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(54) Title: CRUCIATE-RETAINING KNEE PROSTHESIS

(57) Abstract: Certain versions generally provide an improved tibial base member (for example, but not limited to, 10) comprising keel portions (for example, but not limited to, 14a, 14b, 14c) that allow one or both cruciate ligaments to be preserved. Other versions provide improved lateral and/or medial inserts (for example, but not limited to, 110, 210) having a mesial lip (for example, but not limited to, 118, 128) that helps relieve and/or prevent impingement between the femoral component (for example, but not limited to, 400) and the tibial eminence. Other versions provide improved femoral components (for example, but not limited to, 400) having various chamfers (for example, but not limited to, 404, 410, 470) to provide additional clearance with respect to the tibial eminence and posterior cruciate ligament without decreasing bone coverage.



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CRUCIATE-RETAINING KNEE PROSTHESIS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Serial No. 61/372,556 filed on August 11, 2010 and titled “Cruciate-Retaining Knee Prosthesis,” U.S. Provisional Application Serial No. 61/382,287 filed on September 13, 2010 and titled “Cruciate-Retaining Prosthesis,” and U.S. Provisional Application Serial No. 61/299,835 filed on January 29, 2010 and titled “Bi-Cruciate Retaining Tibial Implant,” the contents of all three of which are hereby incorporated by reference.

RELATED FIELDS

[0002] Prostheses for use in knee arthroplasty, such as tibial and/or femoral implants, which may in some instances facilitate the retention of one or both cruciate ligaments.

BACKGROUND

[0003] In total knee arthroplasty, the convention is to resect the entire proximal tibia to create a plateau surface on which a tibial base prosthesis can be implanted. Such conventional resection techniques typically sacrifice one or both of the anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) since the resections removed the bony attachment site for those ligaments (the “tibial eminence”). Often, PCL and ACL functions are replaced by the prosthesis, which may utilize a stabilizing post on the tibial insert and a corresponding receptacle on the femoral component or increased sagittal conformity. While these prostheses generally restore anterior-posterior stability, they may not feel as “natural” as a normal knee and are less tissue-conserving.

[0004] If any one or both of the cruciate ligaments are salvageable, it is sometimes desirable (especially for young and active patients) to conserve either or both the ACL and PCL, in order to preserve natural biomechanics, range of motion, and feeling.

[0005] In current PCL-sparing knee implants, a posterior portion of the tibial insert and/or tibial base member may have a slight cut-out to provide space for the PCL and its attachment site on a remaining portion of the tibial eminence. A surgeon must remain careful

not to resect portions of bone adjacent the PCL attachment areas. The ACL is generally sacrificed when using these so-called posterior cruciate-retaining prostheses.

[0006] Alternatively, a surgeon may attempt to preserve both the ACL and PCL, which is sometimes accomplished by installing two unicondylar implants. The tibial eminence and cruciate ligaments attached thereto are left intact. The medial and lateral tibial plateau areas are resected and replaced with separate unicondylar tibial trays and corresponding inserts. One disadvantage of implanting two separate unicondylar implants includes the difficulty in properly aligning the two implants in relation to each other. If the two implants are not aligned properly, wear may be accelerated, mechanical axis alignment may be compromised, and femoral motion may feel unnatural to the patient. Surgical implantation time may also be increased due to the added complexity of installing two implants instead of one.

[0007] In lieu of two separate unicondylar implants, surgeons have the alternative option of preserving both the ACL and PCL by implanting a single bi-cruciate retaining implant, which comprises a single tibial bearing member (which may be an insert) and/or tibial base member. Prior art bi-cruciate retaining implants are essentially formed of an insert and a base member, each having two unicondylar portions joined by a thin anterior bridge which connects the two. The thin anterior bridges may fail to support the high torsional loading experienced by active patients, and past implants have been known to eventually bend or shear in half over time, requiring premature revision surgery. Even minor bending and shearing experienced by such prior art devices may reduce performance and eventually cause loosening or de-laminating of the implant from the bone on either or both of the medial and lateral sides.

[0008] Additional problems with prior bi-cruciate retaining designs include fracture of the bone adjacent to the area connecting the ACL to the tibia (i.e., the anterior tibial eminence). Such fractures are especially common when bone portions anterior to the ACL attachment point are removed in order to provide enough space for the medial and lateral side portions to be connected by said thin anterior bridge.

SUMMARY

[0009] When compared to prior art designs, at least some of the versions of the cruciate-retaining tibial prostheses described herein provide greater rigidity, torsional and bending stiffness, and resistance to torsional flexing, bending, and/or shearing between medial and lateral tibial portions.

[0010] These and other versions provide additionally or alternatively a tibial prosthesis for at least partially replacing a proximal portion of a tibia, the tibial prosthesis comprising an inferior surface for contact with a resected surface on the proximal portion of the tibia, and a keel for penetration into a cavity formed in the proximal tibia, wherein the keel extends at an inferior-posterior angle away from the inferior surface, wherein the tibial prosthesis defines a central notch extending between the medial and lateral baseplate portions posterior to the connecting baseplate portion, wherein the central notch has a sufficient width and length to receive a portion of a tibial eminence including an anterior cruciate ligament attachment site and a posterior cruciate ligament attachment site, and wherein the central notch comprises a medial edge and a lateral edge, wherein an angle defined by the medial edge and a base of the anterior keel portion is acute, and wherein an angle defined by the lateral edge and the base of the anterior keel portion is obtuse.

[0011] Also disclosed are tibial prostheses wherein a posterior face of the anterior keel portion is offset from a posterior face of the connecting baseplate portion.

[0012] Also disclosed are tibial prostheses wherein a superior surface of the tibial prosthesis includes at least one lock member for securing a tibial insert.

[0013] Also disclosed are tibial prostheses wherein a superior surface of the tibial prosthesis includes at least two lock members for securing a medial tibial insert and a lateral tibial insert.

[0014] Also disclosed are tibial prostheses for at least partially replacing a proximal portion of a tibia, the tibial prosthesis comprising a medial baseplate portion, the medial baseplate portion having a medial inferior surface for contact with a medial resected surface on the proximal portion of the tibia, a lateral baseplate portion, the lateral baseplate portion

having an lateral inferior surface for contact with a lateral resected surface on the proximal portion of the tibia, a connecting baseplate portion extending between the medial and lateral baseplate portions, wherein the tibial prosthesis is asymmetric about a midline extending in an anterior-posterior direction between the medial and lateral baseplate portions and the medial baseplate portion extends further anteriorly than the lateral baseplate portion.

[0015] Also disclosed are tibial prostheses wherein an area defined by the medial baseplate portion in a transverse plane is greater than an area defined by the lateral baseplate portion in the transverse plane.

[0016] Also disclosed are tibial prostheses wherein the tibial prosthesis is a bicruciate-retaining tibial prosthesis.

[0017] Also disclosed are tibial prostheses wherein the tibial prosthesis defines a notch extending in a generally anterior-posterior direction between the medial and lateral baseplate portions and is positioned posterior to the connecting baseplate portion; and wherein the notch is of sufficient length to receive at least a portion of an eminence of the tibia including an anterior cruciate ligament attachment site and a posterior cruciate ligament attachment site.

[0018] Also disclosed are tibial prostheses wherein the notch comprises a medial edge, a lateral edge, and an anterior edge, wherein an angle defined by the medial and anterior edges is acute, and wherein an angle defined by the lateral and anterior edges is obtuse.

[0019] Also disclosed is a tibial prosthesis for at least partially replacing a proximal portion of a tibia, the tibial prosthesis comprising a medial baseplate portion comprising a medial inferior surface for contact with a medial resected surface on the proximal portion of the tibia, a lateral baseplate portion comprising a lateral inferior surface for contact with a lateral resected surface on the proximal portion of the tibia, a connection baseplate portion extending between the medial and lateral baseplate portions, the connection baseplate portion comprises a connection inferior surface, a keel for penetration into a cavity formed in the

proximal tibia, wherein the keel extends at an inferior-posterior angle away from at least one of the medial inferior surface, the lateral inferior surface, and the connection inferior surface.

[0020] Also disclosed are tibial prostheses wherein the keel includes an anterior keel portion, a medial keel portion extending from the medial inferior surface, and a lateral keel portion extending from the lateral inferior surface, wherein the anterior keel portion extends at the inferior-posterior angle away from the connection inferior surface.

[0021] Also disclosed are tibial prostheses wherein at least a part of the anterior keel portion extends in a generally medial-lateral direction on the connection baseplate portion, wherein at least a part of the medial keel portion extends in a generally anterior-posterior direction on the medial baseplate portion, and wherein at least a part of the lateral keel portion extends in a generally anterior-posterior direction on the lateral baseplate portion.

[0022] Also disclosed are tibial prostheses wherein the anterior keel portion joins the medial and lateral keel portions at areas of increased thickness.

[0023] Also disclosed are tibial prostheses wherein the anterior keel portion joins the medial and lateral keel portions at areas of increased width.

[0024] Also disclosed are tibial prostheses wherein the connection baseplate portion increases in thickness in an anterior posterior direction.

[0025] Also disclosed are tibial prostheses wherein the medial and lateral keel portions decrease in height as the medial and lateral keel portions extend in an anterior to posterior direction.

[0026] Also disclosed are tibial prostheses wherein the anterior keel portion extends across the connection baseplate portion in an anterior-medial to a posterior-lateral direction.

[0027] Also disclosed are tibial prostheses wherein a posterior face of the anterior keel portion is offset from a posterior face of the connection baseplate portion.

[0028] Also disclosed are tibial prostheses wherein the tibial prosthesis defines a central notch extending between the medial and lateral baseplate portions posterior to the connection baseplate portion, wherein the central notch has a sufficient width and length to receive a portion of a tibial eminence including an anterior cruciate ligament attachment site and a posterior cruciate ligament attachment site.

[0029] Also disclosed are tibial prostheses wherein the central notch comprises a medial edge and a lateral edge, wherein an angle defined by the medial edge and a base of the anterior keel portion is acute; and wherein an angle defined by the lateral edge and the base of the anterior keel portion is obtuse.

[0030] Also disclosed are tibial prostheses wherein the tibial prosthesis is asymmetric about a midline extending in an anterior-posterior direction between the medial and lateral baseplate portions and the medial baseplate portion extends further anteriorly than the lateral baseplate portion.

[0031] These or other versions provide additionally or alternatively a tibial prosthesis for at least partially replacing a proximal portion of a tibia, comprising a tibial articulation surface for articulation with a femoral condylar articulation surface, wherein the tibial articulation surface defines a mesial lip extending in an anterior to posterior direction along a mesial edge of the articulation surface; wherein the mesial lip is raised by a height relative to a corresponding central portion of the articulation surface; and wherein the height with which the mesial lip is raised relative to the corresponding central portion decreases in an anterior to posterior direction.

[0032] Also disclosed are tibial prostheses wherein the tibial articulation surface is a medial tibial articulation surface and wherein at least a portion of the medial tibial articulation surface is concave in a sagittal plane.

[0033] Also disclosed are tibial prostheses wherein an anterior-mesial portion of the medial tibial articulation surface is curved to at least partially conform to the femoral condylar articular surface.

[0034] Also disclosed are tibial prostheses wherein a posterior-outer portion of the medial tibial articulation surface is substantially flat and does not substantially conform to the femoral condylar articular surface.

[0035] Also disclosed are tibial prostheses wherein the tibial articulation surface is a lateral tibial articulation surface; and wherein the lateral tibial articulation surface is convex in a sagittal plane.

[0036] Also disclosed are tibial prostheses wherein an anterior-mesial portion of the lateral tibial articulation surface is curved to at least partially conform to the femoral condylar articular surface.

[0037] Also disclosed are tibial prostheses wherein a posterior-outer portion of the lateral tibial articulation surface is substantially flat and does not substantially conform to the femoral condylar articular surface.

[0038] Also disclosed are tibial prostheses wherein the tibial prosthesis is a tibial insert; and wherein the tibial insert further comprises an inferior surface that includes at least one lock member for securing to a tibial baseplate.

[0039] Also disclosed is a tibial prosthesis for at least partially replacing a proximal portion of a tibia, comprising a tibial articulation surface for articulation with a femoral condylar articulation surface, wherein the tibial articulation surface defines a mesial lip extending in an anterior to posterior direction along a mesial edge of the articulation surface, wherein the mesial lip is raised by a height relative to a corresponding central portion of the articulation surface, and wherein an anterior-mesial portion of the medial tibial articulation surface is curved to at least partially conform to the femoral condylar articular surface, and wherein a posterior-outer portion of the medial tibial articulation surface is substantially flat and does not substantially conform to the femoral condylar articular surface.

[0040] Also disclosed is a tibial prosthesis for at least partially replacing a proximal portion of a tibia, comprising: a tibial articulation surface for articulation with a femoral condylar articulation surface, wherein an anterior-mesial portion of the tibial articulation surface at least partially conforms to the femoral condylar articulation surface and a posterior-outer portion of the tibial articulation surface does not substantially conform to the femoral condylar articulation surface.

[0041] Also disclosed are tibial prostheses wherein the anterior-mesial portion is curved to at least partially conform to the femoral condylar articulation surface.

[0042] Also disclosed are tibial prostheses wherein the posterior-outer portion is substantially flat such that the posterior-outer portion does not substantially conform to the femoral condylar articulation surface.

[0043] Also disclosed are tibial prostheses wherein the tibial articulation surface is a medial tibial articulation surface; and wherein the medial tibial articulation surface is concave in a sagittal plane.

[0044] Also disclosed are tibial prostheses wherein the tibial articulation surface is a lateral tibial articulation surface; and wherein the lateral tibial articulation surface is convex in a sagittal plane.

[0045] Also disclosed are tibial prostheses wherein the at least one tibial articulation surface generally slopes in an anterior-posterior direction.

[0046] Also disclosed are tibial prostheses wherein the at least one tibial articulation surface comprises a medial articulation surface and a lateral articulation surface, and wherein a slope of the medial articulation surface in the anterior-posterior direction is different from a slope of the lateral articulation surface in the anterior-posterior direction.

[0047] Also disclosed are tibial prostheses wherein the medial articulation surface is associated with a medial insert and the lateral articulation surface is associated with a lateral insert, wherein a thickness of the medial insert at an anterior portion of the medial

insert is different than a thickness of the lateral insert at a posterior portion of the lateral insert.

[0048] Also disclosed are tibial prostheses wherein the medial insert and the lateral insert are part of a kit of inserts having varying slopes in the anterior-posterior direction.

[0049] Also disclosed are tibial prostheses wherein the at least one tibial articulation surface is associated with a tibial base plate.

[0050] Also disclosed are tibial prostheses wherein the thickness of the medial insert at the anterior portion of the medial insert is greater than the thickness of the medial insert at a posterior portion of the medial insert.

[0051] Also disclosed are tibial prostheses wherein a thickness of the medial insert at a posterior portion of the medial insert is different than a thickness of the lateral insert at a posterior portion of the lateral insert.

[0052] Also disclosed are tibial prostheses wherein the thickness of the lateral insert at the anterior portion of the lateral insert is greater than the thickness of the lateral insert at a posterior portion of the lateral insert.

[0053] Also disclosed are tibial prostheses wherein the at least one tibial articulation surface generally slopes in a medial-lateral direction.

[0054] Also disclosed are tibial prostheses wherein the at least one tibial articulation surface comprises a medial articulation surface and a lateral articulation surface, and wherein a slope of the medial articulation surface in the medial-lateral direction is different from a slope of the lateral articulation surface in the medial-lateral direction.

[0055] Also disclosed are tibial prostheses wherein the medial articulation surface is associated with a medial insert and the lateral articulation surface is associated with a lateral insert, wherein a thickness of the medial insert at an anterior portion of the medial insert is greater than a thickness of the lateral insert at an anterior portion of the lateral insert,

and wherein the thickness of the medial insert at a posterior portion of the medial insert is different than the thickness of the lateral insert at a posterior portion of the lateral insert.

[0056] Also disclosed are tibial prostheses wherein the anterior keel portion is positioned anteriorly on the connection inferior surface to engage anterior cortical bone when implanted in a patient.

[0057] Also disclosed are tibial prostheses further comprising at least one tibial articulation surface for articulation with a femoral condylar articulation surface of a femoral component, wherein the femoral component comprises a medial condyle and a lateral condyle and wherein at least one of the medial condyle and the lateral condyle comprises a posterolateral chamfer.

[0058] According to other versions, a tibial prosthesis for at least partially replacing a proximal portion of a tibia is also provided, the tibial prosthesis comprising: a tibial articulation surface for articulation with a femoral condylar articulation surface, wherein the tibial articulation surface defines a mesial lip extending in an anterior to posterior direction along a mesial edge of the articulation surface, wherein the mesial lip is raised by a height relative to a corresponding central portion of the articulation surface, wherein the height with which the mesial lip is raised relative to the corresponding central portion decreases in an anterior to posterior direction, an anterior-mesial portion of the tibial articulation surface at least partially conforms to the femoral condylar articulation surface and a posterior-outer portion of the tibial articulation surface does not substantially conform to the femoral condylar articulation surface.

[0059] Also disclosed are tibial prostheses wherein the anterior-mesial portion is curved to at least partially conform to the femoral condylar articulation surface.

[0060] Also disclosed are tibial prostheses wherein the posterior-outer portion is substantially flat such that the posterior-outer portion does not substantially conform to the femoral condylar articulation surface.

[0061] Also disclosed are femoral components having various chamfers to provide additional clearance with respect to the tibial eminence and PCL without decreasing bone coverage. In some versions, the medial and/or lateral condyles of the femoral component comprise a posterolateral chamfer. In some versions, an anterior flange of the femoral component may comprise an anterolateral chamfer on the lateral and/or medial sides.

[0062] Further areas of applicability will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating certain versions of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0063] The accompanying drawings, which are incorporated in and form a part of the specification, illustrate certain versions of the invention and together with the written description serve to explain the principles, characteristics, and features of the versions. It should be noted that while most or all of the drawings contained herein generally illustrate implants configured for use with a patient's left knee, mirrored implants for use with a patient's right knee and symmetrically configured implants for use with both left and right knees are also envisaged. In the drawings:

[0064] FIGS. 1-3 are bottom isometric views of a tibial base member according to a first version that employs one or more bone ingrowth or cement mantle structures and a plurality of keel portions.

[0065] FIGS. 4-7 illustrate a tibial base member according to a second version that includes an underside recess for receiving a cement mantle.

[0066] FIGS. 8-11 illustrate a tibial base member according to a third version.

[0067] FIGS. 12-15 illustrate a tibial base member according to a fourth version.

[0068] FIGS. 16-19 illustrate a tibial base member according to a fifth version.

- [0069] FIGS. 20-23 illustrate a tibial base member according to a sixth version.
- [0070] FIGS. 24-29 illustrate a tibial base member according to a seventh version, the base member having an anterior wall portion configured to contact an external portion of cortical bone adjacent to the anterior cortex of the tibia.
- [0071] FIGS. 30-35 and 47 illustrate a tibial base member according to an eighth version, the tibial base member having three keel portions.
- [0072] FIGS. 36 and 37 illustrate a tibial base member according to a ninth version, which includes steps, textures, or jagged features provided on the keel portions.
- [0073] FIGS 38-46 illustrate the tibial base member of FIGS. 30-35, and 47, shown assembled with medial and lateral articulating tibial inserts.
- [0074] FIG. 48 illustrates a step of assembling the bicruciate-retaining tibial prosthesis shown in FIGS. 38-46.
- [0075] FIGS. 49-52 are frontal coronal cross-sectional views schematically illustrating mating geometries between a tibial base member and a tibial eminence according to various versions.
- [0076] FIG. 53 is a frontal coronal view of a bicruciate-retaining tibial prosthesis shown implanted on a proximal tibia.
- [0077] FIGS. 54 and 55 illustrate posterior views of a lateral tibial insert.
- [0078] FIG. 56 illustrates a lateral sagittal view of the lateral insert of FIGS. 54 and 55.
- [0079] FIG. 57 shows a coronal cross-sectional view of the lateral insert of FIGS. 54-56 when viewed from the anterior side.

[0080] FIG. 58 shows a sagittal cross-sectional view of the lateral insert when viewed from the lateral side.

[0081] FIGS. 59 and 61 are posterior views of a medial tibial insert.

[0082] FIG. 60 is a medial sagittal view of the medial insert of FIGS. 59 and 61.

[0083] FIG. 62 shows a coronal cross-sectional view of the medial insert when viewed from the anterior side.

[0084] FIG. 63 shows a sagittal transverse cross-sectional view of the medial insert when viewed from the medial side.

[0085] FIGS. 64-66 graphically illustrate the kinematics of one version of a femoral implant when used in conjunction with the bicruciate-retaining tibial prosthesis shown in FIGS. 38-46.

[0086] FIGS. 67a-67q illustrate the kinematics of FIGS. 64-66 for various angles of flexion.

[0087] FIG. 68 is an anterior view of one version of a bicruciate-retaining knee prosthesis (ACL and PCL sparing).

[0088] FIG. 69 is an anterior view of one version of a cruciate-retaining knee prosthesis (PCL sparing).

[0089] FIGS. 70 and 71 are anteromedial views of the bicruciate-retaining and cruciate-retaining knee prostheses of FIGS. 68 and 69, respectively.

[0090] FIGS. 72 and 73 are posteromedial views of the bicruciate-retaining and cruciate-retaining knee prostheses of FIGS. 68 and 69, respectively.

[0091] FIGS. 74 and 75 are posterior views of the bicruciate-retaining and cruciate-retaining knee prostheses of FIGS. 68 and 69, respectively, showing optional clearance chamfers provided to the femoral component.

[0092] FIG. 76 is a superior view of a medial femoral condyle illustrating in partial cross-section an optional posterolateral chamfer according to some versions.

[0093] FIGS. 77 and 78 are lateral sagittal views of the bicruciate-retaining and cruciate-retaining knee prostheses of FIGS. 68 and 69, respectively.

[0094] FIGS. 79 and 80 are posterolateral views of the bicruciate-retaining and cruciate-retaining knee prostheses of FIGS. 68 and 69, respectively.

[0095] FIG. 81 is a superior view of the femoral component shown in FIGS. 67a-80.

[0096] FIGS. 82-84 show various prospective views of the medial and lateral inserts of FIGS. 54-63.

[0097] FIG. 85 shows a bicompartamental knee implant according to another version that employs a medial insert according to some versions and that may be used in conjunction with a medial unicondylar tibial base member (not shown) and that alternatively may be configured as a lateral bicompartamental knee implant (not shown).

[0098] FIG. 86 shows a medial unicondylar knee implant according to another version, which employs a medial insert according to some versions and which may be used in conjunction with a medial unicondylar tibial base member (not shown).

[0099] FIG. 87 shows a lateral unicondylar knee implant according to another version, which employs a lateral insert according to some versions and which may be used in conjunction with a lateral unicondylar tibial base member (not shown).

[00100] FIG. 88 shows a monolithic bicruciate-retaining prosthesis according to one version, wherein the tibial base member comprises integrally-formed articulating surfaces.

[00101] FIG. 89 shows a monolithic bicruciate-retaining prosthesis according to one version, wherein the tibial base member is a fully or partially porous augment comprising integrally-formed articulating surfaces.

[00102] FIGS. 90a-90e show various sagittal cross-sectional views of a lateral insert when viewed from the medial side.

[00103] FIGS. 91a-91k show various coronal cross-sectional views of a lateral insert when viewed from the posterior side.

[00104] FIGS. 92a-92e show various sagittal cross-sectional views of a medial insert when viewed from the lateral side.

[00105] FIGS. 93a-93m show various coronal cross-sectional views of a medial insert when viewed from the posterior side.

[00106] FIG. 94 is a medial sagittal view of a femoral component according to one version.

[00107] FIGS. 95a-95k are various coronal cross sectional views taken along the lines A-A through K-K, respectively, of Figure 94.

[00108] FIG. 96 is a perspective view of a resected tibia prepared to receive the tibial base member of Figures 30-35 and 47.

[00109] FIGS. 97-98 are bottom isometric views of a tibial base member according to a tenth embodiment that includes one or more pegs.

[00110] FIG. 99 is a sagittal cross-sectional view of a lateral insert according to an embodiment.

[00111] FIG. 100 is a sagittal cross-sectional view of a medial insert according to an embodiment.

DETAILED DESCRIPTION

[00112] The following description is merely exemplary in nature of certain selected versions and is in no way intended to limit the invention, its application, or uses.

[00113] 1. Tibial Base Members

[00114] Figures 1-46 and 97-98 show various, non-limiting versions of tibial base members, some of the features of which are discussed below.

[00115] Figures 1-3 show the underside of a first version of a tibial base member. Generally, base member 10 includes a medial portion 12a, a lateral portion 12b, and a connecting portion 12c. In this particular version, the base member 10 has an asymmetric shape in some aspects. For instance, as shown in Figure 3, the medial portion 12a is larger than the lateral portion 12b and aspects of the medial portion 12a extend further anteriorly relative to lateral portion 12b. In other versions, the base member may reflect other asymmetries or may be symmetric.

[00116] The base member 10 of Figures 1-3 includes lips 15a and 15b defining a cutout portion 8 between medial portion 12a and lateral portion 12b, which may provide clearance for a preserved tibial eminence, or portions thereof. In the version shown in Figures 1-3, the central cutout portion 8 is approximately one-quarter to one-third of the tibial medial-lateral width and is thus configured to allow a majority of the tibial eminence to protrude through, although, in some versions, it may be desirable to resect at least anterior portions of the eminence. For instance, in some versions, an anterior portion of the tibial eminence may be resected flush with the medial and lateral tibial bone resections to provide space for the connecting portion 12c. The amount of tibial bone removed to provide room for a connecting portion 12c may, in some versions, be in the range of 1/5 to 1/8 of the total anterior-to-posterior dimension of the tibial eminence prior to bone preparation. In this

particular version, the connecting portion 12c is designed to preserve and protect bone around the ACL attachment point, as well as eliminate stress-risers.

[00117] As shown, the central cutout portion 8 is generally centered in a medial-lateral direction of the tibial base member 10, which facilitates maintaining the medial / lateral widths of the medial 12a and lateral 12b portions to be generally the same (and, in some versions, the medial / lateral widths of inserts used in conjunction with the base member 10). In other versions, it is not necessary for the medial 12a and lateral 12b portions to be the same in medial / lateral dimensions.

[00118] The base member 10 shown in Figures 1-3 includes a keel extending distally therefrom. In some versions, the keel may facilitate securing and retaining the base member to the patient's tibia. In some versions, the keel may add strength, torsional rigidity and stability to the base member. In the particular version shown, keel portions 14a and 16a extend from the medial portion 12a of base member, keel portions 14b and 16b extend from the lateral portion 12b, and keel portion 14c extends from the connecting portion 12c.

[00119] In some versions, the keel portions may extend at an angle between approximately 90 degrees and appropriately 45 degrees with respect to the underside of the base member 10, although more or less pronounced angles are also possible. In some versions, the keel portions may extend distally at the same general angle or may extend at a different angles with respect to one another. In some versions, the keel portions may be symmetric with respect to one another, or may be asymmetrically configured to suit bony anatomy or for other reasons. Other base member versions (discussed below) may have more or less keel portions than the base member 10 of Figures 1-3 and/or have keel portions of different configurations.

[00120] In the particular version of Figures 1-3, and as shown best in Figure 3, the anterior fin 14c angles in a medial-lateral direction such that medial portions of the anterior fin 14c are positioned further anteriorly than lateral portions. Anterior fin 14c also slopes in an anterior/superior to posterior/inferior direction, some of the reasons for which are disclosed in connection with later versions described herein. Anterior fin 16c also includes a

distal notch 13 (see Figure 2) to optimize flexibility, reduce material, improve stress distribution, and/or provide additional rotational stability.

[00121] The base member of Figures 1-3 includes keel portions 16a, 16b extending distally from the medial 12a and lateral 12b portions of base member 10, which, in some versions, may improve stability and/or rigidity of the base member 10 against forces that may be exerted thereon, such as forces having at least a component in an anterior and/or posterior direction. Enhanced stability in the anterior-posterior direction may be desirable in some, although not necessarily all, versions because certain femoral components (such as femoral component 400 shown in Figures 67A-D) may, in some instances and uses, impart such forces on the tibial components used therewith. In some versions, the insertion angle and positioning of the one or more keel portions 16a, 16b may be optimized in space for best fixation and best tibial fit, as well as anterior-posterior and rotational stability within the bone. Geometries for the keel portions 16a, 16b other than those shown explicitly in the Figures are also contemplated.

[00122] Tibial base member 10 according to some versions may have surface finishes that are optimized for use with cemented or uncemented techniques. In some versions, the base members have smooth or polished surfaces, or may have a grit blasted surface finish, or other rough surface finishes and textures such as ridges, grooves, steps, flutes, spines, barbs, and combinations thereof. Bottom or distal surfaces of medial portion 12a and lateral portion 12b may also comprise bone ingrowth structures such as a porous ingrowth surfaces with or without hydroxyapatite. In some versions, one or more pockets may be provided on the distal or inferior undersurface of base member to accommodate a cement mantle for cemented techniques. The one or more pockets may include means for increasing surface area of contact between the implant and a cement mantle such as a waffle pattern, grooves, ridges, indentations, undercuts, porous portions, protrusions, or bumps 15c, which may be a porous metal material or surface-treated portion of the structure.

[00123] The keel portions 14a, 14b, 14c, 16a, and 16b shown in Figures 1-3 include outer face surfaces 14a', 14b', 14c', 16a', 16b' respectively and inner face surfaces 14a'', 14b'', 14c'', 16a'', 16b'' respectively. In some versions, these face surfaces may contain porous ingrowth surfaces, roughened surface treatments, hydroxyapatite, or biologics for improved

fixation. In some versions, inner 14a'', 14b'', 14c'', 16a'', 16b'' and outer 14a', 14b', 14c', 16a', 16b' face surfaces may be parallel to each other, or may extend at acute angles relative to each other. While shown to be generally planar, face surfaces 14a'', 14b'', 14c'', 16a'', 16b'', 14a', 14b', 14c', 16a', 16b' of keel portions 14a, 14b, 14c, 16a, 16b, respectively, may be more complex B-spline or arcuate surfaces.

[00124] The base member 10 of Figures 1-3 includes blends or reinforcing members 18 located between the anterior keel portion 14c and the medial keel portion 14a and the lateral keel portion 14b, which may, in some versions, help to minimize the amount of bone removal necessary to accommodate the implant. For instance, on the medial side, strategic blending of the reinforcing member 18a helps keep the bottom edge of the keel portions away from cortical tibial bone. In this way, reinforcing members 18 form transitional areas between the anterior keel portion 14c and the medial keel portion 14a, and between the anterior keel portion 14c and the lateral keel portion 14b.

[00125] Figures 4-7 illustrate another version of a tibial base member – base member 20. Like the version of Figures 1-3, tibial base member 20 includes a medial portion 22a from which a medial fin 24a extends, a lateral portion 22b from which a lateral fin 24b extends, and a connection (or anterior) portion 22c from which an anterior fin 24c extends. Base member 20 may also comprise oblique medial fin 26a and oblique lateral fin 26b. Like the version of Figures 1-3, anterior fin 24c may include a distal notch 23 (shown in Figure 6). Superior surfaces of the base member 20 may comprise a medial locking portion 22a' and lateral locking portion 22b' in the form of recesses that are configured to receive medial and lateral inserts, respectively. Base member 20 also includes medial bone contacting surface 22a'' and lateral bone contacting surface 22b'' for a cement mantle or which may be a porous ingrowth surface.

[00126] Reinforcement members 28a, 28b are generally cylindrical in shape to facilitate bone preparation. For example, drills or small diameter reamers may be used to prepare the bone to accept the thicker regions that form the intersections between the keel portions 24a, 24c, and 24b. Cylindrical and smooth arcuate shapes for the reinforcing member 28a, 28b generally increase the strength at the corners of the cutout between medial 24a and lateral 24b portions, which, in some versions, may be high stress areas.

[00127] Figures 8-11 illustrate a third version, tibial base member 30, which has similar features as the base members 10 and 20 described above. Base member 30 includes a medial eminence lip 39a, a lateral eminence lip 39b, and an anterior eminence lip 39c, shown in Figures 8 and 11, which may be provided around the eminence cutout area to increase the overall strength of the base member 30 along its inside edges. This added strength may be particularly important in some versions to resist torsional or other forces exerted on the base member 30 when it is loaded posteriorly.

[00128] Figures 12-15 illustrate a fourth version, base member 40, which has similar features as the base members described above with some variations. As one example, as shown in Figure 14, notch 43 is more pronounced. The configuration of reinforcing members 48a, 48b is also different, as reinforcing members 48a, 48b extend posteriorly and also extend further in a distal direction than the keel portions, such as medial keel portion 44a, as shown in Figure 15.

[00129] Figures 16-19 illustrate a fifth version, base member 50, which also has similar features as the base members described above with some variations. As one example, as shown in Figure 17, the reinforcing members 58a and 58b are more pronounced. Moreover, as shown in Figure 17, oblique fins 56a and 56b are positioned differently with respect to medial and lateral portions 52a, 52b than in other versions.

[00130] Figures 20-23 illustrate a six version, base member 60, which has similar features as the base members described above with some variations. For instance, base member 60 includes a medial fin 64a, an anterior fin 64c, and a lateral fin 64b, but does not include oblique fins. As shown in Figure 22, anterior fin 64c includes grooves or other surface modifications. Base member 60 also includes an anterior eminence lip 69c, which extends proximally from a superior surface of the base member (as shown in Figures 22-23).

[00131] Figures 24-29 illustrate a seventh version, base member 70, which has similar features as the base members described above with some variations. Base member 70 includes a medial fin 74a, an anterior fin 74c, a lateral fin 74b, and oblique fins 76a, 76b, which extend at an angle from medial and lateral fins 74a, 74b, respectively. Anterior fin 74c

is positioned more anteriorly than in other versions, so as to engage anterior cortical bone on its inner surface 74c'' and sit on an external cortical bone surface adjacent to the anterior cortex. Base member 70 includes a medial eminence lip 79a, a lateral eminence lip 79b, and an anterior eminence lip 79c, shown in Figures 26 and 29, which may be provided along the medial and lateral sides of the eminence cutout area to increase the overall strength of the base member 70 along inside edges.

[00132] Figures 30-35 and 47 illustrate an eighth version, base member 80, having three keel portions – medial keel portion 84a, anterior keel portion 84c, and lateral keel portion 84b. Figure 96 illustrates a resected tibia 220 prepared to receive the base member 80. As shown in Figure 96, the tibial eminence 222 is in tact. As shown in Figure 35, anterior keel portion 84c extends further distally than medial and lateral keel portions 84a, 84b, which, in some versions, may enhance fixation. In addition, and as with some of the previous versions, anterior keel portion 84c is angled and extends in a superior-anterior to inferior-posterior direction (see Figure 35) in relation to the tibial resection plane and / or the underside of anterior portion 82c, which may, in some versions facilitate increasing the depth of the keel portion for strength and fixation without adversely interfering with the anterior cortex of the tibia, and, in some versions, without requiring the connecting portion 82c to be located so far posteriorly that it would interfere with the ACL attachment point on the eminence. In some versions, the slope of the anterior keel portion 84c helps prevent penetration of the anterior cortical bone of the proximal tibia, or splitting or cracking of the proximal tibia during insertion and impaction. In some versions, the slope of the anterior keel portion 84c increases the amount of bone preserved between the anterior fin 84c and the anterior tibial cortical bone. In this particular version, the angle α between the inside surface 84c'' of the anterior keel portion 82c and a bone contacting undersurface 82a'', 82b'' of the base member 80 is between approximately 50 and approximately 90 degrees, and more preferably between approximately 65 and approximately 75 degrees, for example approximately 70 degrees. In some versions, medial keel portion 84a and lateral keel portion 84b also extend at an inferior-posterior angle in some aspects, e.g. the top surfaces of those keel portions.

[00133] As best shown in Figure 35, in some versions, the posterior face of the anterior connecting portion 84c (which is adjacent to lip 89c) and the posterior side 84c'' of the

anterior keel portion 84c may not intersect at the level of the proximal tibial resection plane, so as, in some versions, help to avoid weakening the anterior portion of the tibial eminence during the anterior keel portion preparation or cause fracture. In other words, the intersection of these two surfaces is offset a predetermined distance (r – shown in Figure 35) to ensure that preparation of the bone for the anterior keel portion 82c does not compromise the preserved eminence.

[00134] As also shown in Figures 34 and 35, the angle θ between the lip 89c of the anterior connecting portion 82c and a bone contacting undersurface 82a'', 82b'' of the base member 80, in this particular version, is between approximately 60 and approximately 90 degrees, and more preferably between approximately 82 and approximately 88 degrees, for example approximately 85 degrees. This angle θ effectively creates an undercut to increase the amount of bone preserved at the anterior base portion of a prepared anterior eminence and thereby reduces bone stresses. In other words, the anterior cut of the eminence is tapered in some versions such that the base area of the eminence is greater than its proximal area, which improves the pull-off strength of the eminence 222. The undercut formed by angle θ may also allow bone cement, putty, or other biologic materials to readily flow to the anterior base regions of the eminence 222 thereby strengthening and filling in stress risers that may be located at the corner of the base of the anterior eminence where the anterior eminence bone cut meets the proximal tibial resection. Material placed or packed into and around the undercut angle θ between the bone and the tibial base member 80 may also hold down portions of the bone once implanted, prevent micromotion of the tibial base member 80, and avoid subsidence. As previously stated, the abovementioned angles and other geometric features may be altered to optimally suit a patient's individual anatomy.

[00135] As best shown in Figure 30, the angle γ between the anterior fin 84c and the inside of the medial portion 82a of this particular version is between approximately 75 and approximately 90 degrees, and more preferably between approximately 82 and approximately 88 degrees, for example approximately 85.5 degrees. As best shown in Figure 32, the angle β between the anterior connecting portion 82c and the inside of the lateral portion 82b, in this particular version, is between approximately 90 and approximately 120 degrees, and more preferably between approximately 92 and approximately 98 degrees, for example approximately 95 degrees. In other words, the anterior edge of the cutout portion between

medial 82a and lateral 82b portions is angled such that the medial side of connecting portion 82c lies more anteriorly than the lateral side of the connecting portion 82c. The additional anterior space on the anteromedial side of the cutout portion of the base member 80, in this particular version, provides better clearance for the ACL, which is generally located more anteriorly on medial sides of the ACL attachment region. The more posteriorly positioned lateral side of connecting portion 82c also avoids interference with the attachment of the posterolateral bundle of the ACL and provides more material on the lateral side for improved strength of the asymmetric design. For custom or patient-specific tibial base members, the abovementioned angles and other geometric features may be altered to optimally suit the patient's individual anatomy. Such changes may be made to satisfy the proper balance between bone conservation and strength.

[00136] In the version shown in Figures 30-35 and 47, keel portions 84a, 84b, 84c widen or thicken as they approach an intersection with the other keel portions. In some versions, such as in the version of Figures 30-35, these blends and transitions of the reinforcing members 88a, 88b on the sides of the anterior portion 82c of the base member 80 reduce the stress risers as the top and inside surface portions of the base member 80 transition to the anterior portion 82c from the medial 82a and lateral 82b sides, where material thickness is limited, so as to preserve minimum tibial insert thicknesses and allow the inserts to slide in and engage locking portions 82a', 82b' from the anterior side.

