(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 February 2012 (23.02.2012)

PCT

(10) International Publication Number
WO 2012/024306 A2

(51) International Patent Classification:
A61B 17/90 (2006.01) *A61F 2/46* (2006.01)
A61B 17/56 (2006.01)

(21) International Application Number:
PCT/US2011/047936

(22) International Filing Date:
16 August 2011 (16.08.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/374,011 16 August 2010 (16.08.2010) US

(72) Inventors; and
(71) Applicants : **AGNIHOTRI, Aashiish** [IN/US]; 1189 East Island Place, Memphis, Tennessee 38103 (US). **SMITH, Richard Michael** [US/US]; 1 North Alicia, Memphis, Tennessee 38112 (US). **NADZADI, Mark Ellsworth** [US/US]; 137 East GE Patterson Avenue, Memphis, Tennessee 38103 (US). **SHARP, Jeffrey Andrew** [US/US]; 1155 E. 2100 S. Apt 845, Salt Lake City, Utah 84106 (US).

(74) Agents: **JEPSEN, Nicholas** et al.; Fish & Richardson P.C., P.O. Box 1022, Minneapolis, Minnesota 55440-1022 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,

[Continued on next page]

(54) Title: SURGICAL GUIDES

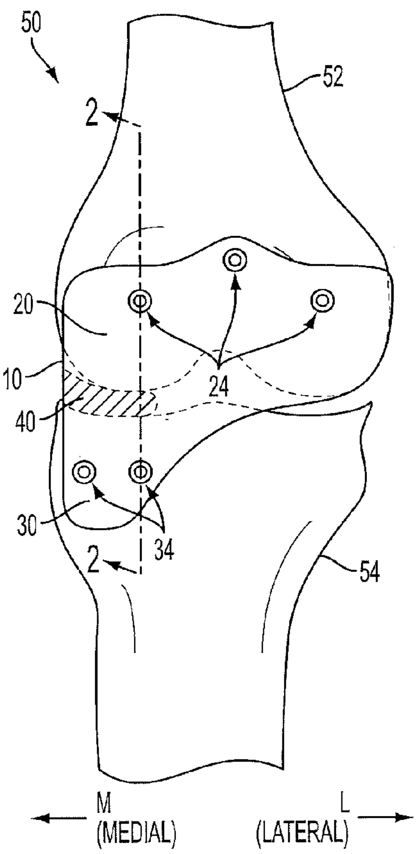


FIG. 1

(57) Abstract: A surgical guide can include a femoral portion that includes a femoral surface dimensioned to conform to a portion of a femur of a patient. The surgical guide can also include a tibial portion that defines a surgical alignment for a tibia of the patient. The femoral portion of the surgical guide can be configured to align the tibial portion relative to the tibia based on engagement of the femoral surface with the femur.

WO 2012/024306 A2

CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

SURGICAL GUIDES

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the full benefit of United States Provisional Application Serial Number 61/374,011, filed August 16, 2010, and titled "Patient Matched Methods and Devices for Knee Arthroplasty," the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

This disclosure relates to surgical guides.

BACKGROUND

Arthroplasty of the knee can include resections and other surgical procedures for the tibia and the femur. Surgeons can use instruments to prepare the tibia and the femur to receive an implant, for example. The alignment of instruments during surgery can determine the properties of the knee when the arthroplasty procedure is complete.

SUMMARY

A surgical guide includes a surface that substantially conforms to a first bone of a patient's joint. The surgical guide defines a surgical alignment relative to another bone of the joint based on the engagement of the surgical guide to the first bone.

A surgical guide can include a surface that is at least in part patient-matched such that one or more surfaces or contours of the guide conform to or substantially conform to a particular patient's anatomy. The surgical guide can mate with a portion of the tibia, a portion of the femur, or portion of the tibia and a portion of the femur, resulting in a desired position and/or orientation with respect to the patient's knee. The surgical guide can also include a patient-matched joint balancing feature configured to align the knee.

In one general aspect, a surgical guide includes: a femoral portion including a femoral surface dimensioned to conform to a portion of a femur of a particular patient; a tibial portion defining a surgical alignment for a tibia of the patient, wherein the femoral

portion of the surgical guide is configured to align the tibial portion relative to the tibia based on engagement of the femoral surface with the femur.

Implementations can optionally include one or more of the following features. For example, the femoral portion defines a surgical alignment for the femur. The tibial portion includes a tibial surface dimensioned to conform to a portion of the tibia, and the surgical guide is configured to align the guide portion of the tibial portion relative to the tibia based on engagement of the tibial surface with the tibia. The tibial portion is configured to mate with the tibia and the femoral portion is configured to mate with the femur while the tibia and the femur are in extension. The tibial portion is configured to mate with the tibia and the femoral portion is configured to mate with the femur while the tibia and the femur are in flexion.

The surgical guide is configured to admit a joint balancing insert for insertion between the femur and the tibia. The surgical guide positions the joint balancing insert relative to the femur and the tibia. The surgical guide includes a joint balancing component configured to be positioned between the tibia and the femur, the joint-balancing component having a patient-specific dimension. The surgical guide includes a patient-specific augment to couple to the surgical guide and to balance the joint after a portion of the tibia or the femur is resected. The surgical guide includes a patient-specific patellar interface and defining a surgical alignment for a patella of the patient. The surgical guide includes a constant-force mechanism configured to be inserted between the tibia and the femur. The femoral portion and the tibial portion are detachable and reattachable. The femoral portion comprises an anterior portion and a detachable distal portion. The femoral portion and the tibial portion are configured to be coupled in a first orientation to engage the femur and the tibia in extension, and to be coupled in a second orientation to engage the femur and the tibia in flexion. The femoral portion and the tibial portion form an integral unit.

In another general aspect, a method of establishing a surgical alignment, includes: obtaining a surgical guide defining a surgical alignment for a tibia and a patient-specific surface dimensioned to conform to a portion of a femur of a particular patient; aligning the surgical guide relative to the tibia based on the engagement of the patient-specific surface with the femur; and inserting one or more pins into the tibia based on the position of the surgical guide while the patient-specific surface is in engagement with the femur.

DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view illustrating an anterior aspect of a surgical guide engaged with a left knee joint.

FIG. 2 is a sectional view illustrating the knee joint and the surgical guide of FIG. 1 across line 2-2.

FIGS. 3 and 4 are perspective views illustrating joint balancing of a left knee joint.

FIGS. 5 and 6 are perspective views of a femur of the knee joint coupled to a cutting block.

FIG. 7 is a perspective view of the knee joint prepared to receive implants for bi-compartmental arthroplasty.

FIG. 8 is a perspective view of the knee joint with implants installed in the knee joint.

FIG. 9 is a perspective view of an anterior aspect of an alternative surgical guide coupled to the knee joint.

FIG. 10 is a perspective view of a medial aspect of the surgical guide of FIG. 9 coupled to the knee joint.

FIGS. 11 and 12 are perspective views of the surgical guide of FIG. 9.

FIG. 13 is a perspective view of an anterior aspect of another alternative surgical guide coupled to the knee joint.

FIG. 14 is a perspective view illustrating an anterior aspect of another alternative surgical guide engaged with the knee joint.

FIG. 15 is a cross-sectional view illustrating a section of the knee joint and the surgical guide of FIG. 14 across line 15-15.

FIGS. 16 to 20 illustrate alternative surgical guides and alternative joint balancing techniques.

FIG. 21 is a perspective view of a femoral module of a modular surgical guide.

FIG. 22 is a perspective view of an anterior portion and a distal portion of the femoral module of FIG. 21.

FIG. 23 is a perspective view of a tibial module configured to engage the femoral module of FIG. 21.

FIG. 24 is a medial view of the femoral module of FIG. 21 engaged with the knee joint in flexion.

FIG. 25 is a medial view of the anterior portion of the femoral module of FIG. 21 and the tibial module of FIG. 23 engaged with the knee joint in extension.

FIG. 26 is a medial view of the anterior portion of the femoral module of FIG. 21, the tibial module of FIG. 23, and an alternative distal portion, engaged with the knee joint in flexion.

FIGS. 27 to 31 are perspective views of surgical guides configured to engage a tibia of the knee joint.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Referring to FIGS. 1 and 2, a surgical guide 10 defines a surgical alignment with respect to a joint, for example, a knee 50 of a particular patient. The guide 10 includes one or more patient-matched or patient-specific features, for example, contours, surfaces, or dimensions, that permit the guide 10 to mate with the knee 50 in a predetermined orientation and/or position. In the predetermined orientation, engagement of the guide 10 with one bone of the knee 50 positions the guide 10 to define a surgical alignment with respect to a different bone of the knee 50. For example, engagement of the guide 10 to a femur 52 determines a surgical alignment with respect to a tibia 54, and vice versa.

Although the techniques described herein are generally configured for procedures on a patient's knee, the techniques may also be used in procedures on other portions of the anatomy, for example, a hip joint, a shoulder joint, an ankle, a wrist, a foot, a hand, an elbow, a spine, or any joint of the body.

Features of a patient's anatomy can be indicated by imaging data acquired with magnetic resonance imaging (MRI), x-ray imaging, ultrasound imaging, x-ray computed tomography (CT), or other techniques. The imaging data can be processed to create a three-dimensional model of the patient's anatomy, and features of interest of the patient's anatomy can be identified. Based on the surfaces and contours indicated by the model, surfaces, contours, dimensions, and other characteristics of the guide 10 can be manufactured to match the patient's anatomy. Additionally, desired surgical alignments can be determined with respect to the model. For example, varus or valgus deformity of the knee 50 can be estimated and alignments can be determined to correct for the deformity. The guide 10 (and the other guides described herein) can be manufactured such that, during surgery, the guide 10 recreates the desired alignments with respect to the patient's anatomy, such as the patient's knee 50.

The guide 10 defines alignments for arthroplasty of the knee 50. Arthroplasty can be complete or partial. The knee 50 includes, for example, a medial compartment, a lateral compartment, and a patellofemoral compartment. Surgical guides can be manufactured to define alignments for arthroplasty of one or more of these compartments. As described herein, surgical guides can thus indicate alignments for uni-compartmental arthroplasty, bi-compartmental arthroplasty, or tri-compartmental arthroplasty (i.e., total knee arthroplasty). The guide 10 defines surgical alignments for a bi-compartmental arthroplasty, for example, preparation of the medial compartment and the patellofemoral compartment of the knee 50.

In partial knee arthroplasty, the posterior cruciate ligament (PCL) and/or the anterior cruciate ligament (ACL) are often retained. The medial collateral ligament (MCL) and lateral collateral ligament (LCL) are also generally retained. Accordingly, the guide 10 can define surgical alignments such that tissue resections do not compromise the ligaments or the intercondylar eminence. For example, the guide 10 can define accurate alignments such that a vertical tibial cut does not compromise the cruciate attachment to the tibia 54.

Referring to FIGS. 1 and 2, the guide 10 includes a femoral portion 20, a tibial portion 30, and a joint balancing portion 40. The portions 20, 30, 40 of the guide 10 are formed as an integral unit. As an alternative, a surgical guide can include one or more detachable and reattachable modules, for example, as described with respect to FIGS. 21 to 26.

The femoral portion 20 includes a patient-matched femoral surface 22 (e.g., a patient-specific interface) that substantially conforms to a portion of the femur 52. For example, the femoral surface 22 can be substantially rigid and can be dimensioned to match the topology of a particular portion of the femur 52, such as an anterior surface 56 and/or a distal surface 57. Engagement of the femoral surface 22 with the femur 52 positions the guide 10 in a predefined orientation and position with the femur 52. For example, the femoral surface 22 can mate with the femur 52 in a unique location and orientation (e.g., in a single position, version, inclination, and/or other rotational position relative to the femur 52).

The patient-matched femoral surface 22 need not extend continuously over the entire inner surface of the femoral portion 20. Rather, only select regions of the femoral portion 20 may include the patient-matched surface 22. In some implementations, the patient-matched femoral surface 22 can be configured to conform to the femur 52 by engaging the femur 52 at distinct points or along one or more contour lines.

