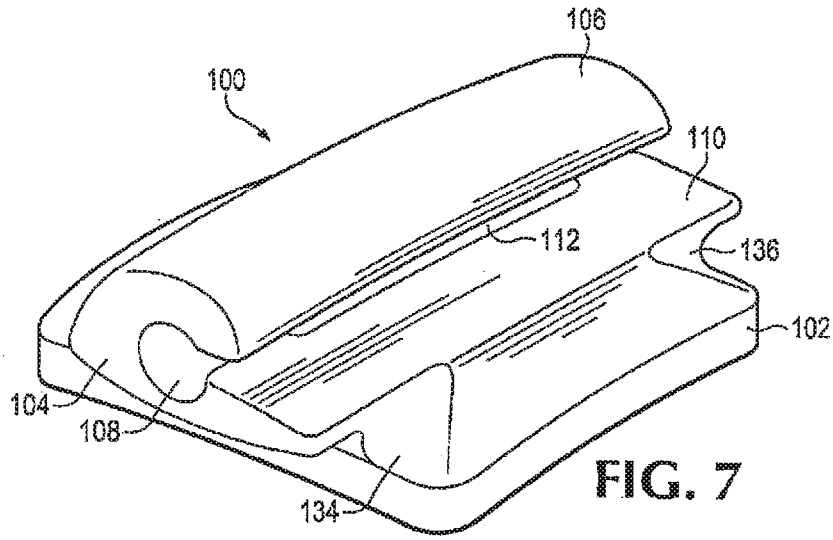
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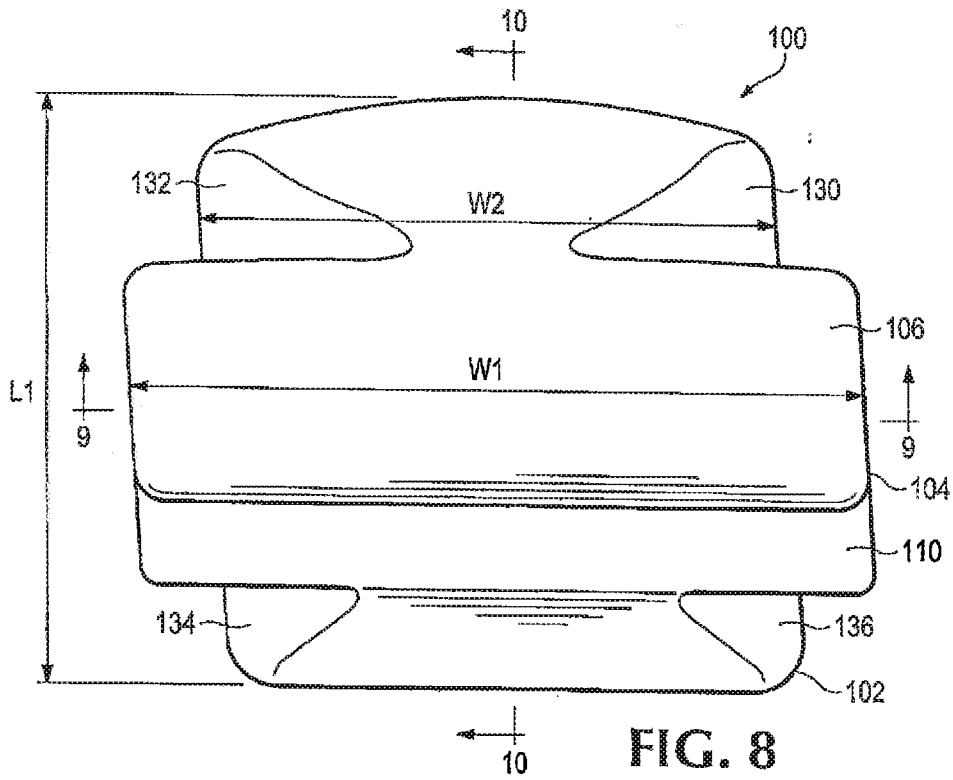
FIG. 7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W2
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FIG. 8