[00137] As shown best in Figure 35, superior-inferior height of the medial 84a and lateral 84b keel portions may generally decrease posteriorly to provide, in some versions, an optimized stress distribution and enough flexibility to prevent stress shielding. Moreover, keel portions 84a, 84b, 84c are generally angled in an anterior-posterior direction to provide support for medial 82a and lateral 82b portions of tibial base member 80. The angles and positioning of the keel portions 84a, 84b, 84c in both anterior-posterior and medial-lateral directions, in at least some versions, provide at least some degree of balance between: (a) supporting the central portion of each side portion 82a, 82b of the base member 80 during posterior loading of the base member 80; and (b) supporting edge portions of the medial and lateral portions 82a, 82b of the base member 80 during extreme edge loading at either the medial or lateral side of the base member 80. Moreover, the angles and positioning of the keel portions 84a, 84b, 84c can be designed to support such loads without necessitating a

relatively wide anterior keel portion 84c, which could otherwise interfere with or protrude through the anterior cortex of the tibia 220 if made too wide. While the illustrations show the lower edge of the angled side keel portions 84a, 84b to be a straight edge, the shape of the distal edges may be curved or stepped in other versions such that the depth change of the medial and lateral keel portions 84a, 84b is a non-linear function with respect to posterior distance. Curved or stepped lower edges of side keel portions 84a, 84b (such as shown in the version of Figure 7) may allow better optimization of stress distributions within the tibial base member 80.

[00138] In some versions, such as the one illustrated in Figures 30-35 and 47, medial and lateral keel portions 84a, 84b may have one or more reinforcing webs 85a, 85b connecting peripheral cement rails 87a, 87b to the keel portions 84a, 84b (Figures 34-35). The reinforcement webs 85a, 85b may be strategically located so as to pass under any high stress points, such as at the corners of locking portions 82a', 82b' (Figures 32-33), which may be, for example, cutout recesses or pockets located on the proximal side of medial 82a and lateral 84a portions and that are configured to receive medial and lateral tibial inserts 110, 120 (discussed below). Although not illustrated, webs 85a, 85b may also be provided in the top pocket portions of the locking portions 82a', 82b', so long as inferior sides of the tibial inserts 110, 120 are also provided with complementary recesses to afford clearance for the webs 85a, 85b.

[00139] As shown in Figure 34, rounded corners, radiuses, or filets 81a, 81b may be provided between eminence lip portions 89a, 89b, 89c of the tibial base member 80 to form the inside surfaces of the cutout portion configured to receive the tibial eminence. Said rounded corners, radiuses, or filets 81a, 81b may, in some versions, reduce the stress risers at those areas thereby overcoming the failures associated with the sharp corners typical of prior bi-cruciate retaining designs. The amount of rounding of the corners, in some versions, may avoid causing interference between the implant and the anterior cruciate ligament attachment point on the tibia 220.

[00140] Moreover, as with other versions, heightened walls or eminence lip portions 89a, 89b, 89c along the medial and lateral sides of the eminence cutout area (see, e.g. Figure 33) may be provided to increase the overall strength of the base member 80 along inside

edges. This added strength may facilitate, in at least some versions, resisting stresses and other forces on the base member 80 when loaded posteriorly. Moreover, eminence lip portions 89a, 89b, 89c, when combined with undersurfaces 82a'', 82b'', may facilitate the creation of a larger boundary for a cement mantle and allow the cement mantle to grow along the base of a prepared tibial eminence. This extra cement along the base corners and sides of the tibial eminence and between the eminence and base member 80 may generally improve the resistance to eminence fracture. Heightened walls or eminence lip portions 89a, 89b, 89c may further serve to isolate tibial inserts from both the cement mantle and the vertical walls of the prepared tibial eminence, and also serve as buttresses for stabilization of the tibial inserts in the medial-lateral direction.

[00141] The anterior connecting portion 82c may define a generally trapezoidal sagittal shape, both in sagittal cross section (see, e.g. Figure 35) and when viewed superiorly (see, e.g. Figure 33). In this version, anterior portion 82c is wider (medial-lateral dimension) towards the posterior. Such geometries may, in some versions, assist in limiting stress concentration in the anterior portion 82c and promote a more even distribution of stress by encouraging the stresses to flow more anteriorly to regions where there are fewer stress risers.

[00142] In this particular version, the anterior connecting portion 82c of the tibial base member 80 is sloped so as to be thicker (superior-inferior dimension) towards the posterior, which, in some versions, may increase strength of the base member 80 proximate the edge of the eminence cutout, while still providing more flexibility on anterior portions of the base member 80 for even stress distribution when the base member 80 is loaded posteriorly. For example, if one of the medial portion 82a or lateral portion 82b is loaded posteriorly more than the other (*e.g.*, in deep flexion), then torsional forces may arise in the anterior portion 82c. In such situations, the flexibility created from a thinner anterior part of the anterior portion 82c more evenly distributes torsional stresses, and the thicker posterior portion of the anterior portion 82c and raised anterior eminence lip 89c provides extra strength and rigidity.

[00143] Figure 41 shows the tibial base member 80 with tibial inserts 110 and 120 mounted thereon. As shown in Figure 41, the transition from the thicker lip portion 89c of the anterior portion 82c to the more recessed medial 89a and lateral 89b eminence lips provides additional material at the high stress area at the corners of the eminence cutout

portion of the base member 80. Therefore, the medial 89a and lateral 89b lips can be shorter than the anterior portion 82c and the anterior eminence lip 89c without adversely affecting the strength of the tibial base member 80. Moreover, reducing the height of the medial 89a and lateral 89b lips could prevent contact between the tops of the lips 89a, 89b and the femoral component 400, especially in instances where thin polymeric inserts 110, 120 are utilized.

[00144] Returning to Figures 32-33, the upper or proximal side of tibial base member 80 may include a medial plateau locking portion 82a' and a lateral plateau locking portion 82b' each having a lock detail that serves to secure a polymeric tibial insert. Such lock details may include, for instance, one or more undercuts, dovetail joints, male-female connections, grooves, ridges, press-fit connections, barbs, latches, pegs, magnets, and other art-recognized connection means. Lock details may allow moderate rotational or translational movement of the inserts for mobile bearing applications as will be discussed below. Figures 38-46 illustrate tibial base member 80 assembled with medial articulating insert 110 and lateral articulating insert 120. In some versions, the peripheries of the tibial base member 80 and/or tibial inserts 110, 120 align closely with the periphery of the resected proximal tibia.

[00145] While not shown, the upper surfaces of the tibial base member 80 may be configured for use with mobile bearings. In other words, the medial and lateral locking portions, in certain versions, may be provided with a means for securing the medial and lateral inserts to the base member, while allowing some finite rotational movement of the inserts. Such means may include, for instance, a male to female connection such as a peg-in-hole configuration or a circular undercut that locks the inserts in 5 degrees of freedom, while still allowing controlled rotation of the inserts relative to the base member. Other means may be provided, such as tracks and followers, which allow controlled translation of the inserts in any one or more of the anterior-posterior and medial-lateral directions.

[00146] Figures 36-37 illustrate a ninth version of a tibial base plate, tibial base plate 90. As with some of the earlier versions described herein, the tibial base plate 90 includes keel portions that are swept back. In this particular version, the keel portions 94a, 94b, 94c are stepped to increase bone compression during implant insertion and to create zones of

increased stress at the corners of the steps. Base member 90 having stepped keel portions 94a, 94b, 94c may also encourage better fixation for both cemented and cementless applications. Instrumentation used to prepare the tibia to receive a tibial base member may include, in some versions, a punch that is or is not stepped to provide more or less interference and press fit engagement.

[00147] Figures 97-98 illustrate a tenth version of a tibial base plate, tibial base plate 1700. As with some of the earlier versions described herein, the tibial base plate 1700 includes keel portions that are swept back. This particular version also includes pegs 1710 or other suitable structure for providing increased fixation with the prepared tibia 220.

[00148] Figures 49-52 are front coronal cross-sectional views showing the mating geometries between tibial base members 80a-80d, such base members having medial eminence lips 89a-89a' and a lateral eminence lips 89b'-89b'', respectively, and a tibial eminence 222 of a prepared tibia 220. As shown in the figures, one or both of anterior cruciate ligament (ACL) 310 and posterior cruciate ligament (PLC) 320 are preserved. Figure 53 is a frontal coronal view of a tibial base member 80 assembled with inserts 110, 120 with respect to a prepared tibia 220 and the tibial eminence 222.

[00149] In some versions, the relative anterior keel portion length and angle can be optimized based on data collected. It has been found that given a fixed anterior keel portion length, increasing the angle of the anterior keel portion from vertical generally increases the amount that the anterior keel portion undercuts the anterior tibial eminence, and that too much angle can reduce strength of the base member. If too much of the anterior keel portion undercuts the eminence, the eminence may also be compromised. Some of the versions of the tibial base member were achieved through a combination of optimizing the shapes to distribute stress more efficiently throughout the base member, refining the target strength by analyzing previous tibial base member designs which were known to fracture, and running computer simulations in an iterative fashion. Input received during cadaver labs was used to identify the amount of and areas for bone removal which were acceptable from an anatomical perspective, and such information was also used to determine the optimal number, geometries, and orientation of keel portions for increased strength and improved initial fixation in various versions. The inventors took into consideration manufacturing the same

tibial base member design from various materials with high and low fatigue resistance in order to increase the robustness of the design regardless of material strength and properties.

[00150] The particular shape of the entire keel selected, combined with the angle of the anterior keel portion, which is in some versions is approximately 70 degrees, essentially creates a “self-anchoring” feature. In other words, since the anterior keel portion undercuts the cancellous bone (relative to the proximal tibial plateau), it provides hold down forces to counteract pull-out forces.

[00151] Also disclosed are methods of implanting a tibial prosthesis. The method includes the steps of determining a resection depth, determining a preferred spatial orientation for the prosthesis, resecting the medial and lateral tibial plateau bone portions without compromising the tibial eminence and ACL/PCL attached thereto, broaching necessary receiving portions for acceptance of one or more fixation features provided on the underside of the tibial prosthesis, and installing the tibial prosthesis using cemented or cementless techniques.

[00152] 2. Tibial Inserts

[00153] The above described and other versions provide improved tibial inserts, such as medial insert 110 and lateral insert 120 illustrated in Figures 38-44 as assembled with base member 80. In some versions, medial insert 110 is thinner than the lateral insert 120 so as to match the varus joint line present on a femoral component. In some versions, for instance, the lateral insert 120 may be approximately 2.5 mm thicker than the medial insert 120, in order to create a 3° varus joint line that matches a 3° varus joint line of the femoral component. The tibial articular geometry of some versions generally includes a concave medial portion on the medial insert 110 and a convex lateral portion on the lateral insert 120. A coronal conformity may be present on inner portions of one or both of the inserts 110, 120. This coronal conformity, for instance, may comprise a mesial lip, which, as described further below, may vary in height along the anterior-posterior direction.

[00154] Figures 54-58 show various views of a version of a lateral insert 120, while Figures 59-63 show various views of a version of a medial insert 110.

[00155] The lateral insert 120 of Figures 54-58 defines a superior articulation surface, defining several different contours in various planes. Figures 57 and 58 are cross sections of the lateral insert 120 in certain coronal (Figure 57) and sagittal (Figure 58) planes. Figure 57 illustrates a contour 126a defined by a relatively anterior, coronal cross section of lateral insert 120. Figure 58 illustrates a contour 124b defined by a relatively middle, sagittal cross section of lateral insert 120. Figures 90a-e are a series of sagittal cross sections of a version of a left, lateral insert illustrating the contours of that insert from relatively mesial (e.g. Figure 90a) to relatively outer (e.g. Figure 90e) portions of the insert. Figures 91a-k are a series of coronal cross sections of the same version as shown in Figures 90a-e, the coronal cross sections of Figures 91a-k progressing from relatively anterior portions (e.g. Figure 91a) to relatively posterior portions (e.g. Figure 91k) of the insert.

[00156] As shown in the versions of Figures 54-58 and 90-91, and as described in further detail below, lateral insert 120 defines a mesial lip 128 and a circumferential chamfer 129. In some versions, at least some parts of the anterior portions and contours of the lateral insert 120 are relatively more conforming to a femoral condylar surface than other portions of the insert 120. As shown in Figure 56, lateral insert 120 may also include peripheral steps 127a, 127b. Figures 56 and 58 illustrate a lock mechanism 122 used to secure lateral insert 120 to the tibial base member.

[00157] As shown in the versions of Figures 54-58 and 90-91, mesial lip 128 is raised relative to other portions and contours of the insert 120. As shown in Figure 58, illustrating a sagittal cross section of the insert 120, such cross section taken through a middle portion of the insert 120, the raised mesial lip 128 extends from anterior to posterior portions of the insert 120. Mesial lip 128, in some versions, provides resistance to lateral femoral translation and prevents impingement between the femoral component 400 and the tibial eminence 222. The height of the mesial lip can be selected to provide a desired level of resistance, with a greater height providing more resistance. As shown in these versions, the height of the mesial lip relative to other portions of the insert 120 gradually decreases as it extends in an anterior to posterior direction. In the versions of Figures 54-58 and 90-91, outer side portions (near chamfer 129) of the lateral insert 120 are substantially flat and have little to no coronal conformity with the femoral condylar articulation surfaces. In some

versions, the maximum height of the mesial lip 128 is between a range of approximately .025 inches and approximately .125 inches relative to the substantially flat outer side portions. In some versions, the maximum height of the mesial lip 128 is between approximately .035 inches and approximately .065 inches for the lateral insert 120.

[00158] Figures 59-63 illustrate a version of a medial insert 110, which defines a superior articulation surface, defining several different contours in various planes. For instance, Figure 62 shows a coronal cross section of the medial insert 110 taken at a relatively middle portion of the insert 110, showing coronal contour 116a. Figure 63 shows a sagittal cross section of the medial insert 110 taken at a relatively middle portion of the insert, showing contour 114b. Figures 92a-e are a series of sagittal cross sections of a version of a left, medial insert illustrating the contours of that insert from relatively mesial (e.g. Figure 92a) to relatively outer (e.g. Figure 92e) portions of the insert. Figures 93a-m are a series of coronal cross sections of the same version as shown in Figures 92a-e, the coronal cross sections of Figures 93a-m progressing from relatively anterior portions (e.g. Figure 93a) to relatively posterior portions (e.g. Figure 93m) of the insert.

[00159] Like the lateral insert, medial insert 110 also includes a mesial lip 118 and a circumferential chamfer 119 (e.g. Figure 60). In some versions, anterior, mesial portions of the insert 110 are more conforming to an associated femoral component than other portions of the insert. As shown in Figure 60, medial insert 110 also includes peripheral steps 117a, 117b. Figures 61 and 63 illustrate a lock mechanism 112 used to secure medial insert 110 to the tibial base member.

[00160] As shown in Figures 62-63 and 92-93, mesial lip 118 is raised relative to other portions and contours of the insert 120. As shown in Figure 63, illustrating a sagittal cross section of the insert 110, such cross section taken through a middle portion of the insert 110, the raised mesial lip 118 extends from anterior to posterior portions of the insert 110. Mesial lip 118, in some versions, provides resistance to lateral femoral translation and prevents impingement between the femoral component 400 and the tibial eminence 222. The height of the mesial lip can be selected to provide a desired level of resistance, with a greater height providing more resistance. As shown in these versions, the height of the mesial lip relative to other portions of the insert 110 gradually decreases as it extends in an anterior to

posterior direction. In the versions of Figures 62-63 and 92-93, outer side portions (near chamfer 119) of the medial insert 110 are substantially flat and have little to no coronal conformity with the femoral condylar articulation surfaces. In some versions, the maximum height of the mesial lip 118 is between a range of approximately .025 inches and approximately .125 inches relative to the substantially flat outer side portions. In some versions, the maximum height of the mesial lip 118 is between approximately .035 inches and approximately .065 inches for the medial insert 118.

[00161] Figures 64-67 illustrate graphically and pictorially the kinematics of the medial and lateral inserts 110, 120 of Figures 54-63 when used with other components, such as a femoral component 400 and patellar component 600 in certain arthroplasty procedures. Using LifeMOD™ computer simulations, the inventors have determined that providing a mesial lip 118 on the medial tibial insert 110 serves to prevent the femoral component 400 from translating laterally in response to the lateral forces applied to the femoral component 400 by the patella due to the quadriceps angle, or “Q-angle.” In some versions, without the mesial lip 118, the femoral component 400 may translate laterally in flexion due to patella shear, creating an environment where the medial condyle 408 moves too close to the attachment point of the posterior cruciate ligament 320 and surrounding bone 220, 222. In addition to increasing the overall performance of the prosthesis over prior art designs, in some versions, the raised mesial lip 118 further provides additional tibio-femoral contact when the leg is in extension. In some versions, it is envisaged that the medial insert 110 comprises a mesial lip 118 and the lateral insert 120 does not comprise a mesial lip 128, although mesial lips 118, 128 may be added to both inserts 110, 120 for additional stabilization.

[00162] Figures 64-66 graphically illustrate the medial femoral rollback, lateral femoral rollback, and external femoral rotation respectively of femoral implant 400 when used in conjunction with the implant 100 shown in the version of Figures 38-46. This, in some versions, may be in contrast to at least some previous bicruciate-retaining designs, which employed overly-conforming coronal profiles in regions adjacent to the femoral component towards the midline and outer peripheral edges of the tibial insert. This over-conformity present in some prior art designs negatively constrains internal-external rotation of the femoral component and reduces or eliminates medial-lateral translation. At least some

known designs have also demonstrated high amounts of conformity at anterior and posterior portions of the insert, which negatively limit femoral rotation during knee extension and flexion. The design shown in Figure 68, in this particular version, generally only provides coronal conformity towards a midline of the tibia, said coronal conformity gradually reducing towards the posterior edges of the insert. Because of this reduction in conformity, this particular design more freely allows internal and external rotation of the femoral component 400 and more closely replicates normal knee kinematics in flexion, where the femoral component 400 is rotated externally relative to the tibial prosthesis 100. Other versions, however, may feature relatively highly conforming inserts similar to those of other prior art designs.

[00163] In some instances, a plurality of different posterior slope angle options may be provided to tibial inserts 110 and/or 120. In one version, inserts such as 110 and/or 120 are thinned posteriorly by different amounts so as to effectively rotate the articular surfaces by a flexion-extension angle relative to the bottom surfaces of the inserts 110, 120 and provide more posterior slope. Such an option may, in some versions, allow a surgeon to selectively adjust joint laxity when the knee is in flexion. For instance, several pairs of medial 110 and lateral 120 inserts may be provided, each pair differing in posterior slope from the other pairs by a specified number of degrees between about 1-4 degrees, for instance 2 degrees. Other options may include pairing medial 110 and lateral 120 inserts, wherein the posterior slope of the medial insert 110 differs from the posterior slope of the lateral insert 120. Such options may generally allow the flexion space to be adjusted without necessarily requiring a re-cut of tibial bone 220. Multiple thickness options for each of the medial 110 and lateral 120 inserts are also provided for the abovementioned options to afford proper ligament balance. Various combinations and configurations of insert thicknesses, medial-lateral slope, and anterior-posterior slope may be utilized to suit the particular anatomical needs of an individual patient. The options of multiple thickness, medial-lateral slope, and anterior-posterior slope may also be configured in the tibial base plate to provide these configurations while using a single insert.

[00164] In some versions, the articular geometries of the medial 110 and lateral 120 inserts may be provided by a single cruciate-containing insert 500, which, as shown in Figures 69, 71, 73, 75, 78, and 80, comprises concave medial and lateral articulating surfaces.

As shown in Figure 80, the lateral portion 510 of the insert 500 may be thicker (in some versions, approximately 2.5 mm thicker) than the medial portion to allow functionality with the femoral components 400 shown. The thicker lateral portion 510, in this particular version, serves to match the varus joint line present on the femoral component 400.

[00165] In other versions, medial 110 and lateral 120 inserts may be provided, each having different posterior slope angles or thicknesses, and may be utilized in various combinations in order to address different medial and lateral collateral ligament balancing needs. In some instances, a set of inserts 110, 120 including a plurality of sizes may be provided in a surgical implant kit, wherein a general angle between a bottom plane of a particular insert 110, 120 and its corresponding articulating surface varies between inserts. This angle may increase or decrease in either or both of an anterior-posterior direction and a medial-lateral direction independently or collectively. Providing multiple posterior slope options may advantageously reduce the need for re-cutting the tibia 220.

[00166] Figures 56 and 68 illustrate an example of a convex lateral insert 120, which facilitates external rotation of the femoral component 400 during flexion and through lateral femoral rollback, while the medial femoral condyle 408 is constrained by the sagittal concave geometry of the medial insert 110 as provided by some versions.

[00167] As another alternate to using separate tibial inserts 110, 120, a tibial base member 1500 shown in Figure 88 may comprise integrally-formed monolithic articulating surfaces. Other versions, such as shown in Figure 89, may include a tibial prosthesis 1600 formed of a porous structure material 1602 such as a metal foam, with articulating surfaces 1604 modularly or integrally provided at a proximal region of the porous structure 1602, as shown in Figure 89. For instance, the articulating surfaces 1604 may be formed as a solid metal, ceramic, polymer, coating, or compliant material disposed on a proximal side of the porous structure. This may be accomplished using conventional rapid manufacturing techniques such as selective laser sintering (SLS), electron beam welding (EBM), 3D printing, or stereolithography. Alternatively, the porous structure 1602 may be overmoulded with a polymer to form a monolithic base member 1600 having a porous structure 1602 and an articulating surface 1604 of different materials.

[00168] 3. Femoral Components

[00169] Also provided are improved femoral components. For example, the femoral component 400 shown in Figures 67-75 includes a medial condyle 408 and a lateral posterior condyle 406 that comprises a posterolateral chamfer 404 (see, e.g., Figures 68-69, 72-74) As shown in Figures 74-75, in some versions, posterolateral chamfer 404 has a depth or distance d of between approximately 1 and approximately 5 mm, and more preferably between approximately 2 and approximately 4 mm, for example approximately 2.8 mm, and an angle Φ between approximately zero and approximately 25 degrees, and more preferably between approximately 5 and approximately 15 degrees, for example approximately 10 degrees, to create a clearance with the posterior lateral tissue such as the popliteal tendon in deep knee flexion. The chamfer 404 may originate a distance D from a proximal bone engaging surface configured to mate with a distal femoral bone cut, said distance D , for example, being between approximately 3 and approximately 20 mm, and more preferably between approximately 8 and approximately 15 mm, for example, approximately 11 mm. Distances d and D may increase proportionally or disproportionately with increasing femoral component 400 sizes. In some versions, for example, larger sizes of femoral component 400 may employ an angle Φ of approximately 10° and a distance D of approximately 11mm, whereas smaller sizes of femoral component 400 may employ a smaller distance D of approximately 10 mm.

[00170] Similarly, medial posterior condyle 408 may comprise on its inner surface a posterolateral chamfer 410, shown in Figures 74, 76, 79-81, having an angle ψ between approximately 0 and approximately 10 degrees and more preferably between approximately 3 and approximately 7 degrees, for example approximately 5 degrees as shown in Figure 74. Such a chamfer may be combined with another chamfer 470 that may be swept around an inner sagittal radius of posterior medial condyle 408 to provide additional clearance with the tibial eminence 222 and posterior cruciate ligament 320, without decreasing bone coverage. In some versions, the posterolateral chamfer 470 starts just posterior to patella contacting areas of the femoral component 400, and therefore, it may not sweep around intercondylar patellar contacting regions 412 of the femoral component. Rather, posterolateral chamfer 470 may be more pronounced in posterior portions of the medial femoral condyle 408. Top edges

of the tibial eminence 222 may also be chamfered using a rongeur to further avoid impingement with the femoral component 400.

[00171] Figure 94 is a medial sagittal view of a medial condyle 455 of a femoral component 450 according to one aspect. The medial posterior condyle 455 may comprise on its inner surface a posterolateral chamfer 470. Figures 95a-95k are various coronal cross sectional views taken along the lines A-A through K-K, respectively, of Figure 94 illustrating posterolateral chamfer 470. As shown in Figures 95a-95k, femoral component includes a rounded edge 460 when viewed along lines A-A, J-J- and K-K, and includes a posterolateral chamfer 470 when viewed along lines B-B, C-C, D-D, E-E, F-F, G-G, H-H, I-I. The angle ψ of posterolateral chamfer 470 is between approximately 15 and approximately 40 degrees in some versions.

[00172] As shown in Figure 68, the anterior flange of the femoral component 400 may comprise an anterolateral chamfer 402 on lateral and/or medial sides to reduce tension on the retinaculum tissue, which may be common with some prior art femoral designs.

[00173] Various modifications could be made to the exemplary versions, as described above with reference to the corresponding illustrations, without departing from the scope of the invention, and therefore, it is intended that all matter contained in the foregoing description and shown in the accompanying drawings shall be interpreted as illustrative rather than limiting. For example, the novel features of the tibial inserts disclosed may be readily applied to instrumentation such as tibial insert trials, as well as implants designed to be implanted. Thus, the breadth and scope of the invention should not be limited by any of the above-described exemplary versions, but should be instead defined only in accordance with any claims which may be appended hereto and their equivalents. Moreover, it is envisioned that a skilled person could use any or all of the features disclosed in the above versions in any compatible combination or permutation.

CLAIMS

1. A tibial prosthesis for at least partially replacing a proximal portion of a tibia, the tibial prosthesis comprising:
 - (a) an inferior surface for contact with a resected surface on the proximal portion of the tibia; and
 - (b) a keel for penetration into a cavity formed in the proximal tibia, wherein the keel extends at an inferior-posterior angle away from the inferior surface.
2. The tibial prosthesis of claim 1, wherein the keel includes an anterior keel portion, a medial keel portion, and a lateral keel portion, and wherein the anterior keel portion extends at the inferior-posterior angle away from the inferior surface.
3. The tibial prosthesis of claim 2, wherein the tibial prosthesis further comprises a medial baseplate portion, a lateral baseplate portion, and a connecting baseplate portion extending between and connecting the medial baseplate portion and lateral baseplate portion; wherein at least a part of the anterior keel portion extends in a generally medial-lateral direction on the connecting baseplate portion; wherein at least a part of the medial keel portion extends in a generally anterior-posterior direction on the medial baseplate portion; and wherein at least a part of the lateral keel portion extends in a generally anterior-posterior direction on the lateral baseplate portion.
4. The tibial prosthesis of claim 3, wherein the anterior keel portion joins the medial and lateral keel portions at areas of increased thickness.
5. The tibial prosthesis of claim 3, wherein the anterior keel portion joins the medial and lateral keel portions at areas of increased width.
6. The tibial prosthesis of claim 3, wherein the connecting baseplate portion increases in thickness in an anterior to posterior direction.
7. The tibial prosthesis of claim 3, wherein the medial and lateral keel portions decrease in height as the medial and lateral keel portions extend in an anterior to posterior direction.

8. The tibial prosthesis of claim 2, wherein the anterior keel portion includes an anterior face and a posterior face, wherein the anterior face extends at an inferior-posterior anterior face angle away from the inferior surface; and wherein the posterior face extends at an inferior-posterior posterior face angle away from the inferior surface.

9. The tibial prosthesis of claim 2, wherein the anterior keel portion extends across the connecting baseplate portion in an anterior-medial to a posterior-lateral direction.

10. The tibial prosthesis of claim 9, wherein the tibial prosthesis defines a central notch extending between the medial and lateral baseplate portions posterior to the connecting baseplate portion, wherein the central notch has a sufficient width and length to receive a portion of a tibial eminence including an anterior cruciate ligament attachment site and a posterior cruciate ligament attachment site.

11. A tibial prosthesis for at least partially replacing a proximal portion of a tibia, comprising a tibial articulation surface for articulation with a femoral condylar articulation surface,

wherein the tibial articulation surface defines a mesial lip extending in an anterior to posterior direction along a mesial edge of the articulation surface;

wherein the mesial lip is raised by a height relative to a corresponding central portion of the articulation surface; and

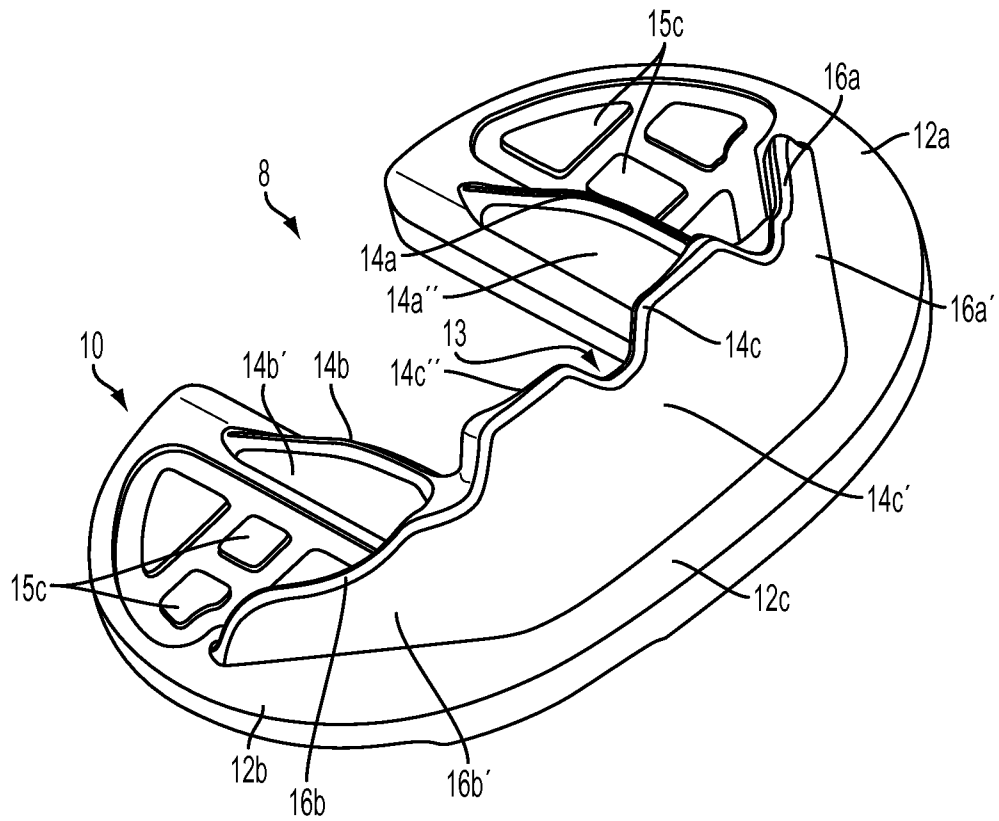
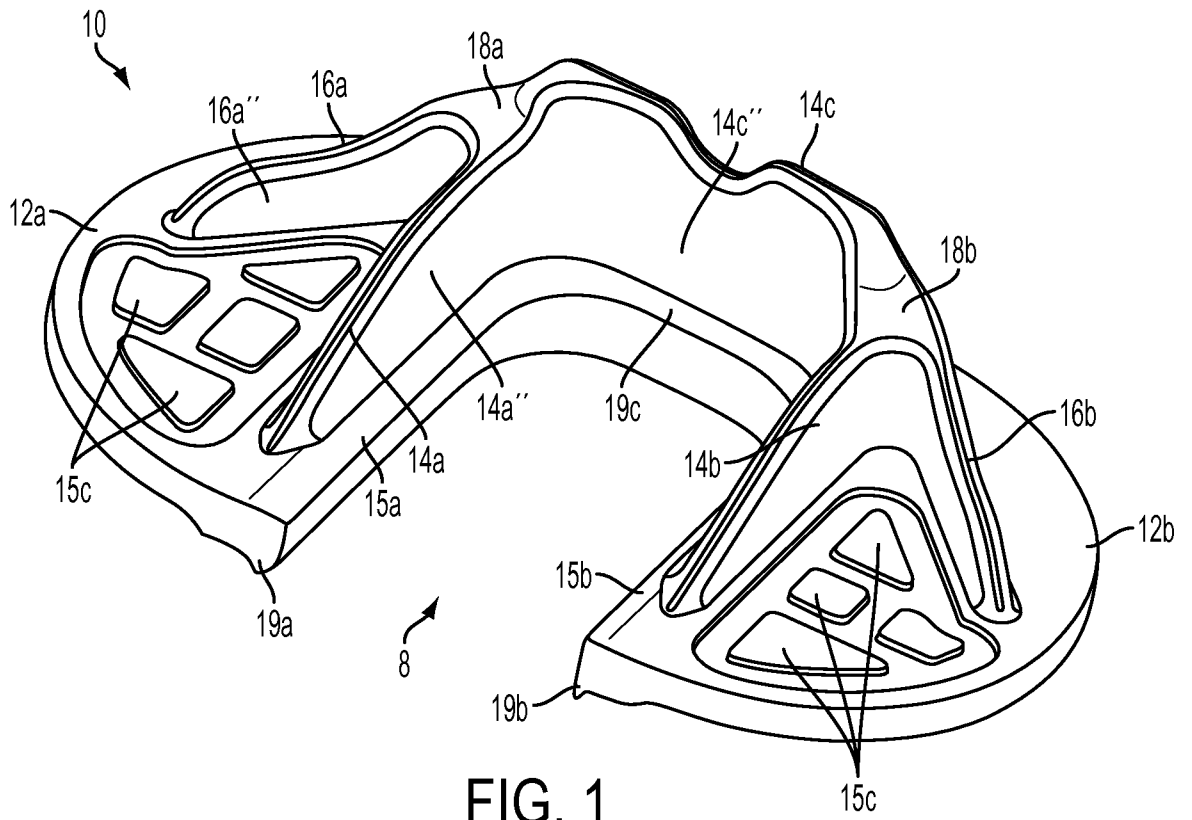
wherein the height with which the mesial lip is raised relative to the corresponding central portion decreases in an anterior to posterior direction.

12. The tibial prosthesis of claim 11, wherein the tibial articulation surface is a medial tibial articulation surface and wherein at least a portion of the medial tibial articulation surface is concave in a sagittal plane.

13. The tibial prosthesis of claim 12, wherein an anterior-mesial portion of the medial tibial articulation surface is curved to at least partially conform to the femoral condylar articular surface.

13. The tibial prosthesis of claim 13, wherein a posterior-outer portion of the medial tibial articulation surface is substantially flat and does not substantially conform to the femoral condylar articular surface.
14. The tibial prosthesis of claim 11, wherein the tibial articulation surface is a lateral tibial articulation surface; and wherein the lateral tibial articulation surface is convex in a sagittal plane.
15. The tibial prosthesis of claim 14, wherein an anterior-mesial portion of the lateral tibial articulation surface is curved to at least partially conform to the femoral condylar articular surface.
16. The tibial prosthesis of claim 15, wherein a posterior-outer portion of the lateral tibial articulation surface is substantially flat and does not substantially conform to the femoral condylar articular surface.
17. The tibial prosthesis of claim 11, wherein the tibial prosthesis is a tibial insert; and wherein the tibial insert further comprises an inferior surface that includes at least one lock member for securing to a tibial baseplate.