The patient-matched surface 22 can be textured to improve the overall stability of the guide 10 with respect to the patient's anatomy. For example, the texturing may include serration, points, cross-hatch, grooves, ridges, triangles, bumps, or barbs that increase the friction between the femur 52 and the patient-matched femoral surface 22.

Mating the guide 10 with the femur 52 causes guide holes 24 defined by the femoral portion 20 to be positioned at patient-specific locations and orientations relative to the femur 52. The guide 10 directs a drill bit or alignment pin along a path defined by the guide holes 24. Alignment pins can be inserted through the guide holes 24 to secure the guide 10 to the femur 52 and to indicate alignments for tissue resection or other procedures. Similarly, alignment holes can be pre-drilled for subsequent use.

Mating the guide 10 with the femur 52 also aligns the tibial portion 30 of the guide 10 relative to the tibia 54. The guide 10 mates with the knee 50 while the knee 50 is in extension. In this position, the predetermined position of the femoral portion 20 relative to the femur 52 corresponds to a predetermined position of the tibial portion 30 relative to the tibia 54. The tibial portion 30 defines a surgical alignment with respect to the tibia 54. For example, the tibial portion 30 defines guide holes 34 that can guide the trajectory of a drill bit or an alignment pin. The location and orientation of the guide holes 34 can be selected for the particular patient. For example, as discussed below, the location and orientation of the guide holes 24, 34 in the guide 10 can ultimately establish the location and orientation of tissue resections of the tibia 54 and the femur 52.

The location and orientation of the guide 10 relative to the knee 50, and in particular, relative to the tibia 54, can be achieved primarily or completely based on the fit between the femoral portion 20 and the femur 52. Orienting the tibial alignment based on the features of the femur 52 can be advantageous. For example, the femur 52 can present anterior features and contours that are more varied than anterior features and contours of the tibia 54, resulting in a more stable engagement with the femur 52 than with the tibia 54. In addition, features of the femur 52 may be more accessible during surgery than features of the tibia 54. In particular, during a bi-compartmental arthroplasty, both medial and lateral surfaces of the anterior femur 52 may be exposed. However, only one of the medial or lateral portions of the anterior tibia 54 may be exposed. When replacing the medial compartment, for example, the surgeon may be reluctant to remove tissue on or near the lateral portion of the tibia 54, resulting in less surface area for engagement of the guide 10 with the tibia 54 than with the femur 52. As a result, engagement of the guide 10 with the femur 52, or with both the femur 52 and the tibia 54, can provide a more stable or more easily reproducible engagement than engagement with the tibia 54 alone.

The guide 10 can be configured to simultaneously engage both the femur 52 and the tibia 54. In the mating position of the guide 10 and the knee 50, the tibial portion 30 of the guide 10 can contact a portion of the tibia 54, for example, an anterior portion of the tibia 54. Contact between the tibia 54 and the tibial portion 30 can indicate that full extension of the knee 50 has been achieved, and thus that the femur 52 and the tibia 54 have reached a desired alignment. In some implementations, the guide 10 mates with the knee 50 in flexion, and engagement of the guide 10 with both the femur 52 and the tibia 54 can indicate an appropriate degree of flexion has been achieved.

Engagement of the guide 10 with the tibia 54 can also stabilize and orient the guide 10 in the mating position relative to the knee 50. The tibial portion 30 can optionally include a patient-matched tibial surface 32 that conforms to one or more portions of the tibia, 54, for example, an anterior surface 58 of the tibia 54. The tibial surface 32, like the femoral surface 22, mates with the knee 50 in the predetermined mating position, for example, by engaging the anterior surface 58 of the tibia 54.

Because the guide 10 may simultaneously mate with the femur 52 and the tibia 54, the mating position of the guide 10 defines a predetermined position of the femur 52 relative to the tibia 54. For example, the guide 10 establishes a predetermined rotational position of the tibia 54 about its longitudinal axis relative to the femur 52. Engagement of the guide 10 to both the femur 52 and the tibia 54 can establish the appropriate rotational position of the femur 52 to the tibia 54 in extension, permitting accurate surgical alignment and ultimately permitting the reconstructed compartment to exhibit the desired range of tibiofemoral rotation.

The alignment and degree of tibiofemoral rotation can affect implant sizing and patellar tracking in the reconstructed joint. The guide 10 can align tibiofemoral rotation in extension to permit the maximum size of the tibial implant, ensuring that the tibial surface is correctly reconstructed.

The joint balancing portion 40 of the guide 10 is located between the femur 52 and the tibia 54 when the guide 10 is mated to the knee 50. The joint balancing portion 40 is sized to adjust the alignment of the femur 52 and the tibia 54, for example, to balance the knee 50.

Referring to FIGS. 3 and 4, the natural knee 50 may be misaligned, for example, due to disease or wear. A straight leg x-ray image of the femur 52 and the tibia 54 can indicate the positions of the femur 52 and the tibia 54 in the frontal plane. Analysis of the x-ray image may indicate, for example, that a femoral mechanical axis, FM, is out of alignment with a tibial mechanical axis, TM, by an angle, θ. The femoral mechanical axis, FM, may be defined as a line intersecting the femoral head and a mid-condylar point between the cruciate ligaments. The tibial mechanical axis, TM, may be defined as a line intersecting the center of the tibial plateau and the center of a tibial plafond.

In a balanced knee, the mechanical axes, FM, TM, are substantially collinear. To correct the alignment of the knee 50, a preferred joint spacing distance, D, is calculated that brings the mechanical axes, FM, TM, into alignment. The distance, D, can be a generally superior-inferior distance indicating a desired joint spacing should be increased in either the medial or lateral compartment of the knee 50. In the example illustrated, the knee 50 exhibits varus misalignment, and thus the space between the femur 52 and the tibia 54 should be increased in the medial compartment by the distance, D, to balance the knee 50. To address a valgus deformity, a lateral bi compartmental arthroplasty can be performed, and the balancing component would be inserted into the lateral compartment.

Referring again to FIGS. 1 and 2, the joint balancing portion 40 is formed such that, when the joint balancing portion 40 is inserted between the femur 52 and the tibia 54, the joint balancing portion 40 establishes a preferred spacing between the femur 52 and the tibia 54 that balances the knee 50. For example, the joint balancing portion 40 can be substantially rigid and can be formed with a patient-matched thickness, T, that equals the preferred joint spacing distance, D. As an alternative, the thickness, T can be slightly less than the distance, D, to slightly under-correct the alignment of the knee 50 toward a varus condition. By under-correcting the balance of the knee 50, the surgeon can avoid overloading a healthy compartment of the knee 50 that will not be replaced. The thickness, T, can vary across the joint balancing portion 40 to create the desired spacing and to fit the contours of the femur 52 and the tibia 54.

The joint balancing portion 40 can extend into the joint space 60 between the femur 52 and the tibia 54, for example, substantially to the center of the joint space 60 along an anterior-posterior direction. The joint balancing portion 40 can extend a greater or lesser distance into the joint space 60, and may extend completely through the joint space 60.

The joint balancing portion 40 can optionally include an upper surface 42 that is patient-matched to conform to a distal surface 57 of the femur 52, for example, a distal condylar surface. The joint balancing portion 40 can also optionally include a lower surface 44 that is patient-matched to conform to a proximal surface 59 of the tibia 54, for example, the proximal tibial plateau. The engagement of the patient-matched surfaces 42, 44 to the knee 50 can contribute further stability to the engagement of the guide 10 to the knee 50. In particular, the patient-matched surfaces 42, 44 can contribute to the anterior-posterior stability of the engagement of the guide 10 to the femur 52 and the tibia 54, and the relative rotational orientation (e.g., internal or external rotation) of the femur 52 and the tibia 54.

To use the guide 10, a surgeon creates an incision and exposes the knee 50. The surgeon places the guide such that (i) the femoral surface 22 mates with the femur 52, (ii) the tibial surface 32 mates with the tibia 54, and (iii) the joint balancing portion 40 is inserted between the femur 52 and the tibia 54. The joint balancing portion 40 mates with the femur 52 and the tibia 54 and balances the alignment of the knee 50 so that the surgical alignments can be made with respect to the balanced knee 50.

In this position, the guide holes 24, 34 indicate desired surgical alignments for, for example, inserting alignment pins. The surgeon inserts the alignment pins along the trajectories defined by the guide holes 24, 34 and removes the guide 10 from the knee 50, leaving the alignment pins in place. The alignment pins can orient subsequently attached guides that define alignments for, for example, osteotomy of the femur 52 and the tibia 54. As an alternative, guide holes can be drilled in the bones 52, 54 through the guide holes 24, 34, and alignment pins, posts, or other components can be aligned relative to the guide holes after the guide 10 is removed.

The positions of the alignment pins define surgical alignments for further surgical procedures. Other guides, such as cutting blocks for the femur 52 and the tibia 54, can be coupled to the knee 50 based on the position of the alignment pins, for example, by sliding onto the alignment pins. In other words, the guide 10 defines the alignment for the alignment pins, and the alignment pins define the alignment for one or more cutting blocks. The one or more cutting blocks define alignments for tissue resections to prepare the bones 52, 54 to receive implants.

Because the alignment pins are positioned relative to the balanced knee 50, the alignment pins can align osteotomies calculated to result in the desired joint balance when arthroplasty is complete. By pre-balancing the knee 50, the location and orientations of boney resections can be planned to address boney defects. Ligament tension can be addressed by performing ligament releases if necessary.

In some implementations, the surgeon need not perform an initial resection of one bone 52, 54 and then manually balance the knee 50 to vary the alignment for resection of the other bone 52, 54. Rather, the alignment pins can indicate alignments for both the femur 52 and the tibia 54 resulting in the desired joint balance, without requiring manual joint balancing adjustment by the surgeon during surgery. Thus the surgeon may avoid uncertainty and delays associated with attempting to manually achieve joint balance during surgery using the implant trialing process or by varying tissue resection positions.

The patient-matched positions of the of the alignment pins, resulting from the patient-matched fit of the guide 10 to the knee 50 and the patient-matched positions of the guide holes 24, 34, permit the surgeon to use standard cutting blocks to perform customized resections, resulting in a customized joint balance and implant fit. As an alternative, patient-matched cutting blocks can be used.

In some implementations, the guide 10 can be dimensioned to mate with the knee 50 in flexion, rather than in extension as illustrated. The femoral patient-matched surface 22 can conform to, for example, the distal portion 57 of the condylar surface femur 52, and may also conform to the anterior portion 56 of the femur 52. The joint balancing portion 40 can be dimensioned to conform to the posterior portion of the femoral condylar surface and the proximal tibial plateau. Thus the joint balancing portion 40 can balance the knee 50 in flexion by being located between the posterior of the femoral condyle and one or more proximal portions of the tibia 54.

In some implementations, the joint balancing portion 40 includes a strain gauge or other sensor. The strain gauge can indicate, for example, tension of ligaments of the knee. The guide 10 can include an additional joint balancing portion that extends between the femur 52 and the tibia 54 into the lateral compartment of the knee 50 and also includes a strain gauge. Measurements from the different strain gauges can indicate the relative tension of the ligaments in the medial and lateral compartments, permitting the surgeon to make adjustments to balance the tension. As an alternative, the surgeon can insert one or more strain gauges into the knee 50 that are separate from the guide 10, and can measure ligament tension during flexion and extension of the knee 50.

Referring to FIGS. 5 to 7, examples of tissue resections for the bi-compartmental arthroplasty of the knee 50 are illustrated, one or more of which can be aligned based on the positions of the alignment pins positioned along alignments defined by the guide holes 24, 34 of the guide 10. The tissue resections can include, for the tibia 54, for example, a vertical (e.g., sagittal) cut 82 and a transverse cut 84 (FIG. 7), which can be aligned using a tibial cutting block (not shown) that engages alignment pins of the tibia 54.