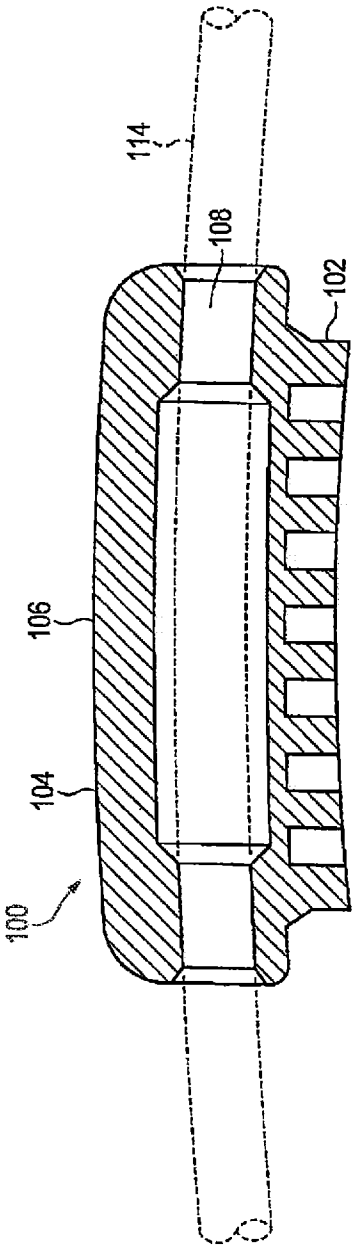

FIG. 9

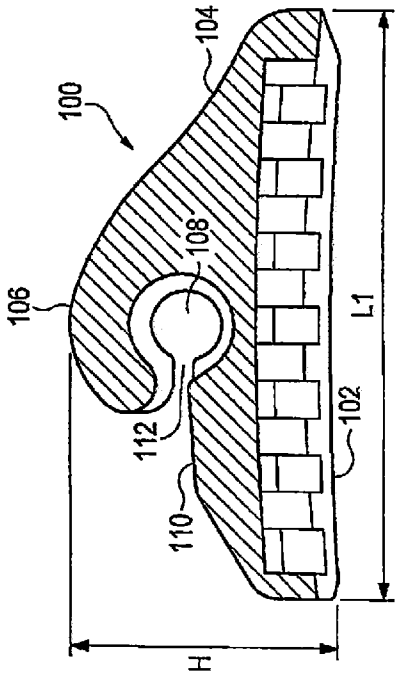

FIG. 10

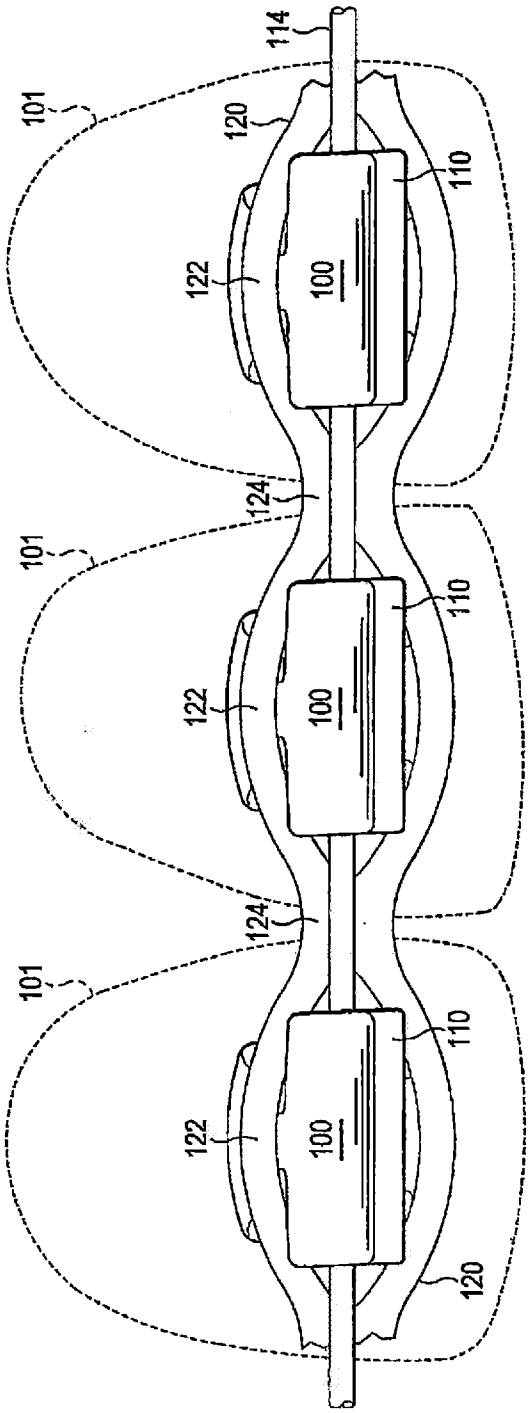
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FIG. 11