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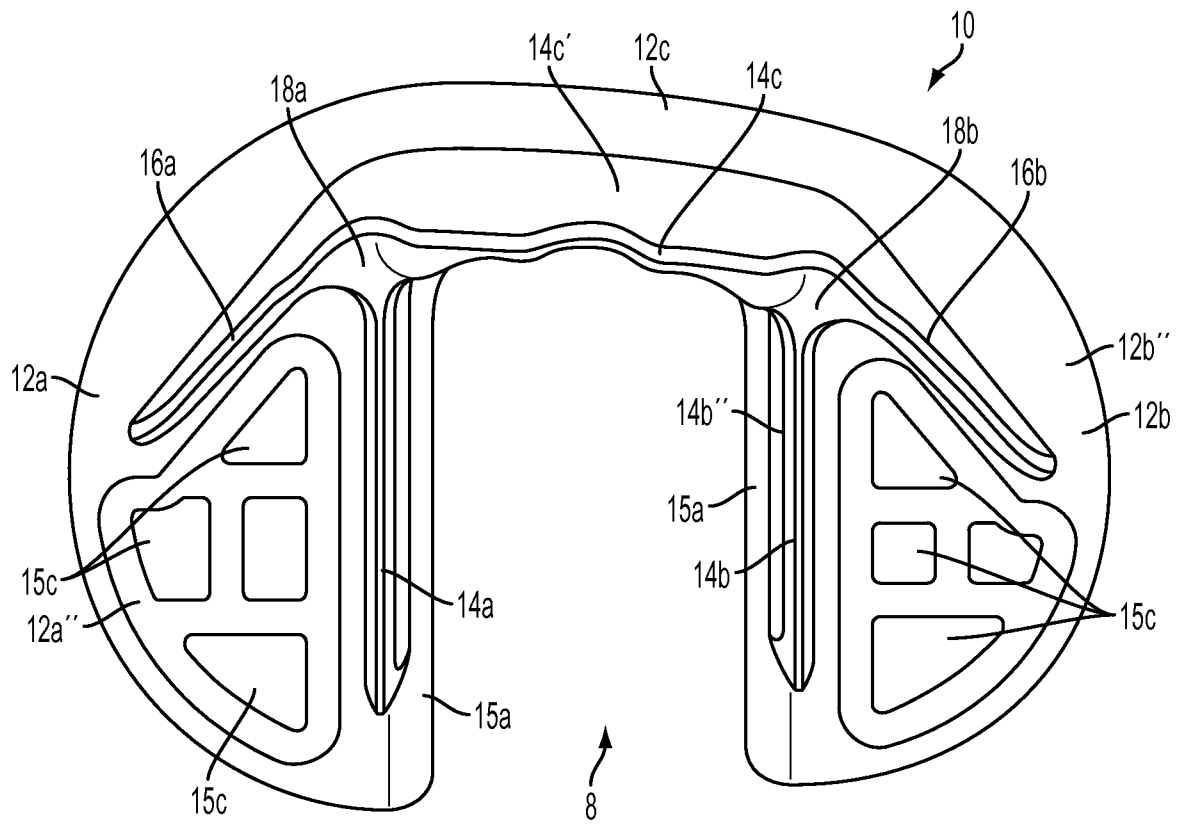
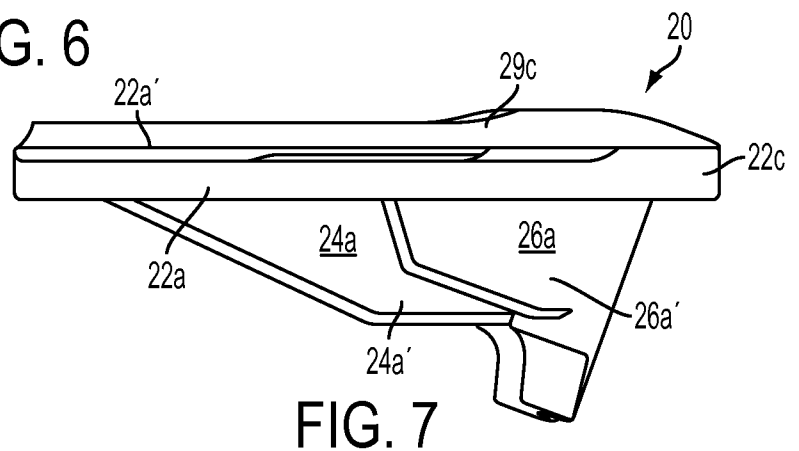
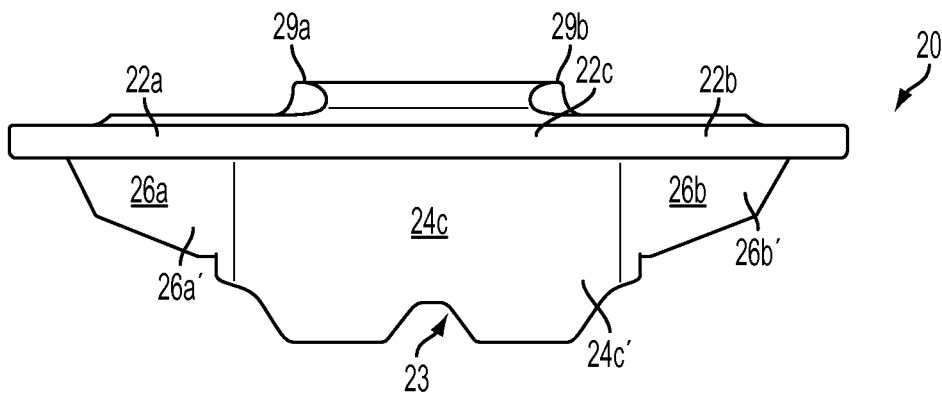
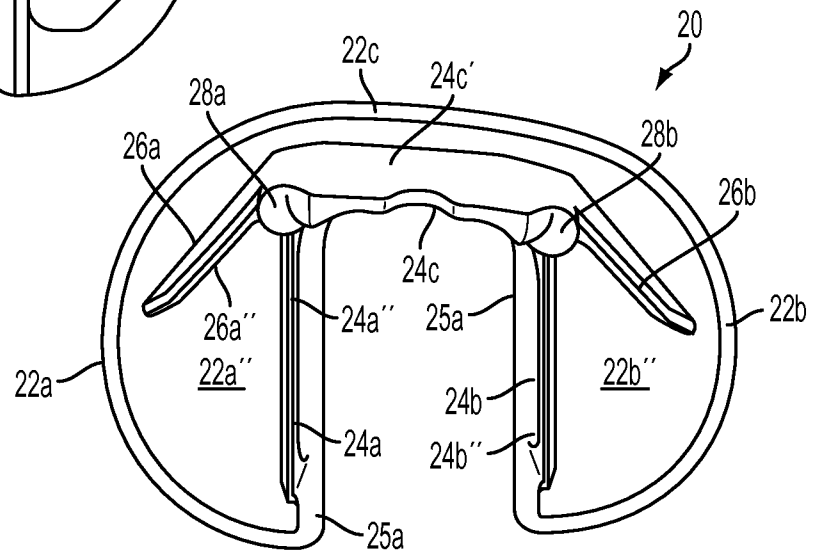
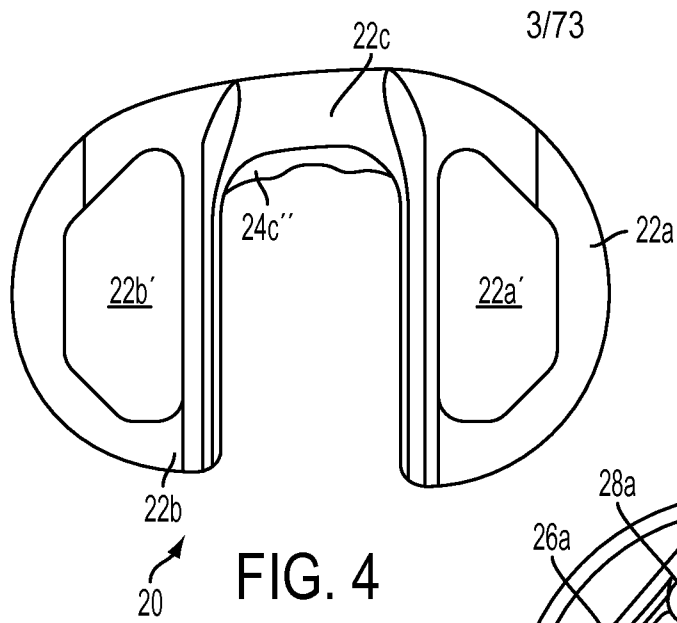
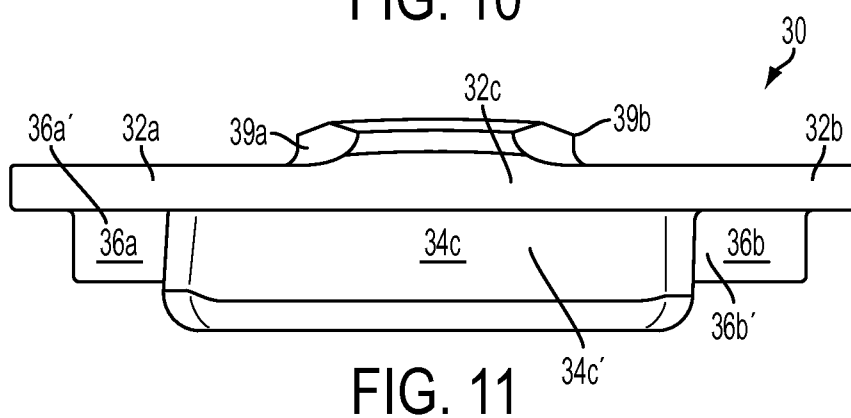
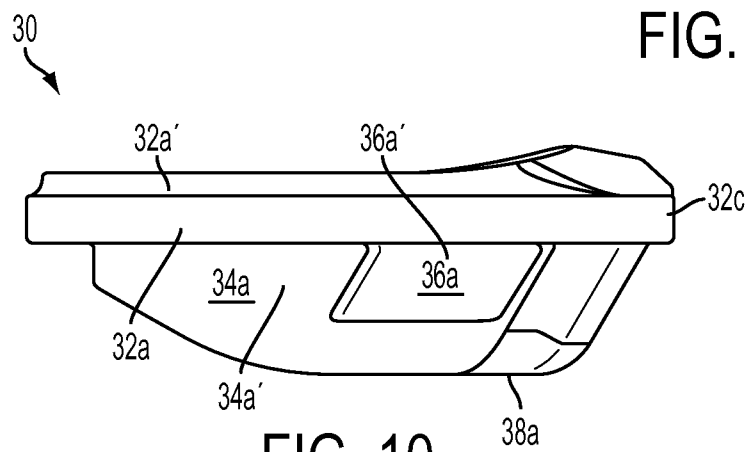
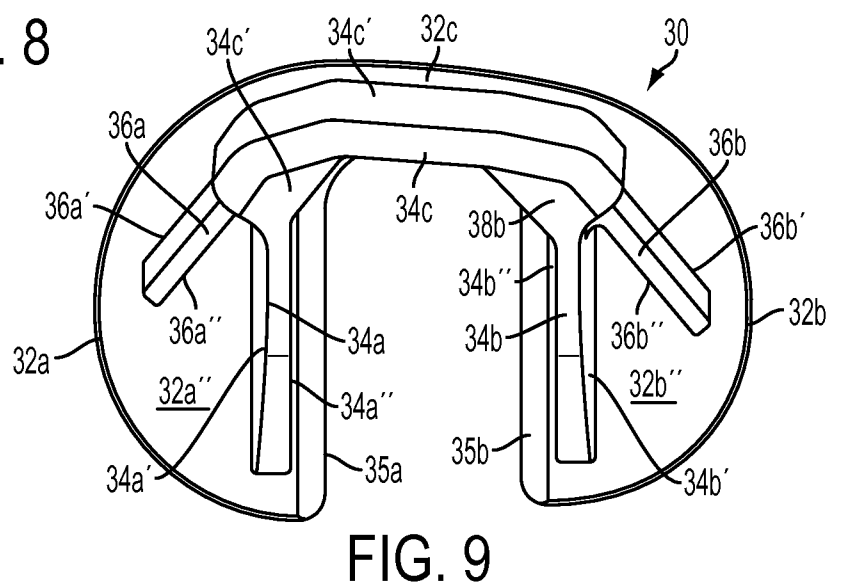
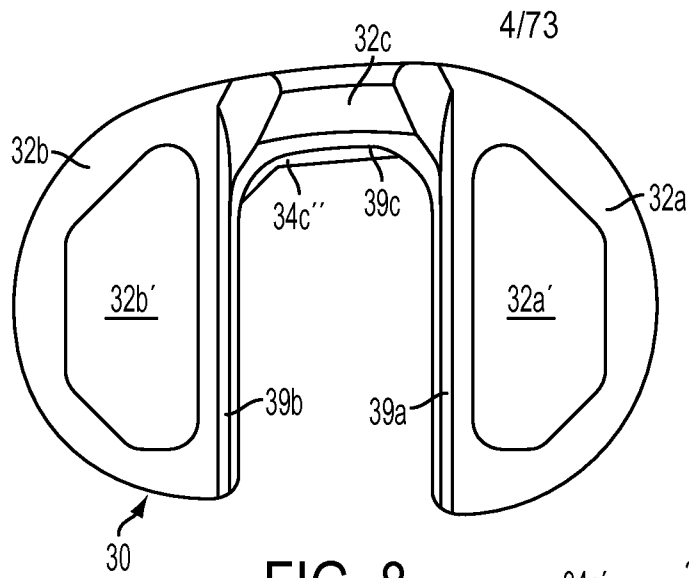


FIG. 3





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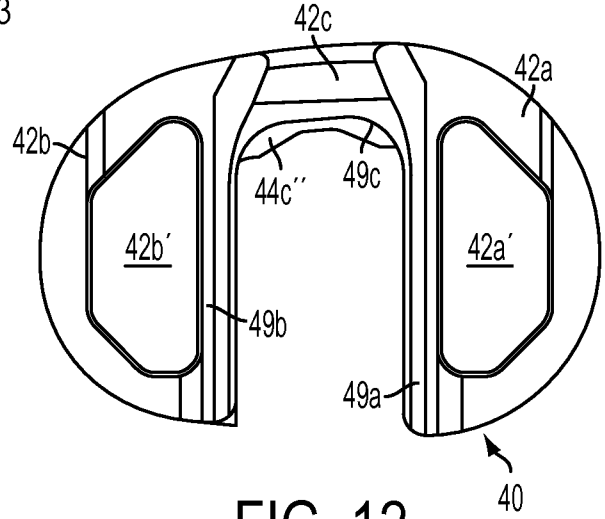


FIG. 12

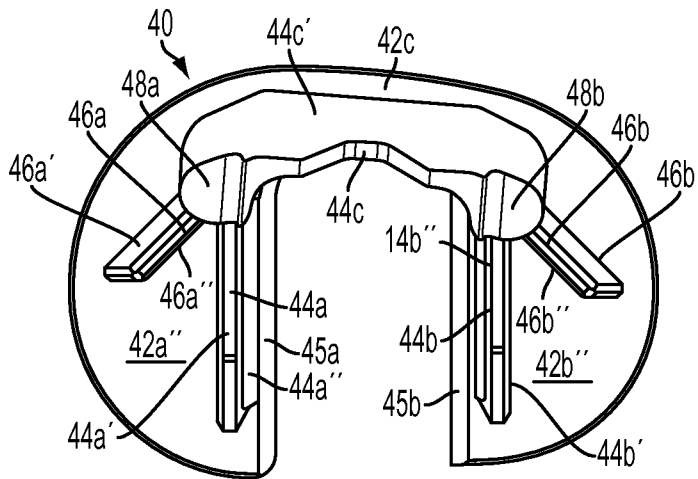


FIG. 13

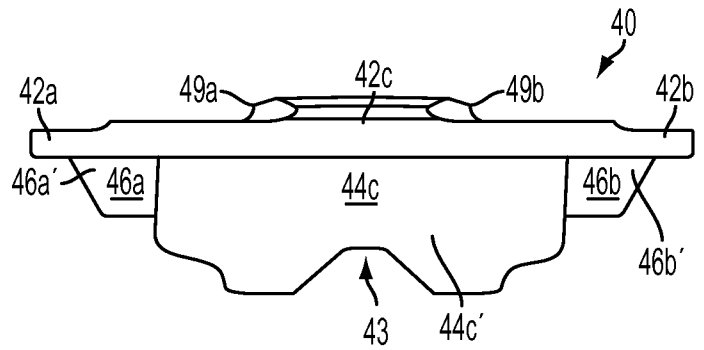


FIG. 14

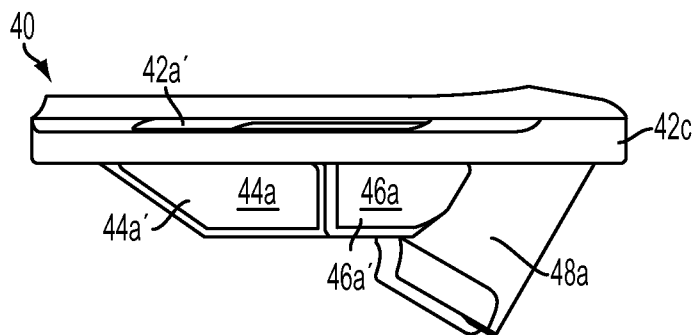


FIG. 15

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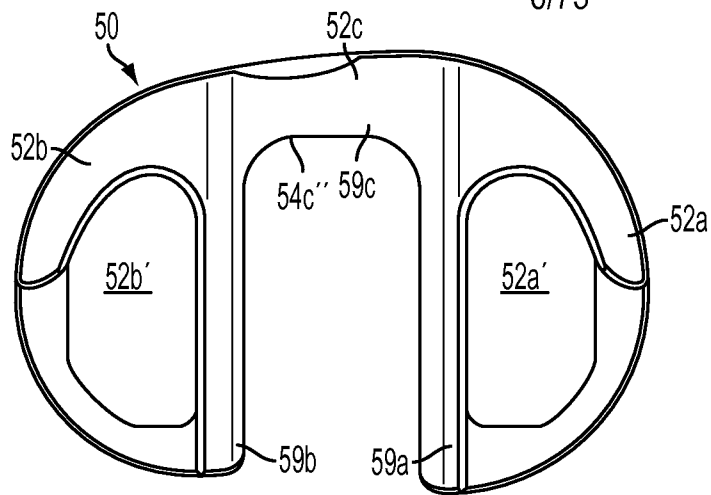


FIG. 16

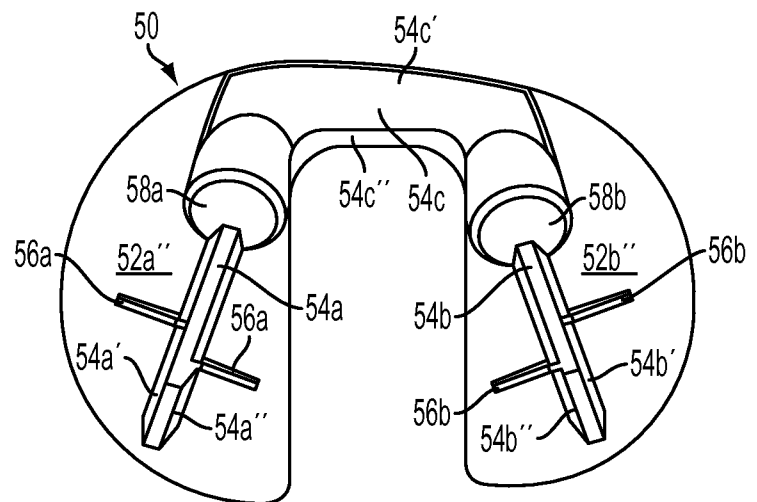


FIG. 17

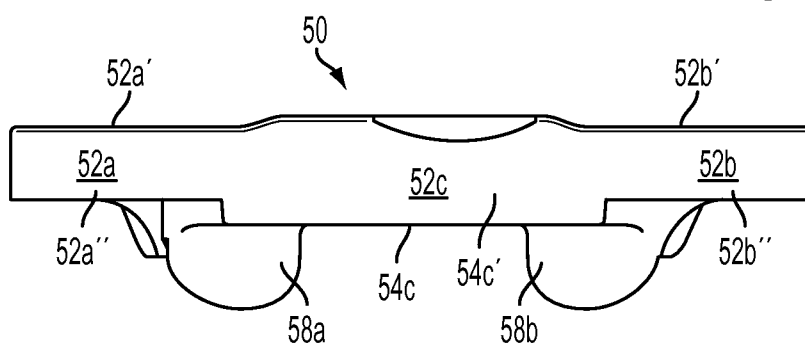


FIG. 18

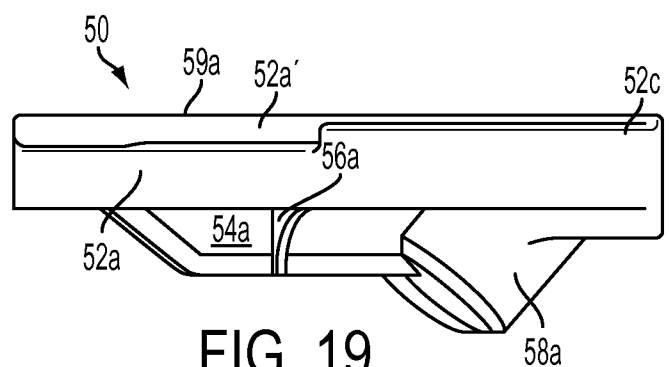


FIG. 19

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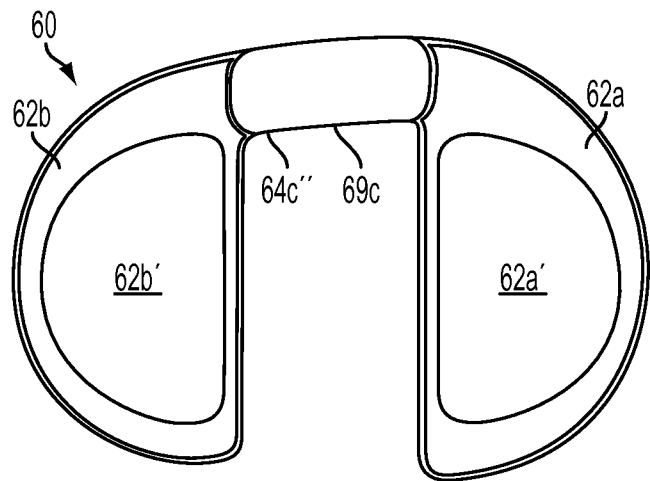


FIG. 20

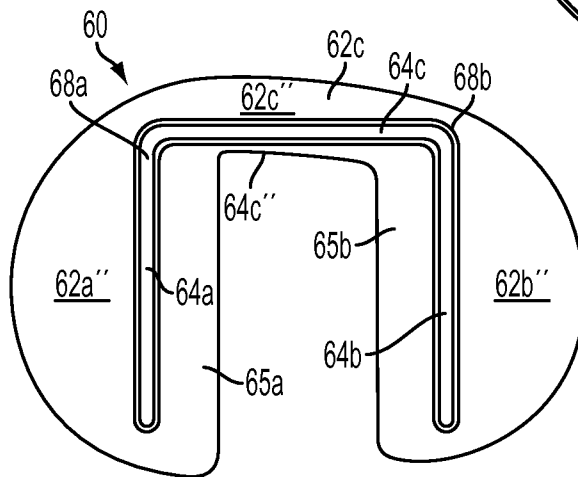


FIG. 21

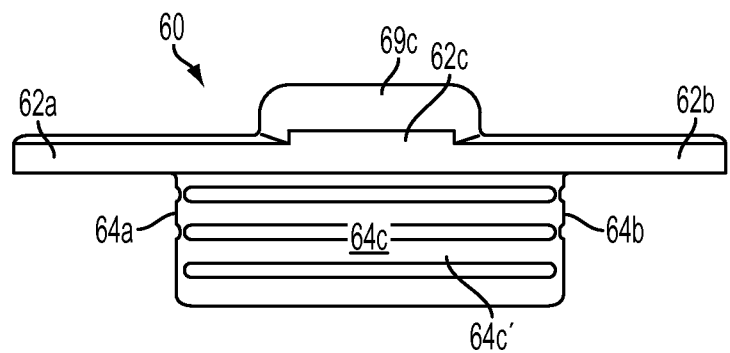


FIG. 22

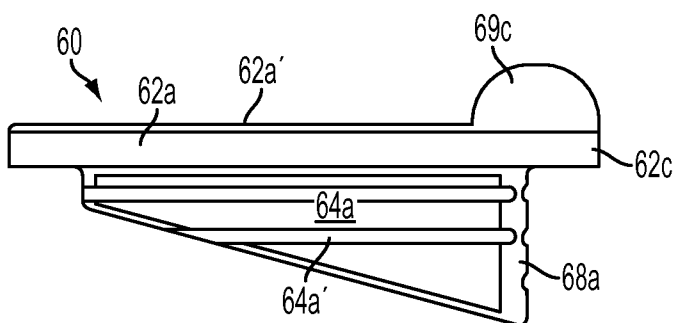


FIG. 23

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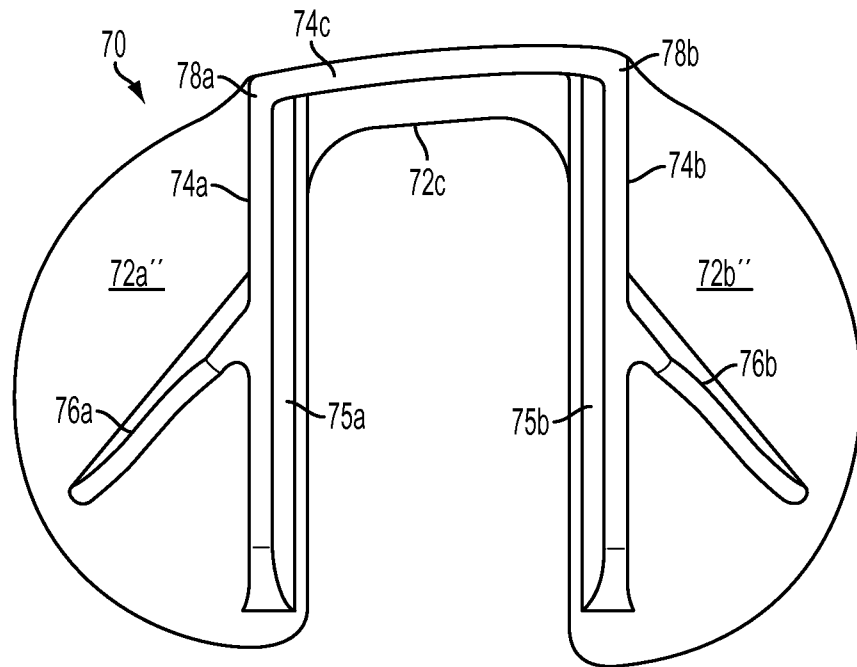


FIG. 24

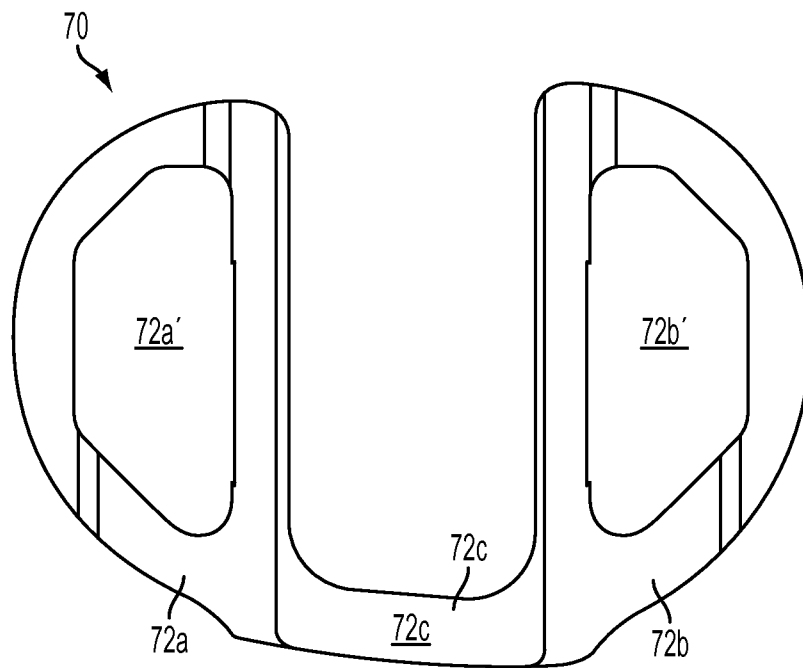


FIG. 25

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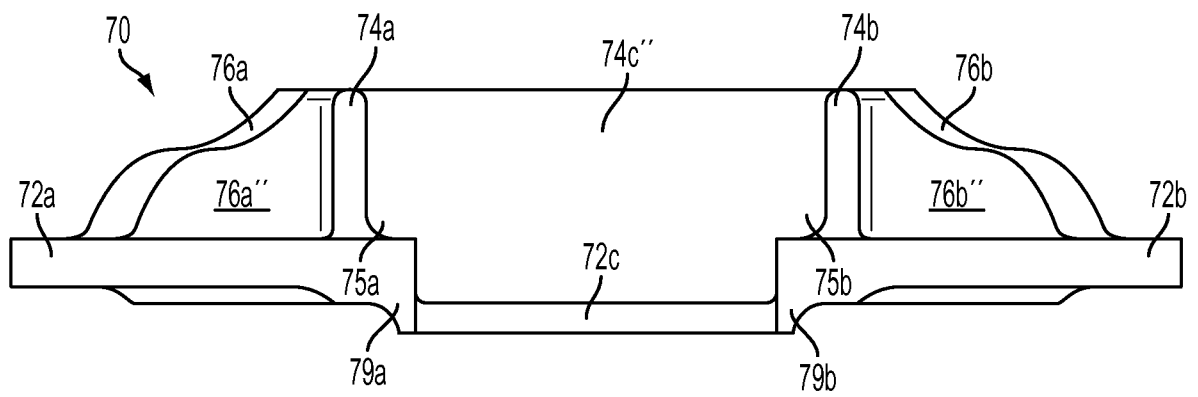


FIG. 26

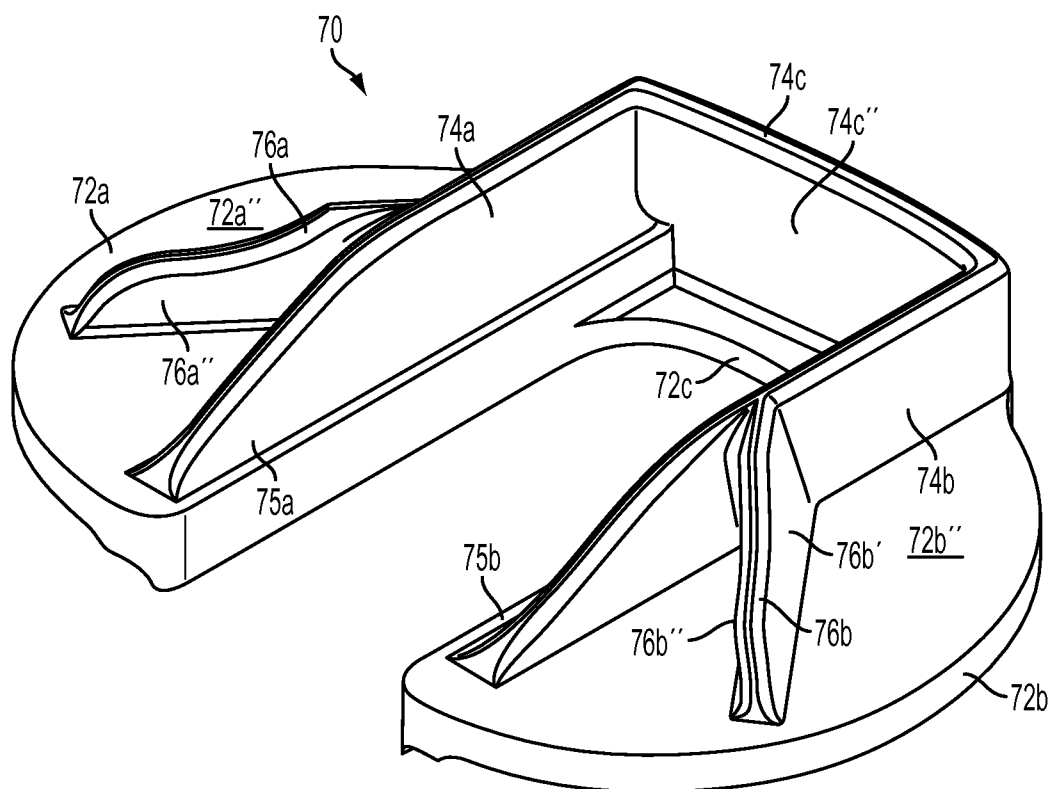


FIG. 27

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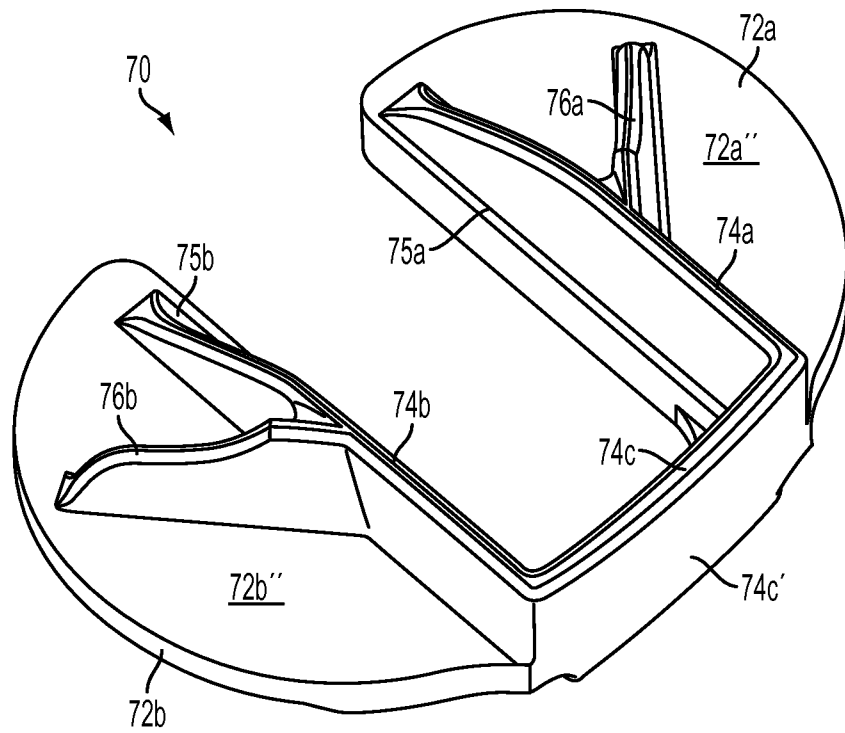


FIG. 28

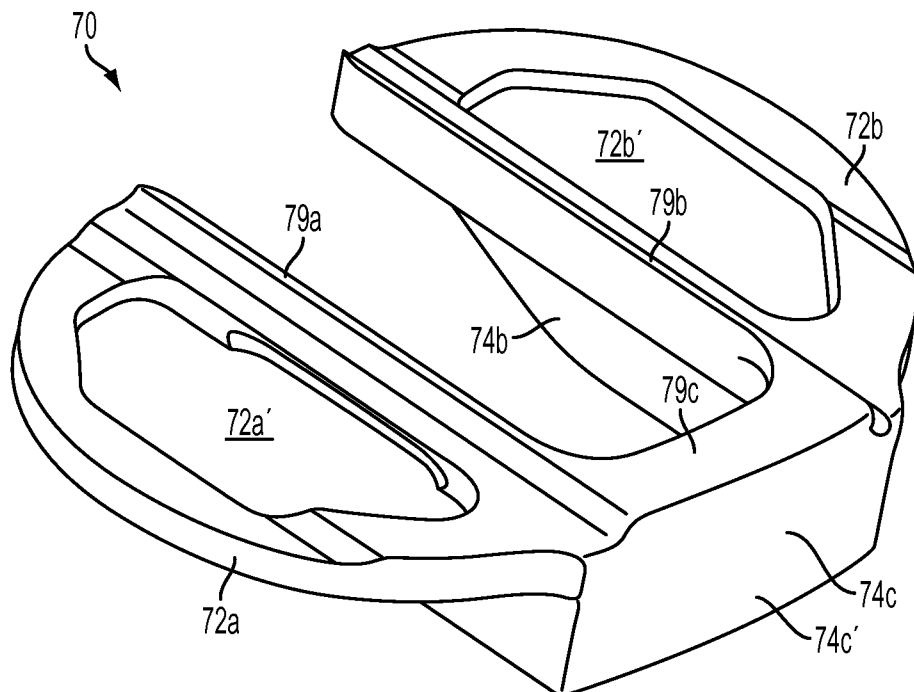


FIG. 29

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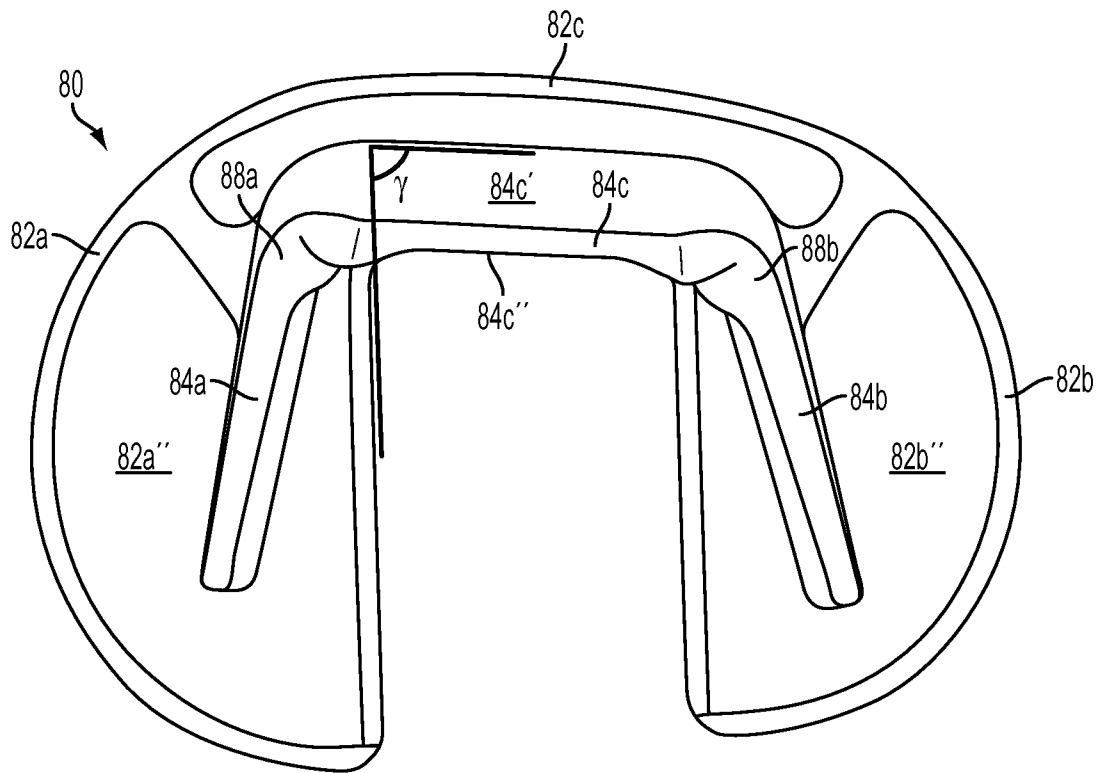


FIG. 30

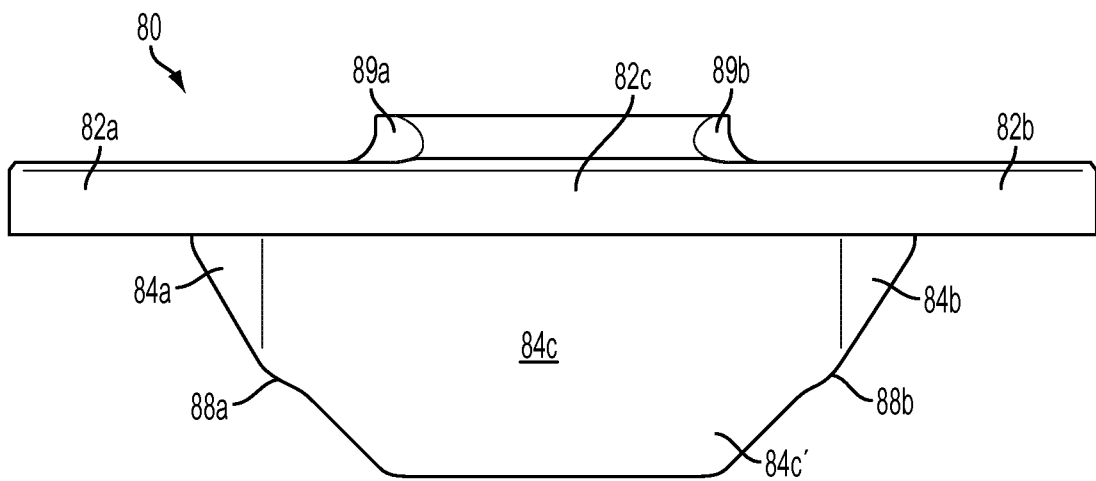


FIG. 31

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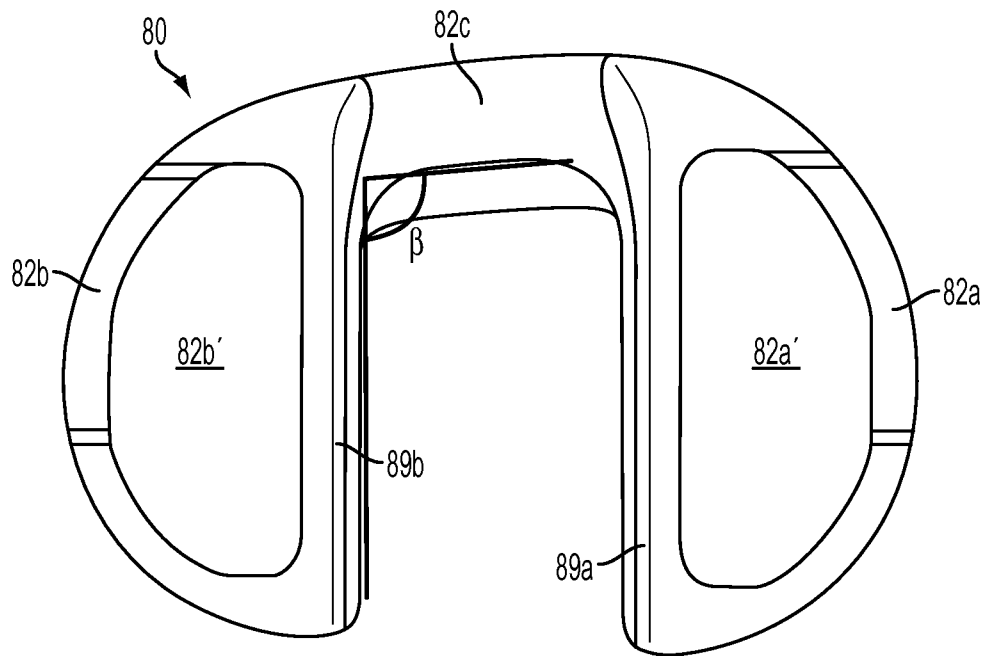