For the femur 52, tissue resections can include, for example, an anterior cut 86 and a distal transverse cut 88 (FIG. 7), which can be aligned using a first femoral cutting block (not shown) that engages one or more alignment pins of the femur 52. Additional femoral resections can include, for example, a posterior condylar cut 90, a posterior chamfer cut 92, an anterior chamfer cut 94, and a transition cut 96 (FIGS. 5 and 6). Other transition cuts can also be made. These resections can be aligned using second femoral cutting block 70 that engages one or more alignment pins 72, one or more of which can be placed based on the positions of the guide holes 34 of the guide 10. Additional resections or different resections can be made based on the positions of the alignment pins as needed to accommodate implants for the knee 50. For example, the arthroplasty can also include reaming, resection, or resurfacing of the patella (not shown).

Referring to FIG. 8, after the resections are completed, the surgeon installs a femoral implant 74 at the femur 52 and a tibial implant 76 at the tibia 54. A patellar implant can also be installed to the patella.

Referring FIGS. 9 to 12, an alternative surgical guide 110 can define guide holes 124, 134 for drilling or pin insertion, which can then be used to align cutting blocks for tissue resections. The guide 110 can also define one or more cutting slots 126 that guide tissue resection while the guide 110 is mated to the knee 50.

The guide 110 includes a femoral portion 120, a tibial portion 130, and a joint balancing portion 140. The femoral portion 120 includes a patient-matched surface 122 that conforms to at least part of the anterior portion 56 of the femur 52, and the tibial portion 130 includes a patient-matched surface 132 that conforms to at least part of the anterior portion 58 of the tibia 54. The joint balancing portion 140 is dimensioned to balance the knee 50 in extension, and includes patient-matched portions 142, 144 that conform to a distal surface 57 of the femur 52, and a proximal surface 59 of the tibia 54, respectively.

The patient-matched surfaces 122, 132, 142, 144, as well as other patient-matched surfaces described herein, can include features as described above for the surfaces 22, 32, 42, 44 of the guide 10. Like the guide 10, the guide 110 is configured to mate with the knee 50 in a predetermined position and/or orientation, for example, in a single position.

The femoral portion 120 includes extensions, for example, pin towers 123, through which guide holes 124 are defined. The femoral portion 120 also defines an anterior cutting slot 126 configured to receive an instrument, for example, a saw blade or milling instrument, while the guide 110 is mated with the knee 50. The anterior cutting slot 126 aligns the anterior cut 86 with respect to the femur 52. The cutting slot 126 is configured to perform a captured cut, for example, by limiting movement of an instrument received in the anterior cutting slot 126 in an anterior direction and in a posterior direction. In some implementations, the guide 110 can additionally or alternatively include cutting slots to align one or more of, for example, the femoral distal cut 88 or the tibial transverse cut 84 while the guide 110 is mated to both the femur 52 and the tibia 54.

The guide holes 124 extend through the femoral portion 120 and traverse the anterior cutting slot 126. The pin towers 123 can act as drill guides to stabilize a drill bit or alignment pin during insertion through the guide holes 124, and to facilitate alignment through regions of the femoral portion 120 separated by the anterior cutting slot 126. The femoral portion 120 extends posteriorly about the femur 52 and defines oblique guide holes 128 directed at a medial portion 51 and a lateral portion 53 of the femur 52. Alignment pins can be inserted through the oblique guide holes 128 such that they do not intersect the trajectory of the anterior cut 86. The trajectories of the oblique guide holes 128 can be angled, for example, at substantially a 45 degree angle from a medial-lateral axis in a transverse plane. Alternatively, the trajectories be defined at other angles, or can be substantially parallel to the medial-lateral axis.

To use the guide 110, the surgeon mates the guide 110 with the knee 50 in extension, and the joint balancing portion 140 balances the knee 50. The surgeon inserts guide pins through the oblique guide holes 128 and pre-drills alignment holes in the femur 52 and the tibia 54 in the orientations defined by the guide holes 124, 134. The surgeon can then bring the knee 50 into flexion, decoupling the guide 110 from the tibia 54 but with the guide 110 still mated and pinned to the femur 52. The surgeon then performs the anterior cut 86. The surgeon can then remove the guide 110 from the knee 50.

After the guide 110 is removed, the surgeon may place additional guides along the pre-drilled trajectories of the guide holes 124, 134. For example, a separate femoral guide and a tibial guide, which each may or may not include patient-matched features, can separately be positioned based on the positions of the pre-drilled alignment holes to perform one or more of the resections described with respect to FIGS. 5 to 7.

When the guide 110 is mated with the knee 50, the femoral portion 120 can engage, but need not engage, the medial portion 51 and the lateral portion 53 of the femur 52. In some implementations, the patient-matched surface 122 extends to engage and conform to the medial portion 51 and/or the lateral portion 53, for example, wrapping partially about and conforming to portions of the condyles of the femur 52.

In some implementations, the guide 110 can define cutting slots for the tibial transverse cut 84, the femoral distal cut 88, and the femoral anterior cut 86. The transverse cut 84 and the distal cut 88 can be made with the knee 50 in extension, and with the guide 110 mated to both the femur 52 and the tibia 54. The femoral anterior cut 86 can be made with the knee 50 in flexion, in which the guide 110 is mated to the femur 52 and not to the tibia 54.

In some implementations, the guide 110 is dimensioned to mate with the knee 50 in flexion rather than extension. The joint balancing portion 140 can thus be inserted between a posterior of a femoral condyle and the proximal tibial plateau. When the guide 110 is configured to mate with the knee 50 in flexion, the femoral portion 120 can optionally define cutting slots to establish alignments for one or more of the anterior cut 86, the distal cut 88, and the transition cut 96. The tibial portion 130 can define cutting slots that establish alignments for the transverse cut 84 and/or the vertical cut 82. The tibial portion 130 can additionally or optionally define locations for guide holes to be drilled or for pins to be inserted, which can subsequently align another tibial guide.

Referring to FIG. 13, an alternative surgical guide 210 defines, for example, a femoral anterior cutting slot 226 that aligns the femoral cut 86 while the guide 210 is mated with the knee 50. The guide 210 also defines, for example, a tibial transverse cutting slot 236 that aligns the tibial transverse cut 84 while the guide 210 is mated with the knee 50. The guide can also define a patellar cutting slot 256 that aligns a patellar cut

98 that resects a portion of the patella (not shown). Thus surgical alignments for the femur 52, the tibia 54, and the patella can be defined by a single integral guide 210.

Similar to the guides 10, 110, the guide 210 includes a femoral portion 220, a tibial portion 230, and a joint balancing portion 240, one or more of which can include patient-matched surfaces that conform to portions of the knee 50, permitting the guide 210 to mate with the knee 50 in a predetermined location and orientation. The patient-matched portions can extend from the anterior of the knee 50 in a posterior direction, about both the femur 52 and the tibia 54. For example the patient-matched surfaces can engage and conform to the medial portion 51 and the lateral portion 53 (not shown) of the femur 52 and can engage and conform to a medial portion 51 and a lateral portion (not shown) of the tibia 54.

The joint balancing portion 240 of the guide 210 extends substantially completely through the joint space 60. The femoral portion 220 defines guide holes 224 that guide drilling and insertion of pins into the medial portion 51 and lateral portion 53 of the femur 52. The tibial portion 230 defines guide holes 234 that guide drilling and insertion of pins into the medial portion 61 and lateral portion (not shown) of the tibia 54. Pins aligned along the guide holes 224, 234 can be used for stabilization of the guide 210 while mated to the knee 50 and/or for alignment of surgical procedures after the guide 210 is removed from the knee 50.

The guide 210 defines a recess 250 that is configured to receive the patella. The guide 210 can include a patient-matched patellar surface 252 that conforms to one or more anterior portions of the patella. The patella thus mates with the recess 250 in a predetermined position and orientation, for example, a single position. The guide 210 defines one or more guide holes 254 through which pins can be inserted to maintain the patella in its mated position relative to the guide 210. The depth of the recess 250 and the position of the patella relative to the patellar cutting slot 256 can be set for the needs of the particular patient. The guide 210 can mate with the patella when the guide 210 is not engaged to the femur 52 or the tibia 54, for example, the surgeon can remove the guide 210 from the femur 52 and the tibia 54 and before performing the patellar cut 98.

To perform the patellar cut 98, the surgeon inverts the patella and mates the anterior surface of the patella with the patent-matched patellar surface 252. A portion of the patella is received in the recess 250, and a portion of the patella, for example, a posterior portion of the patella, extends out of the recess 250. The surgeon inserts one or more pins through the guide holes 254 into the patella, securing the patella to the guide 210. In the mating position, the patella is positioned such that the patellar cutting slot 256 aligns the patellar cut 98 at an orientation and position determined for the particular patient. In some implementations, rather than aligning a captured patellar cut 98, the patellar cutting slot 256 can include an edge of the guide 210 that defines an alignment for an uncaptured patellar cut 98. After the patellar cut 98 is performed, a patellar implant can be installed and the patellar implant can be released from the guide 210.

As an alternative, the guide 210 can be configured to engaged the knee 50 in flexion. In such an implementation, the cutting slot 226 can be located to define the alignment for a distal cut 88 for the femur 52, and the joint balancing portion 240 can be dimensioned to balance the knee 50 in flexion.

Referring to FIGS. 14 and 15, an alternative surgical guide 310 can be used for minimally-invasive uni-compartmental arthroplasty of, for example, the medial compartment of the knee 50. Accordingly, the guide 310 is dimensioned with patient-matched surfaces 322, 332 to conform to anterior portions 56, 58 of the knee 50, on the medial side of the knee 50. The guide 310 need not extend to contact a lateral anterior portion 302 of the femur 52.

The position of guide 310 in its mating position with the knee 50 is determined by the engagement of the guide 310 with the femur 52, and optionally with the tibia 54. Additionally, a joint balancing portion 340 can place the knee 50 in balance before establishing surgical alignments. Thus the position of alignment holes 324, 334 relative to the knee 50, and cutting slots 311, 312 can be positioned relative to a balanced knee 50 and based on the position of the guide 310 with the femur 52. Optionally, the guide 310 can define locations and orientations for, for example, the femoral distal cut 88 with the cutting slot 311 and the tibial transverse cut 84, which may each be performed while the guide 310 is mated with the knee 50 in extension.

In many instances, a femoral anterior cut 86 is not performed for a uni-compartmental arthroplasty. If a femoral anterior cut 86 is desired, however, an additional guide can be attached based on the locations of drilled holes in the femur 52, and positioned based on the positions of the alignment holes 324. Alternatively, a cutting slot for an anterior cut 86 can be defined by the guide 310.

Referring to FIG. 16, an alternative surgical guide 410 includes an adjustment mechanism 414 to define surgical alignments that correct for varus or valgus deformity of the knee 50. The guide 410 includes a femoral portion 420 and a tibial portion 430 that are moveable relative to each other while mated with the knee 50. The adjustment mechanism 414 can adjust the relative position of cutting slots 426, 436 defined by the guide 410 or the positions of other surgical alignments defined by the guide 410. As a result, tissue resections can be aligned to correct for varus or valgus deformity of the knee 50 without inserting a portion of the guide 410 into the joint space 60. Rather than balancing the knee 50 to relative to fixed cutting slots, the relative position of the slots can be adjusted relative to the bones 52, 54 of the knee 50.

The adjustment mechanism 414 increases or decreases a space, S, between the femoral portion 420 and the tibial portion 430. The adjustment mechanism 414 can include, for example, a bolt 416 that extends between the femoral portion 420 and the tibial portion 430. The bolt 416 can be coupled to one portion 420, 430 of the guide 410 and can engage a threaded receiving portion of the other portion 420, 430 of the guide 410. Turning the bolt in opposing directions increases or decreases the space, S. The adjustment mechanism 414 can adjust the spacing on one side of the knee 50, for example, the medial side, while the spacing on the other side of the knee 50, for example, the lateral side, is maintained or is adjusted to a lesser degree. For example, the guide 410 can include a joint 417, for example, a flexible portion, located opposite the adjustment mechanism 414. In some implementations, a hinge, pivot, or other joint can attach the femoral portion 420 and the tibial portion 430. The guide 410 can define a patient-matched, non-adjusable degree of tibiofemoral rotation for the knee 50 while permitting adjustment to balance the knee 50.