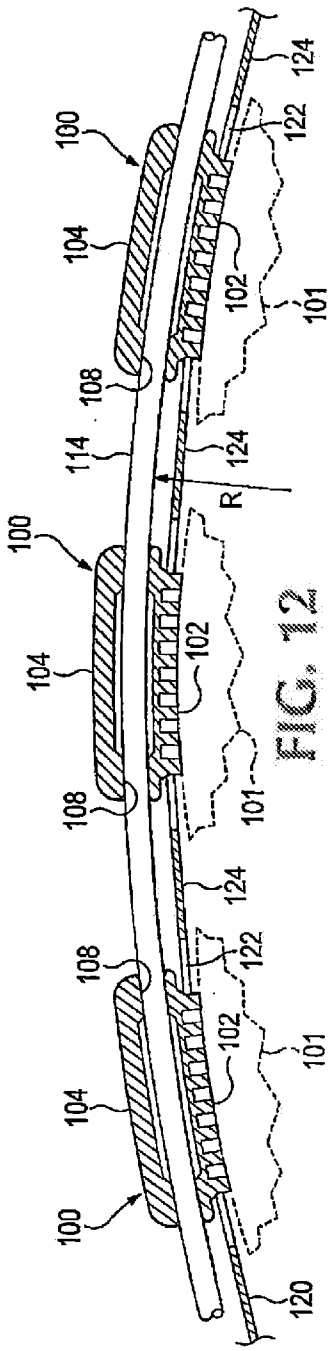
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FIG. 12

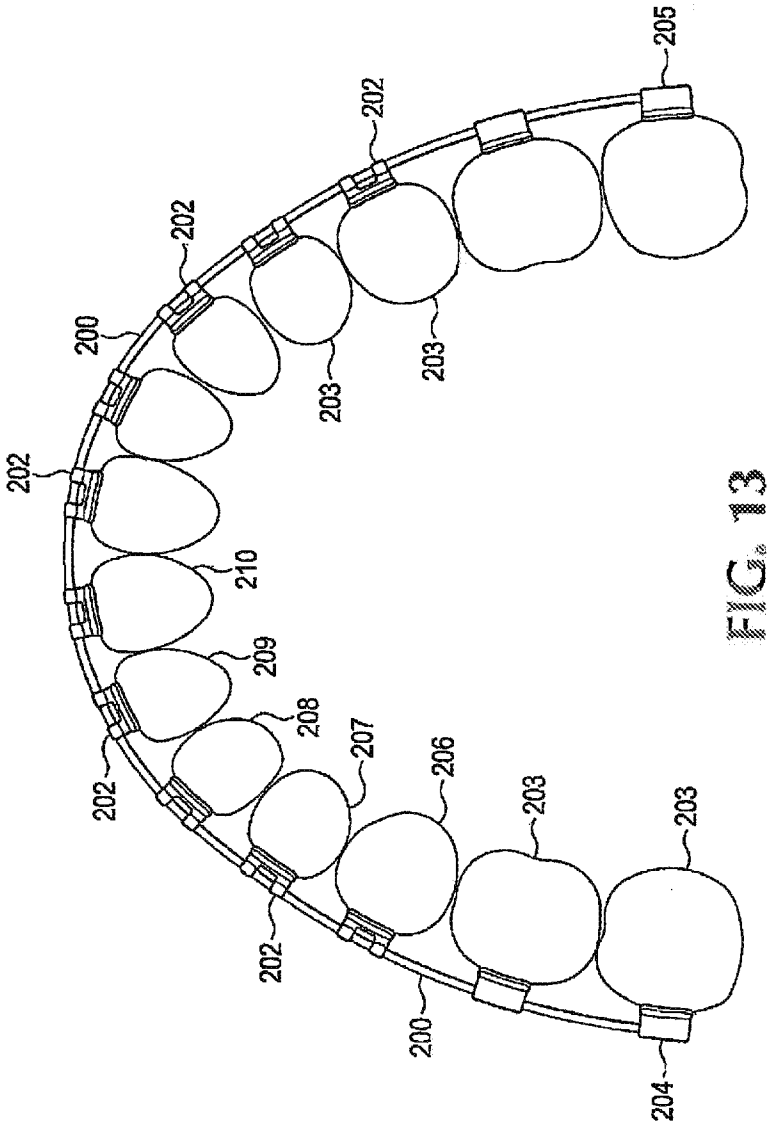
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FIG. 13