FIG. 32

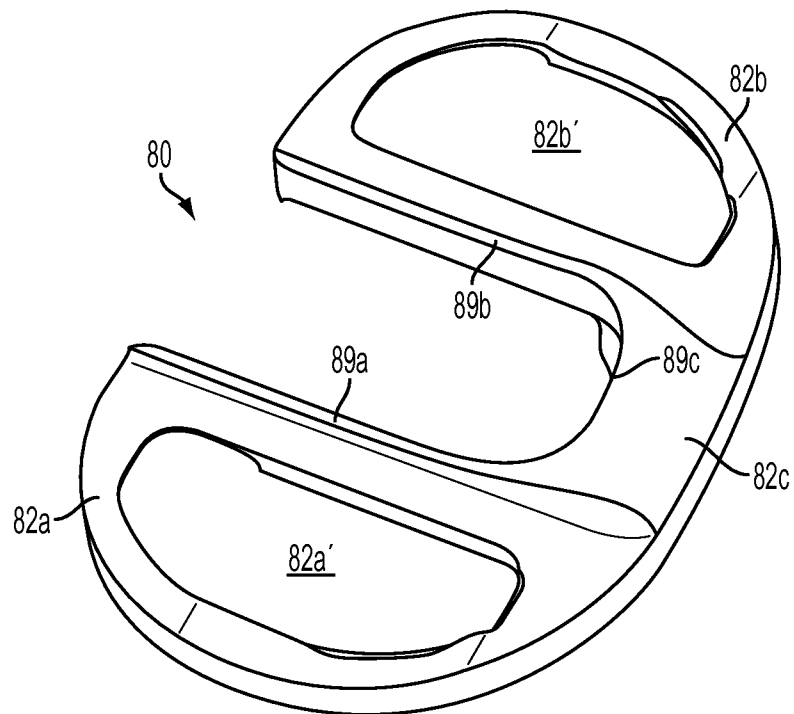


FIG. 33

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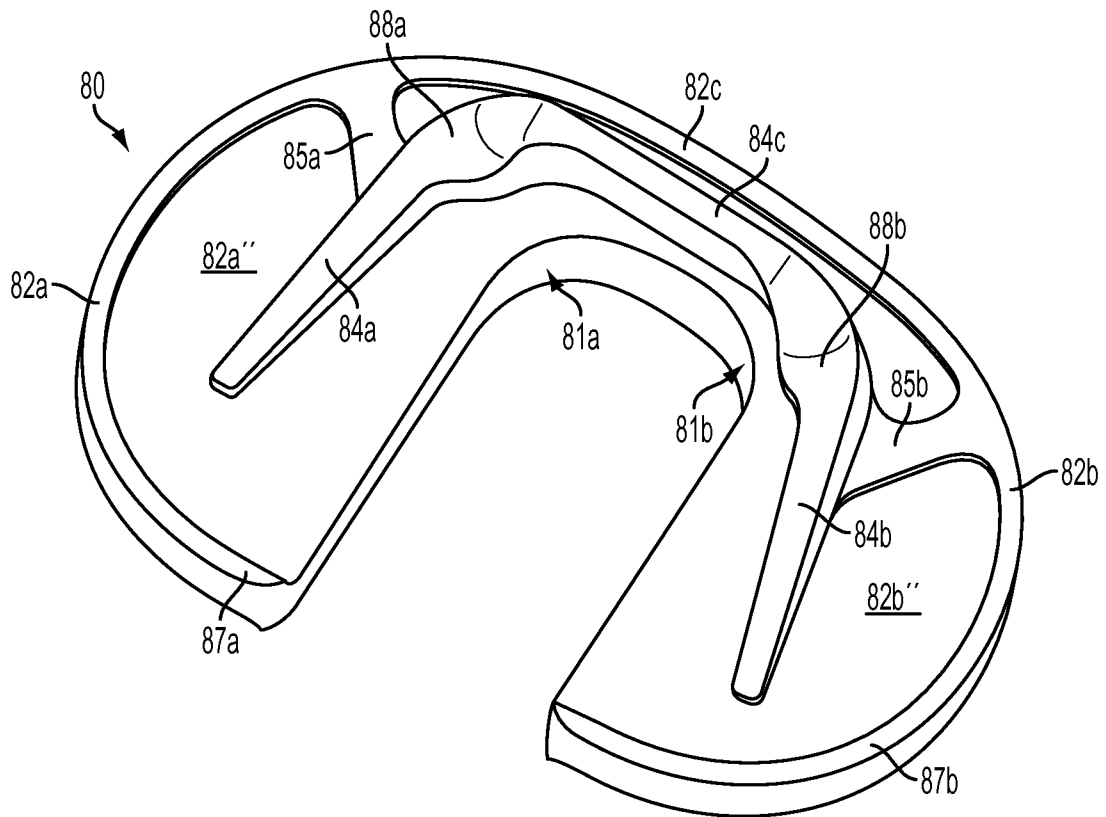


FIG. 34

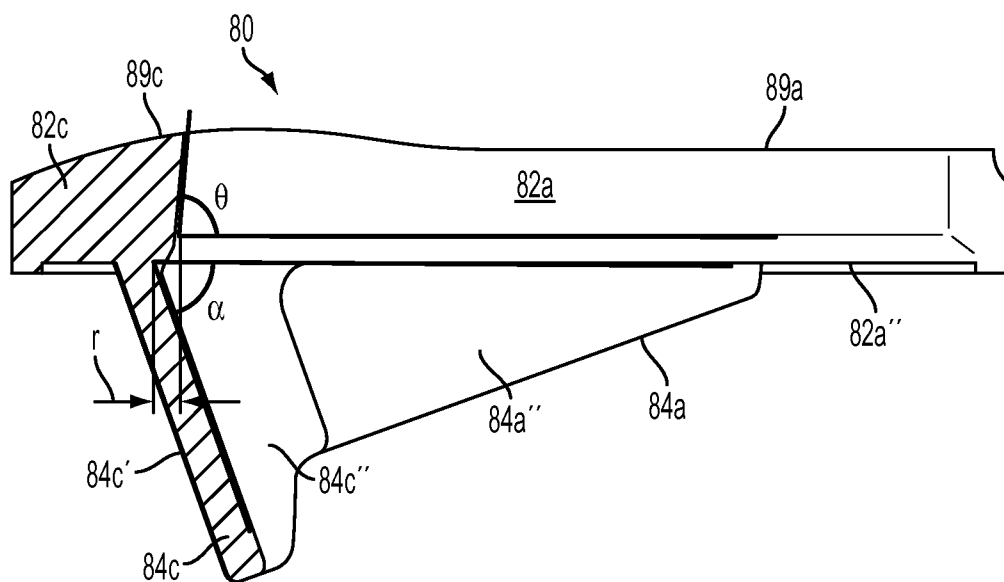


FIG. 35

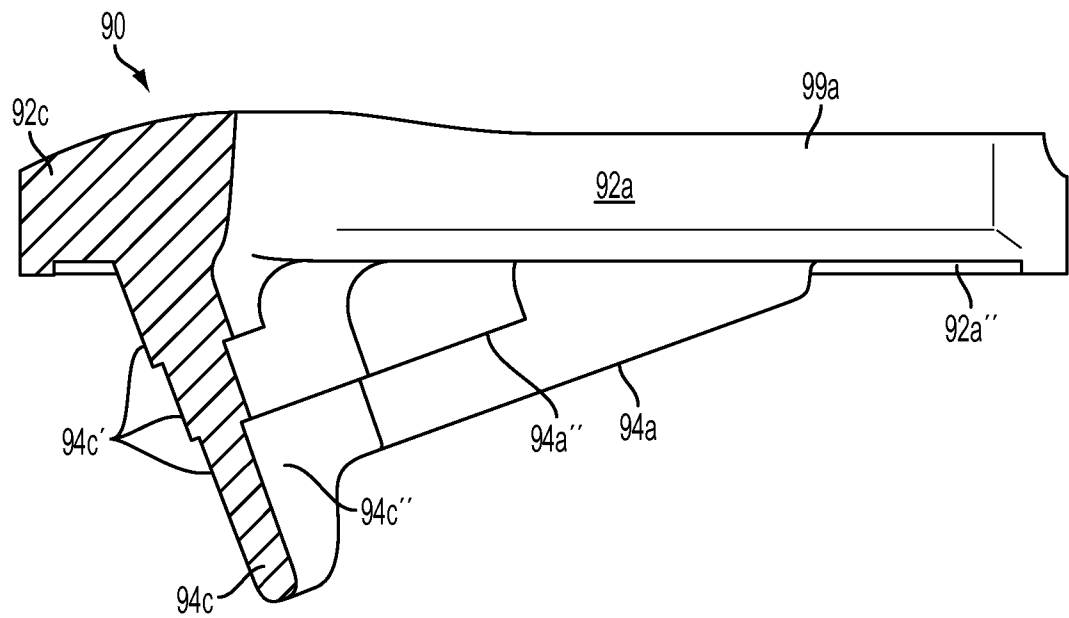


FIG. 36

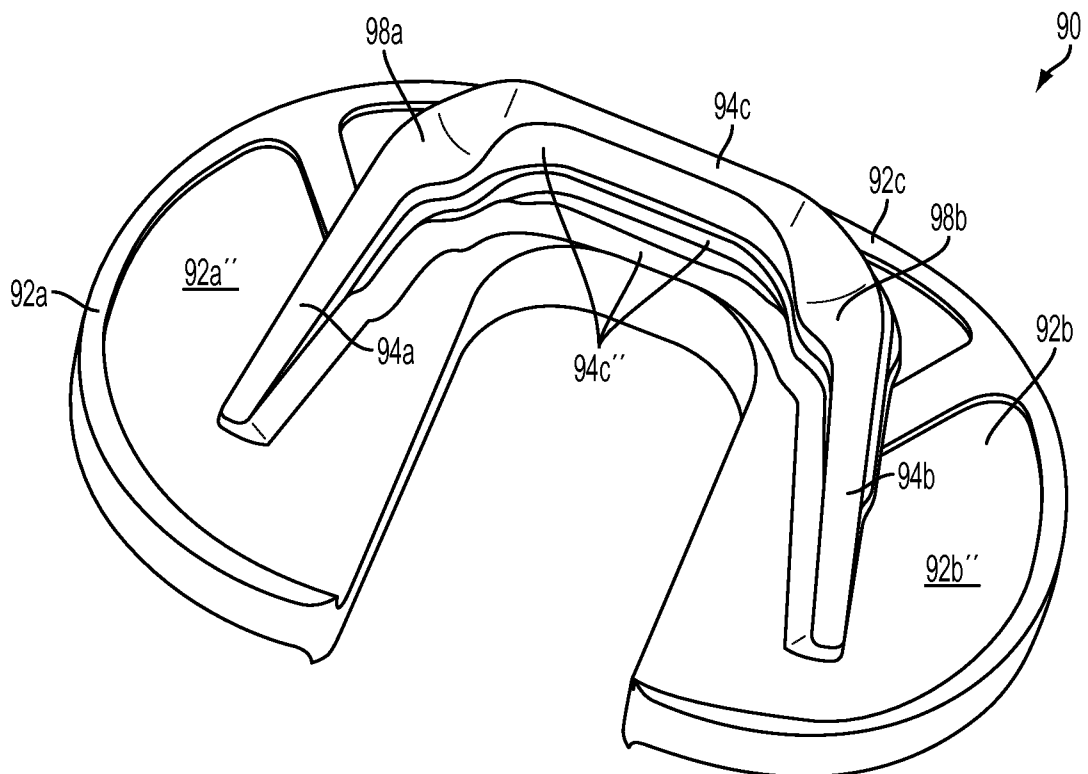


FIG. 37

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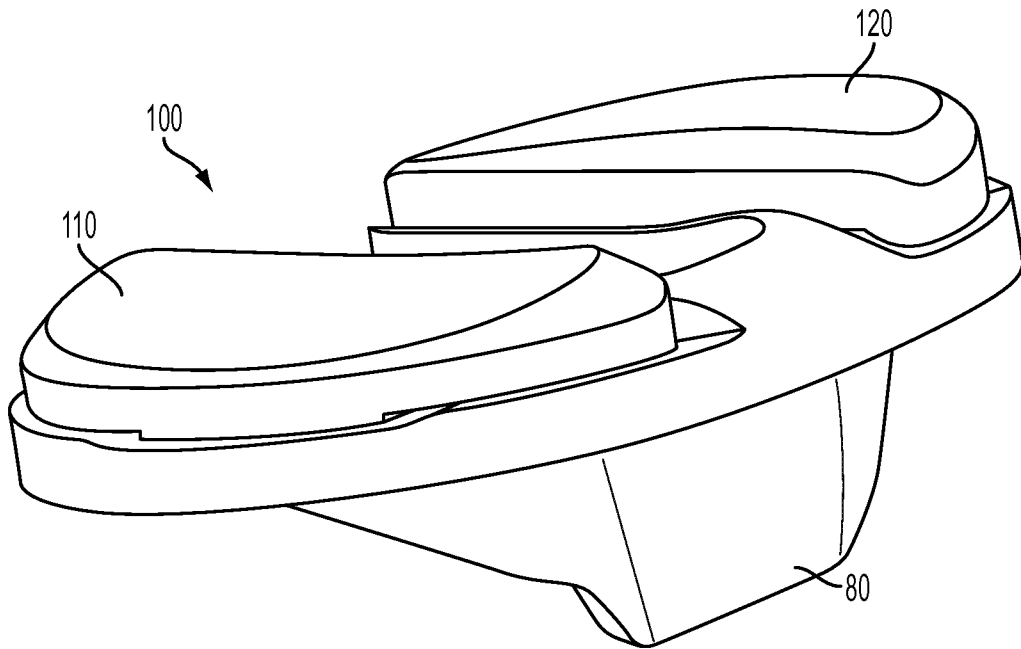


FIG. 38

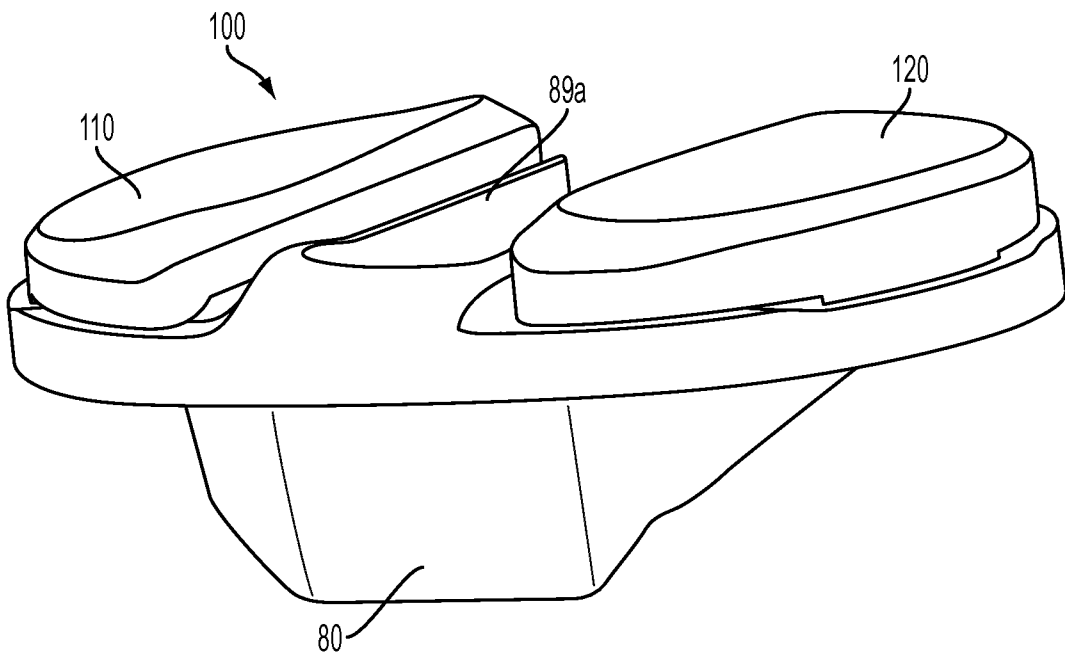


FIG. 39

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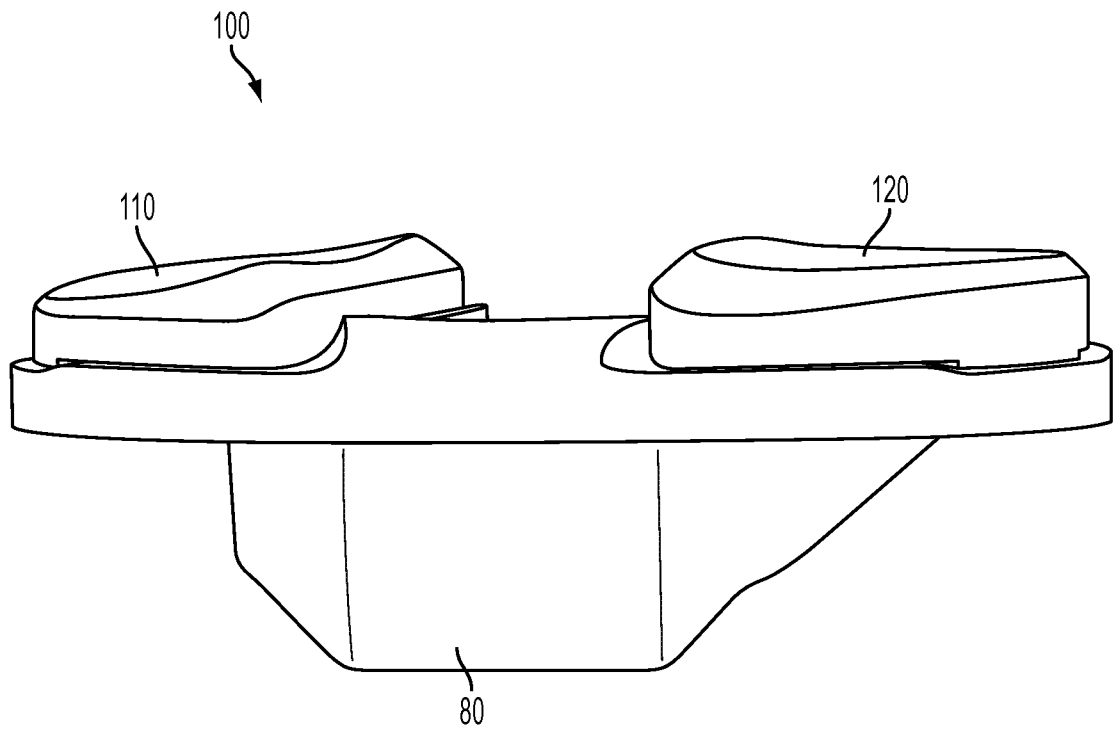


FIG. 40

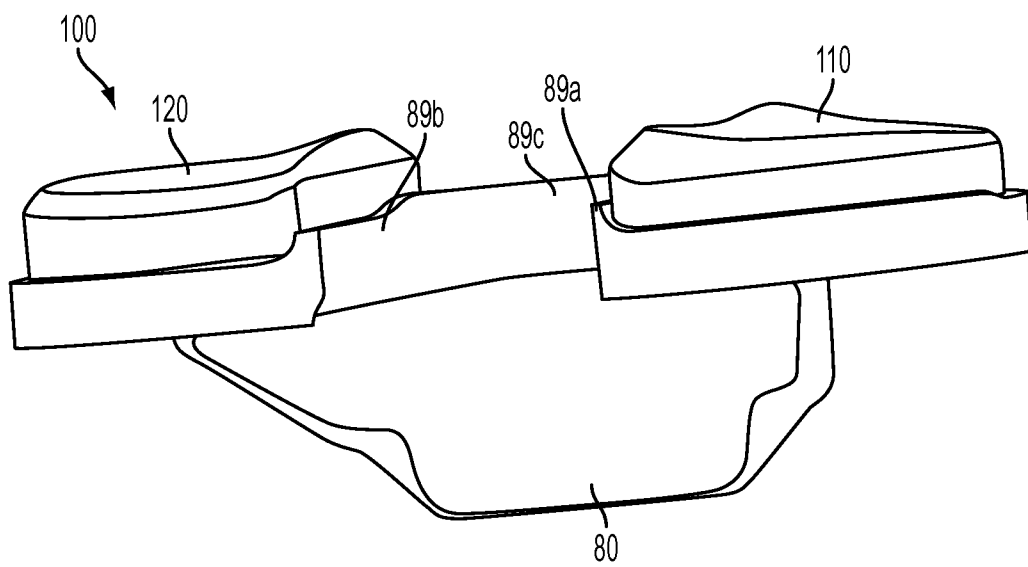


FIG. 41

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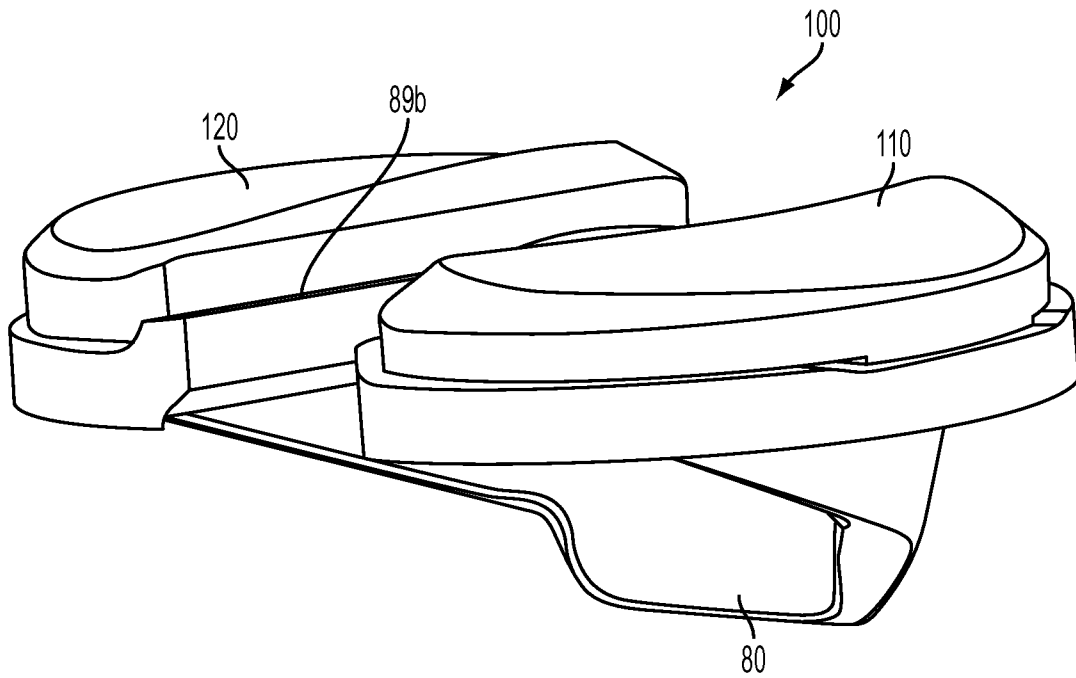


FIG. 42

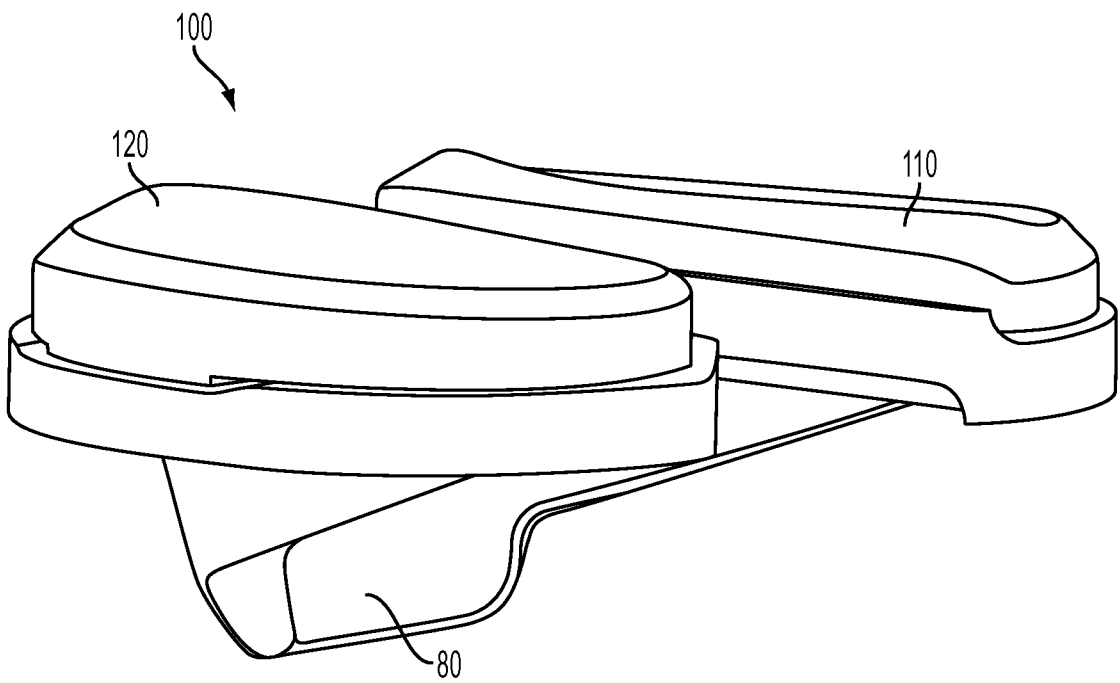


FIG. 43

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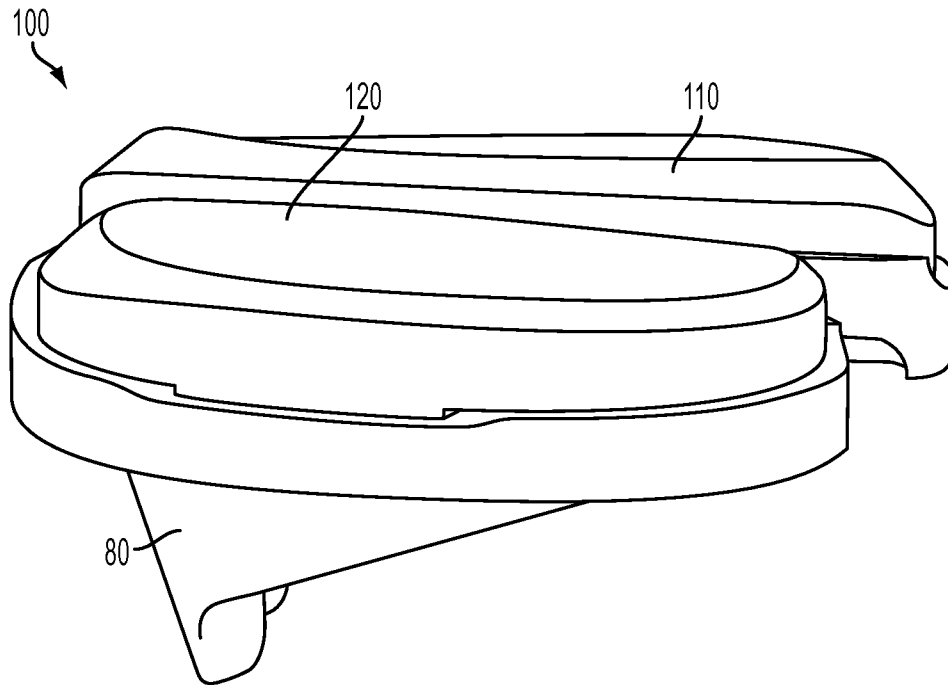


FIG. 44

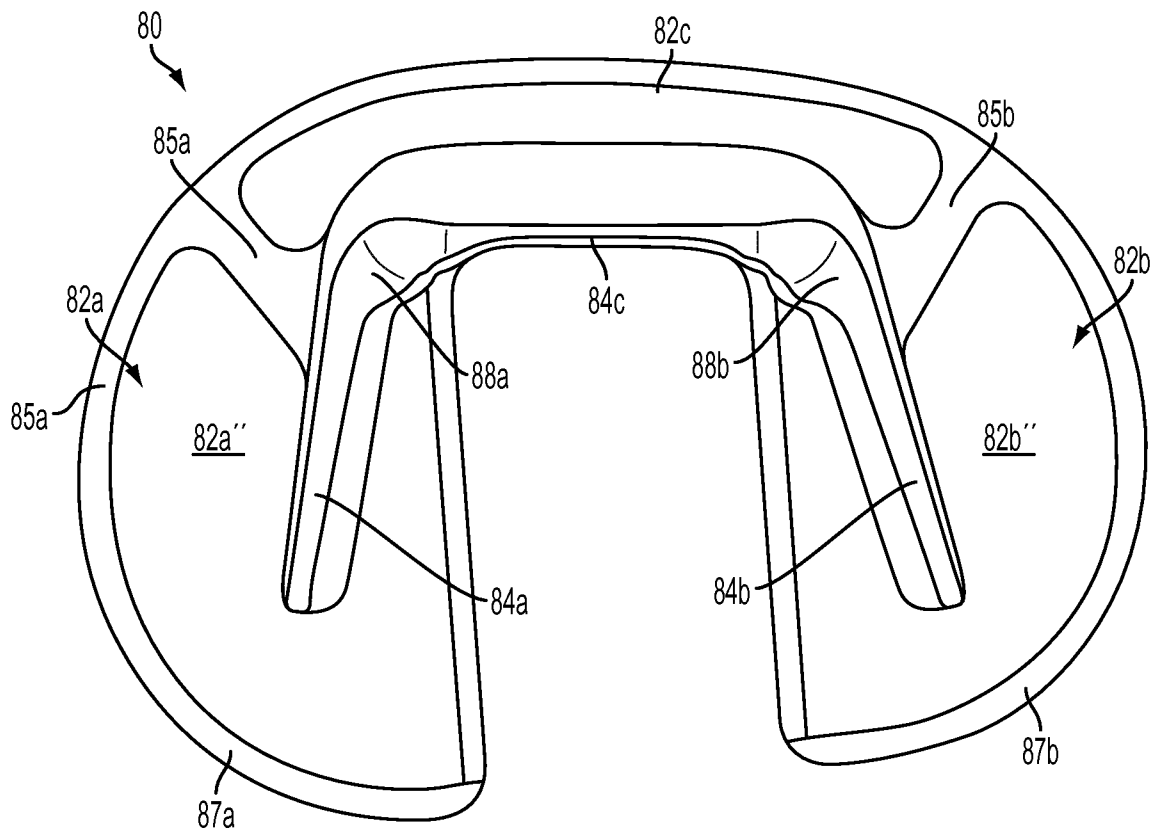


FIG. 45

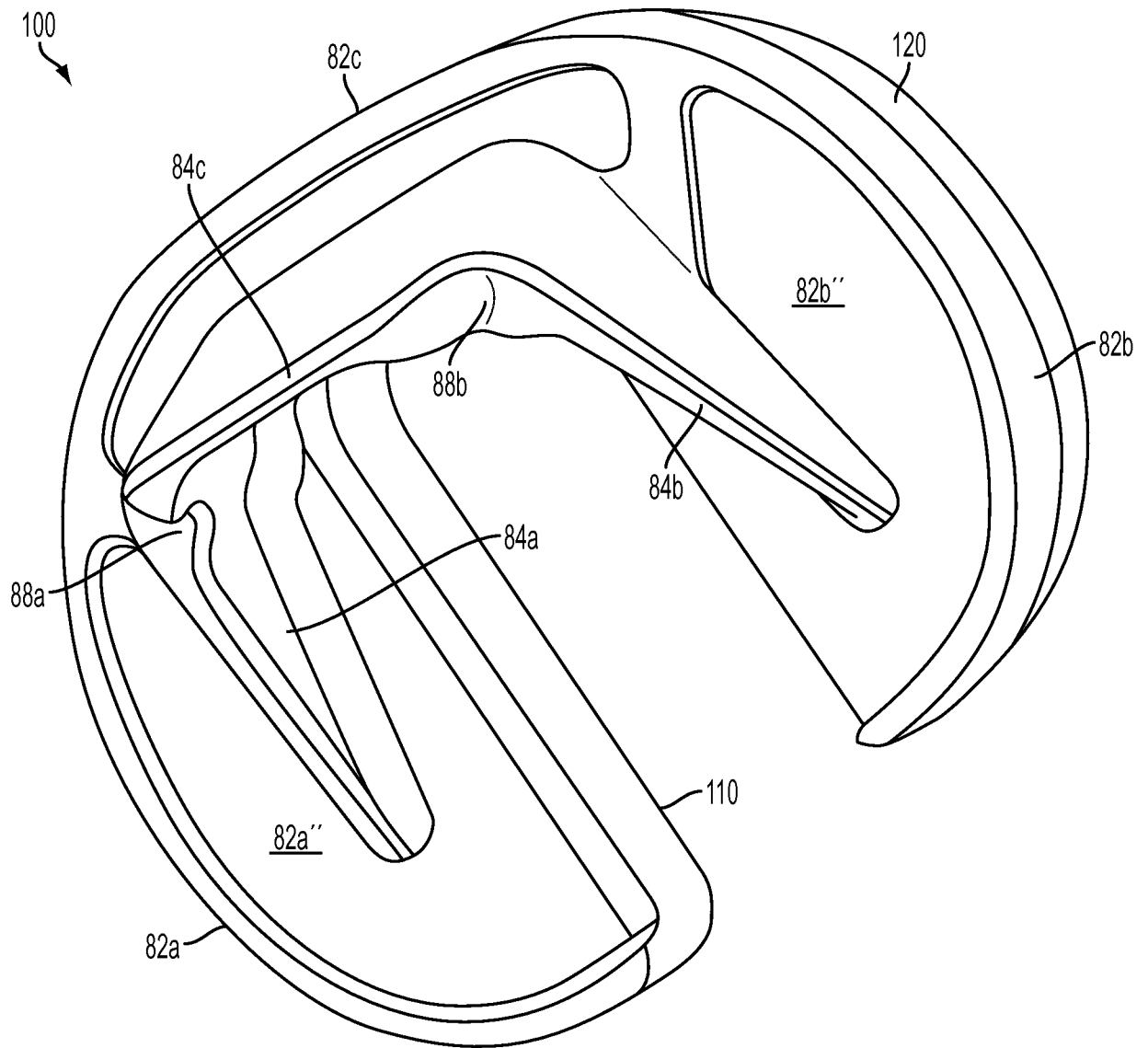


FIG. 46

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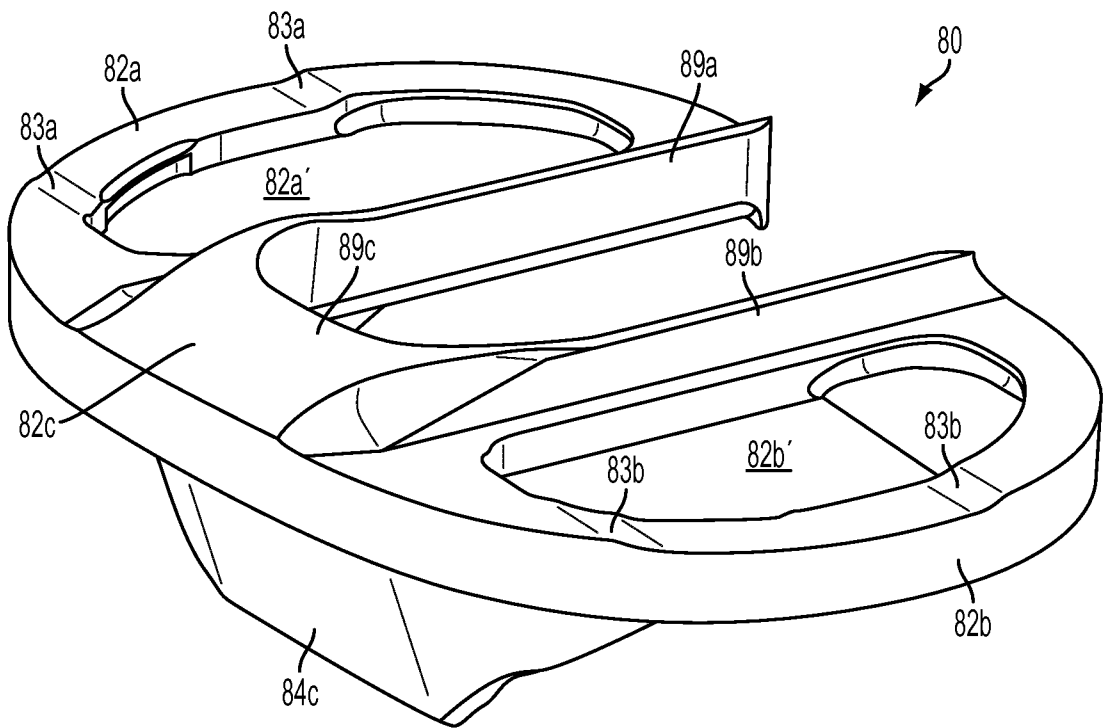


FIG. 47

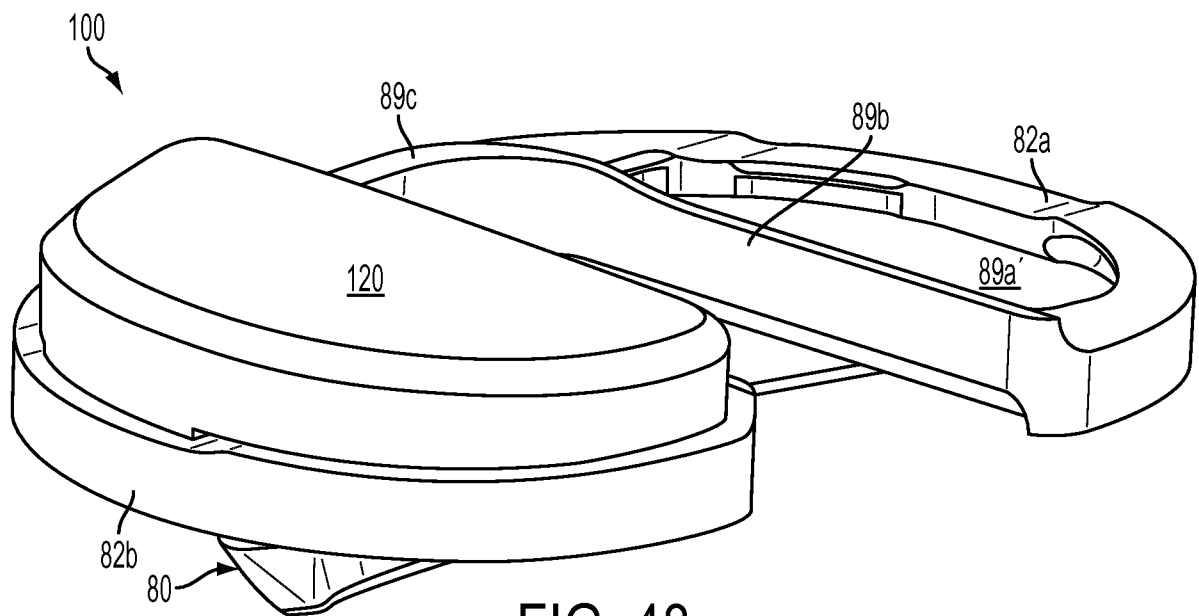


FIG. 48

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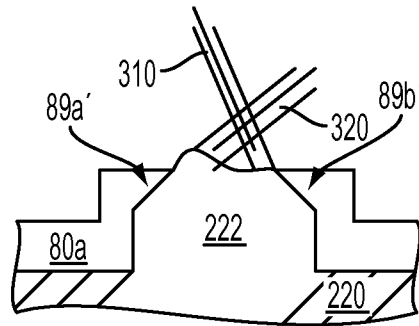