In use, a surgeon mates a patient-matched surface of the tibial portion 430 with the tibia 54, and inserts pins through guide holes 412 defined by the tibial portion 430. The surgeon then adjusts the adjustment mechanism 414 to change the relative positions of the cutting slots 426, 436. The desired positions of the cutting slots 426, 436 may be determined based on anatomical landmarks of the knee 50. Alternatively, the adjustment mechanism 414 can be adjusted to a predetermined position determined based on imaging data for the knee 50. When the desired adjustment is achieved, the surgeon pins the femoral portion 420 to the femur 52, and the cutting slots 426, 436 define alignments that can result in the desired joint balance in the reconstructed knee 50.

As an alternative, the surgeon can first mate a patient-matched surface of the femoral portion 420 to the femur 52, pin the guide to the femur 52 through the guide holes 413, adjust the adjustment mechanism 414, and then pin the tibial portion 430 to the tibia 54 based on the aligned position.

In some implementations, pins can be placed in the femur 52 through elongated holes in the femoral portion 420 that permit movement of the femoral portion 420 relative to the pins. As the surgeon balances the knee 50 using the adjustment mechanism 414, the femoral portion 420 and the femoral cutting slot 426 move relative to the femur 52. The surgeon can then move the femoral cutting slot 426 into a planned position, and after tissue resections are performed, can release ligaments as needed for joint balance.

In some implementations, the cutting slots 426, 436 of the guide 410 can be separately adjustable from portions of the guide 410 that balance the knee 50. For example, the guide 410 can be pinned to the femur 52 and the tibia 54, for example, through captured holes of the guide 410. Moving the adjustment mechanism 414 can change the position of the femur 52 and the tibia 54 relative to each other. A separate portion of the guide 410 can define the cutting slots 426, 436. The position of the cutting slots 426, 436 can be fixed. For example, the cutting slots 426, 436 can remain parallel to each another at a planned location and orientation, which can be patient-specific. Alternatively, the location and orientation of the cutting slots can be adjustable separately from the adjustment mechanism 414.

Referring to FIG. 17, an alternative guide 450 defines surgical alignments relative to the femur 52 and the tibia 54 when the knee 50 is in extension. The guide 450 includes a patient-matched surface 460 that conforms to, for example the anterior portion 56 of the femur 52. The guide 450 also includes surfaces 462 that conform to, for example, the anterior portion 58 of the tibia 54. One or more of the patient-matched surfaces 462, or another portion of the guide 450, can extend into the joint space 60 of the knee 50 to balance the knee 50.

The guide 450 defines a femoral distal cutting slot 470 that aligns the distal cut 88 for the femur 52 and defines a tibial transverse cutting slot 472 that aligns the transverse cut 84. The position of the cutting slot 472 is independent from the varus and valgus correction for the knee 50, permitting fine adjustment of the alignment of the transverse cut 84 by the surgeon.

Several portions of the guide 450 can be configured to move relative to each other. The positions of the cutting slots 470, 472 can move inferiorly or superiorly so that the resection level can be adjusted. In use, a tibial portion of the guide 450 can be initially pinned to the tibia 54, and the guide 450 can be adjusted to move the cutting slots 470, 472 into desired positions relative to the tibia 54 and the femur 52.

For example, the portions of the guide 450 defining the cutting slots 470, 472 can pivot as a single unit about an axis, for example, about an axis relative to the portion of the guide 450 that includes the patient-matched surfaces 462. A portion of the guide 450 defining the femoral distal cutting slot 470 and a portion of the guide 450 defining the tibial transverse cutting slot 472 can move along a linear axis relative to the portion that includes the patient-matched surfaces 462. By moving these portions relative to each other, a level can be set for the femoral distal cutting slot 470 at a desired distance from, for example, the patient-matched surfaces. In some implementations, a level for femoral distal cutting slot 470 can be adjusted with either a sliding or screwing mechanism. After a desired alignment of the guide 450 is achieved, the portions of the guide 450 defining the cutting slots 470, 472 can be pinned to the femur 52 and the tibia 54, respectively, so that the desired alignment is maintained.

Referring to FIG. 18, an alternative surgical guide 510 can include one or more constant force elements 512, for example, one or more springs, that balance the knee 50. The constant force element 512 can be part of a joint balancing portion 514 of the guide 510 that is configured to be inserted between the femur 52 and the tibia 54 when the guide 510 is mated with the knee 50, in extension as illustrated, or in flexion. With the surgical guide 510 mated to the knee 50, tissue resections can be performed in the balanced knee 50.

At a given displacement or spacing, the constant force element 512 can exert a predetermined and patient-matched amount of force, for example, in an inferior-superior direction, B, between the femur 52 and the tibia 54. The constant force element 512 exerts an amount of force that, for example, positions the knee 50 in a desired alignment to correct for varus or valgus deformity. The desired alignment can be, for example, a space, S_1, between the femur 52 and the tibia 54 in the medial compartment. The constant force element 512 can place a desired amount of tension on the ligaments of the knee 50, permitting balancing of the ligaments.

The guide 510 includes a femoral portion 520 that includes a patient-matched surface 522 that conforms to a portion of the femur 52. The femoral portion 520 mates with the femur 52 in a predetermined position and orientation, orienting the guide 510 relative to the femur 52 and positioning a guide portion, for example, a portion defining a femoral cutting slot 523 or guide hole, relative to the femur 52.

A tibial portion 526 of the guide 510 defines, for example, a tibial cutting slot 527 or guide hole. The tibial portion 526 may engage the tibia 54 but need not do so. When the guide 510 is mated with the femur 52, the constant force element 512 establishes a position of the femur 52 relative to the tibia 54. Consequently, the constant force element 512 moves the tibia 54 into a desired alignment relative to the tibial cutting slot 527 of the tibial portion 526. The tibia 54 can then be pinned or otherwise secured in this position so that the tibial cut can be performed.

The alignment of the tibial cutting slot 527 can thus be established relative to the tibia 54 as a result of the fit between the femoral portion 520 and the femur 52 and the force exerted by the constant force element 512 between, for example, the distal portion 57 of the femur 52 and the proximal portion 59 of the tibia 54. In some implementations, the alignment of the tibial cutting slot 527, and in particular, the height of the tibial cutting slot 527 along the longitudinal axis of the tibia 54, is not determined by engagement of the tibial portion 526 with the tibia 54.

Referring to FIG. 19, the guide 510 can include constant force elements 512 that are inserted into the medial and lateral compartments. The forces exerted by each constant force element 512 can be different. For example, the force exerted by the constant force element 512 in the medial compartment can be larger than the force exerted by the constant force element 512 in the lateral compartment to correct for a varus deformity. The guide 510 can include strain gauges to measure the forces applied in each of the medial and lateral compartments.

Referring to FIG. 20, an alternative surgical guide 550 includes a femoral portion 552 and a tibial portion 554, which each define surgical alignments relative to the femur 52 and the tibia 54, respectively. The femoral portion 552 is patient-matched to conform to, for example, the anterior femoral cortex (e.g., the anterior portion 56) and a portion of the distal femoral condyle, and the tibial portion 554 is patient-matched to conform to, for example, the anterior tibial cortex (e.g., the anterior portion 58).

Rather than including a fixed joint balancing portion, the guide 550 defines a slot 558 or window through which an alignment component can be inserted. In the mating position of the guide 550 with the knee 50, the slot can be located at or near the joint line or interface of the femur 52 and the tibia 54. The alignment component can be, for example, a spoon-like insert 560 that can be introduced through the slot 558 and between the femur 52 and the tibia 54. Alternatively, a flat insert of a particular thickness or a shim with a varying thickness can be inserted. The insert 560 can be an instrument of a standard size, for example, selected from a set of instruments to match the anatomy of the patient. Alternatively, the insert 560 may be formed with patient-matched contours to fit the knee 50.

The guide 550 can mate with the femur 52 and the tibia 54, for example, at anterior portions 56, 58 of the femur 52 and the tibia 54, in a predetermined position. Introducing the insert 560 into the joint space 60 can establish the desired position of the tibia 54 relative to the guide 550, for example, adjusting the position of the tibia 54 relative to a cutting slot 562 defined by the tibial portion 554. The position of the insert 560 relative to the knee 50 can assist to position the guide 550 relative to the knee 50.

The insert 560 can optionally include a distraction-controlled or load-controlled mechanism. In some implementations, the insert 560 can include a strain gauge or other sensor to measure force between the femur 52 and the tibia 54, which can be used to determine ligament balance in the knee 50.

In some implementations, an extramedullary tower or drop rod can be used to establish or verify one or more surgical alignments. A surgeon can attach an extramedullary tower to the patient's ankle with a clamp. The tower can be aligned with the tibia 54, and the surgeon can use the tower to align a resection device or pinning device to correct mechanical alignment of the leg.

With the guide 550 mated to the knee 50, the surgeon can attach a drop rod to the guide 550, for example, using an adaptor that fits into the slot 558 or a cutting slot of the guide 550. While the drop rod is coupled to the guide 550, the surgeon can verify or modify the alignment of a cutting device or pinning device so that, for example, the drop rod is parallel to a mechanical axis of the femur 52 and/or the tibia 54.

Referring to FIGS. 21 to 25, an alternative surgical guide can include separable and reattachable modules, for example, a modular femoral portion 620 and a modular tibial portion 650. The femoral portion 620 can be used separately from the tibial portion 650 to establish surgical alignments. The tibial portion 650 be positioned based on the position of the femoral portion 620 to establish other surgical alignments.

The femoral portion 620 engages the femur 52 in a predetermined orientation. The femoral portion 620 can be an assembly including an anterior portion 630 and a detachable distal portion 640. The anterior portion 630 and the distal portion 640 can together establish a position relative to the femur 52, and the portions 630, 640 can be separated after the position is established.

The anterior portion 630 includes a patient-matched surface 632 that conforms to, for example, the anterior portion 56 of the femur 52. The distal portion 640 includes a patient-matched surface 642 that conforms to, for example, the distal portion 57 of the femur 52, such as condylar surfaces of the femur 52. The distal portion 640 can engage distal portions of the femoral condyles while defining a space 643 to admit, for example, the cruciate ligaments of the knee 50. The engagement of the patient-matched surfaces 632, 642 with the femur 52 mates the femoral portion 620 to the femur 52 in a predetermined orientation and position.

The anterior portion 630 includes a guide portion 634 that defines a distal cutting slot 636 that establishes the alignment for the distal cut 88. The anterior portion 630 is formed to define a patient-specific location and orientation for the cutting slot 636. In a similar manner, the distal portion 640 includes a guide portion 644 that defines an anterior cutting slot 646 that establishes the alignment for the anterior cut 86.

The anterior portion 630 and the distal portion 640 can be coupled at an interface or joint 625. Interlocking structures at the interface 625 couple the portions 630, 640, for example, securing the portions 630, 640 in a single predetermined orientation. As shown in FIG. 22, the interlocking structures can include, for example, one or more extensions 628, such as a clasp, hook, or post, and one or more corresponding receiving portions 629. Other fastening mechanisms can alternatively be used.

The tibial portion 650 engages the anterior portion 630 to define surgical alignments relative to the tibia 54 while the knee 50 is in extension. The tibial portion 650 derives its location and orientation relative to the tibia 54 completely or partially due to its engagement with the anterior portion 630. The tibial portion 650 includes an extension 652 that engages the anterior portion 630. For example, the extension 652 can be shaped to be received in the distal cutting slot 636 of the anterior portion 630 when the knee 50 is in extension, resulting in a predetermined location and orientation relative to the anterior portion 630. The tibial portion 650 can include a surface 651 to contact the tibia 54, for example, at the anterior portion 58. The surface 651 can be, but need not be, patient-matched to conform to the anterior portion 58.

The tibial portion 650 can define, for example, a transverse cutting slot 654 to align the transverse cut 84 and a vertical cutting slot 656 to align the vertical cut 82. The tibial portion 650 can also define guide holes 653 to align drilling or pin insertion. The positions of the cutting slots 654, 656 and the extension 652 may be patient-matched to define the preferred surgical alignments determined for the patient based on imaging data for the knee 50. For example, a patient-specific height, H, between the extension 652 and the transverse cutting slot 654 can determine the location of the transverse cut 84. The shape and other dimensions of the tibial portion 650 can also be patient-matched to establish the proper location and orientation, including rotation, relative to the tibia 54. The location and orientation defined for the tibial cuts 82, 84 can be set such that the cuts result in a balanced knee 50 when the arthroplasty is complete.