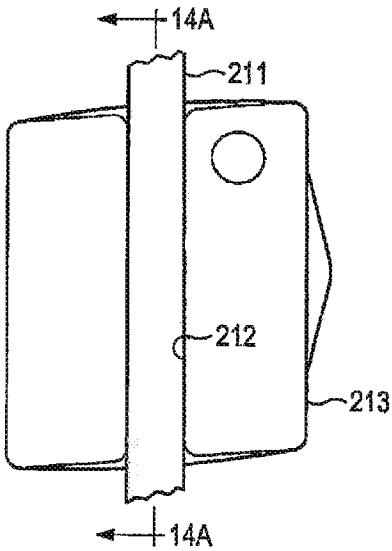

FIG. 14
PRIOR ART

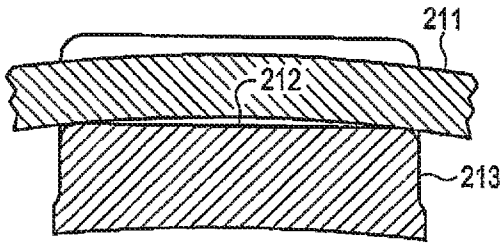

FIG. 14A
PRIOR ART

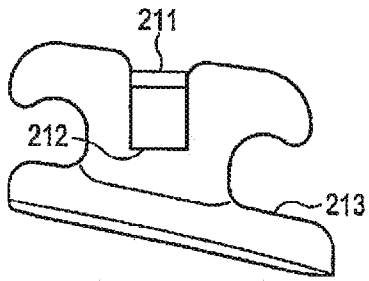

FIG. 14B
PRIOR ART

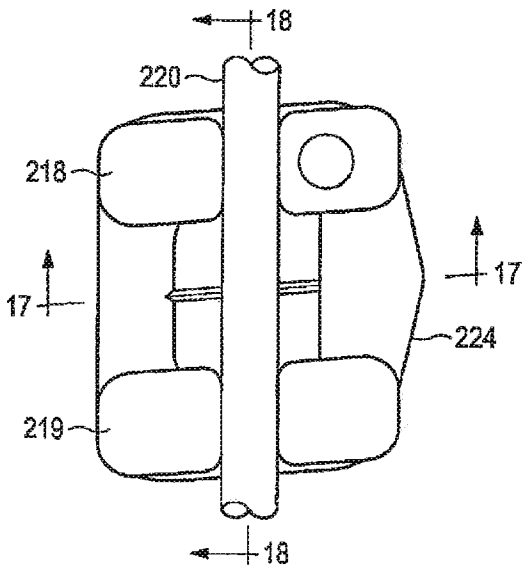

FIG. 15A

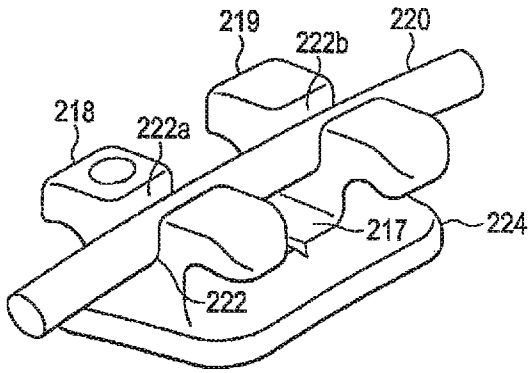

FIG. 15B

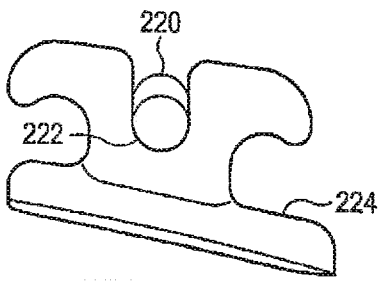

FIG. 16