FIG. 49

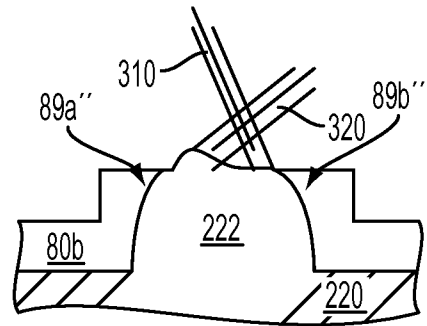


FIG. 50

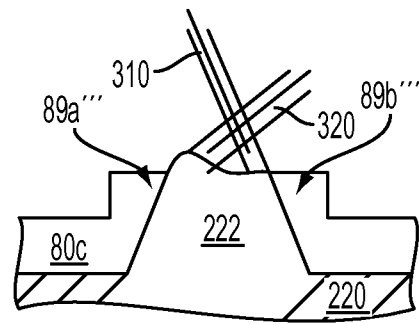


FIG. 51

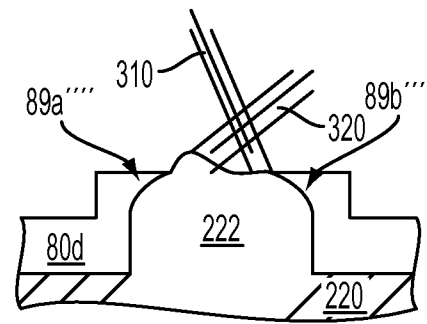


FIG. 52

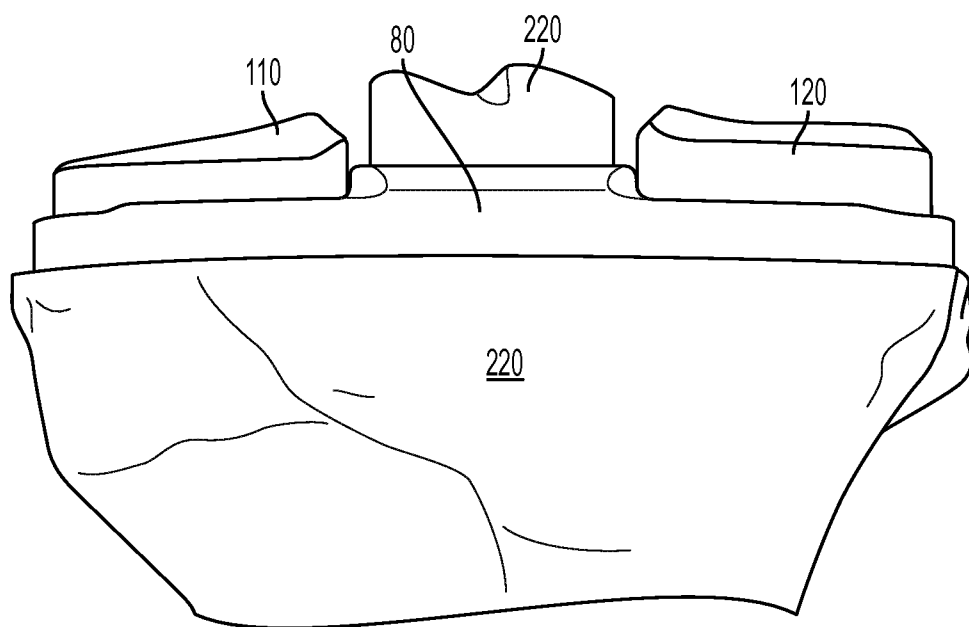


FIG. 53

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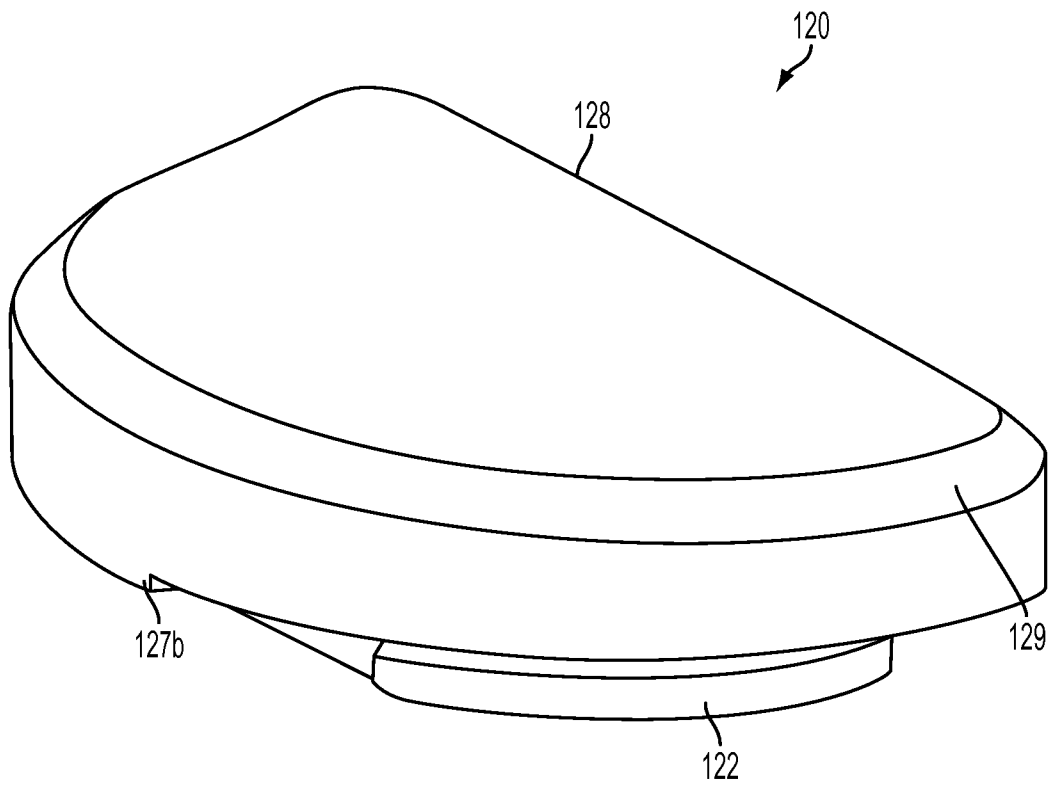


FIG. 54

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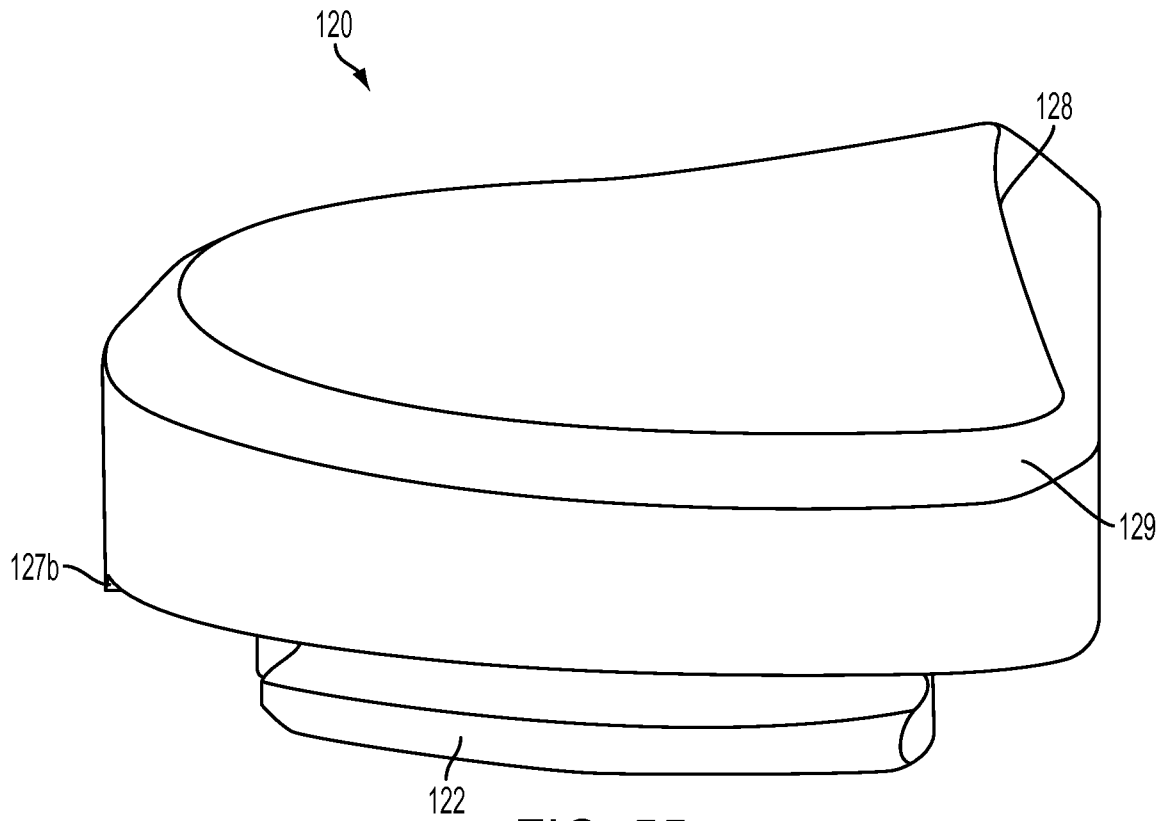


FIG. 55

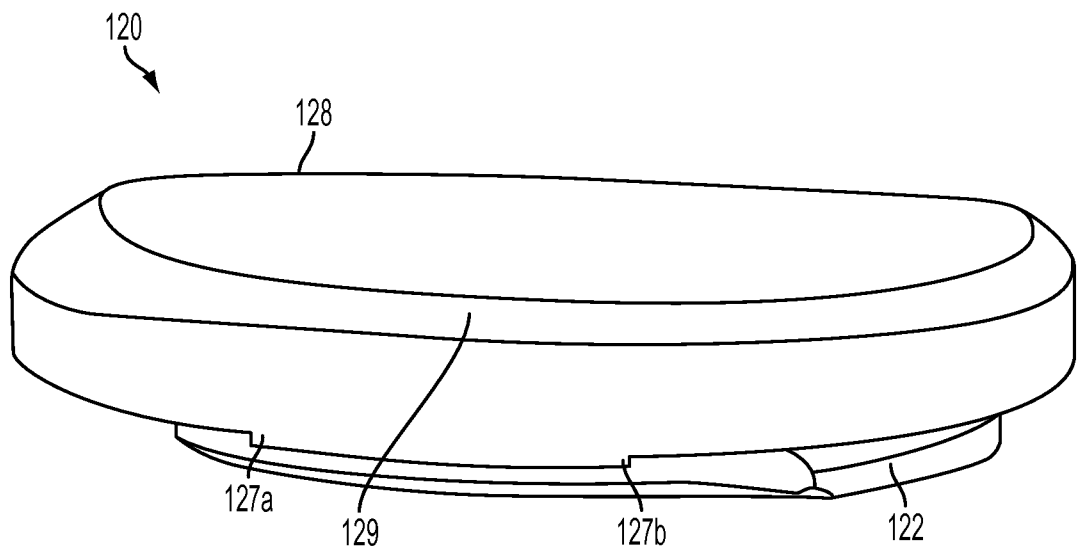


FIG. 56

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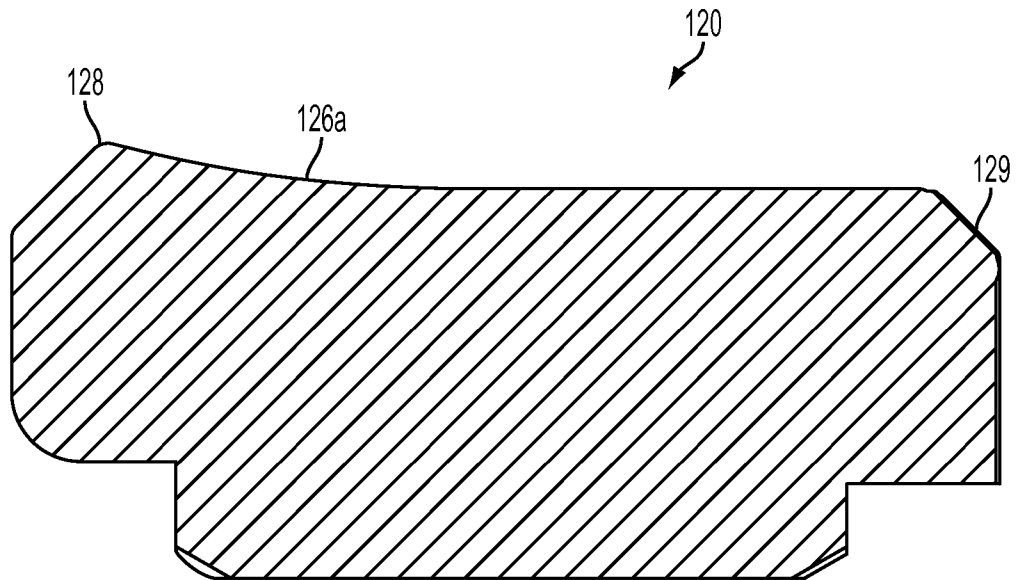


FIG. 57

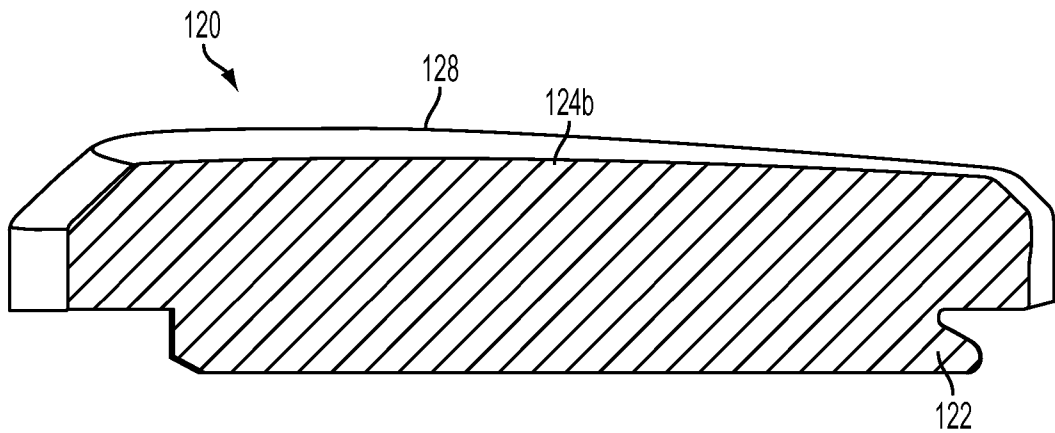


FIG. 58

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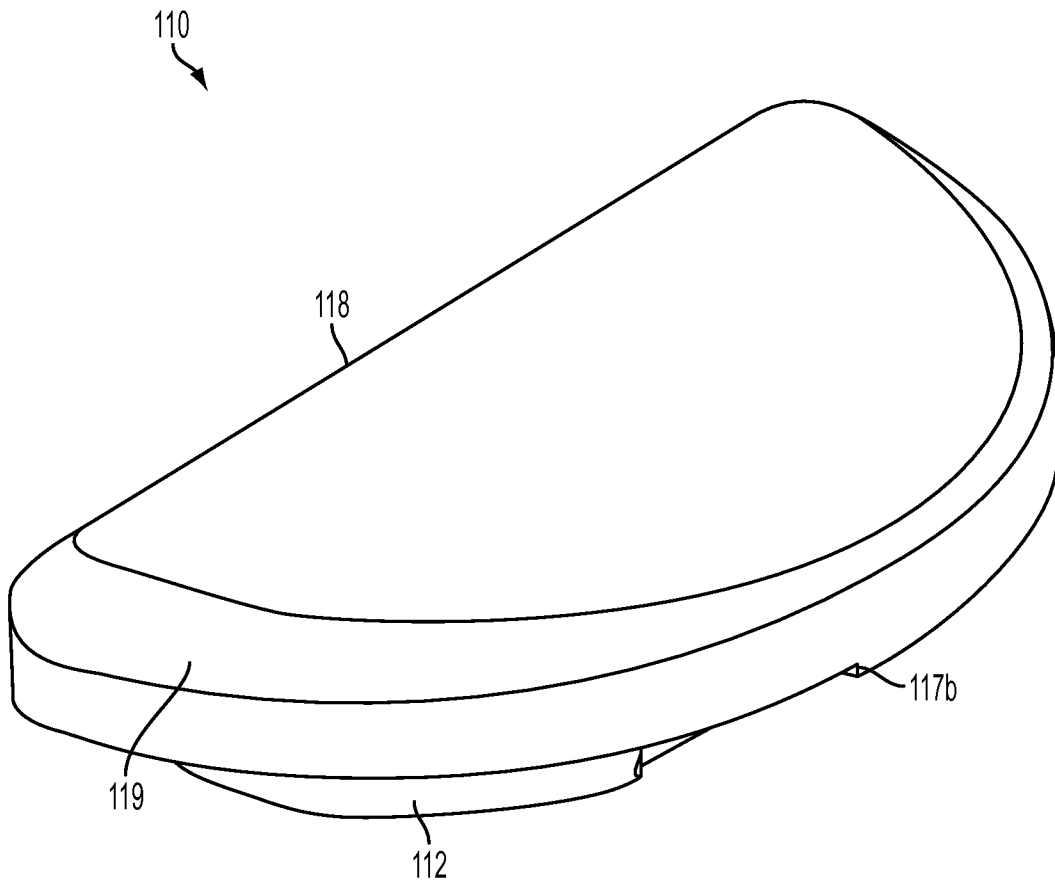


FIG. 59

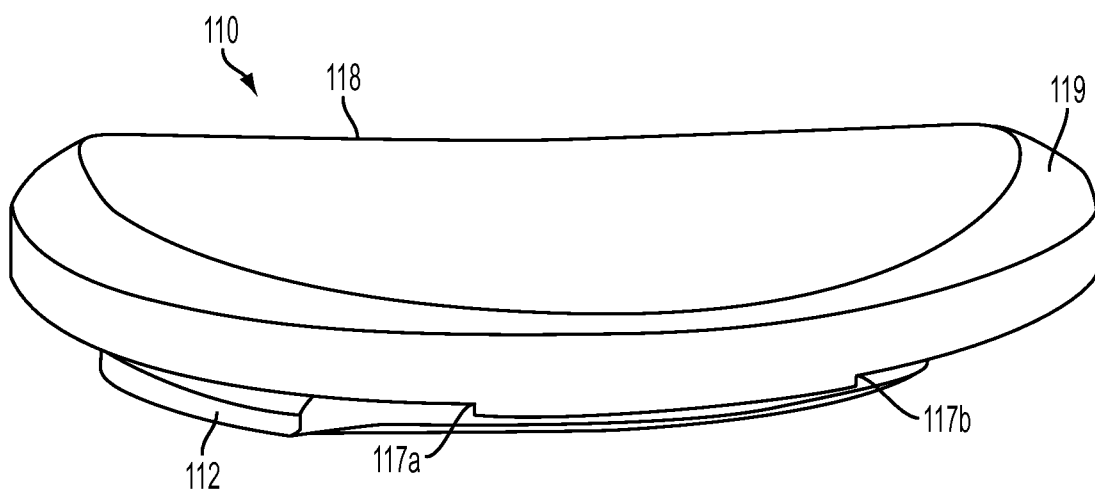


FIG. 60

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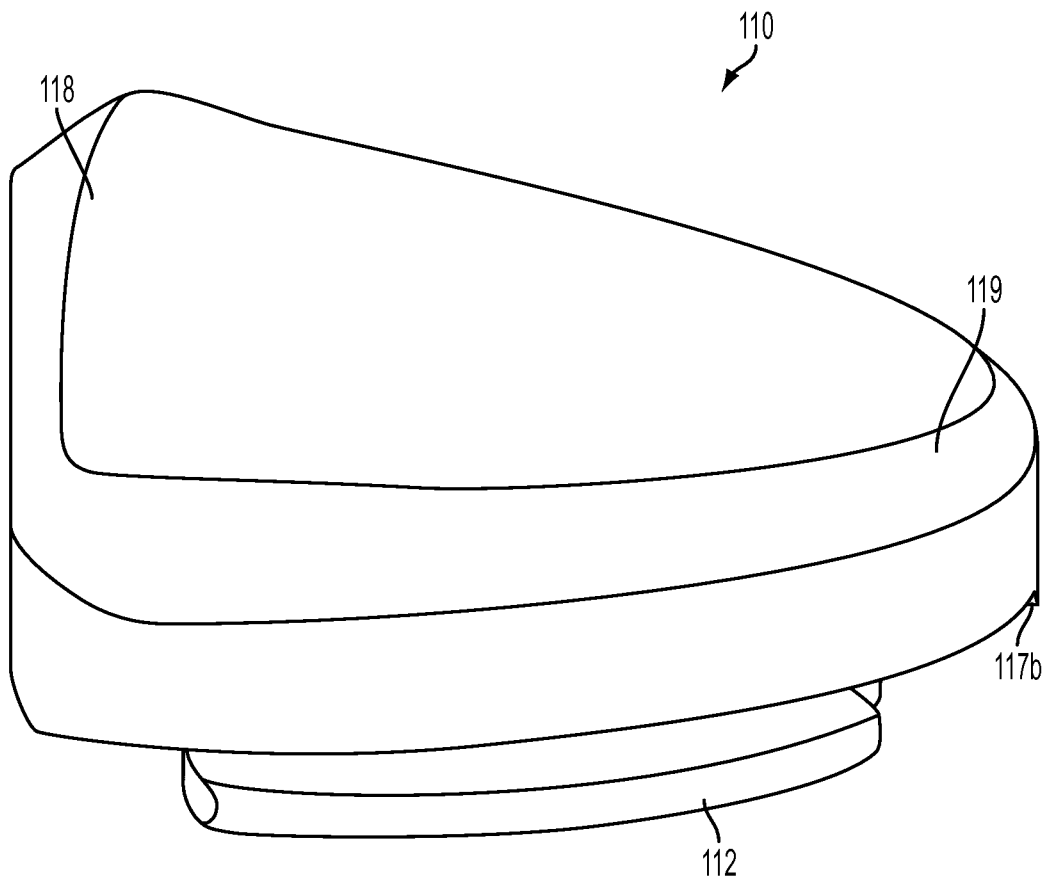


FIG. 61

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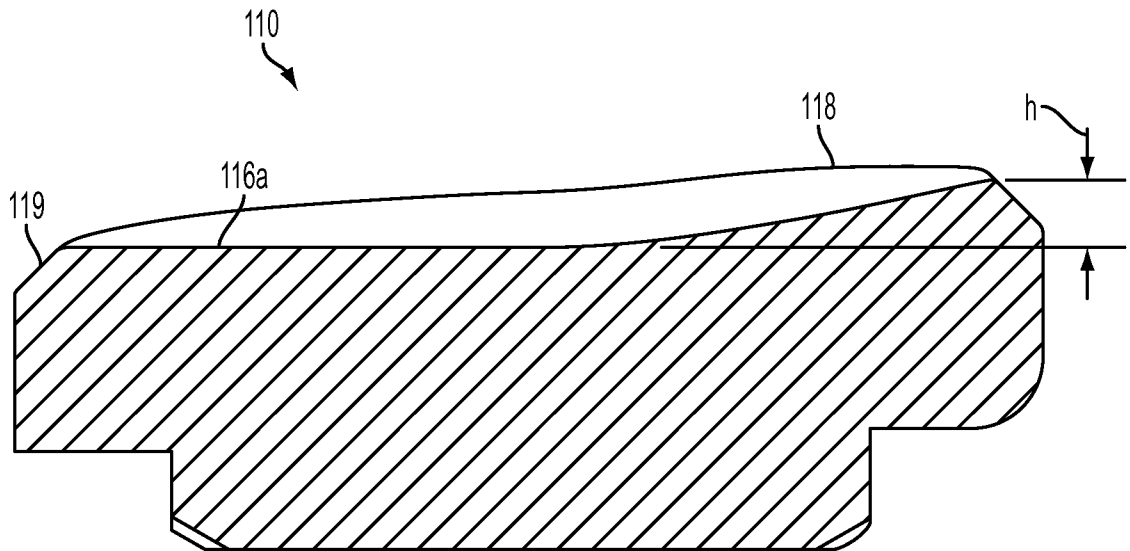


FIG. 62

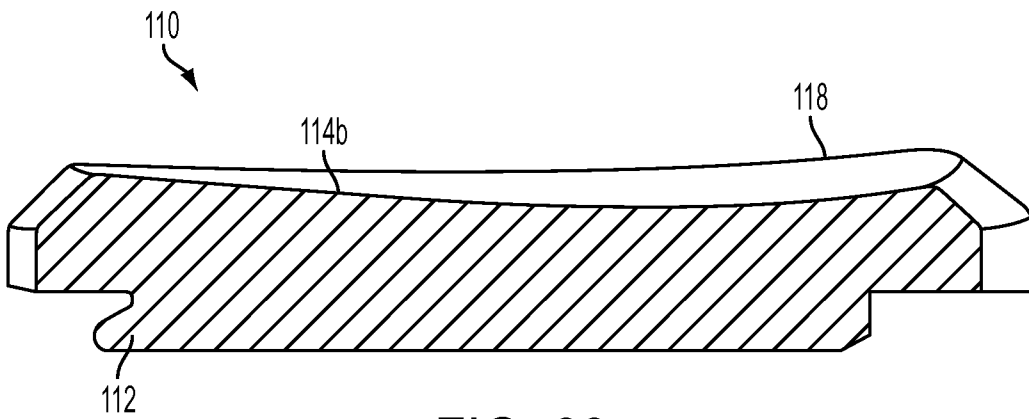


FIG. 63

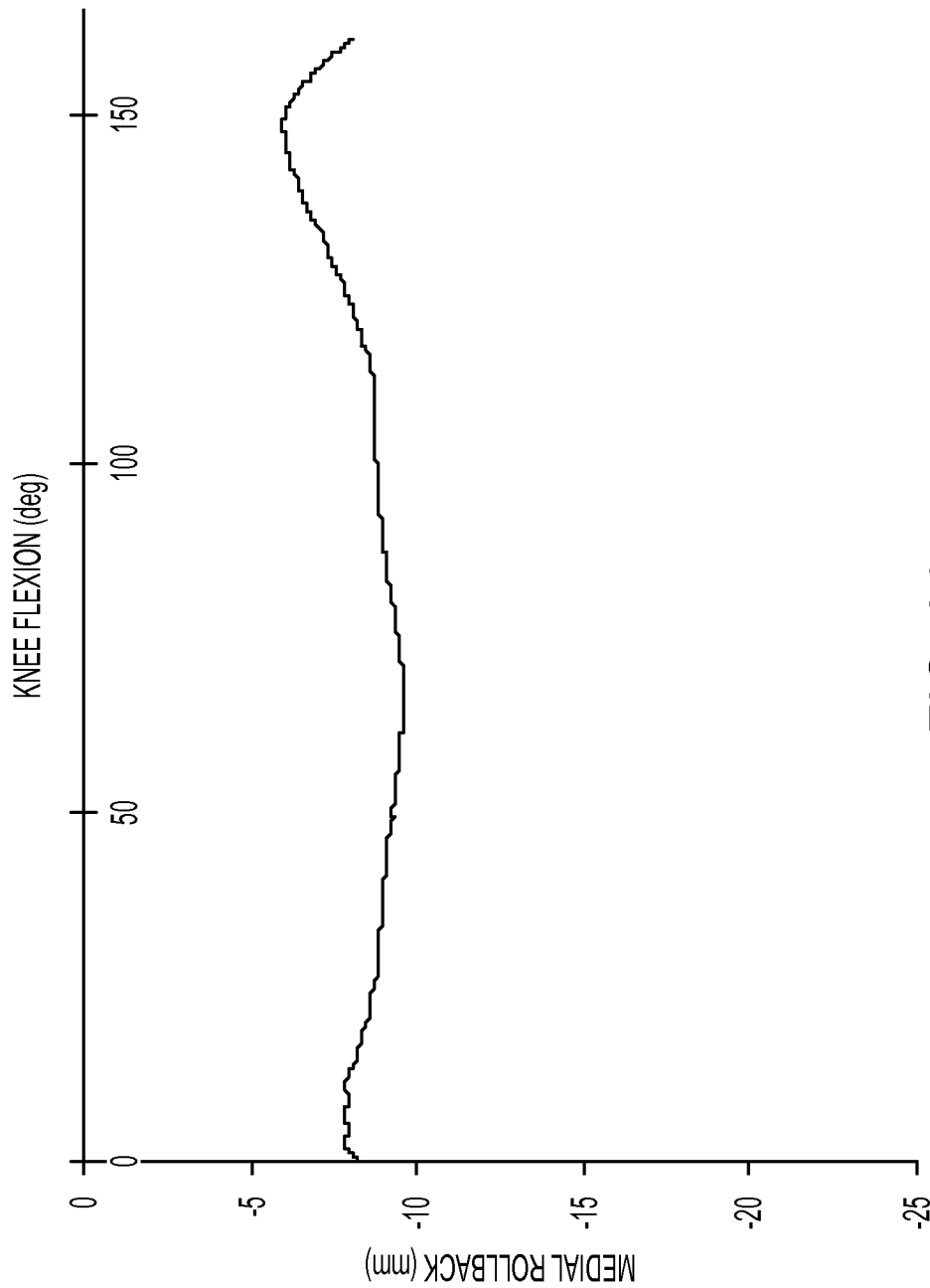


FIG. 64

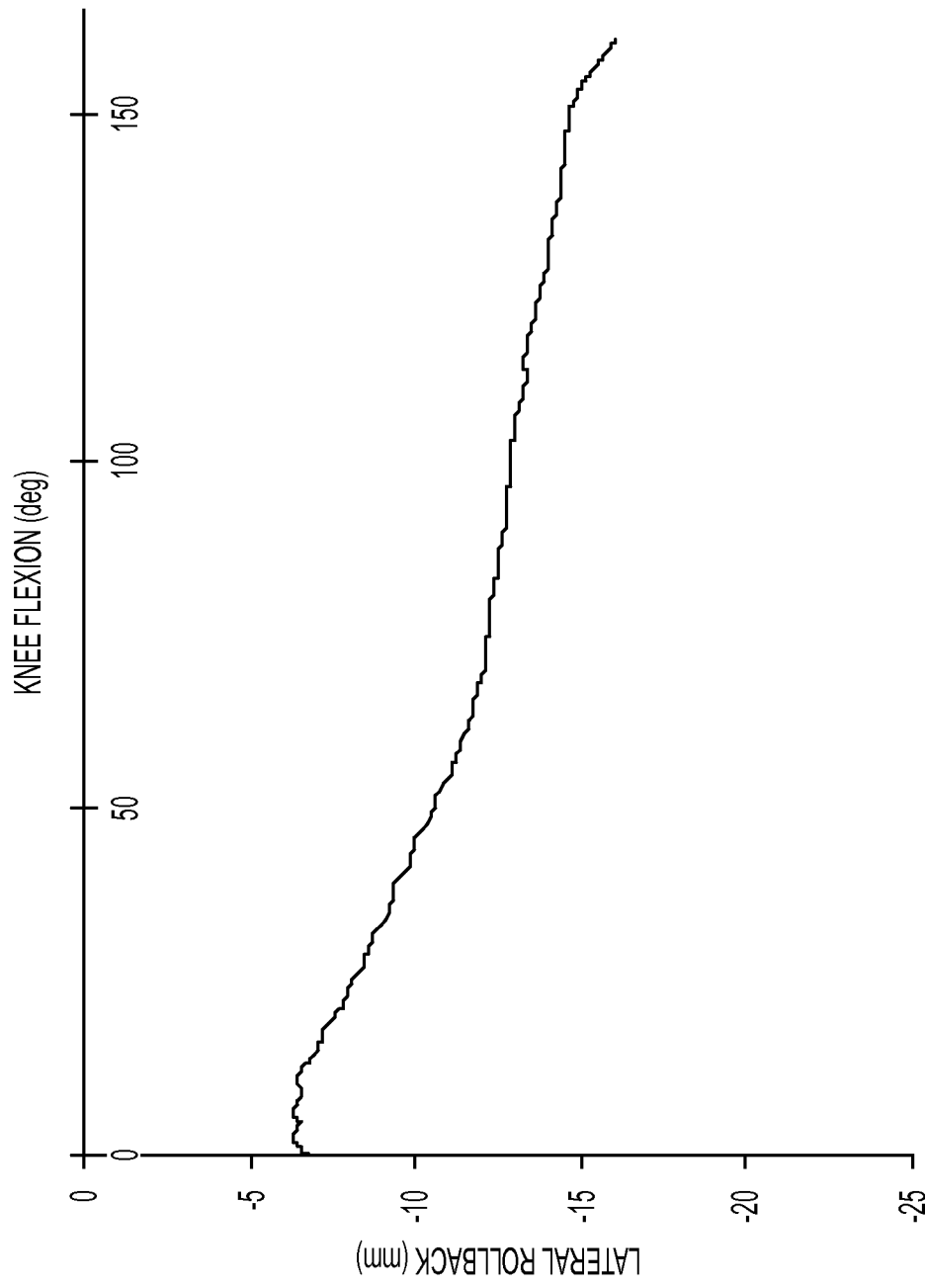


FIG. 65

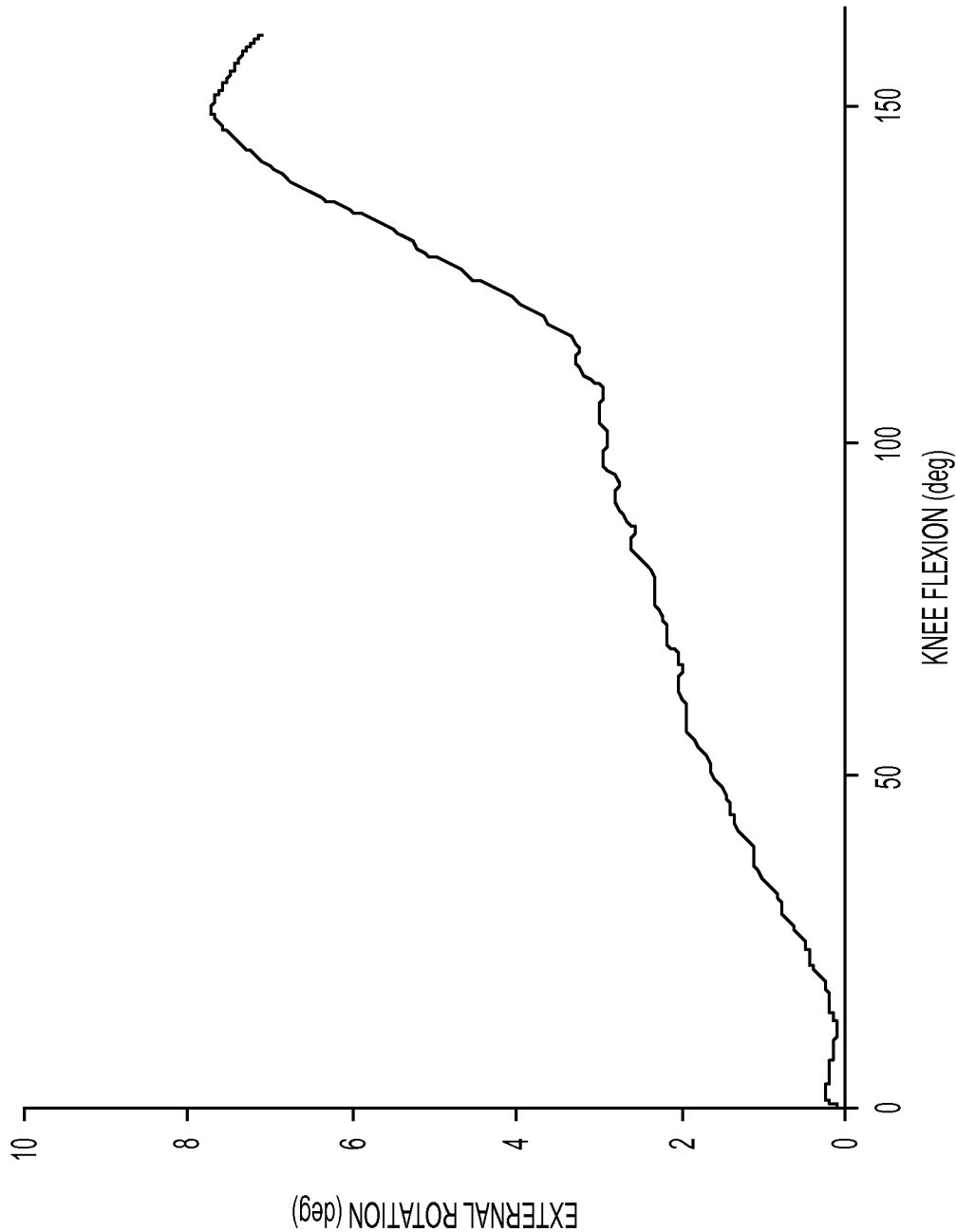


FIG. 66

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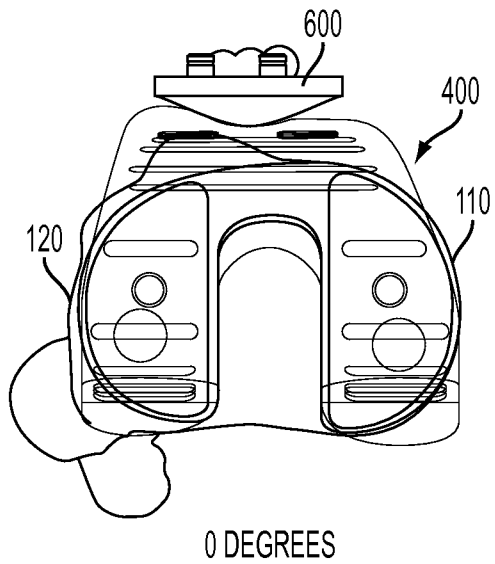


FIG. 67A

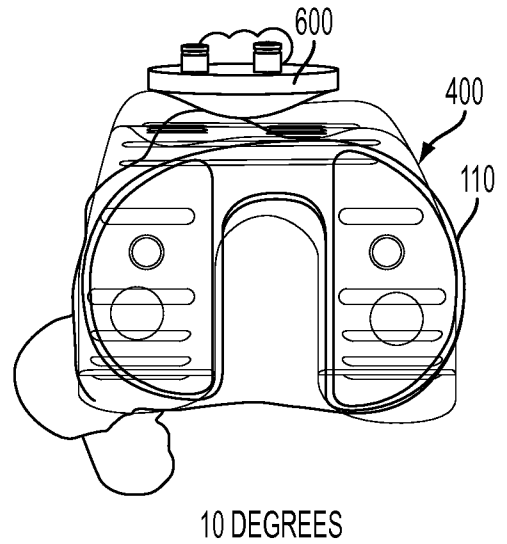


FIG. 67B

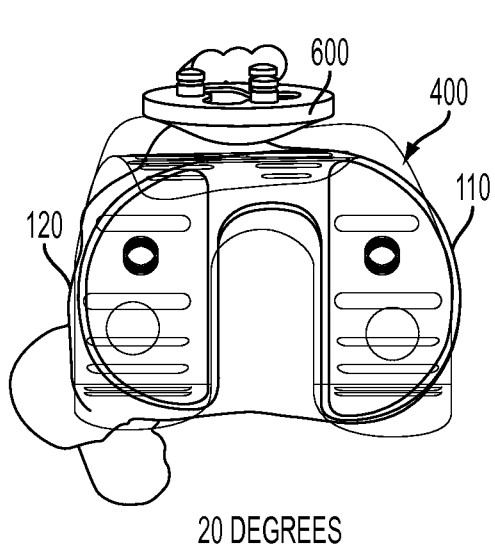


FIG. 67C

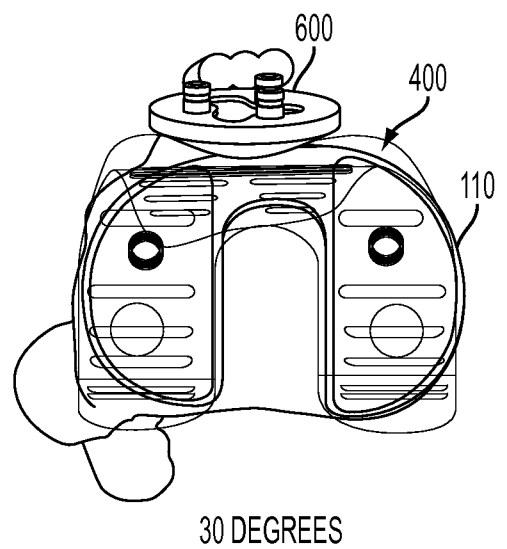


FIG. 67D

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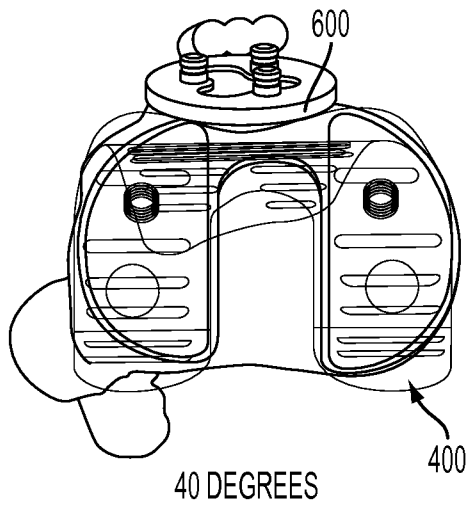