In use, the surgeon brings the knee 50 into flexion, for example, approximately 90 degrees of flexion (FIG. 24). The surgeon couples the anterior portion 630 and the distal portion 640 together to form the femoral portion 620. The surgeon engages the femoral portion 620 to the femur 52 in, for example, a unique position in which the femoral portion 620 mates with the femur 52. In this position, the anterior cutting slot 646 and the distal cutting slot 636 define their respective patient-specific surgical alignments relative to the femur 52. The surgeon can drill alignment holes into the femur 52 through guide holes 638, 648 defined by the anterior portion 630 and the distal portion 640. The guide holes 638, 648 can be defined through pin towers 639, 649 that extend away from the femur 52. The surgeon inserts pins into the femur 52 through the guide holes 648 to perform the anterior cut 86. The surgeon then removes the pins from the guide holes 648, inserts pins into the femur 52 through the guide holes 638 and performs the distal cut 88. As an alternative, the surgeon may perform the distal cut 88 before performing the anterior cut 86.

Referring to FIG. 25, the surgeon then detaches the distal portion 640 from anterior portion 630, and removes the distal portion 640 from the femur 52. Resected tissue can be cleared from the knee 50. One or more pins 661 can secure the anterior portion 630 to the femur 52. The pins 661 can extend through the guide holes 638 along pre-drilled holes in the femur 52, permitting the anterior portion 630 to be positioned in in the initial mating position with the femur 52 even though the anterior portion 56 of the femur 52 has been resected and thus the patient-matched surface 632 does not match the anterior surface 663 of the femur 52 after the anterior cut 86. In some implementations, as described below, an augment or spacer may be placed between the anterior surface 663 and the anterior portion 630 to stabilize the position of the anterior portion 630.

The surgeon brings the knee 50 into extension. The surgeon couples the tibial portion 650 to the anterior portion 630 in a predetermined position, which can be, for example, a unique position of engagement with the anterior portion 630. For example, the surgeon can insert the extension 652 of the tibial portion 650 into the distal cutting slot 636. The tibial portion 650 is thus aligned based on the position of the anterior portion 630. The surgeon can then pin the tibial portion 650 to the tibia 54 through the guide holes 653 and perform the transverse cut 84, guided by the cutting slot 654, and the vertical cut 82 guided by the cutting slot 656.

As an alternative, the femoral portion 620 can be dimensioned such that the distal portion 640 can be coupled to the anterior portion 630 in extension of the knee 50. The distal portion 640 can be formed without the pin towers 649, for example, and the distal portion 640 can include patient-matched thickness to balance the knee 50 in extension.

In some implementations, the anterior portion 630 extends to engage a part of the distal portion 57 of the femur 52, and the anterior portion 630 defines both the distal cutting slot 636 and the anterior cutting slot 646. For example, the interface 625 between the anterior portion 630 and the distal portion 640 can be located between the anterior cutting slot 646 and the guide holes 648 of the distal portion. The distal portion 640 can be used to facilitate the initial fit of the anterior portion 630 to the femur 52, or in some implementations, a distal portion may not be used.

In some implementations, after the surgeon establishes pin placement positions relative to the femur 52 using the anterior portion 630, the surgeon can attach an additional surgical guide that permits the surgeon to adjust the locations of one or more femoral cuts. For example, the additional guide can define, or permit adjustment of, the posterior cut 90 and the other femoral cuts to correct for differences in the balance of the knee 50 during flexion and extension.

The surgical guides described herein can be coupled to augments dimensioned to engage a site from which bone has been resected. After an osteotomy is performed, an augment can be inserted in place of resected bone, substantially replacing the resected tissue to stabilize and orient a guide. The augment can thus facilitate returning the guide to substantially the same position established using a patient-matched fit before the osteotomy. Augments can engage, for example, the patient-matched surfaces of a guide, or bone surfaces created by resection of tissue. Augments can additionally or alternatively include surfaces that are patient-matched to conform to natural surfaces of the patient’s anatomy, for example, bone surfaces before tissue is resected.

Augments can have patient-matched dimensions that, for example, substantially match one or more dimensions of a resected portion of tissue. Prior to surgery, for example, the size and shape of tissues to be resected can be determined using the three-dimensional digital model for the knee 50. Augments can then be formed to correspond to the dimensions of tissues that will later be resected during surgery.

For example, the dimensions of the bone segment to be resected with the anterior cut 86 of FIG. 24 can be calculated, and an augment of those dimensions can be formed prior to surgery. After the anterior cut 86 is performed, the augment can be inserted between the anterior surface 663 of the femur 52 and the patient-matched surface 632 of the anterior portion, helping secure the anterior portion 630 in the position shown in FIG. 25. Pins placed through the guide holes 638 can extend through the augment to position the augment. The augment, or an additional augment, can replace the bone segment removed by the distal cut 88, and can be formed with dimensions that balance the knee 50.

In some implementations, rather than adding a modular augment to a guide portion, a replacement guide portion can be pre-formed to include the augment. For example, an anterior portion formed to include an integral patient-specific augment can be used instead of the anterior portion 630 of FIG. 25 following the anterior cut 86. Similar augments can be formed to replace resected portions of the tibia 54.

Referring to FIG. 26, the femoral portion 620 can include a distal portion 670 as an alternative to the distal portion 640. The distal portion 670 can attach to the anterior portion 630 to balance the joint and to provide alignment for the femoral posterior cut 90. In addition, the distal portion 670 can couple to the tibial portion 650, aligning the tibial portion 650 relative to the tibia 54 when the knee 50 is in flexion. The distal portion 670 and the anterior portion 630 can be detachable or alternatively can form an integral unit.

The distal portion 670 can include a joint balancing portion 672 dimensioned to fit between the posterior portion of the femoral condylar surface and the proximal portion of the tibial plateau to balance the knee 50 in flexion. The joint balancing portion 672 can include patient-matched surfaces 673, 674 to respectively conform to the posterior portion of the femoral condylar surface and to the tibial plateau. The joint balancing portion 672 can extend to engage posterior portions of a condyle of the femur 52 in a compartment that is to be replaced.

The thickness of the joint balancing portion 672 can also be patient-matched. As an alternative to an integral joint balancing portion 672, a modular insert, such as a shim, spoon, blade, or wedge, or can be inserted between the femur 52 and the tibia 54 to balance the joint in flexion. As another alternative, the joint balancing portion 672 may be formed as part of the tibial portion 650, or may be a modular portion that attaches to the distal portion 670 or the tibial portion 650.

The tibial portion 650 can be dimensioned to provide alignment for the tibial cuts 82, 84 in flexion based on engagement with the distal portion 670. For example, the position of the tibial portion 650 can be based on the position of an anterior cutting slot 686, a posterior cutting slot 687, pin towers 689, or alignment holes 688. For example, the extension 652 of the tibial portion 650 can be received in the posterior cutting slot 687. The surgeon can thus simultaneously engage the portions 630, 640, 670 to the knee 50 in flexion. The surgeon can pin the tibial portion to the tibia 54 through the tibial guide holes 653 before performing the anterior cut 86 or the distal cut 88.

In some implementations, the tibial portion 650 can be positioned relative to the tibia 54 in flexion and also in extension. The extension 652 can be received in the posterior cutting slot 687 of the distal portion 670 in flexion (FIG. 26), and can be received in the anterior cutting slot 636 of the anterior portion 630 in extension (FIG. 25). In some implementations, a different portion of the tibial portion 650 can be received in the different cutting slots 687, 636.

In some implementations, the distal portion 670 can be retained in engagement with the femur 52 in both flexion and extension of the knee 50. For example, the distal portion 670 can be formed without protruding surfaces, such as pin towers. The distal portion can include contours and a thickness that are patient-matched to balance knee 50 and to engage both the femur 52 and the tibia 54 in both flexion and extension.

Referring to FIG. 27, a surgical guide 700 defines surgical alignments relative to the tibia 54. The guide 700 can be mated with the knee 50 in flexion. The surgical guide 700 defines a transverse cutting slot 702 to align the transverse cut 84 and defines a vertical cutting slot 704 to align the vertical cut 82. The surgical guide 700 also includes patient-matched surfaces 706, 708 that conform to the anterior and proximal portions of the tibia 54, respectively. The guide 700 can thus engage the tibia in, for example, a single location and orientation. The guide 700 can also include a patient-matched upper surface 709 that conforms to the contours of the posterior portion of a condylar surface of the femur 52.

The surgical guide 700 includes a substantially vertical alignment feature 710 that can provide alignment relative to the femur 52. The alignment feature 710 can be aligned with, for example, one or more of a femoral condyle edge, a tibial spine, and/or fibers of the ACL. The alignment feature 710 can engage one or more of these anatomical features to determine a position relative to the knee 50. For example, to define alignments for a medial compartment arthroplasty, a lateral surface 712 of the alignment feature 710 can engage a lateral portion of the medial condyle of the femur 52 (e.g., with the alignment feature 710 located between the medial and lateral condyles). As an alternative, a medial surface 714 of the alignment feature opposite the lateral surface 712 can engage a medial portion of the medial condyle (e.g., with the alignment structure 710 located medial of the medial condyle).

Referring to FIG. 28, a surgical guide 750 defines surgical alignments relative to the tibia 54 while the knee 50 is in extension. The guide 750 can include a constant-force element, such as a spring 751 that balances the knee 50. The guide 750 can include a surface 752 that mates with, for example, a distal portion of the femur 52. The surface 752 can be dimensioned to fit the distal surface of the femur 52 after the distal cut 88 (FIG. 7) has been performed. Alternatively, the surface 752 can conform to the distal portion of the femur 52 before the distal cut 88 is performed.

The position of a cutting slot 753 can be based on engagement of the guide 750 between the femur 52 and the tibia 54, and need not be based on engagement with the anterior portion of the tibia 54 or the anterior portion 56 of the femur 52.

Referring to FIG. 29, a surgical guide 800 defines alignments relative to the tibia 54 based on engagement with the femur 52 and the tibia 54. The guide 800 can be configured to mate with the knee 50 in extension or in flexion. The guide 800 includes extensions 802, 804 that are dimensioned to balance the knee 50 when inserted into the joint compartment 60 of the knee 50. Each extension 802, 804 can include patient-matched contours to fit the femur 52 and/or the tibia 54. The guide 800 defines a space 806 to admit the cruciate ligaments of the knee 50. The guide 800 defines, for example, cutting slots 810, 812 to align the tibial transverse cut 84 and the tibial vertical cut 82 and or alignment holes (not shown) for drilling or pin insertion.

Referring to FIGS. 30 and 31, a surgical guide 850 defines uncaptured cuts for the tibia 54. The guide 850 can be aligned to the tibia 54 based on the position of alignment holes drilled using one of the other guides described above. For example, guide holes 851 of the guide 850 can attach to pins previously placed in the tibia 54.

The guide 850 includes a surface 860 that defines the location and orientation for the transverse cut 84. The surface 860 can be sloped to match the natural slope for the patient, as determined by imaging data for the knee 50. For example, the slope defined for the tibial transverse cut 84 can be substantially aligned with a slope 880 of the proximal tibia 54, for example, a portion of the tibial plateau. For example, patients typically have a dropping slope that begins at the anterior horn of the tibia 54 and drops off posteriorly. The posterior slope may be, for example, between 3 to 7 degrees, and the slope can vary significantly from one patient to another. Because the surface 860 is formed to match the slope 880 of a particular patient, the tibial transverse cut 84 can be aligned and performed at the anatomical posterior slope for the patient.

The guide 850 also includes an extension 865 that defines the location and the orientation (e.g., rotation or angular position relative to the tibia 54) of the vertical cut (not shown). The position of the extension 865 can optimize sizing for a tibial implant. For example, in arthroplasty of a medial compartment, the vertical cut can be located as lateral as possible without interfering with the attachment of the cruciate ligaments. The vertical cut can be defined by a side surface of the extension 865.