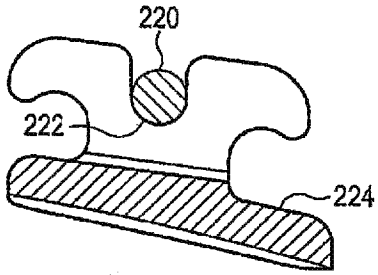

FIG. 17

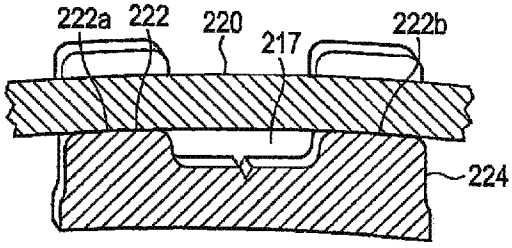

FIG. 18

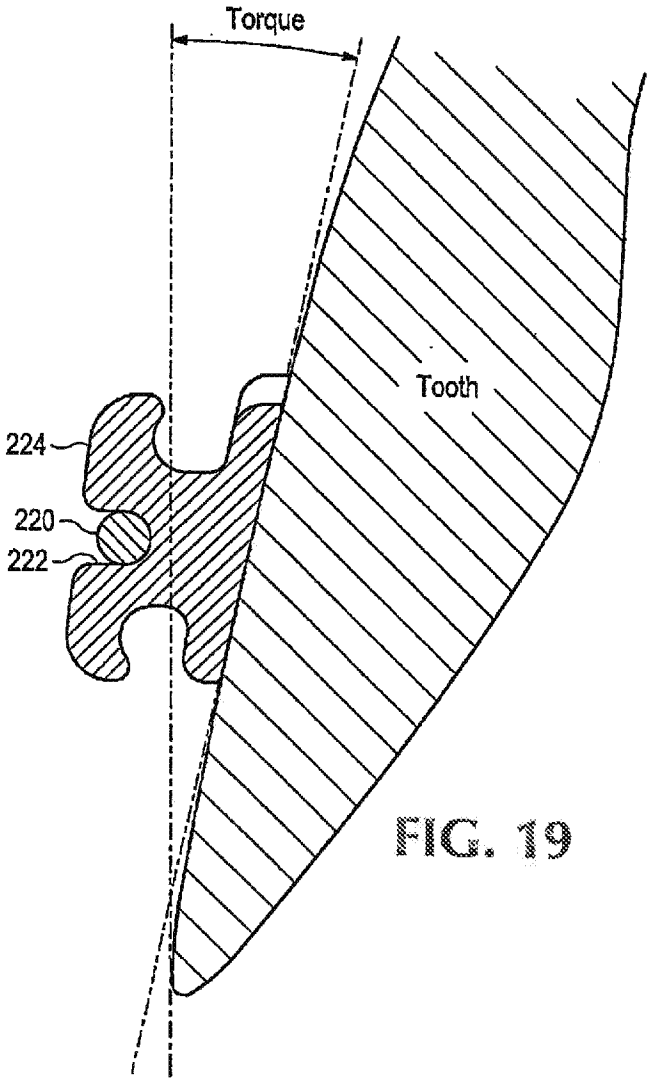

FIG. 19

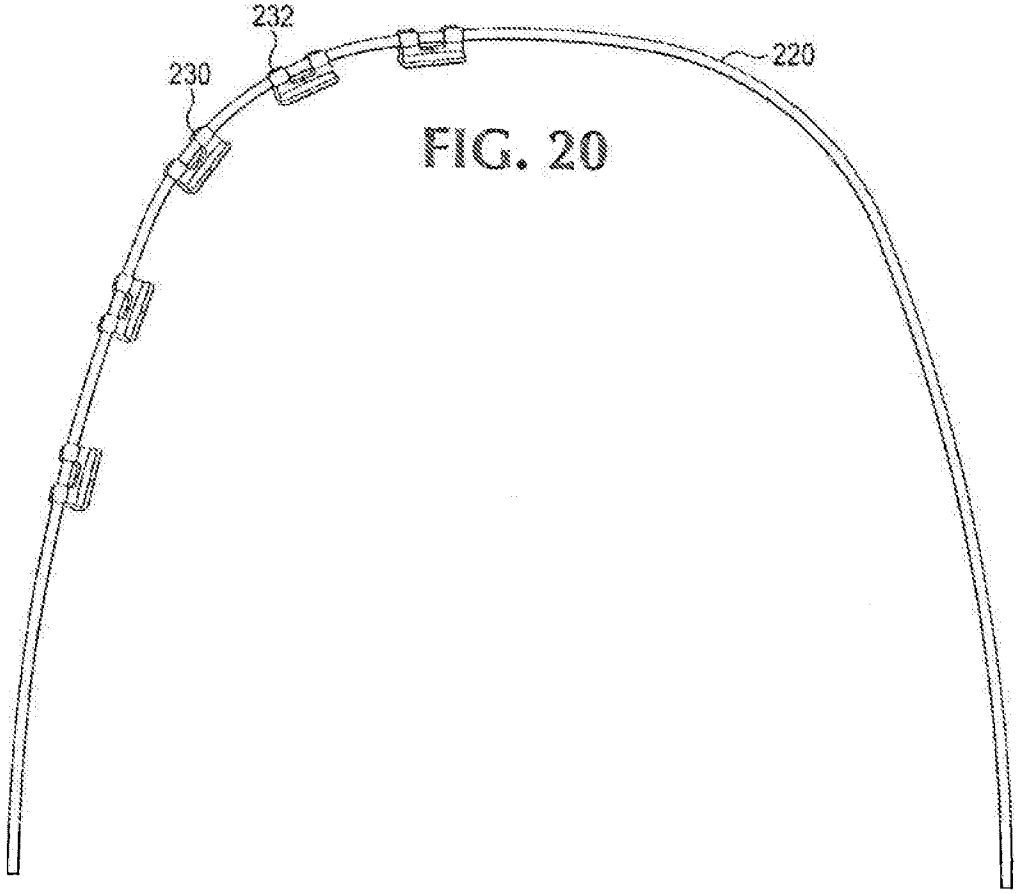

FIG. 20

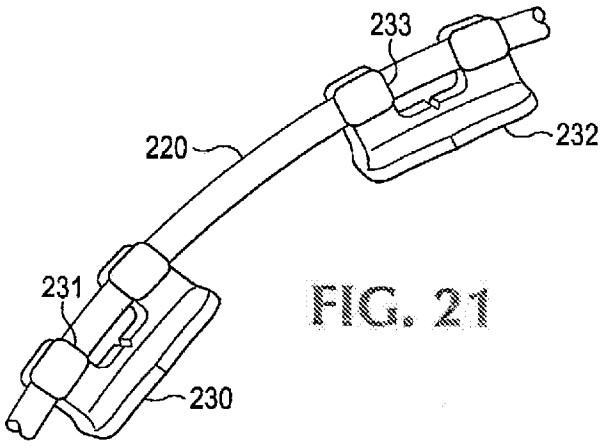

FIG. 21

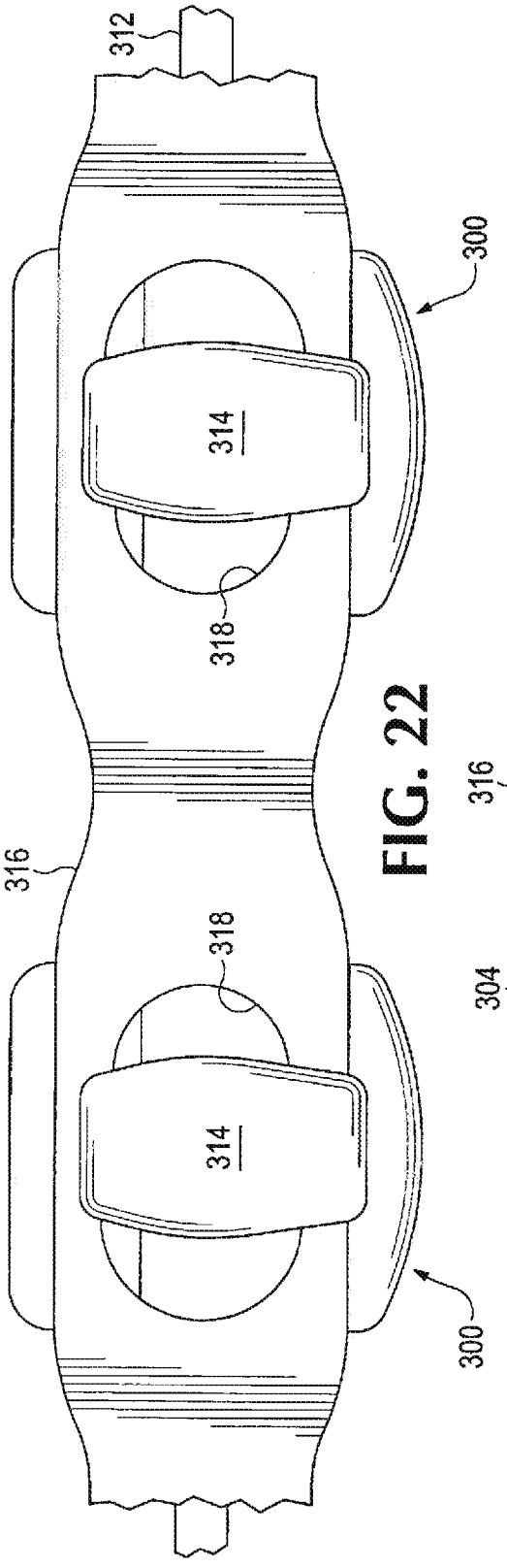

FIG. 22

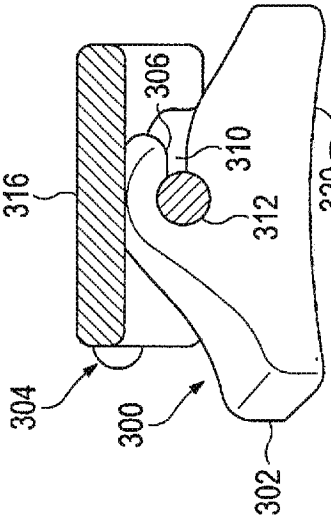

FIG. 23