FIG. 67E

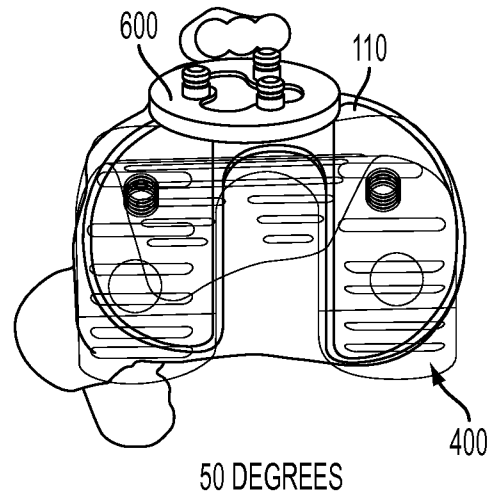


FIG. 67F

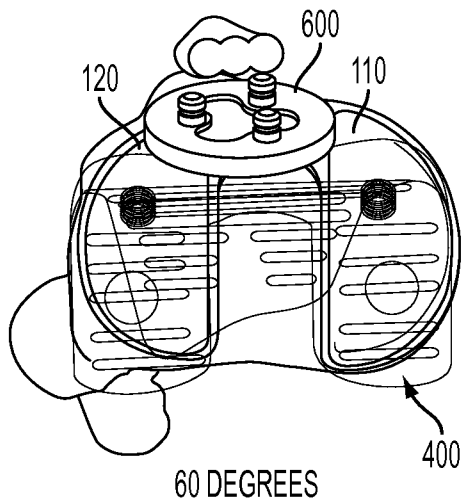


FIG. 67G

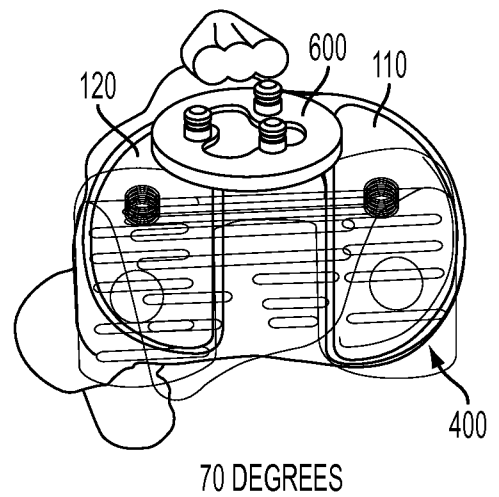
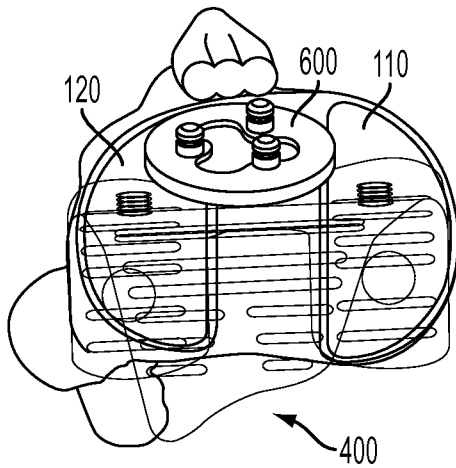


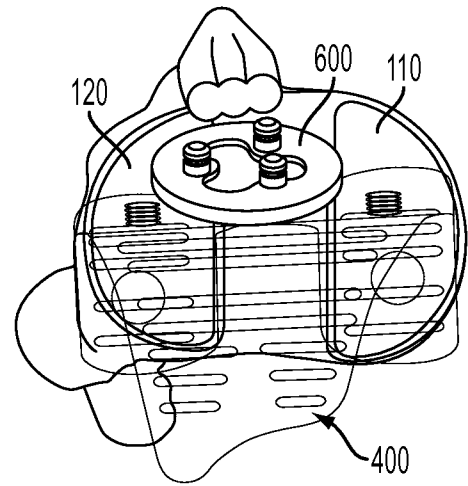
FIG. 67H

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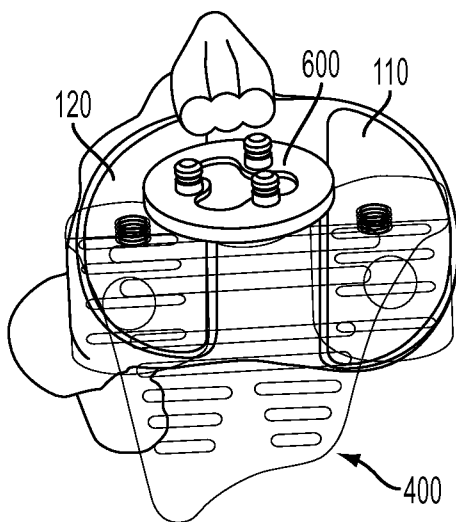
80 DEGREES

FIG. 67I



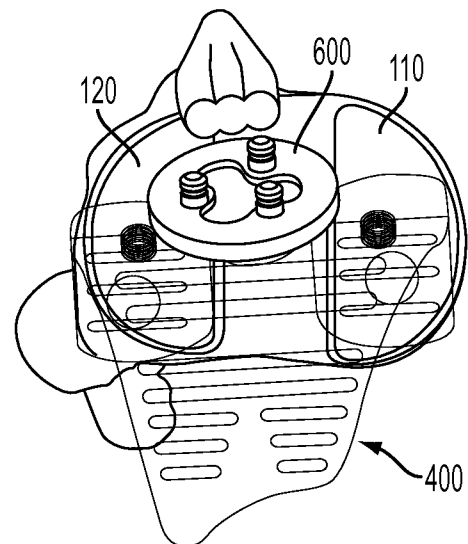
90 DEGREES

FIG. 67J



100 DEGREES

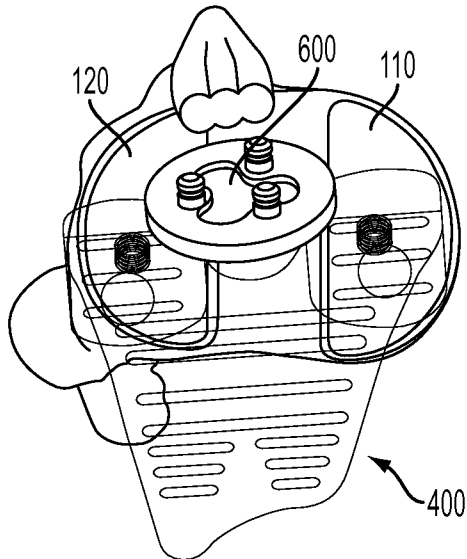
FIG. 67K



110 DEGREES

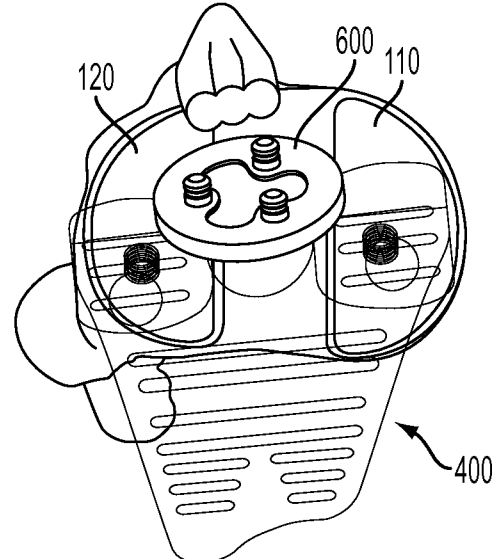
FIG. 67L

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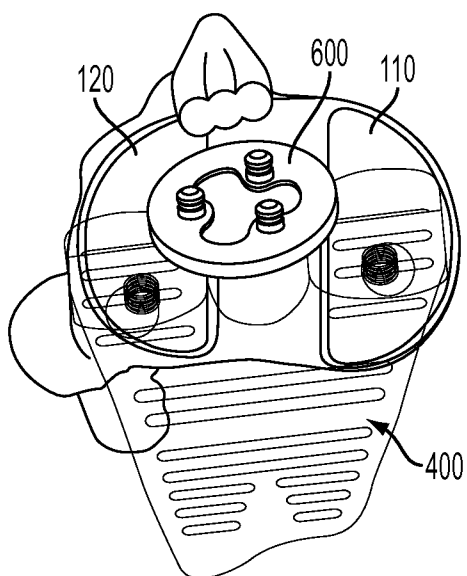
120 DEGREES

FIG. 67M



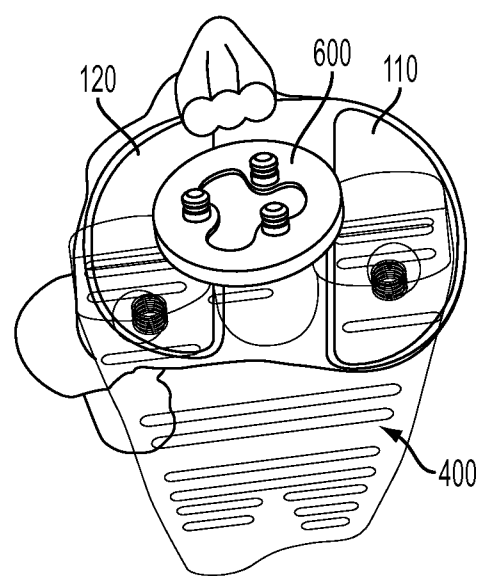
130 DEGREES

FIG. 67N



140 DEGREES

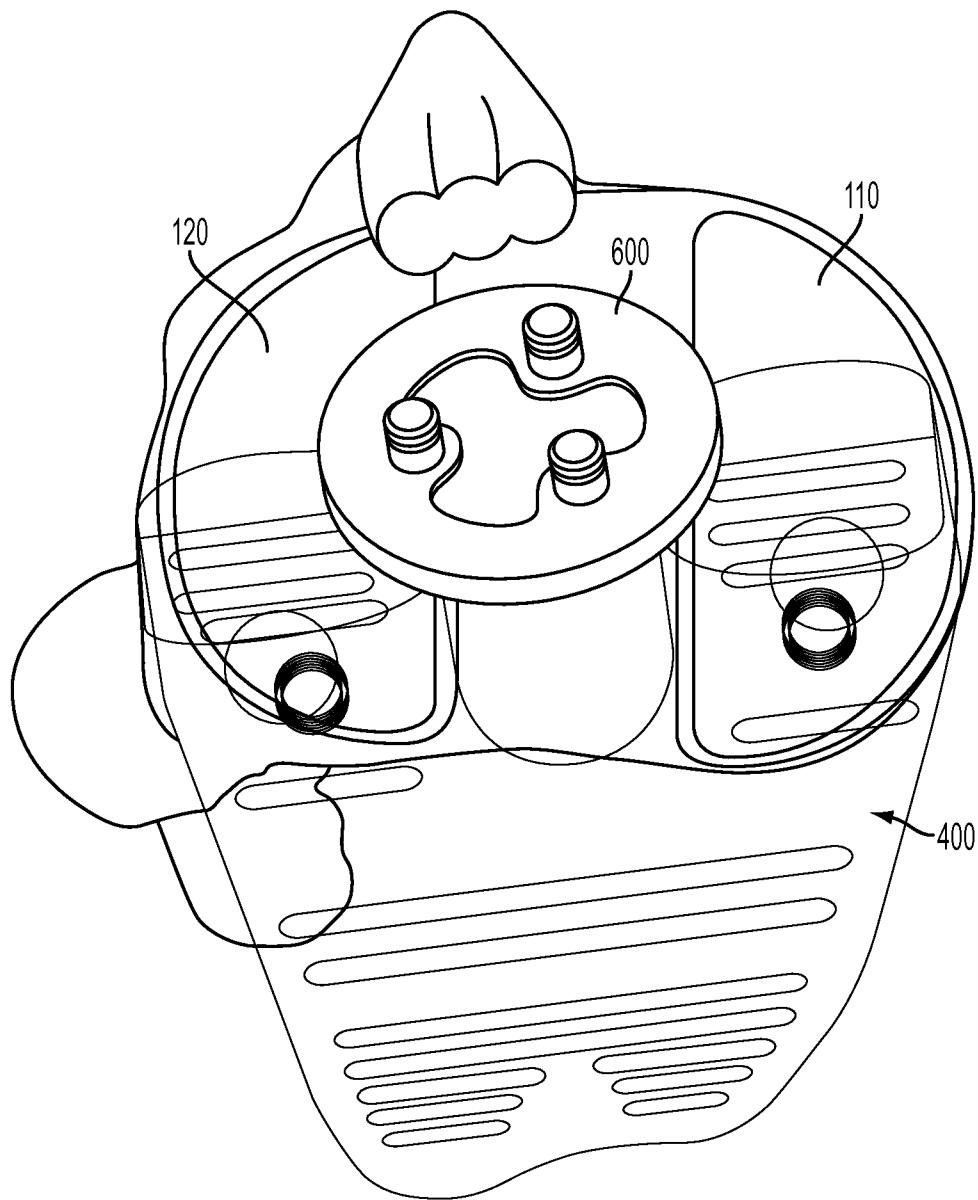
FIG. 67O



150 DEGREES

FIG. 67P

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160 DEGREES

FIG. 67Q

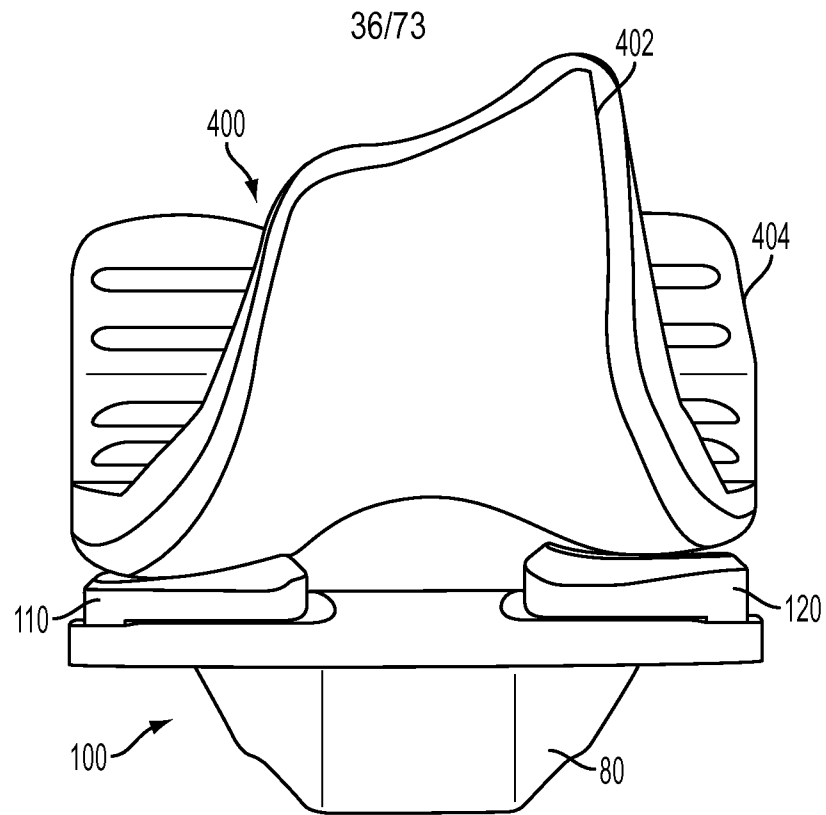


FIG. 68

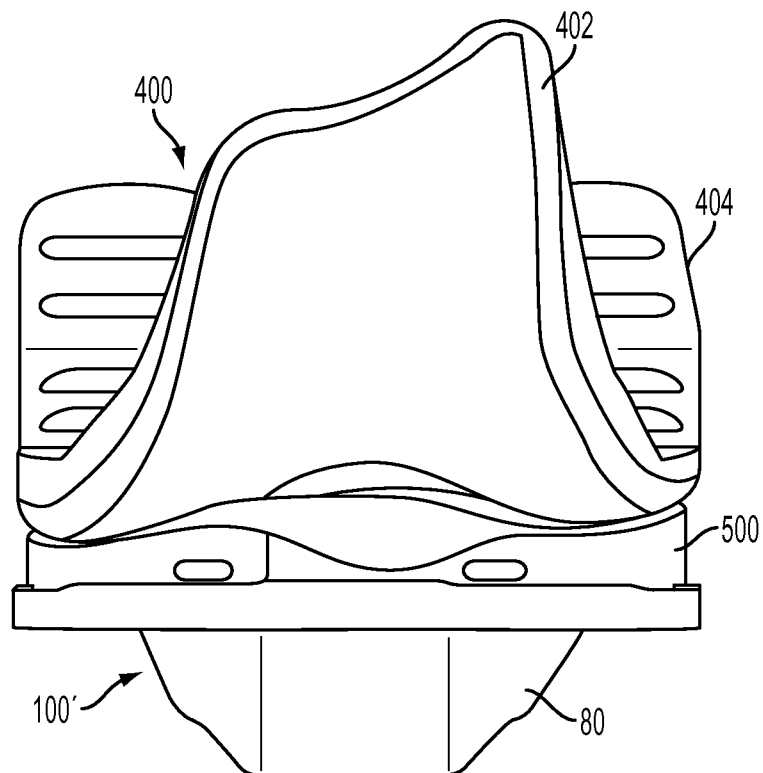


FIG. 69

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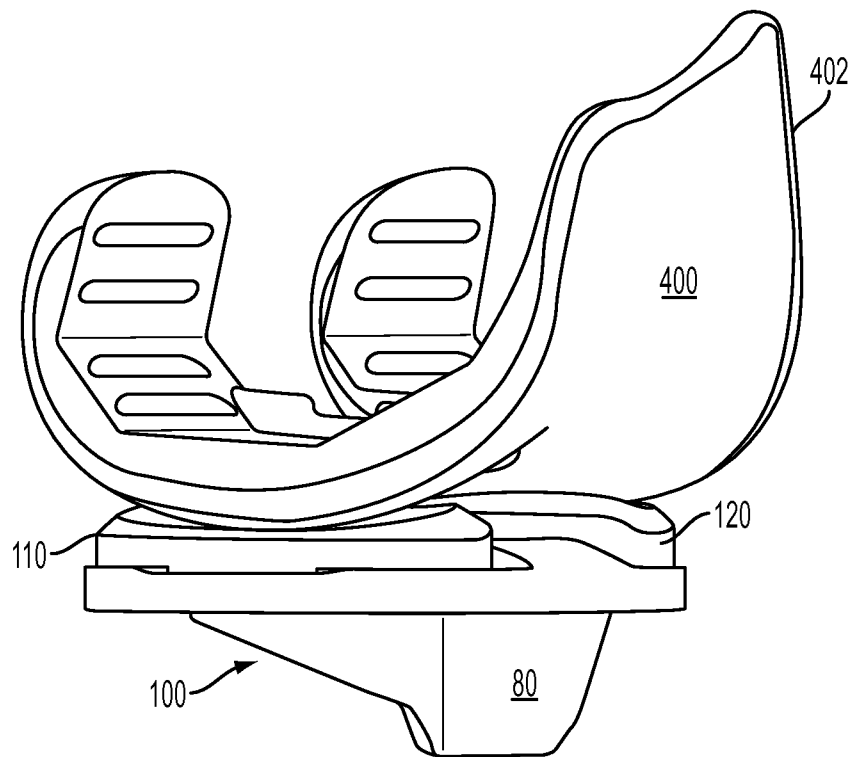


FIG. 70

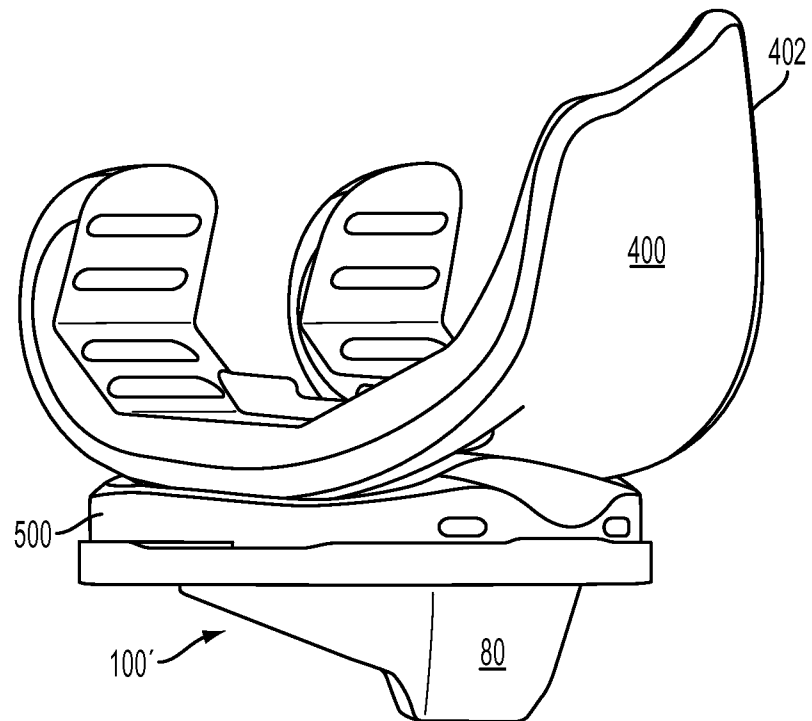


FIG. 71

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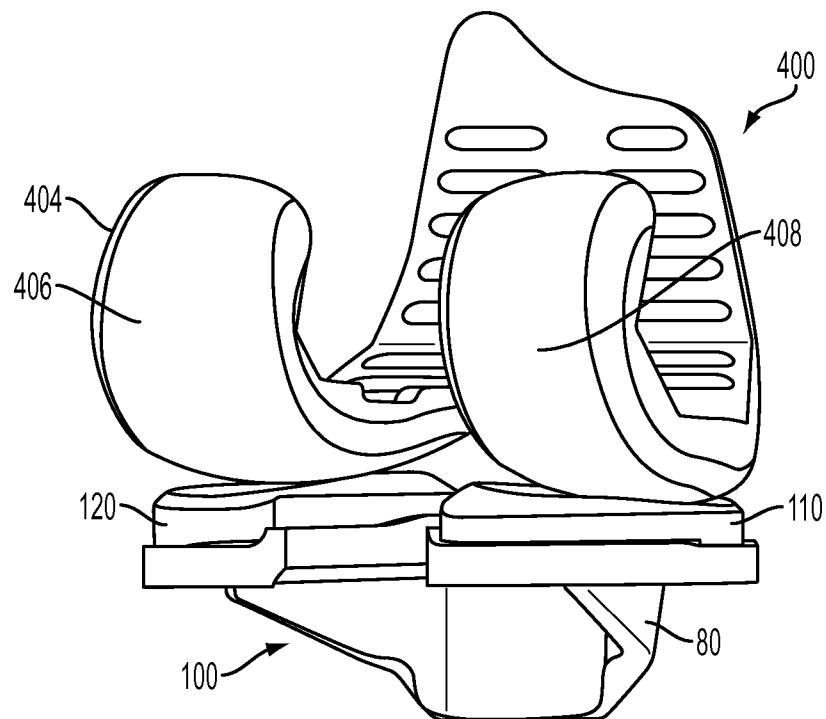


FIG. 72

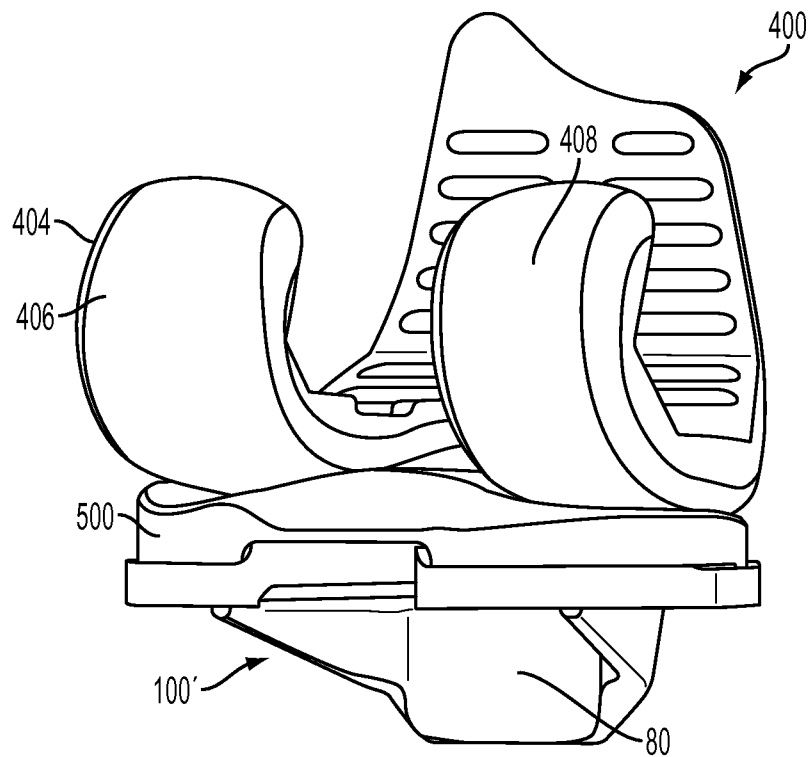


FIG. 73

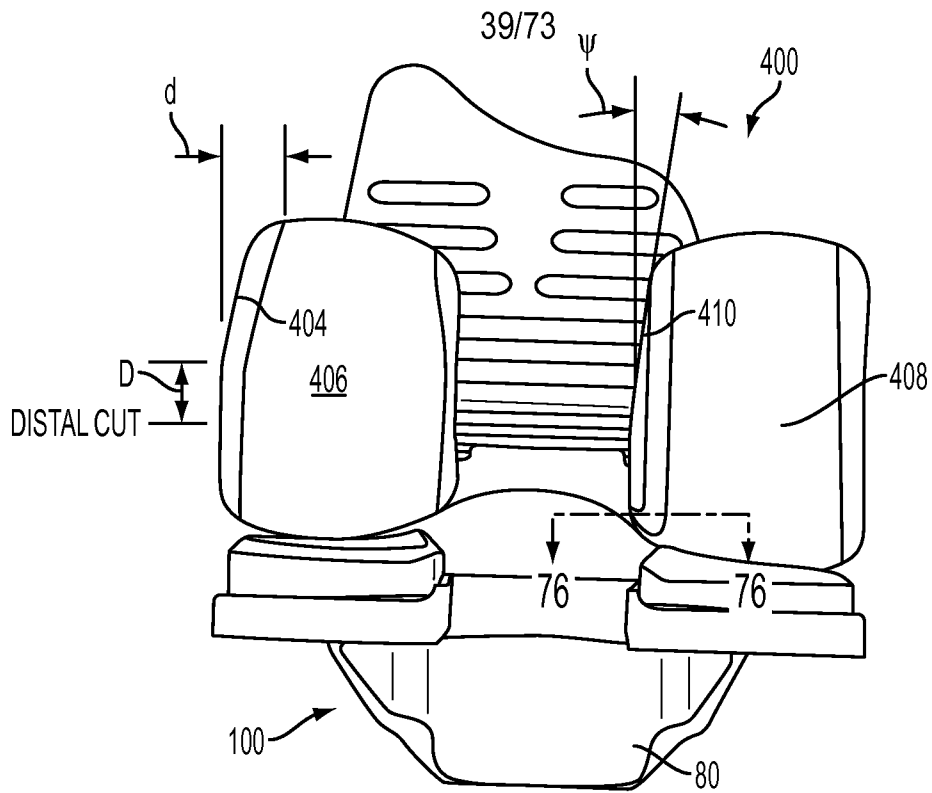


FIG. 74

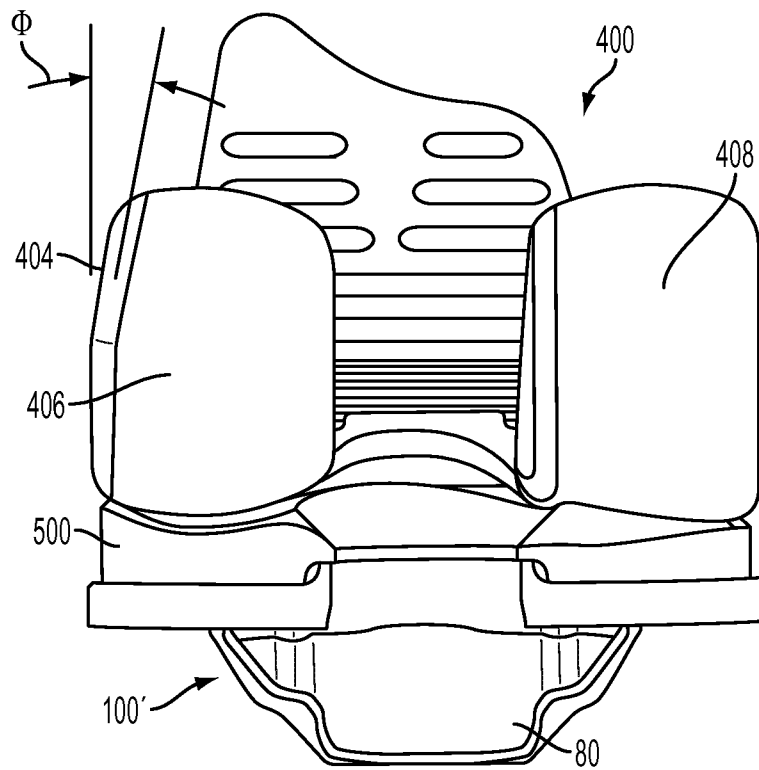


FIG. 75

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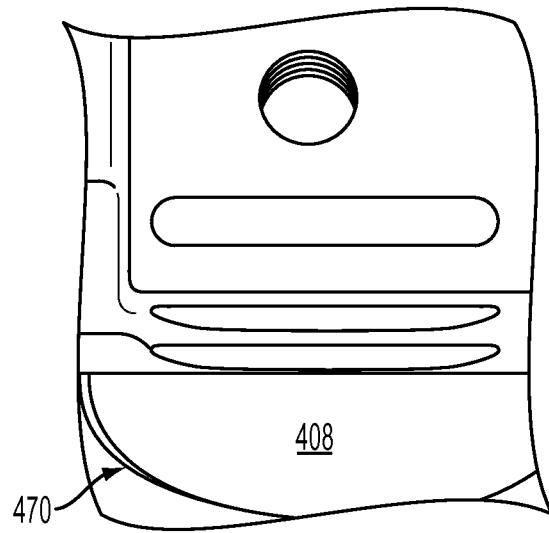


FIG. 76

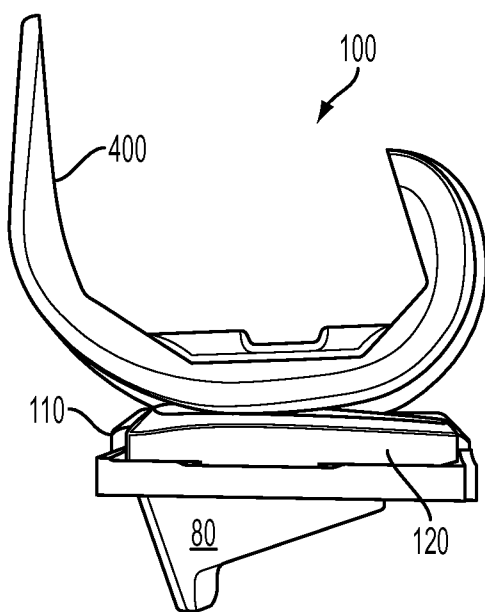


FIG. 77

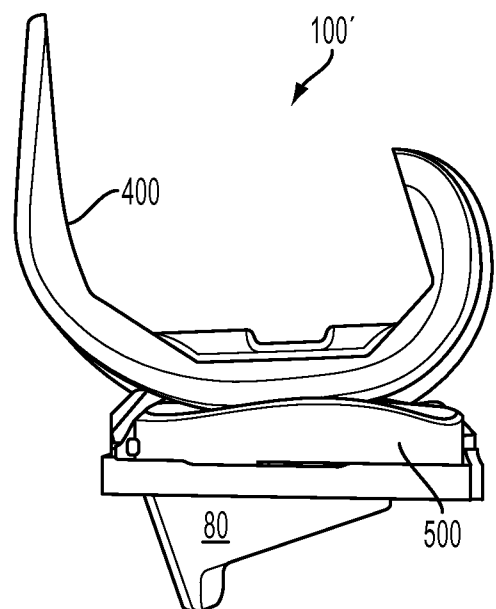


FIG. 78

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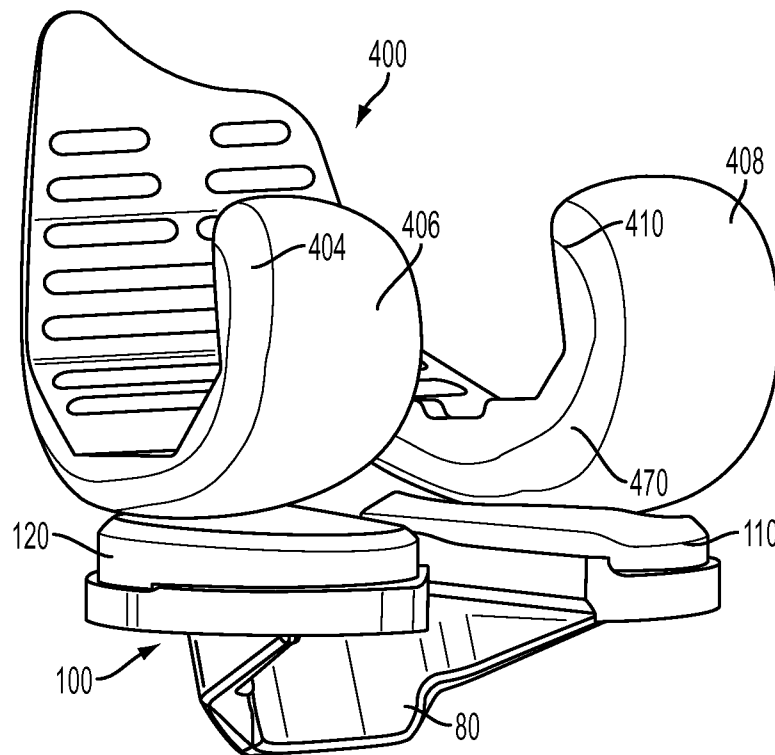


FIG. 79

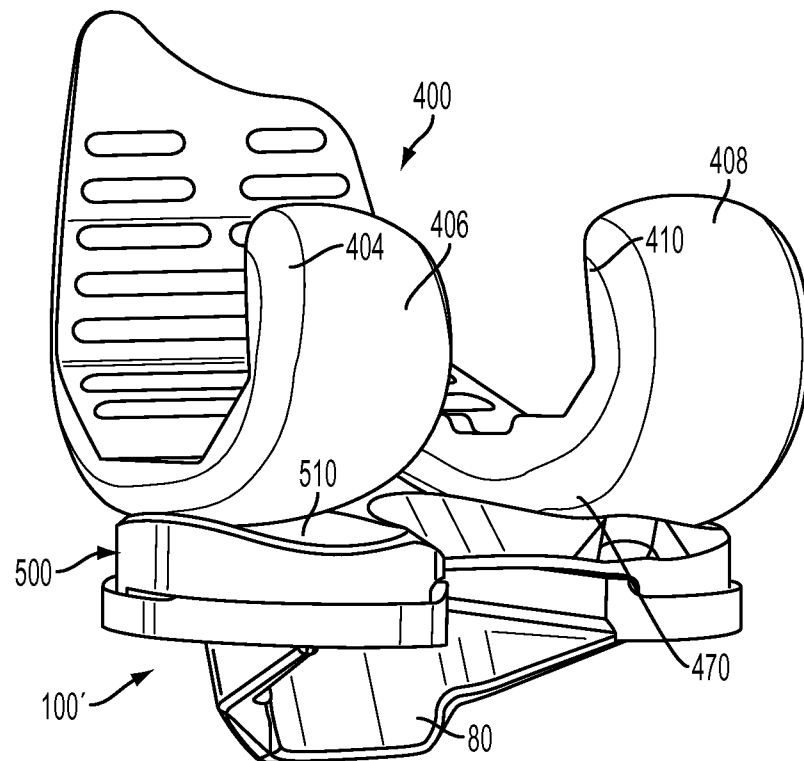


FIG. 80

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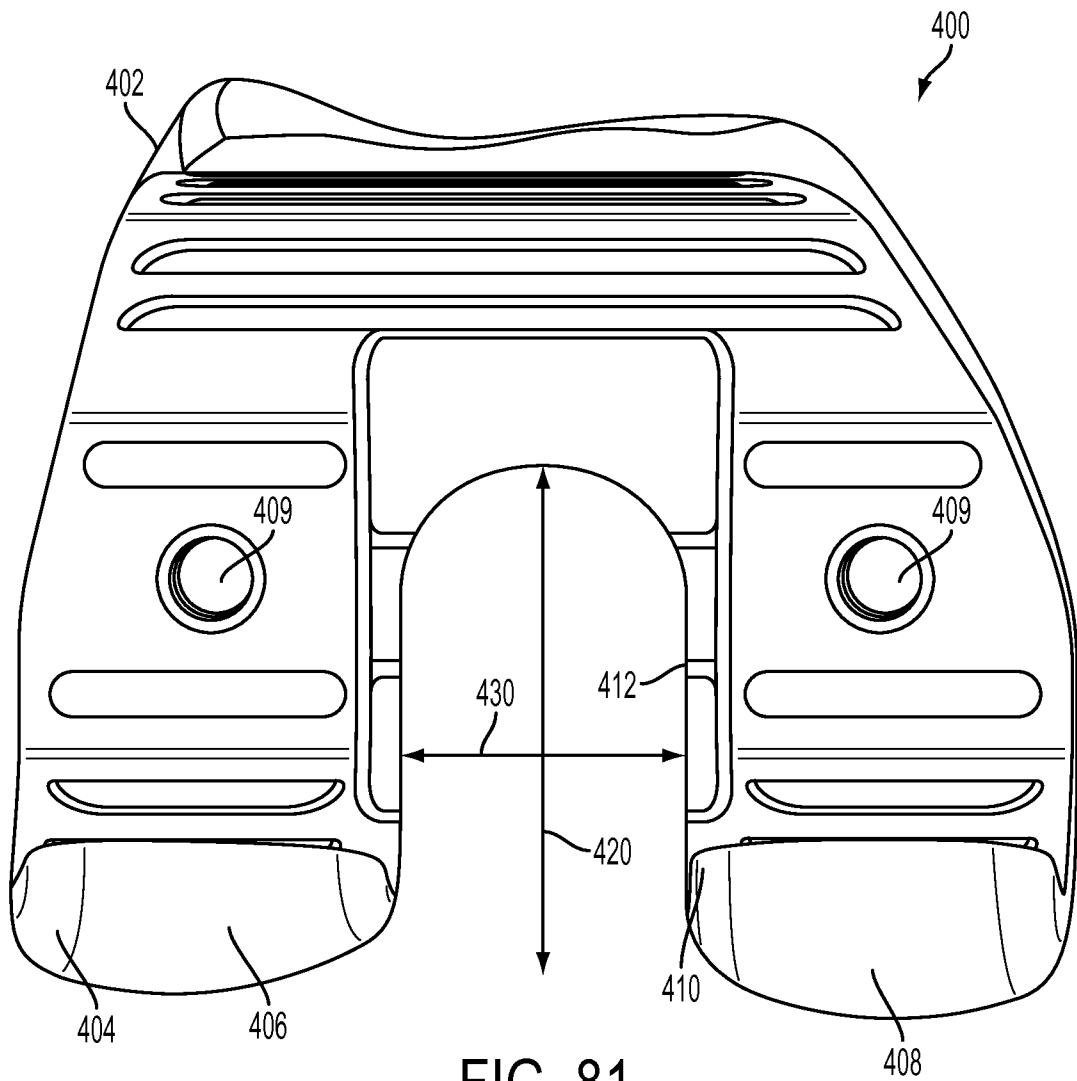