To perform arthroplasty using the surgical guides described above, multiple guides can be used in sequence. At different stages of a procedure, the contours of the femur 52 and the tibia 54 can change, for example, due to osteotomies. Guides can be formed prior to the procedure to match the different shapes of the bones 52, 54 that will be present at different stages of the procedure.

For example, a first guide can define one or more surgical alignments. The first guide can be patient-matched to conform to features of the patient's natural anatomy. An osteotomy can be performed based on alignment of the first guide, and the first guide can be removed from the knee 50. A second guide can be mated to the knee 50 to define additional surgical alignments. The second guide can include patient-matched features that conform to a site of a tissue resection, for example, a bone surface exposed due to the osteotomy. The second guide can establish a position relative to the knee 50 at least in part due to engagement with the tissue resection site. The second guide can also conform to features of the patient's natural anatomy, for example, portions unchanged by the osteotomy. Additional guides can be used at other stages of the procedure.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. For example, each of techniques shown can be used for arthroplasty of a left knee or a right knee. The guides described above may be configured for arthroplasty of a medial compartment or a lateral compartment, or both, and may or may not define alignments for arthroplasty of a patellofemoral compartment. The guides can, but are not required to, include joint balancing features to assist in balancing the knee. Joint balancing features can each include a strain gauge or other sensor. Each of the joint balancing features described above can be integral to a surgical guide, can be modules that securely attach to a guide at a predetermined position, or can be separate components. In addition, each guide may be configured to define surgical alignments relative to the knee in extension, or in flexion, or in some implementations, both flexion and in extension. Guides described as being modular may alternatively be implemented as integral, monolithic components, and guides described as being integral can be implemented as multiple modules. Accordingly, other implementations are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. A surgical guide comprising:

a femoral portion including a femoral surface dimensioned to conform to a portion of a femur of a particular patient;

a tibial portion defining a surgical alignment for a tibia of the patient,

wherein the femoral portion of the surgical guide is configured to align the tibial portion relative to the tibia based on engagement of the femoral surface with the femur.

2. The surgical guide of claim 1, wherein the femoral portion defines a surgical alignment for the femur.

3. The surgical guide of any of the preceding claims, wherein the tibial portion includes a tibial surface dimensioned to conform to a portion of the tibia, and the surgical guide is configured to align the tibial portion relative to the tibia based on engagement of the tibial surface with the tibia.

4. The surgical guide of claim 3, wherein the tibial portion is configured to mate with the tibia and the femoral portion is configured to mate with the femur while the tibia and the femur are in extension.

5. The surgical guide of claim 3 or 4, wherein the tibial portion is configured to mate with the tibia and the femoral portion is configured to mate with the femur while the tibia and the femur are in flexion.

6. The surgical guide of any of the preceding claims, wherein the surgical guide is configured to admit a joint balancing insert for insertion between the femur and the tibia.

7. The surgical guide of any of the preceding claims, comprising a joint balancing component configured to be positioned between the tibia and the femur, the joint-balancing component having a patient-specific dimension.

8. The surgical guide of any of the preceding claims, comprising a patient-specific augment to couple to the surgical guide and to balance the joint after a portion of the tibia or the femur is resected.

9. The surgical guide of any of the preceding claims, comprising a patient-specific patellar interface and defining a surgical alignment for a patella of the patient.

10. The surgical guide of any of the preceding claims, comprising a constant-force mechanism configured to be inserted between the tibia and the femur.

11. The surgical guide of any of the preceding claims, wherein the femoral portion and the tibial portion are detachable and reattachable.

12. The surgical guide of any of the preceding claims, wherein the femoral portion comprises an anterior portion and a detachable distal portion.

13. The surgical guide of any of the preceding claims, wherein the femoral portion and the tibial portion are configured to be coupled in a first orientation to engage the femur and the tibia in extension, and to be coupled in a second orientation to engage the femur and the tibia in flexion.

14. The surgical guide of any of claims 1 to 10, wherein the femoral portion and the tibial portion form an integral unit.

15. A method of establishing a surgical alignment, comprising:

obtaining a surgical guide defining a surgical alignment for a tibia and a patient-specific surface dimensioned to conform to a portion of a femur of a particular patient;

aligning the surgical guide relative to the tibia based on the engagement of the patient-specific surface with the femur; and inserting one or more pins into the tibia based on the position of the surgical guide while the patient-specific surface is in engagement with the femur.

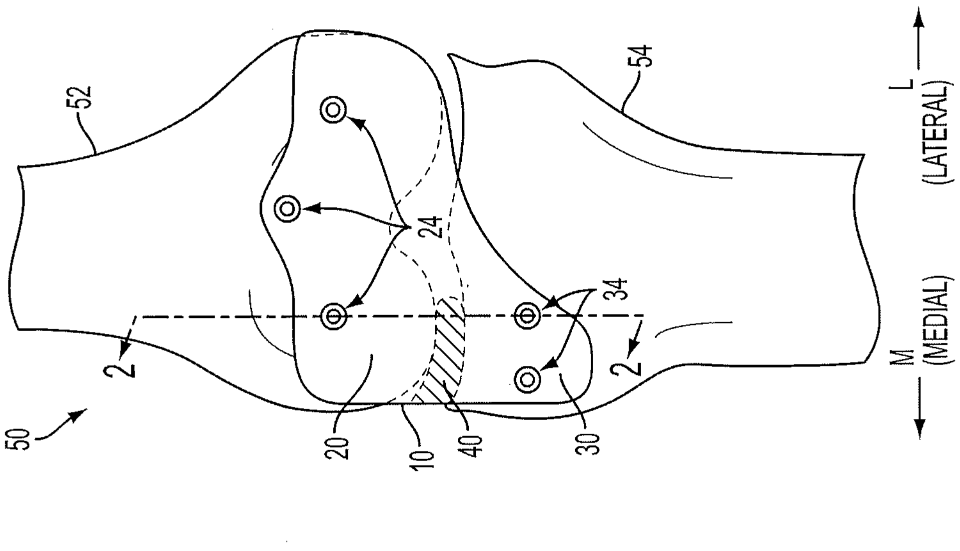

50
52
54
24
20
10
40
30
34
2
2
M
(MEDIAL)
L
(LATERAL)

FIG. 1

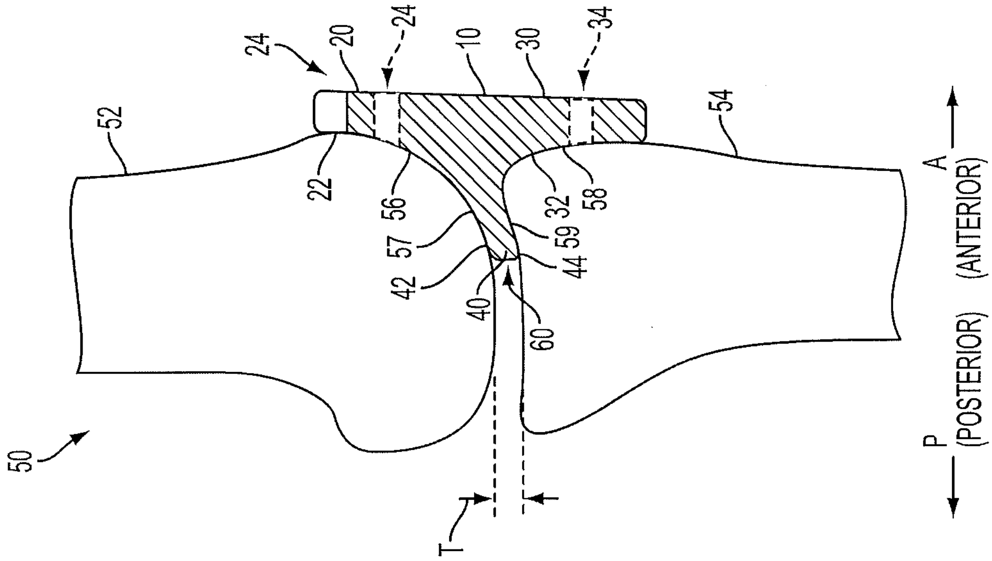

50
52
54
24
20
24
10
30
34
22
56
57
42
40
60
44
59
32
58
T
P
(POSTERIOR)
A
(ANTERIOR)