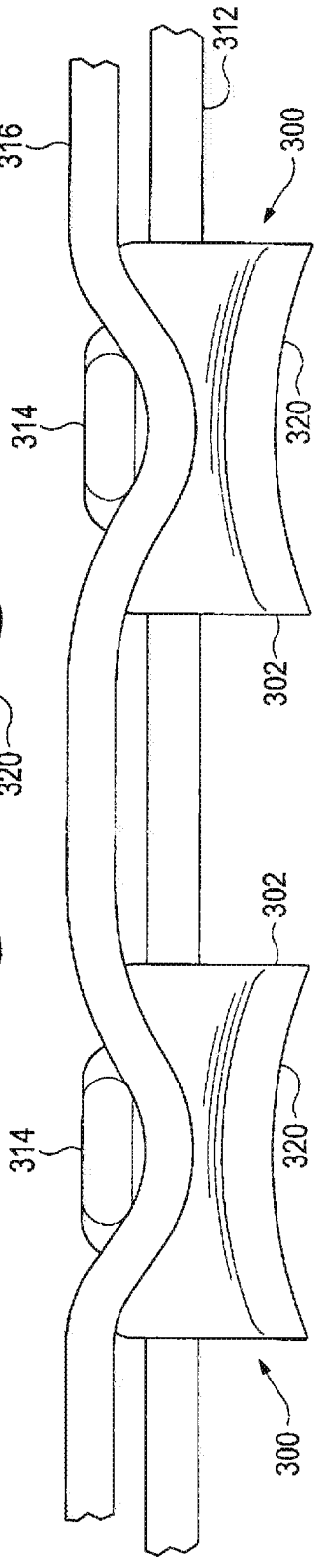

FIG. 24

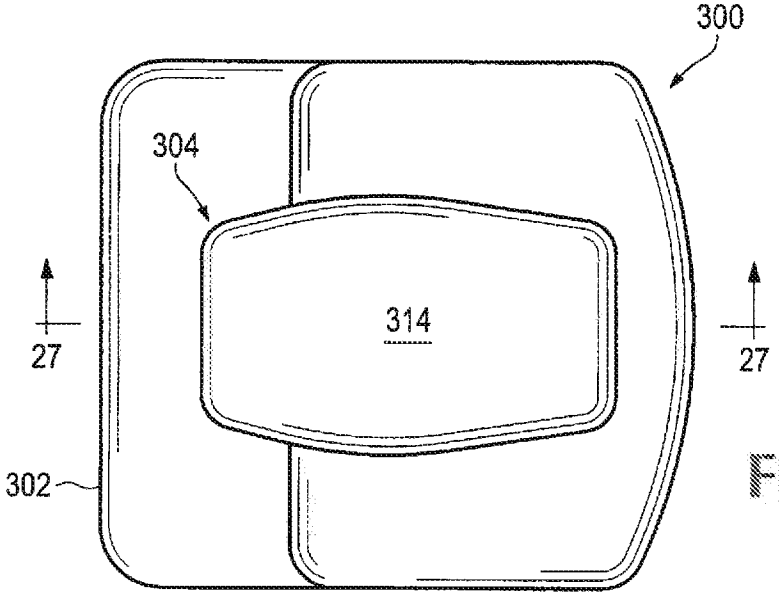

FIG. 25

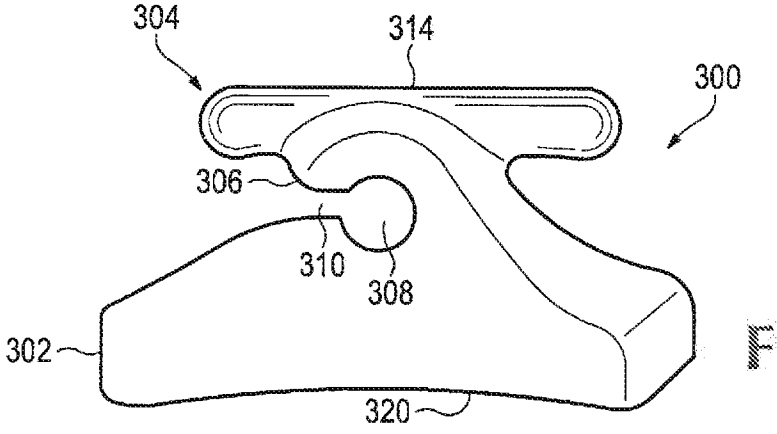

FIG. 26

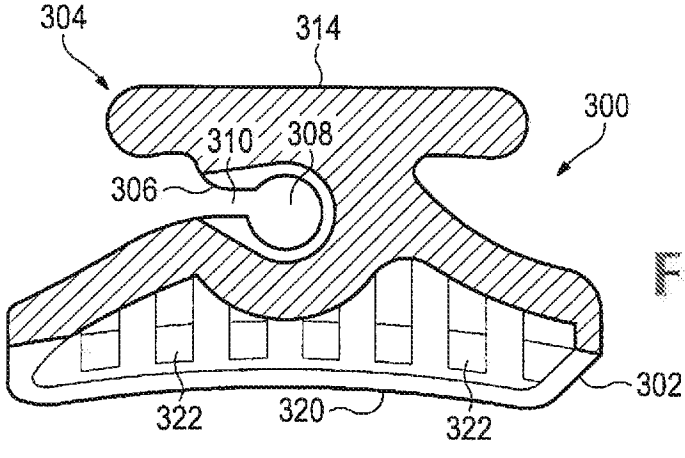

FIG. 27

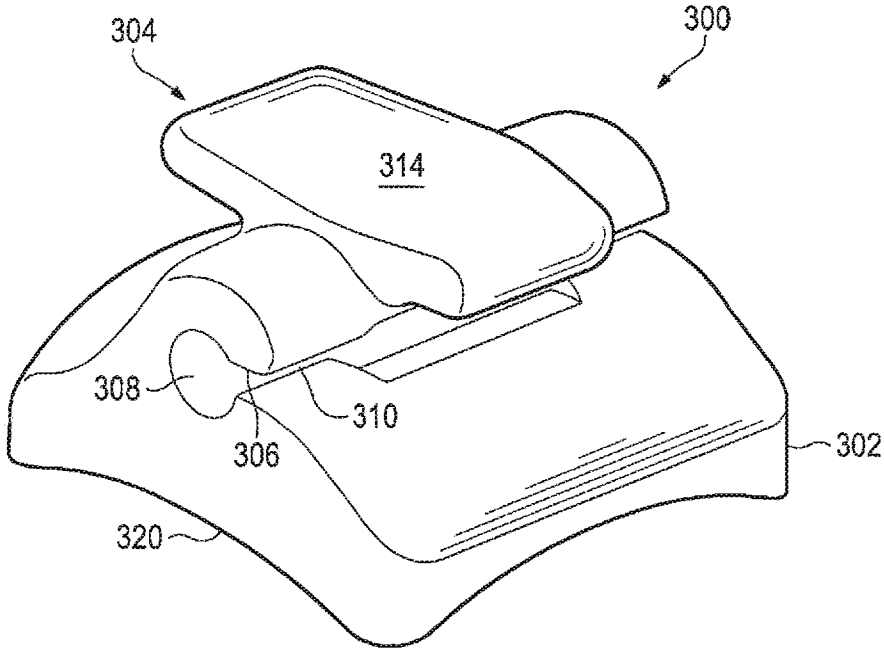

FIG. 28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US16/44802

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **A61C 3/00**(2006.01)

USPC: 433/8
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 433/8

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8,807,995 B2 (Kabbani et al.) 19 August 2014, see entire document.	1-9
A	US 5,474,448 (Andreiko et al.) 12 December 1995, see entire document.	1-9
A	US 3,052,028 (Wallshein Melvin) 04 September 1962, see entire document.	1-9
A	US 2009/0130621 A1 (Chikami) 21 May 2009, see entire document.	1-9
A	US 4,416,627 (Beazley) 22 November 1983, see entire document.	1-9

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 September 2016 (20.09.2016)	26 SEP 2016
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-8300	Authorized officer Tom Barrett Telephone No. 571-272-4300