FIG. 81

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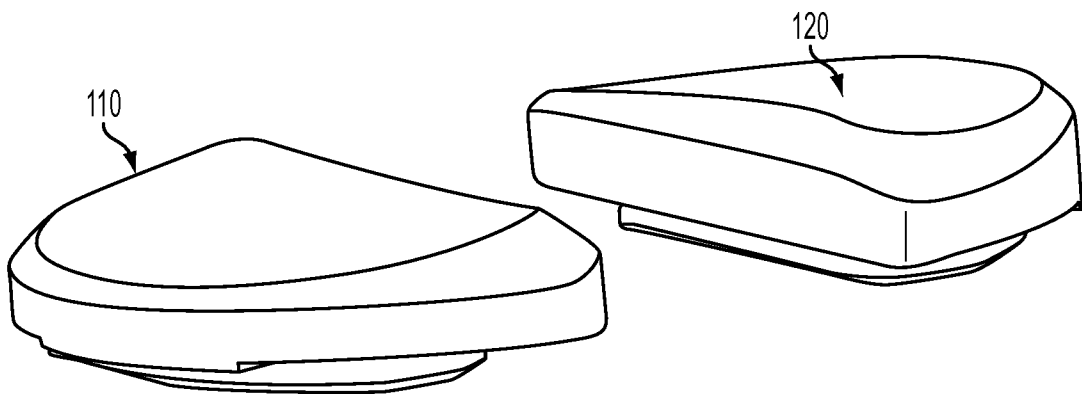


FIG. 82

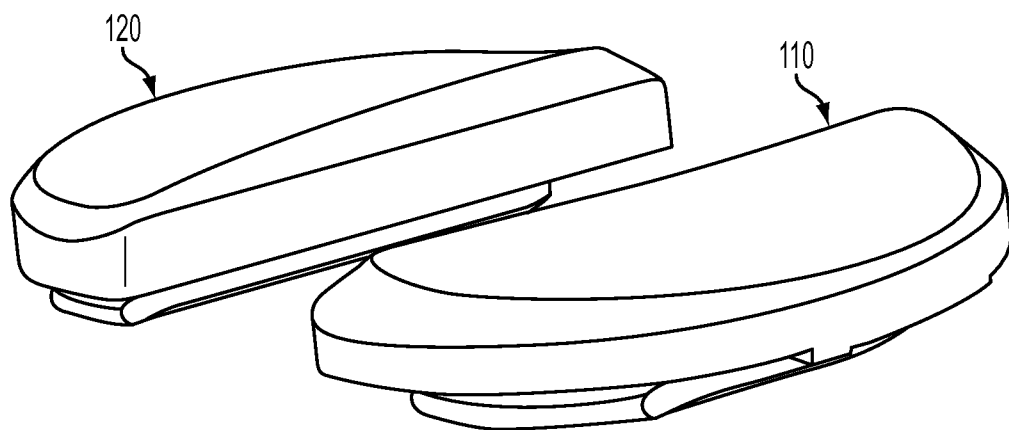


FIG. 83

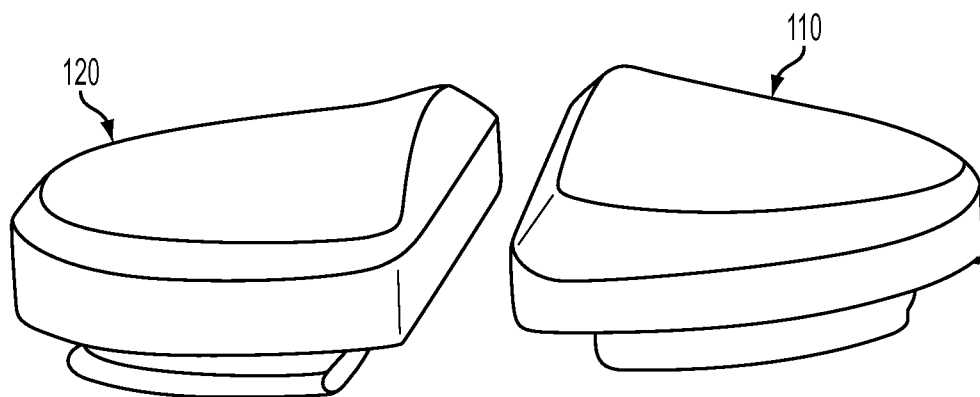


FIG. 84

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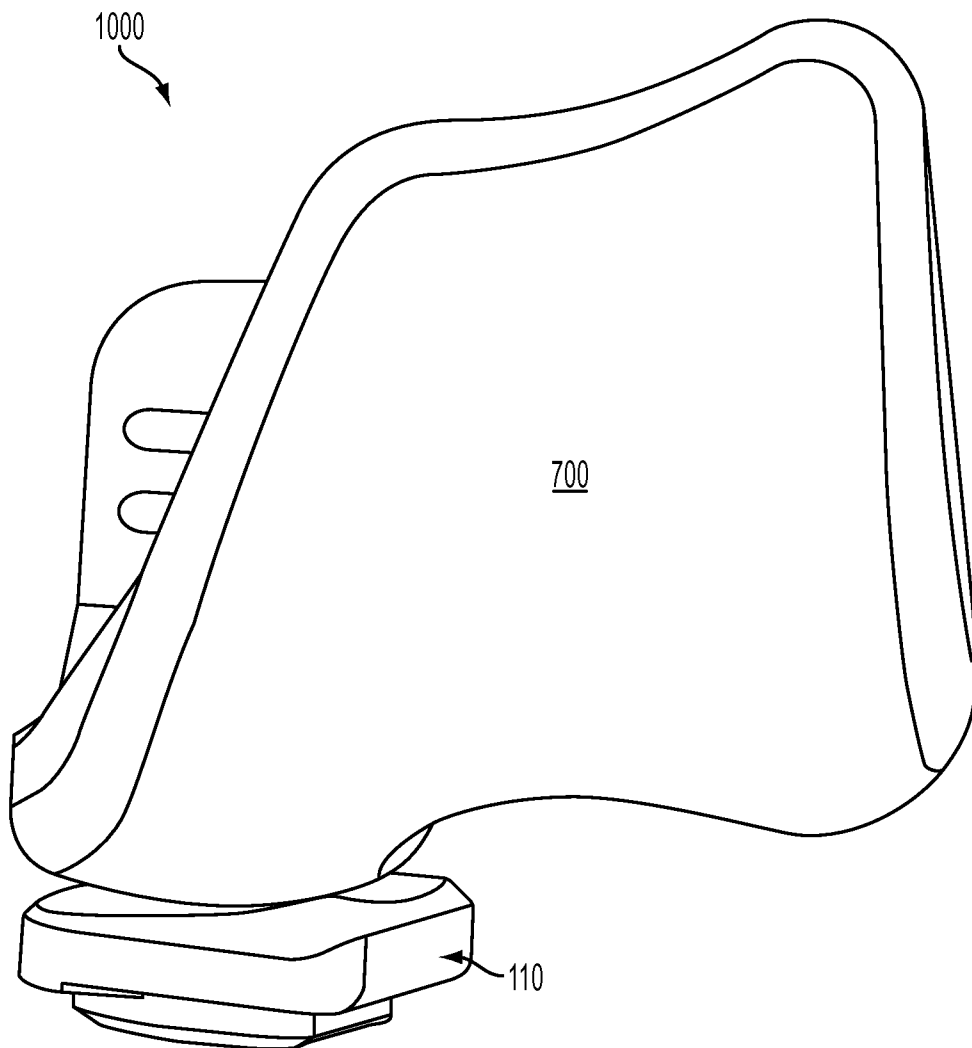


FIG. 85

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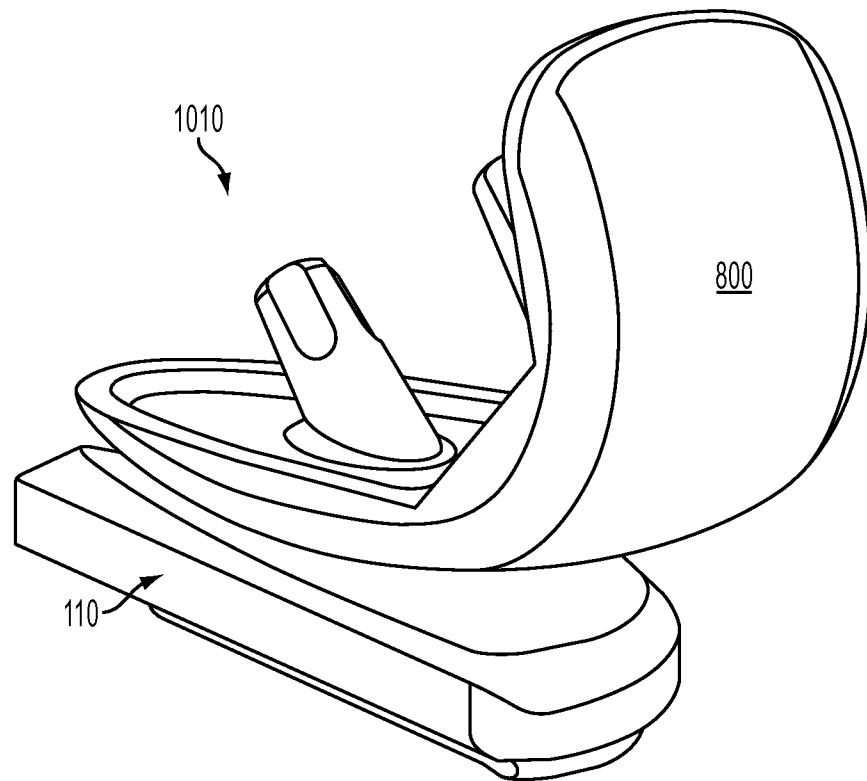


FIG. 86

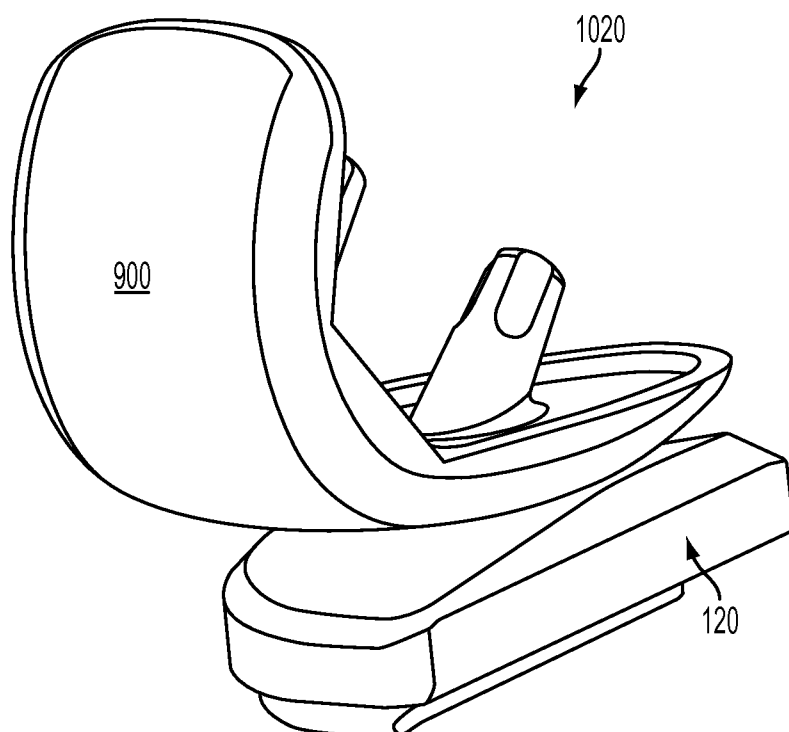


FIG. 87

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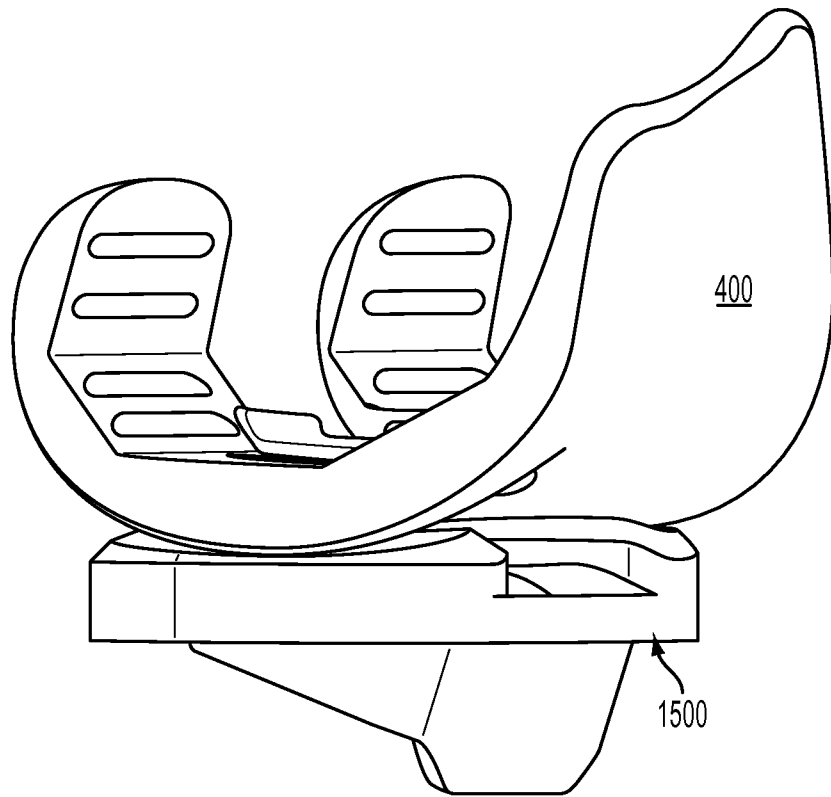


FIG. 88

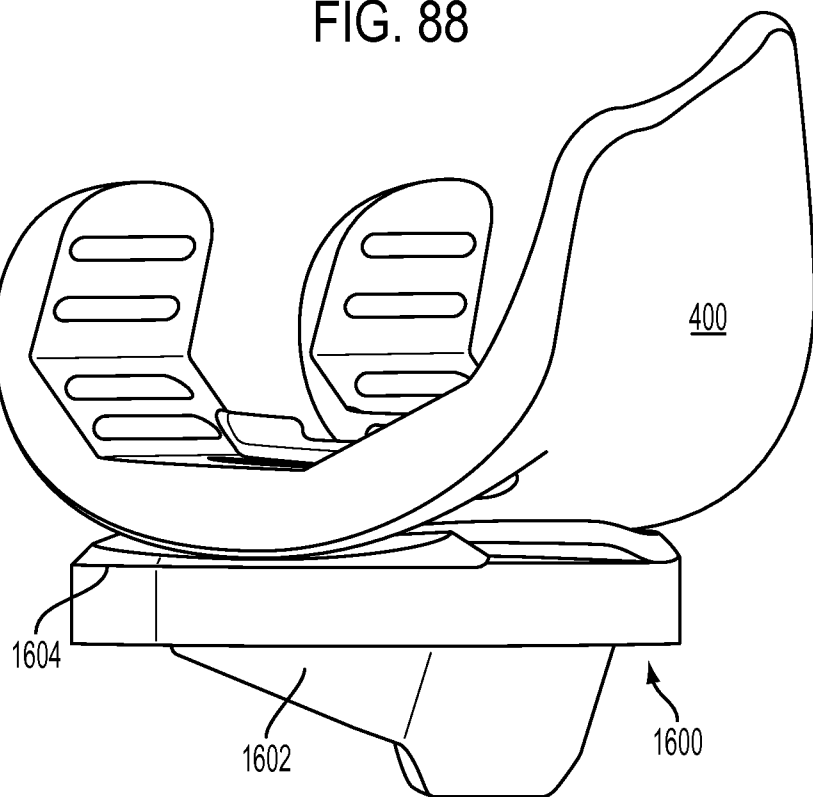


FIG. 89

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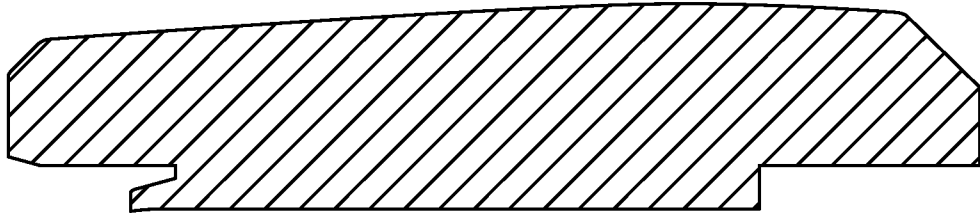


FIG. 90a

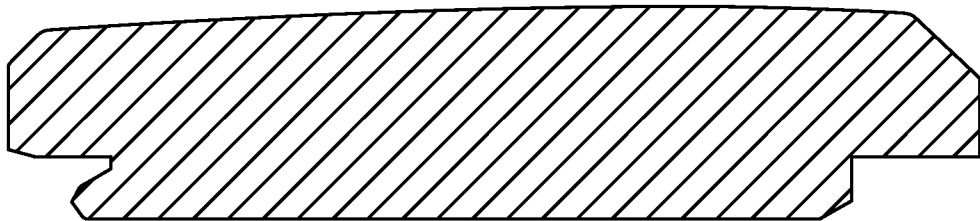


FIG. 90b

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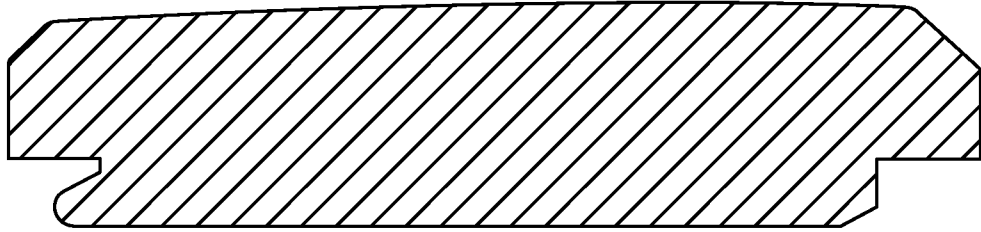


FIG. 90c

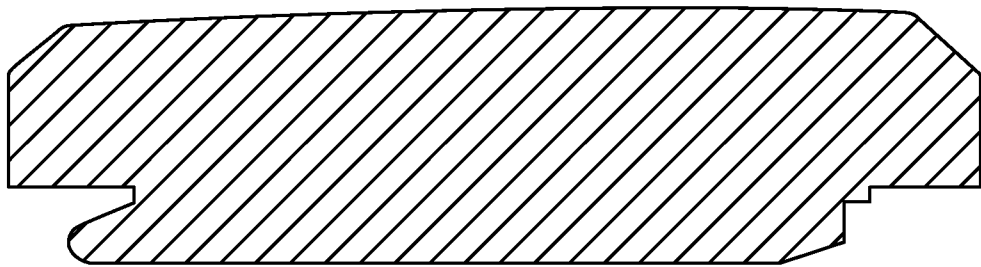


FIG. 90d

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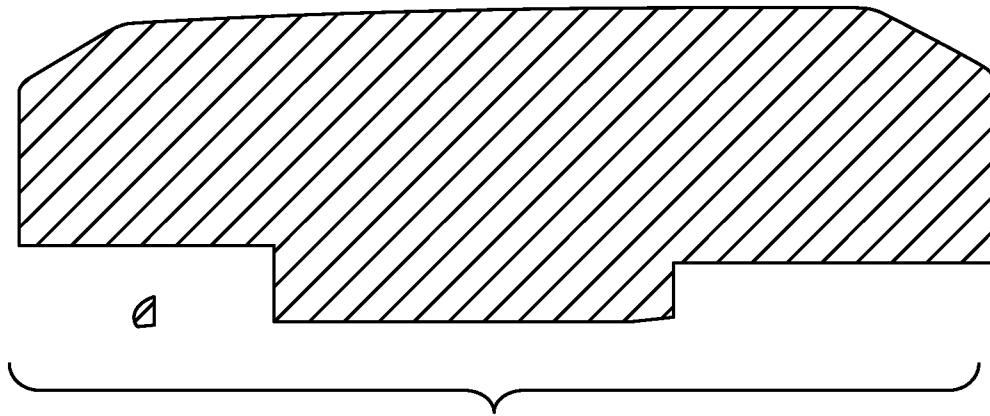


FIG. 90e

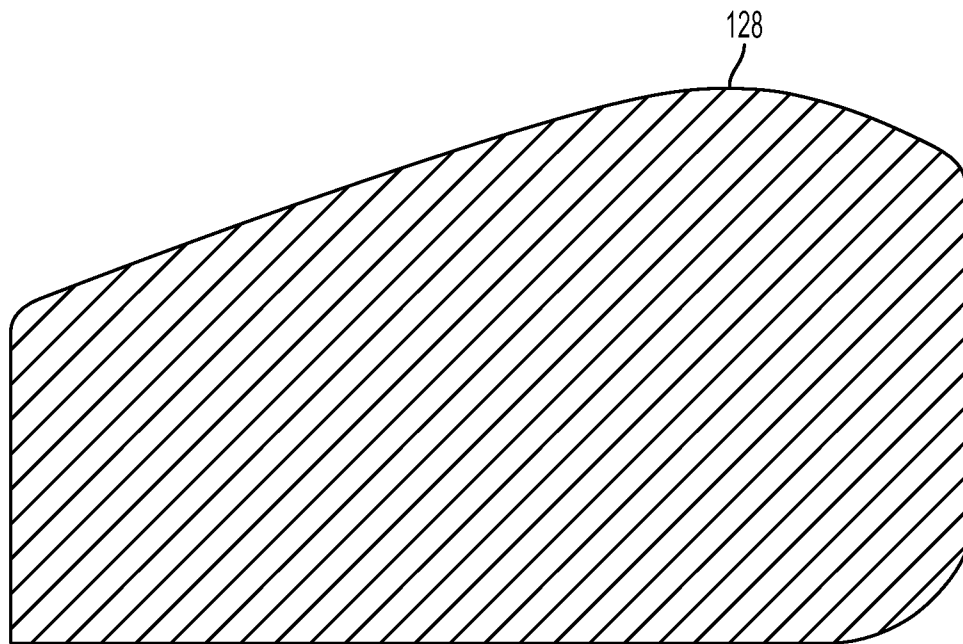


FIG. 91a

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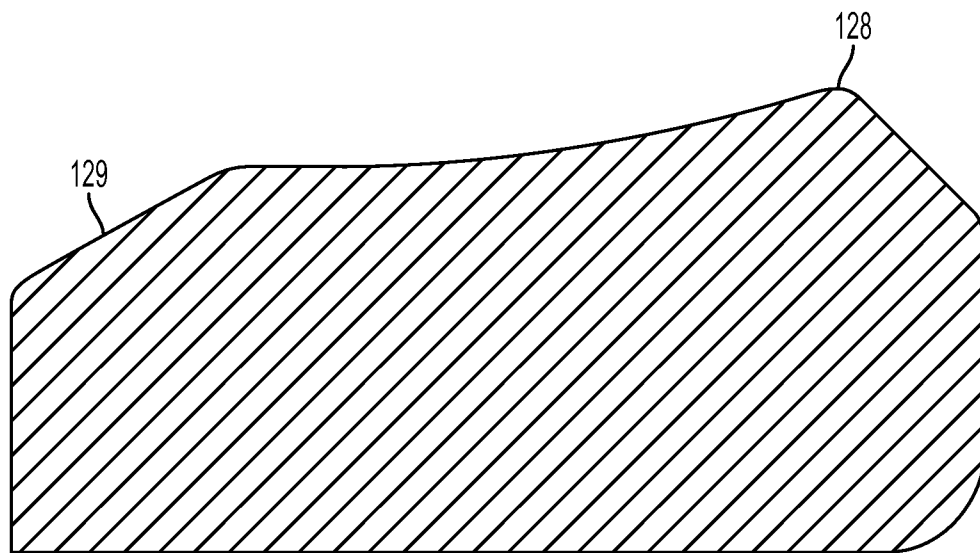


FIG. 91b

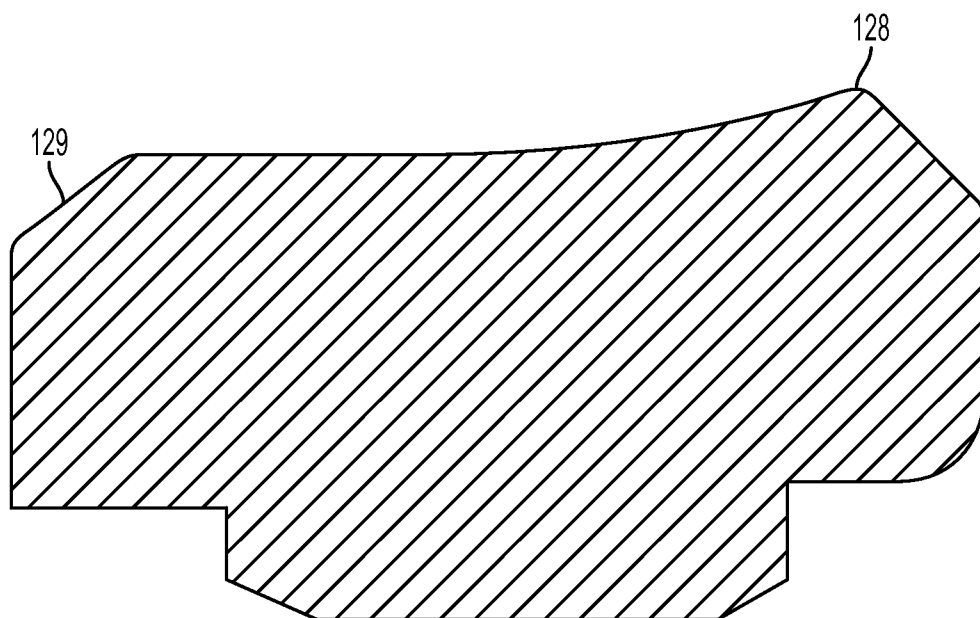


FIG. 91c

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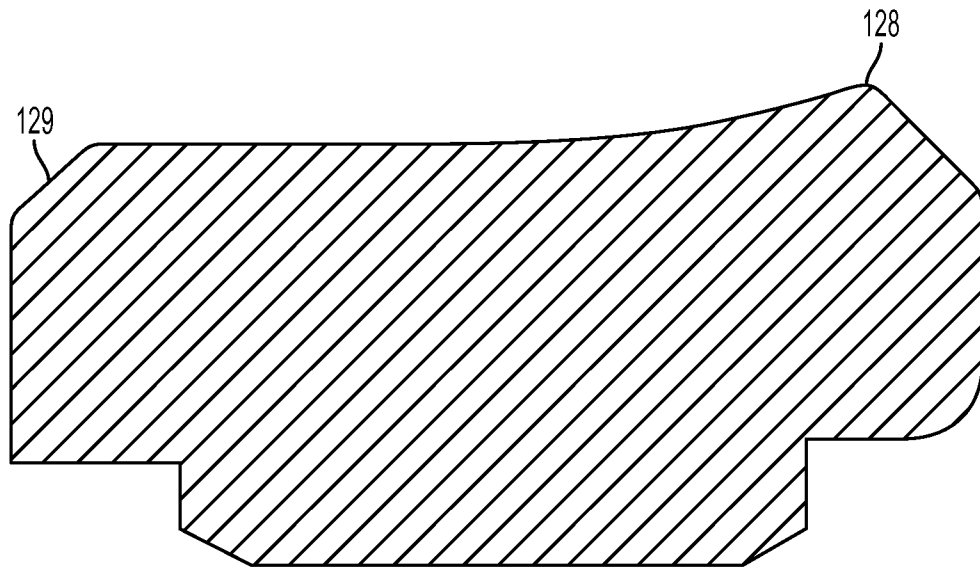


FIG. 91d

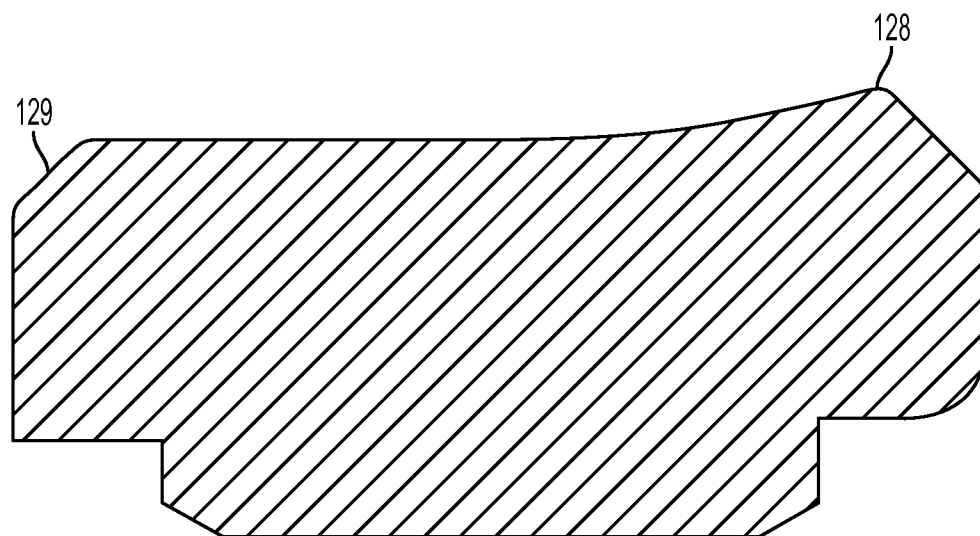


FIG. 91e

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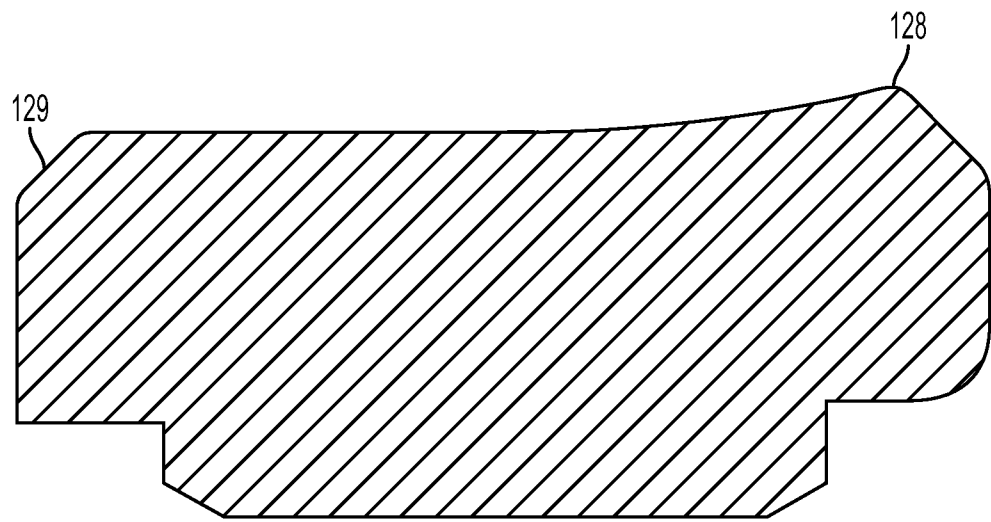


FIG. 91f

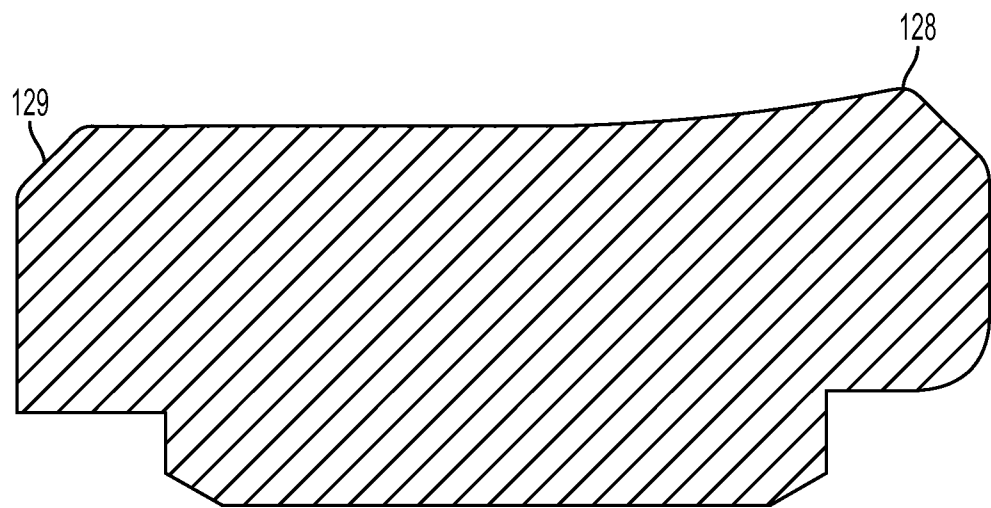


FIG. 91g

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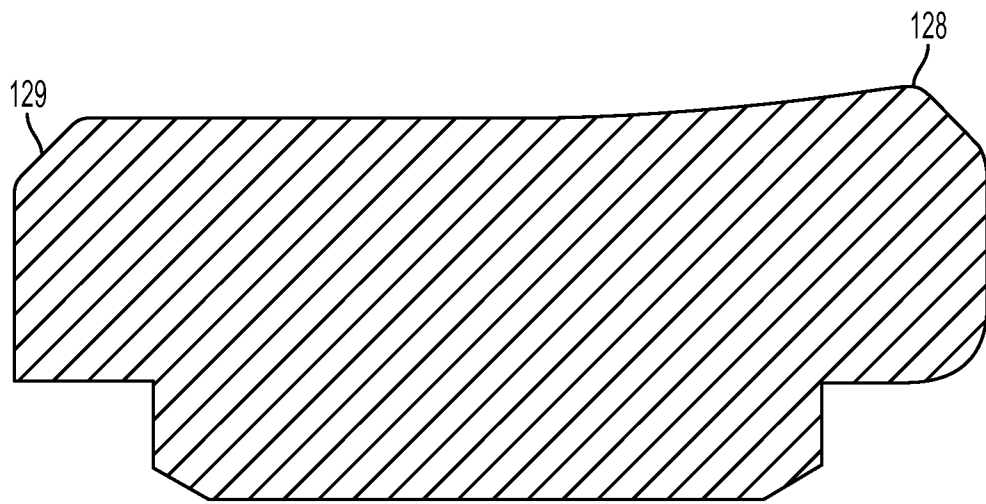


FIG. 91h

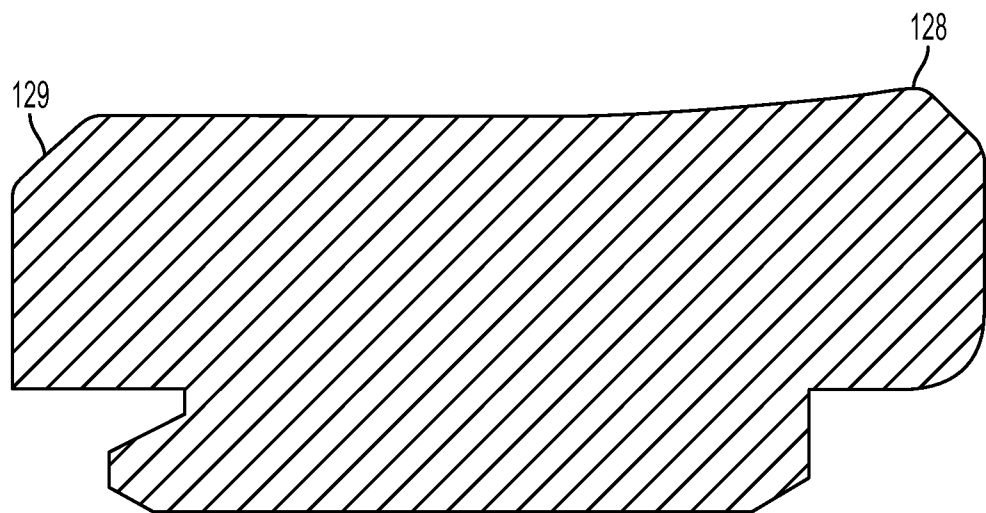


FIG. 91i

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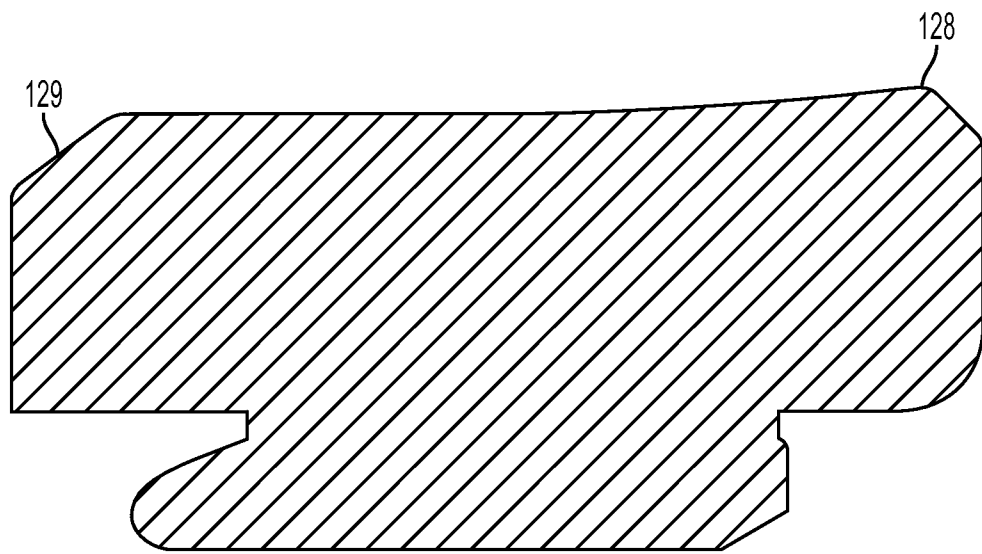


FIG. 91j

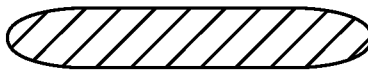
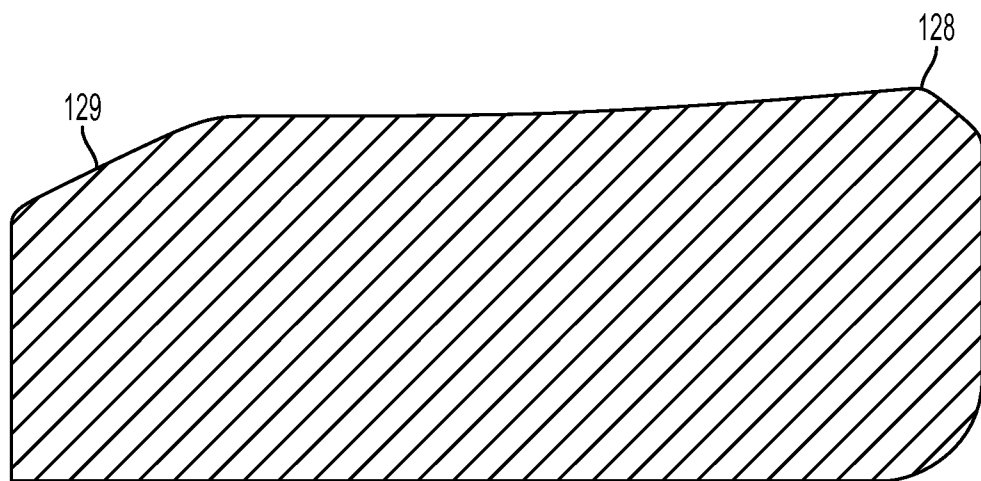


FIG. 91k

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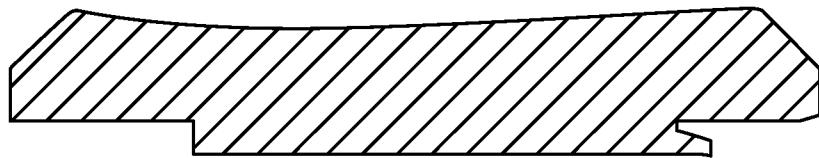