FIG. 2

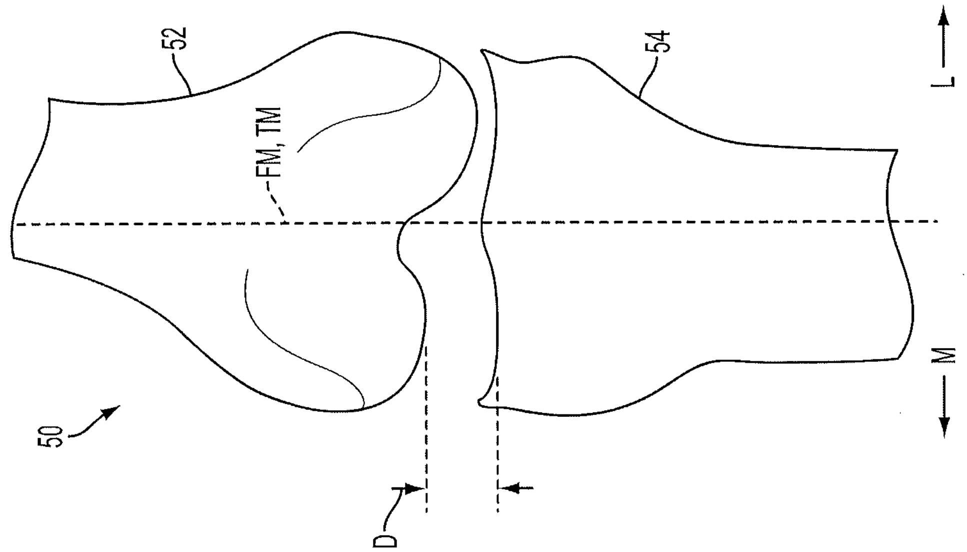


FIG. 4

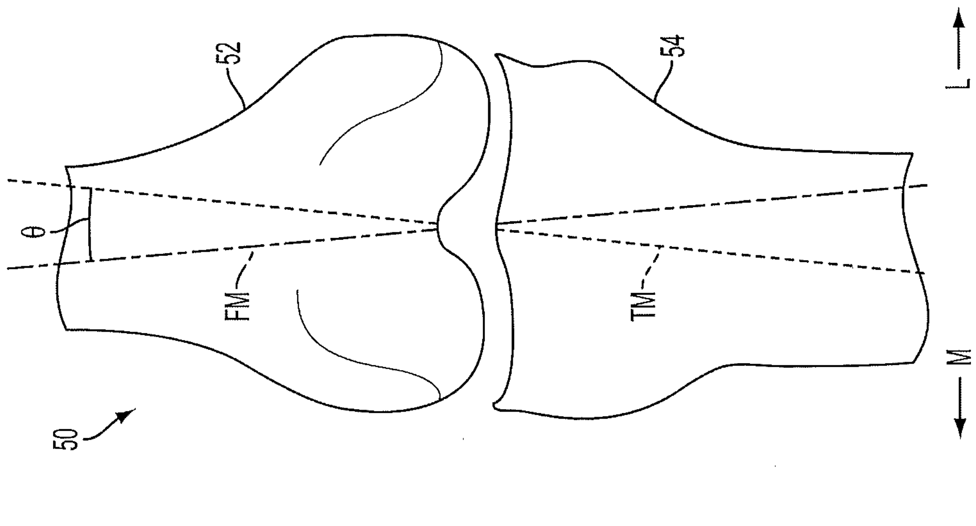


FIG. 3

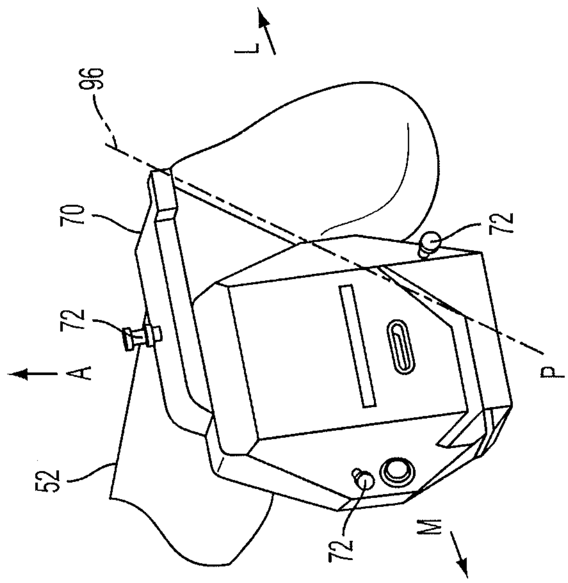


FIG. 6

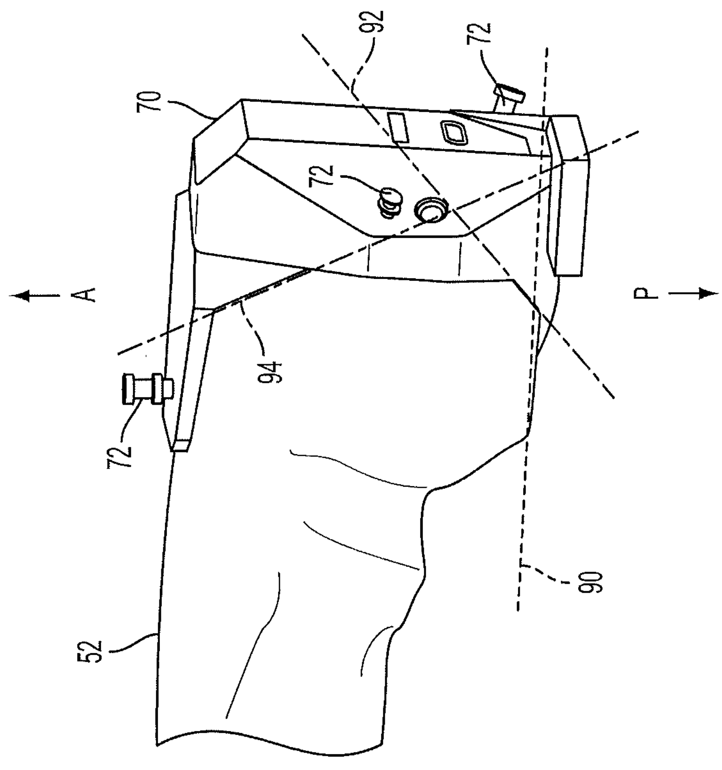


FIG. 5

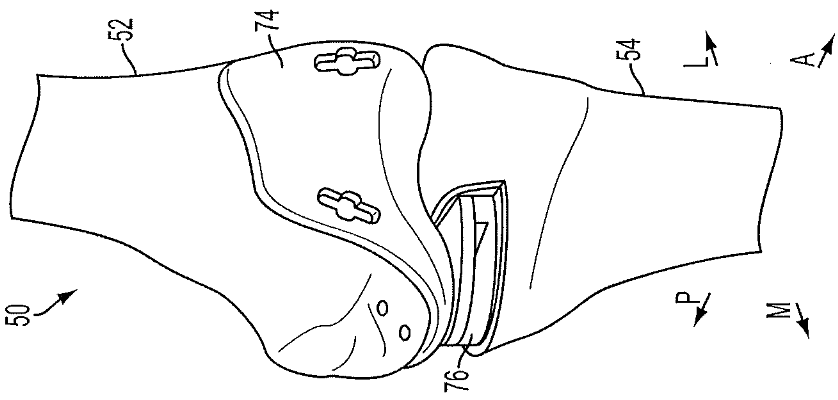


FIG. 8

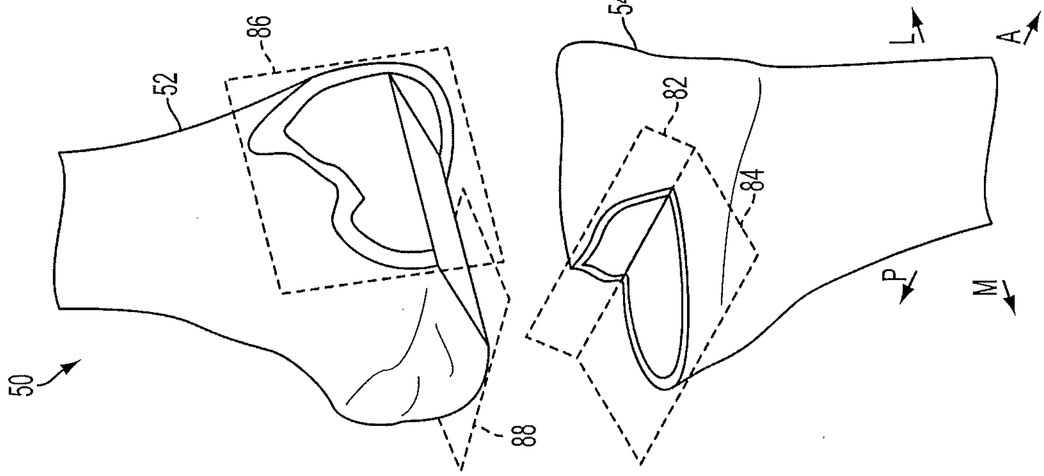


FIG. 7

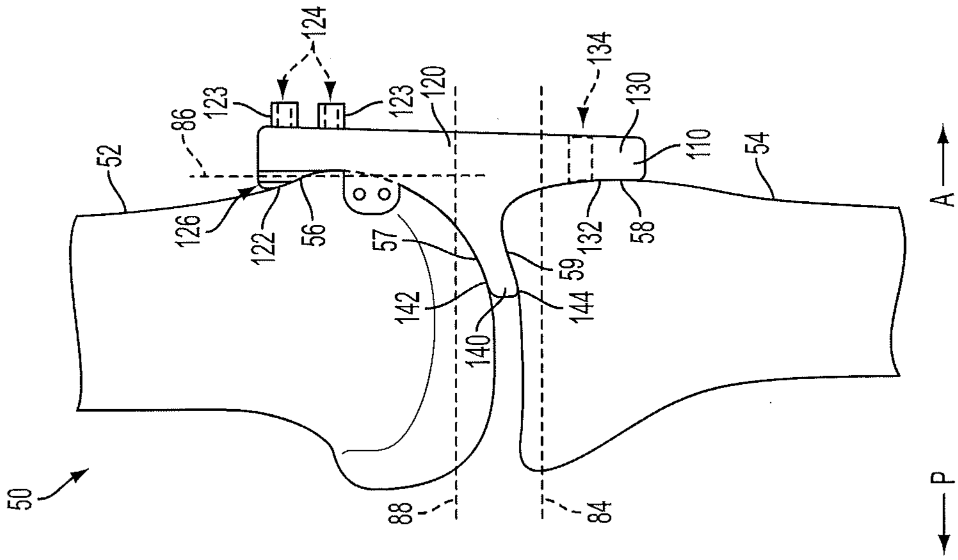

50
52
86
123
124
123
120
134
130
110
54
126
122
56
57
142
140
144
59
132
58
88
84
A
P

FIG. 10

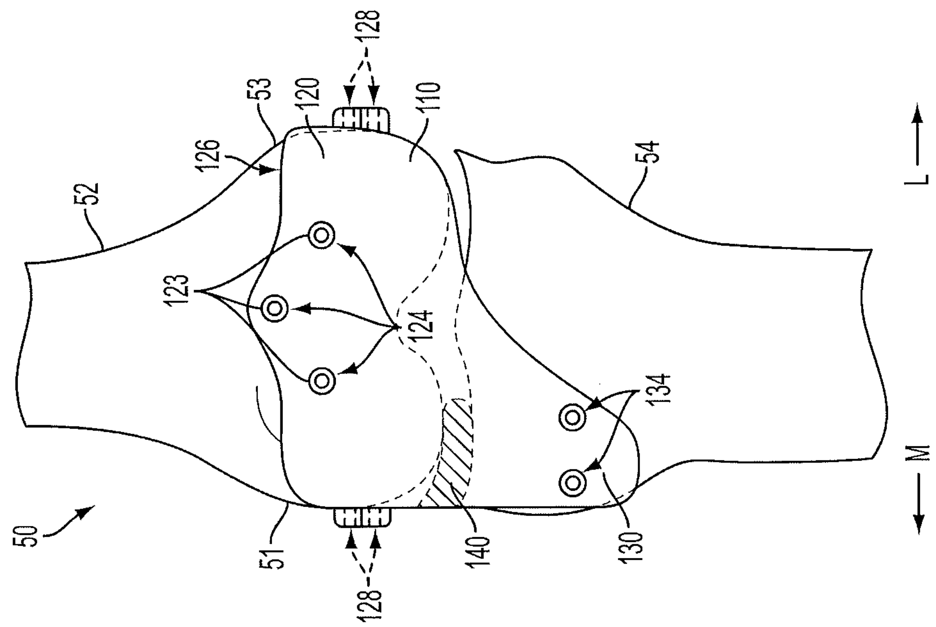
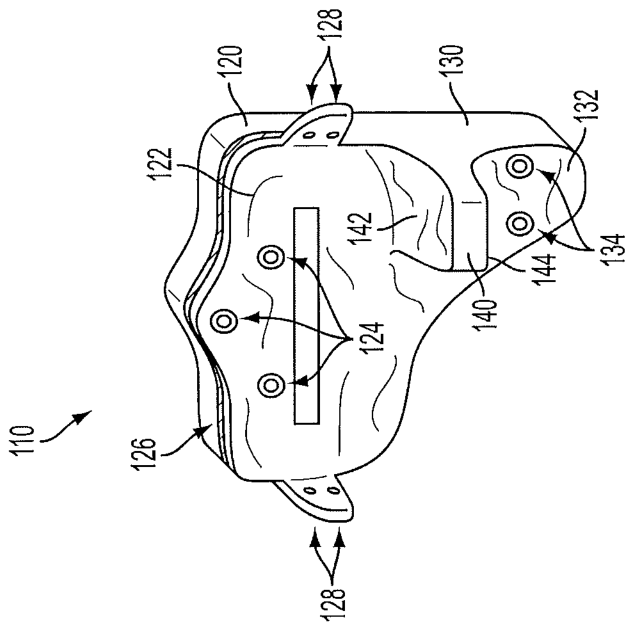
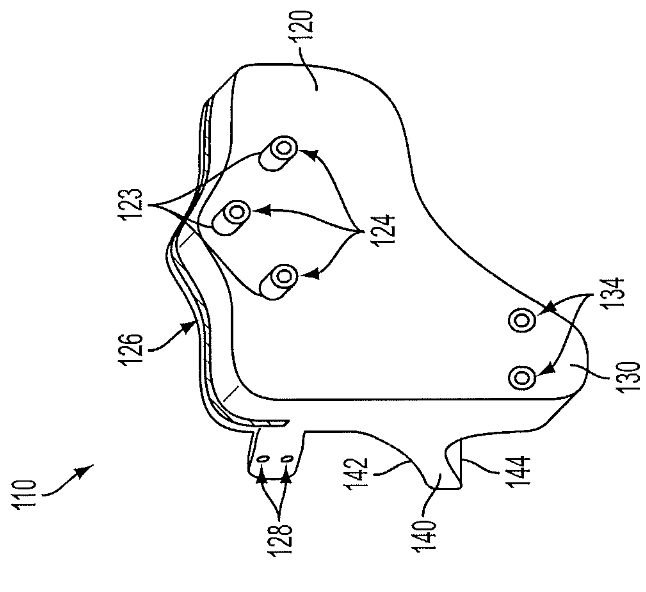