FIG. 92a

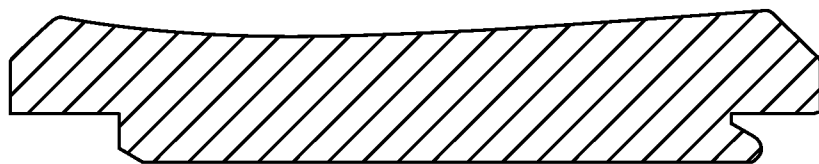


FIG. 92b

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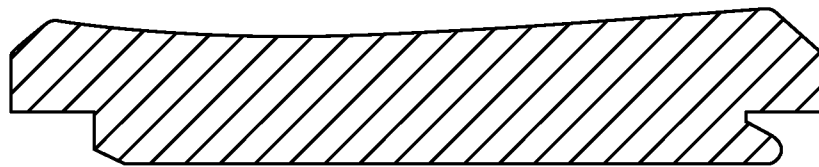


FIG. 92c

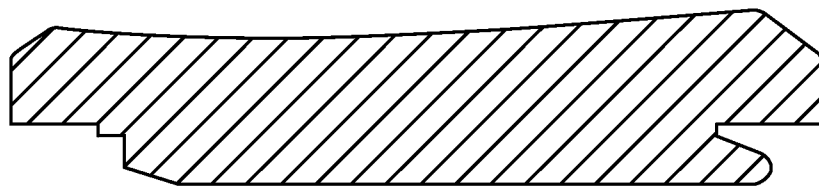


FIG. 92d

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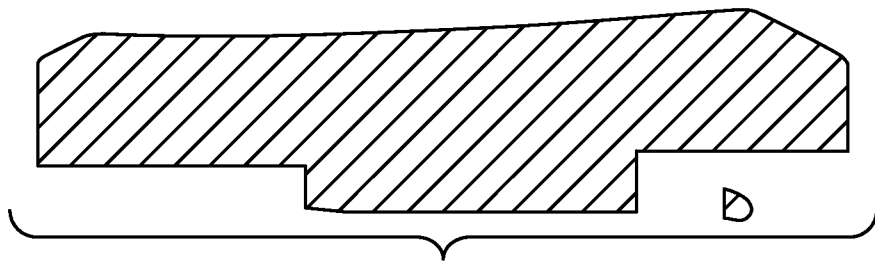


FIG. 92e

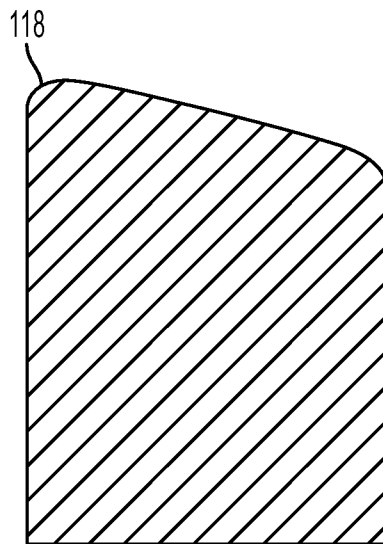


FIG. 93a

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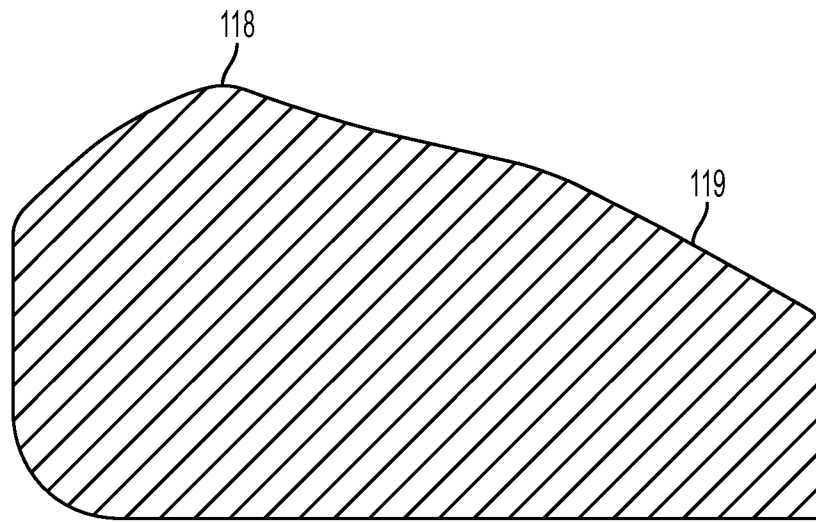


FIG. 93b

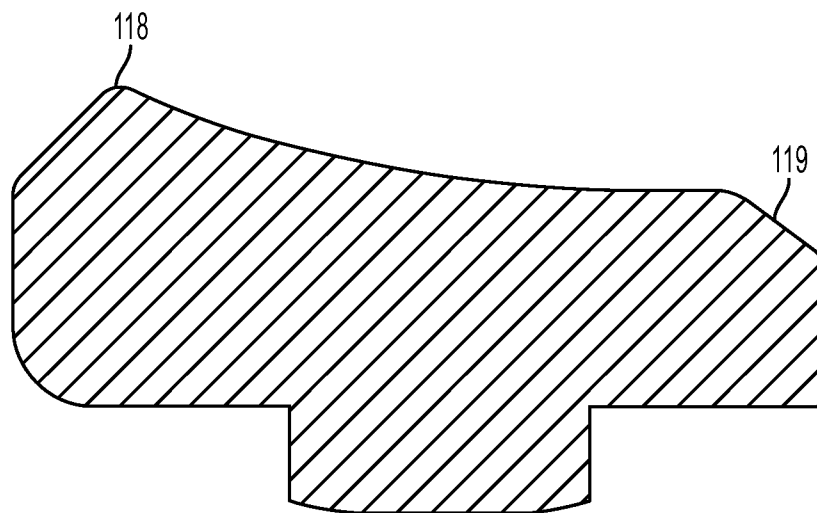


FIG. 93c

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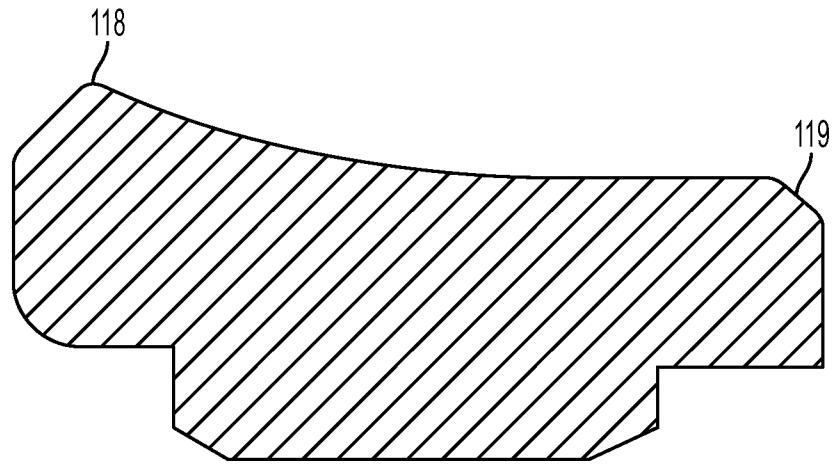


FIG. 93d

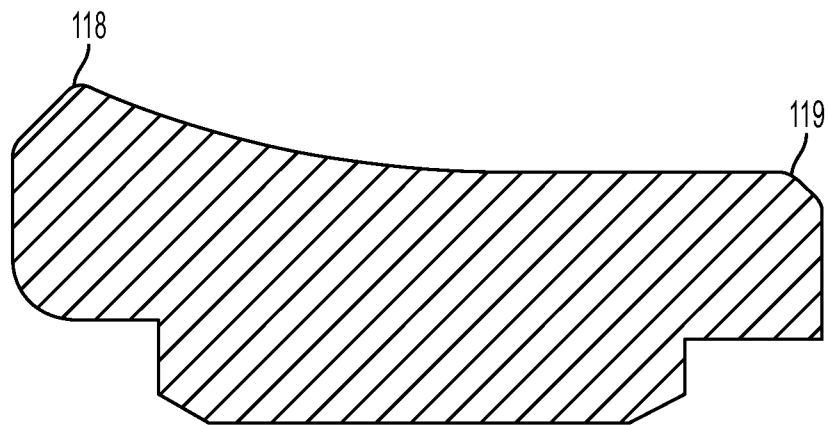


FIG. 93e

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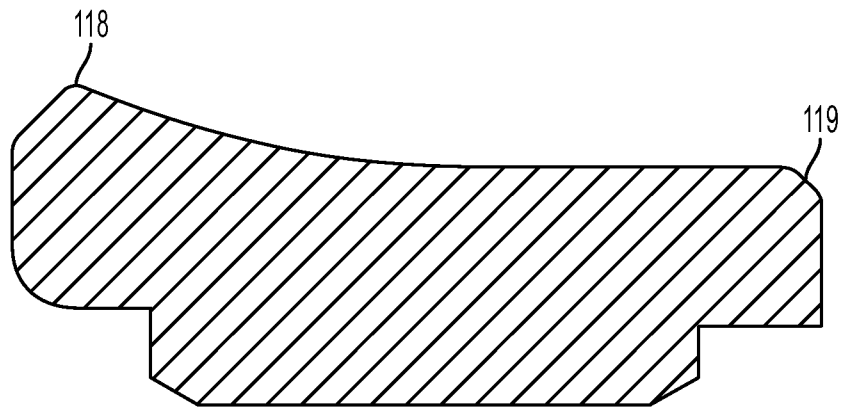


FIG. 93f

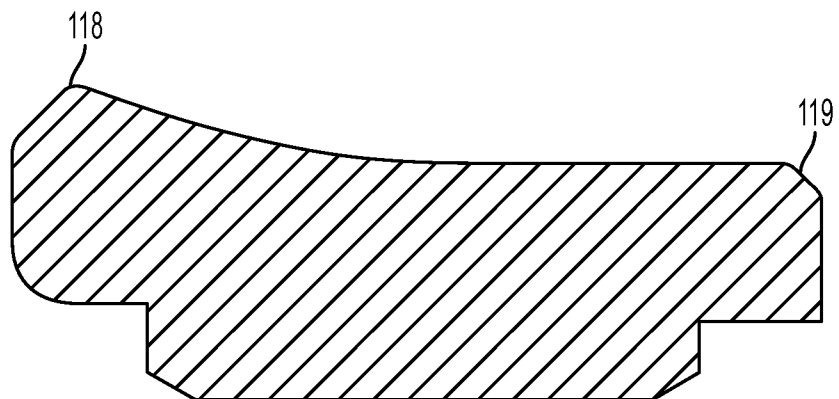


FIG. 93g

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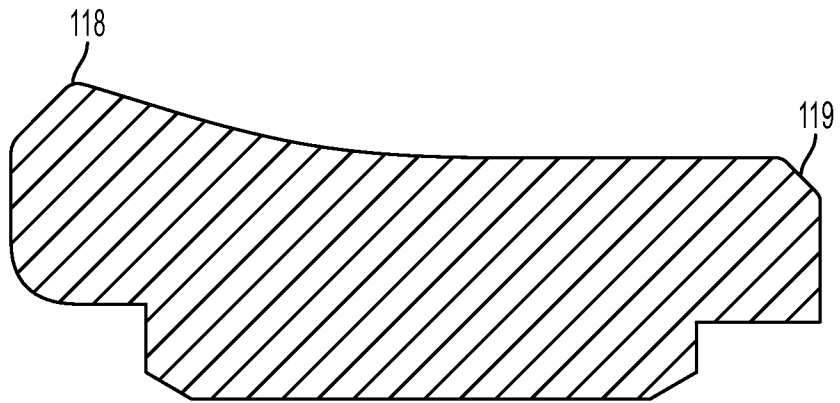


FIG. 93h

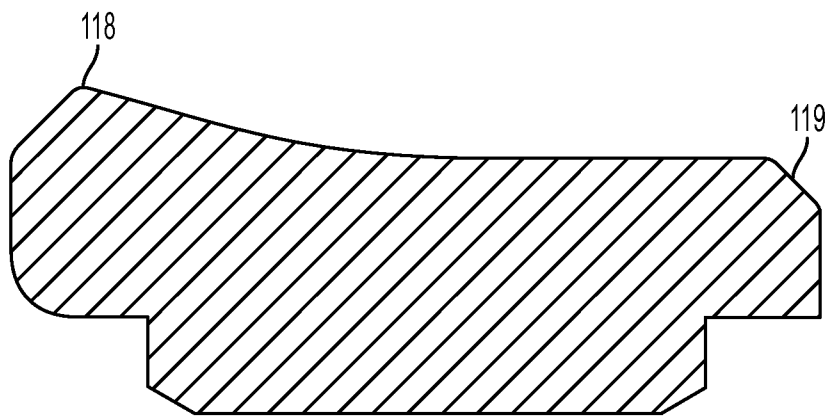


FIG. 93i

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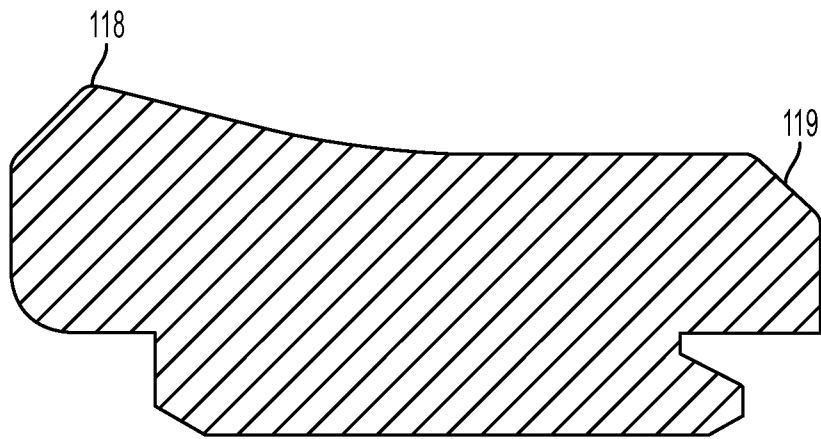


FIG. 93j

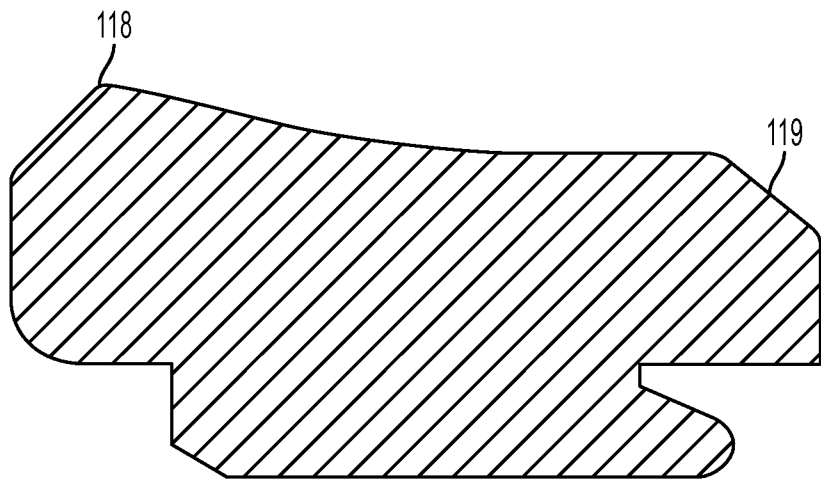


FIG. 93k

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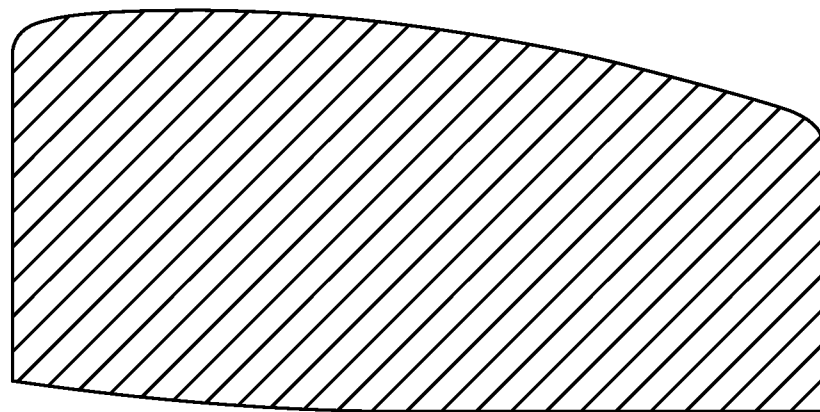
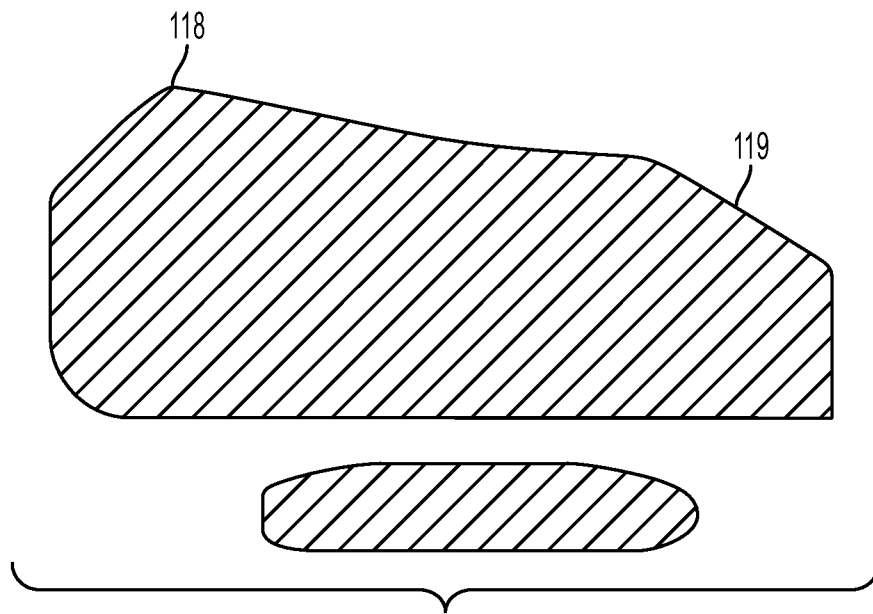


FIG. 93m

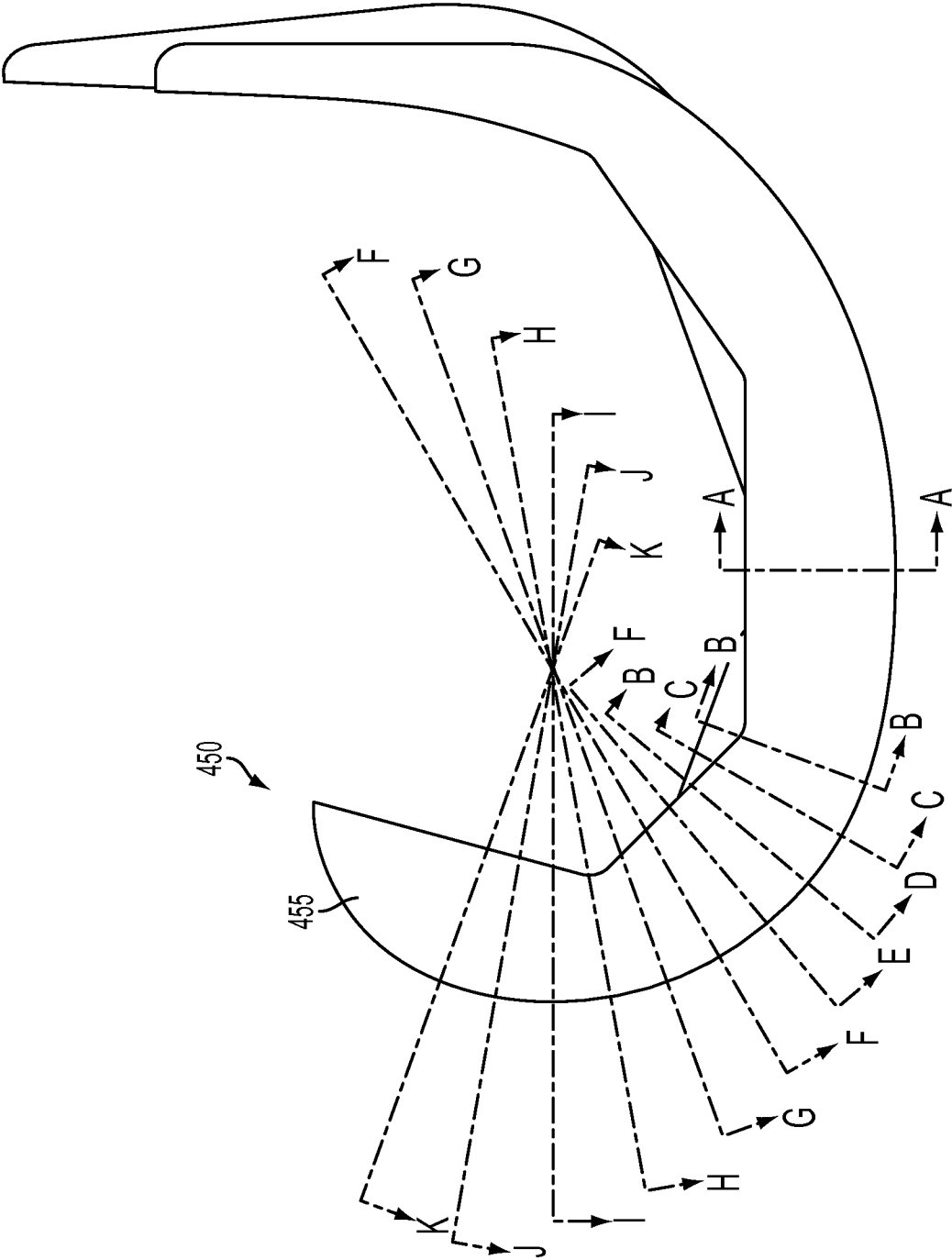


FIG. 94

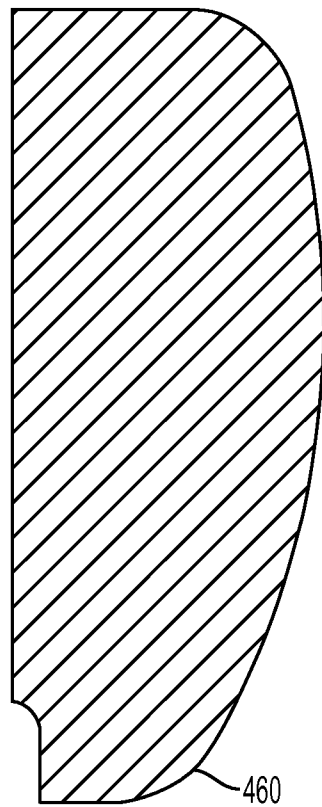


FIG. 95a

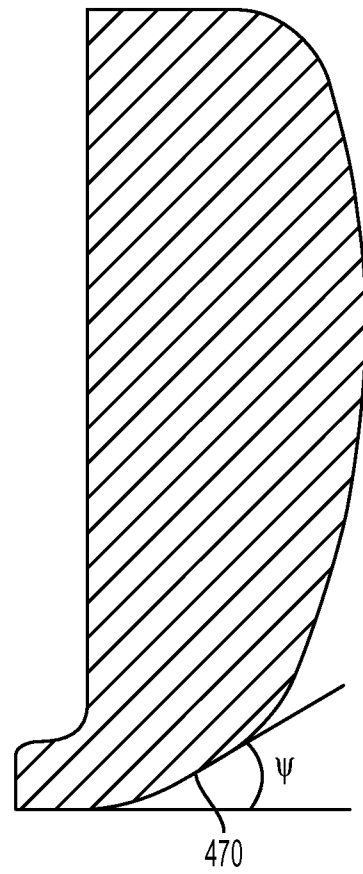


FIG. 95b

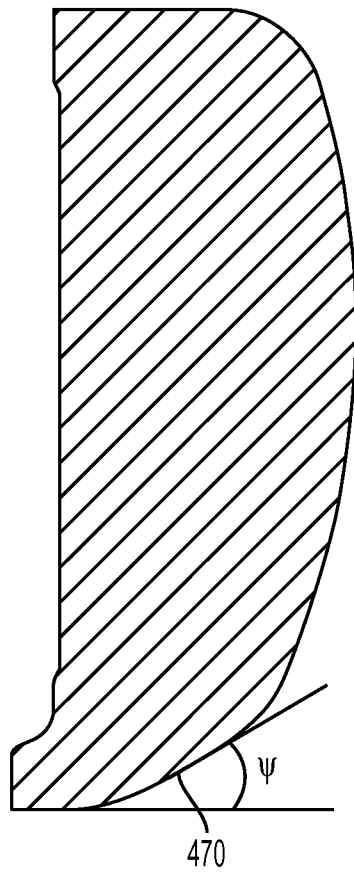


FIG. 95c

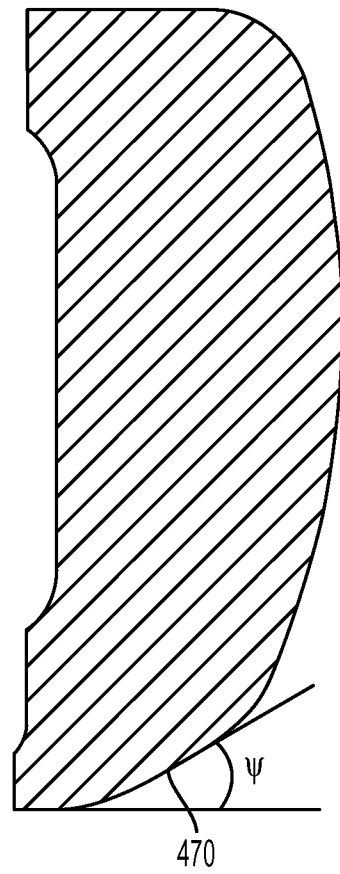


FIG. 95d

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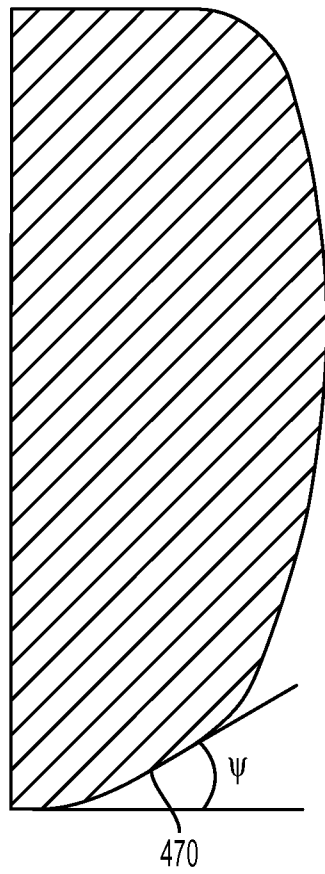


FIG. 95e

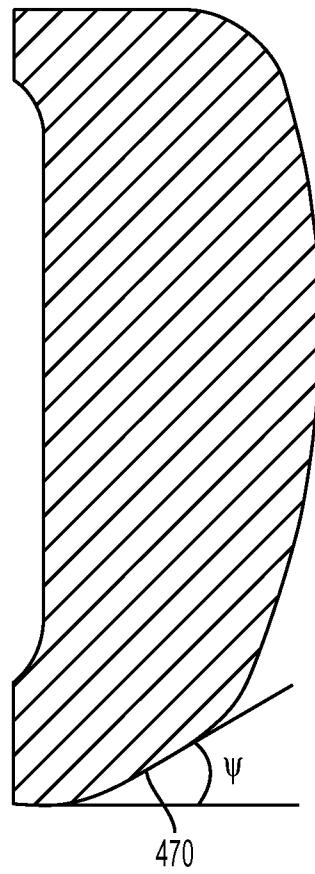


FIG. 95f

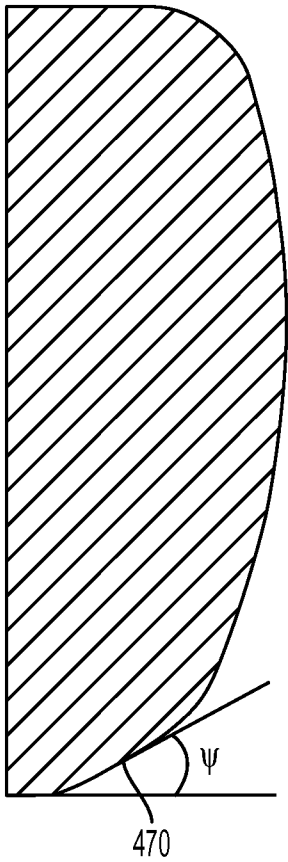


FIG. 95g

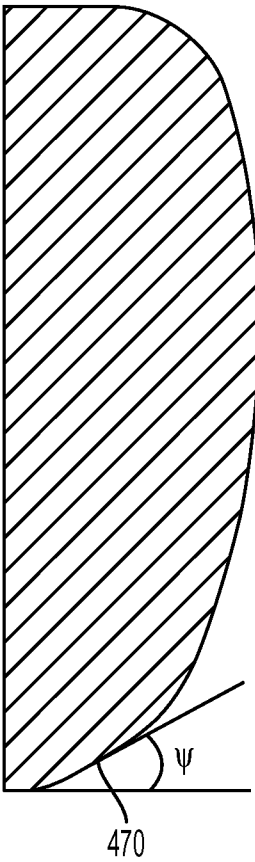


FIG. 95h

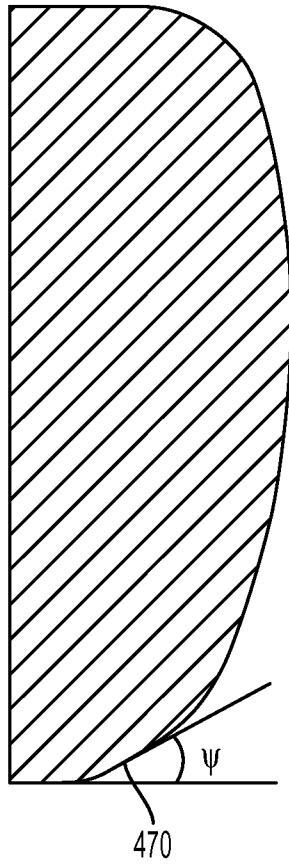


FIG. 95i

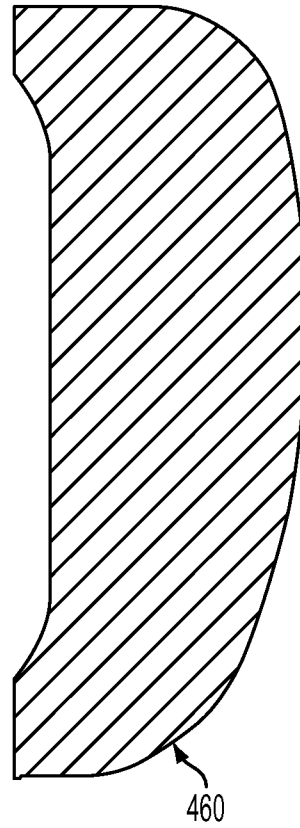


FIG. 95j

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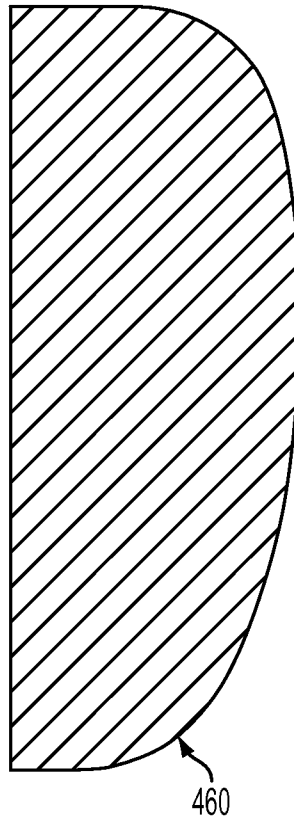


FIG. 95k

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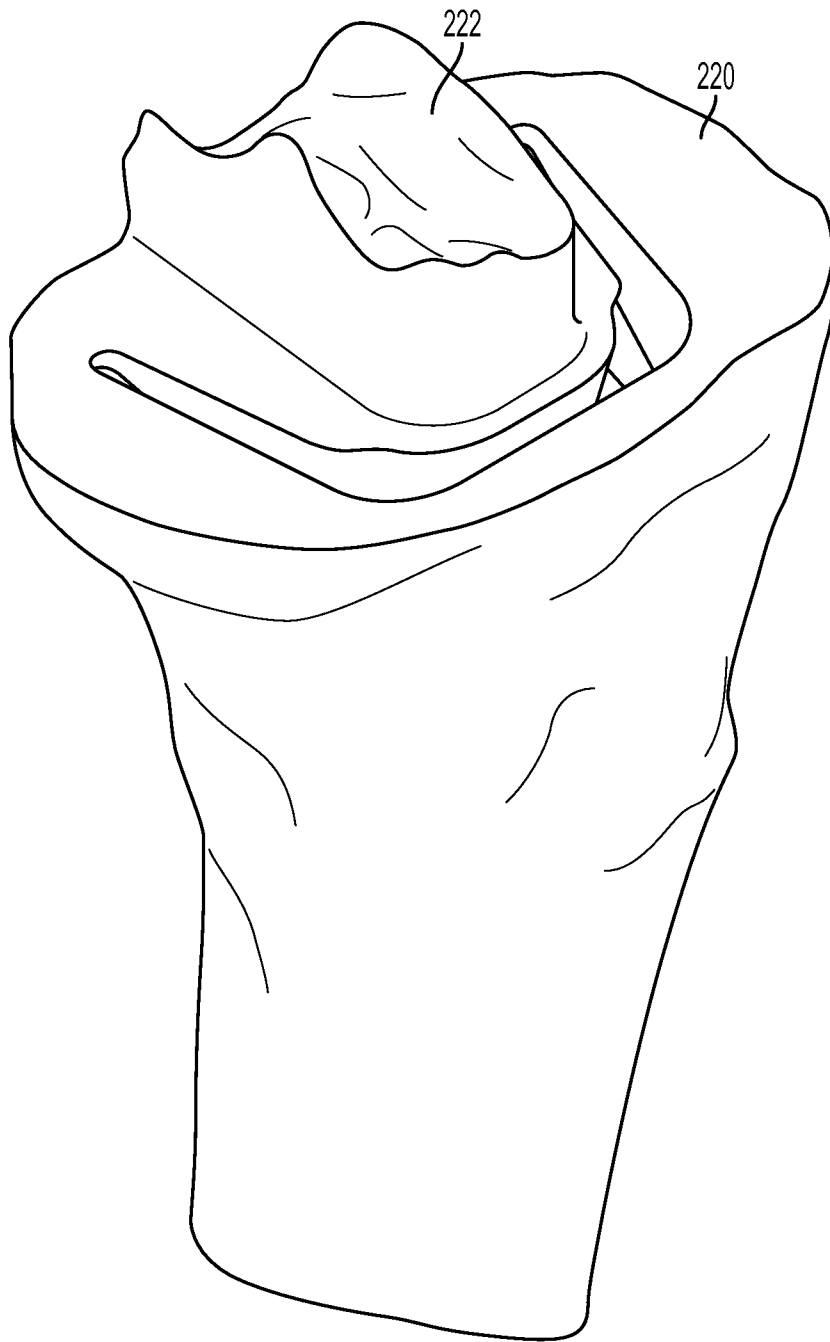


FIG. 96

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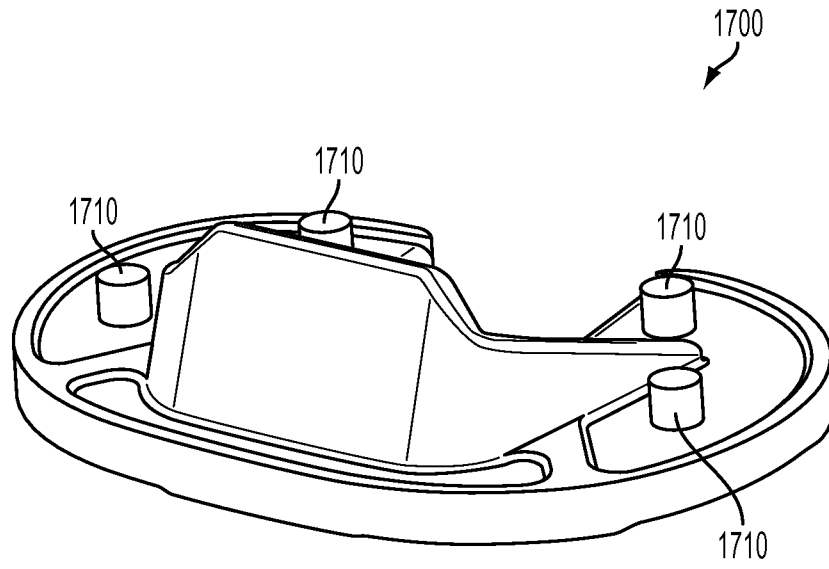


FIG. 97

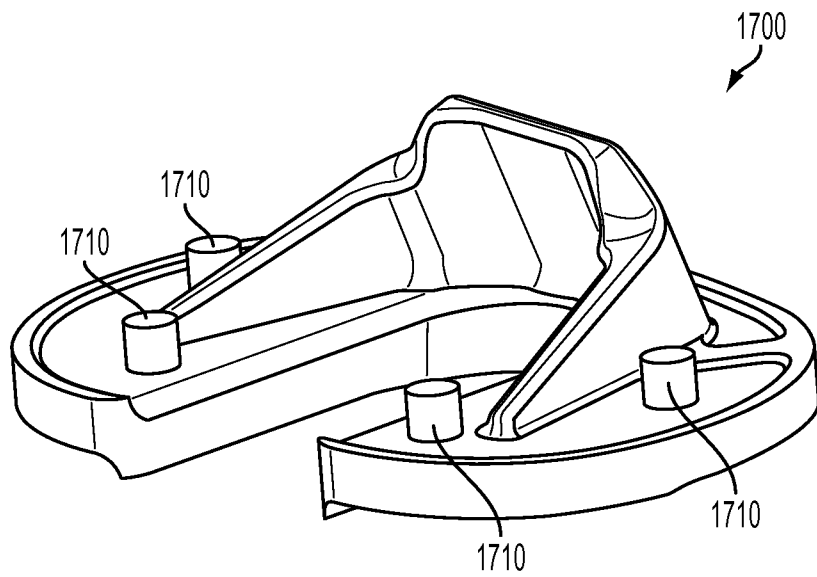


FIG. 98

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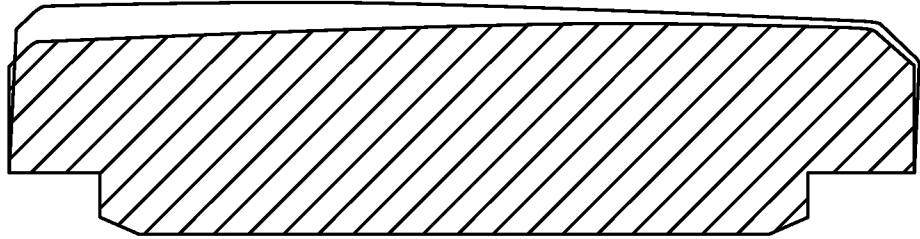


FIG. 99

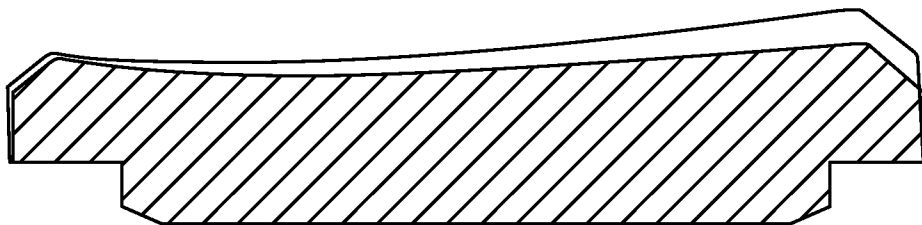


FIG. 100