50
52
126
53
120
128
110
54
123
124
134
51
140
130
128
L
M

FIG. 9


110
120
122
124
126
128
128
130
132
134
140
142
144
FIG. 12


110
120
123
124
126
128
130
134
140
142
144
FIG. 11

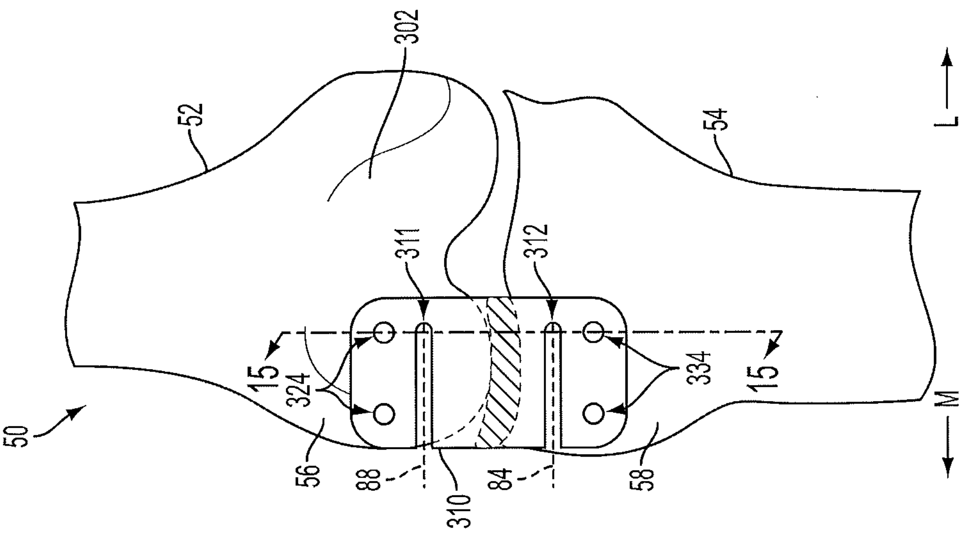

50
52
302
54
311
312
15
324
334
15
56
88
310
84
58
L
M

FIG.14

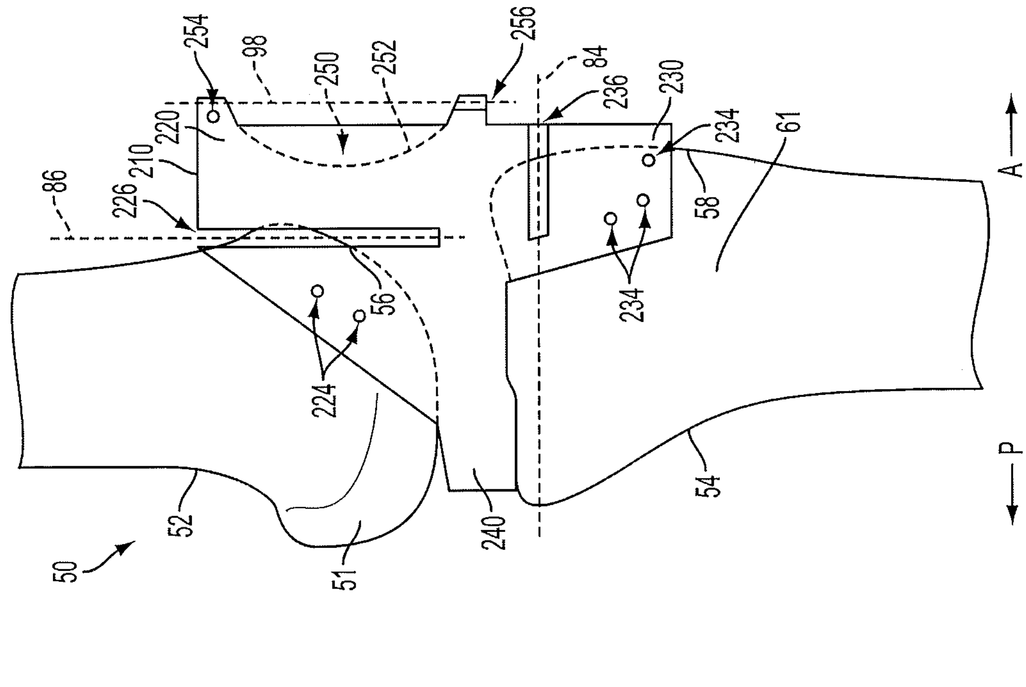

254
98
250
252
256
84
236
230
234
61
86
226
210
220
56
224
234
58
52
51
240
54
50
A
P

FIG. 13

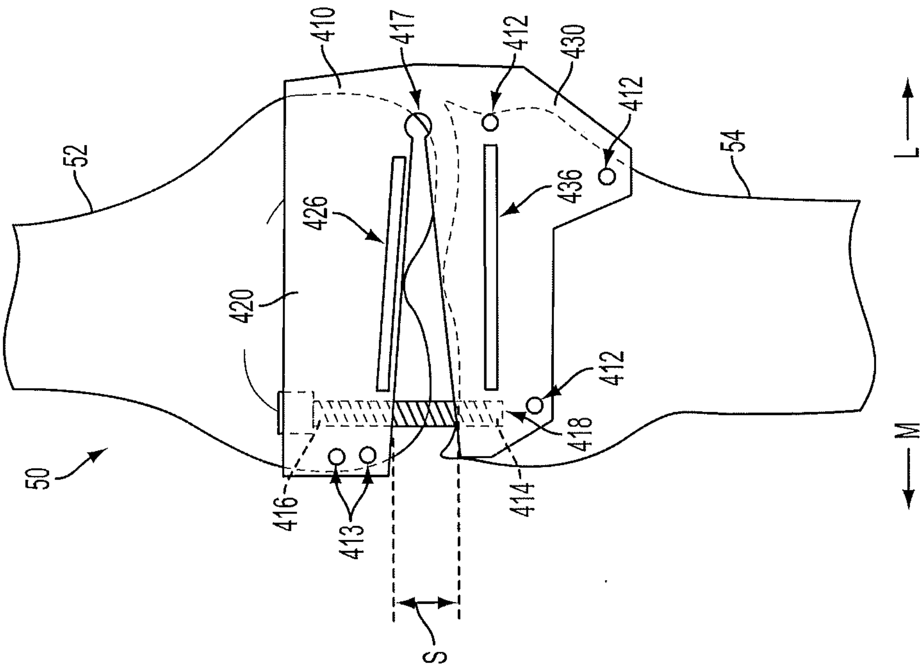

410
417
412
430
412
52
54
426
436
420
412
50
418
416
414
413
S
L
M

FIG.16

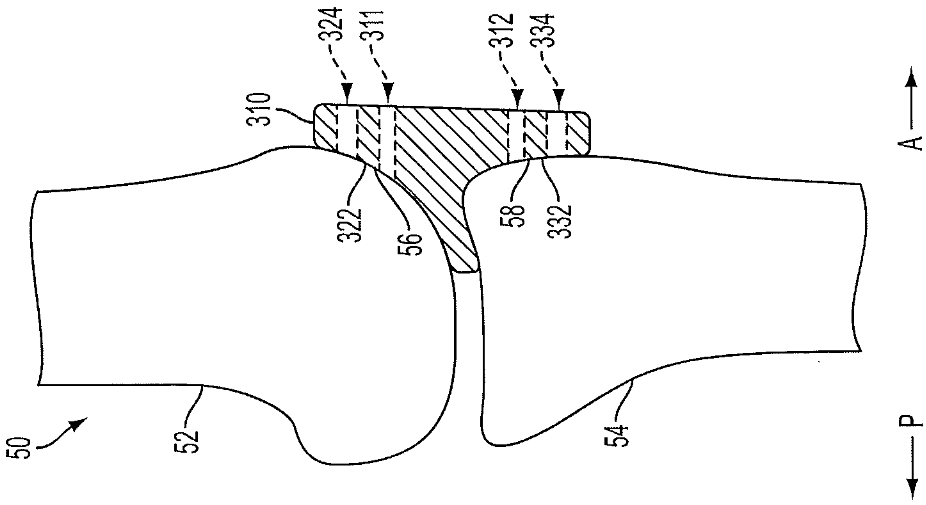

324
311
312
334
310
322
56
58
332
50
52
54
A
P

FIG. 15

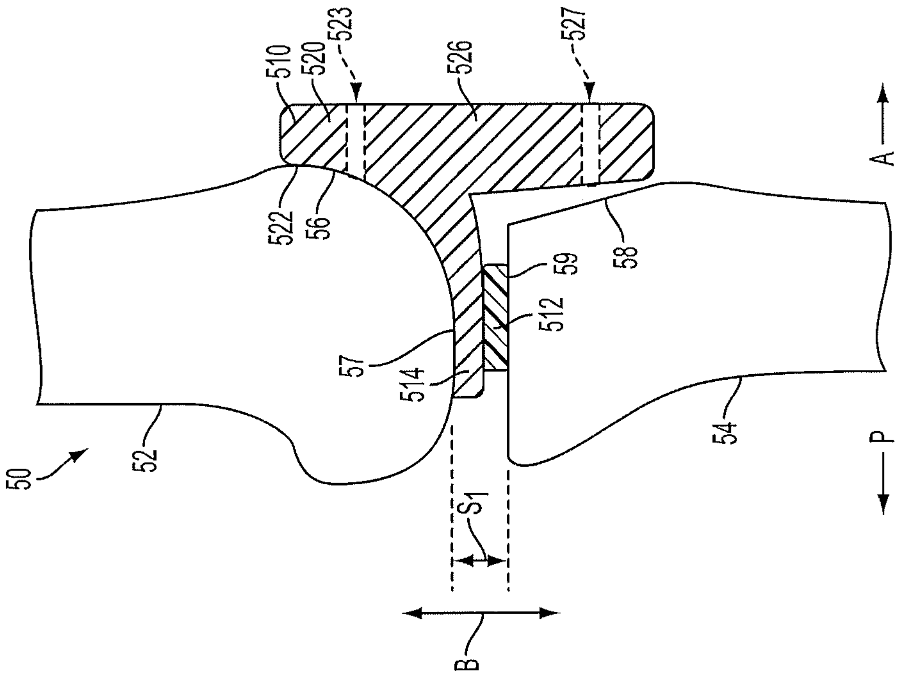

510
520
523
526
527
522
56
58
59
512
57
514
50
52
54
A
P
S1
B

FIG. 18

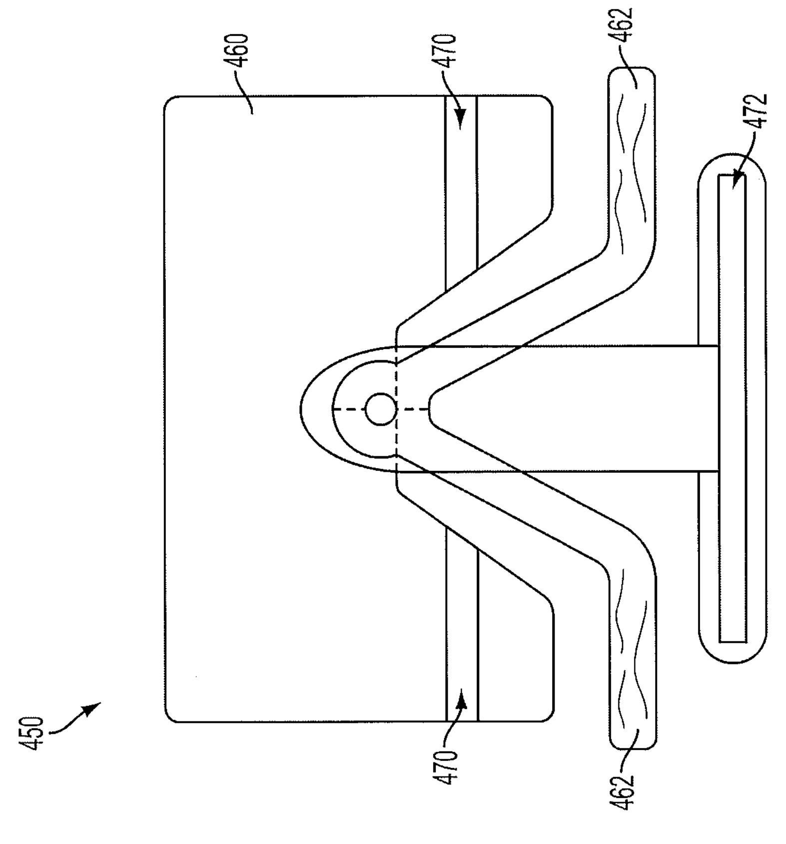

460
470
462
472
450
470
462

FIG. 17

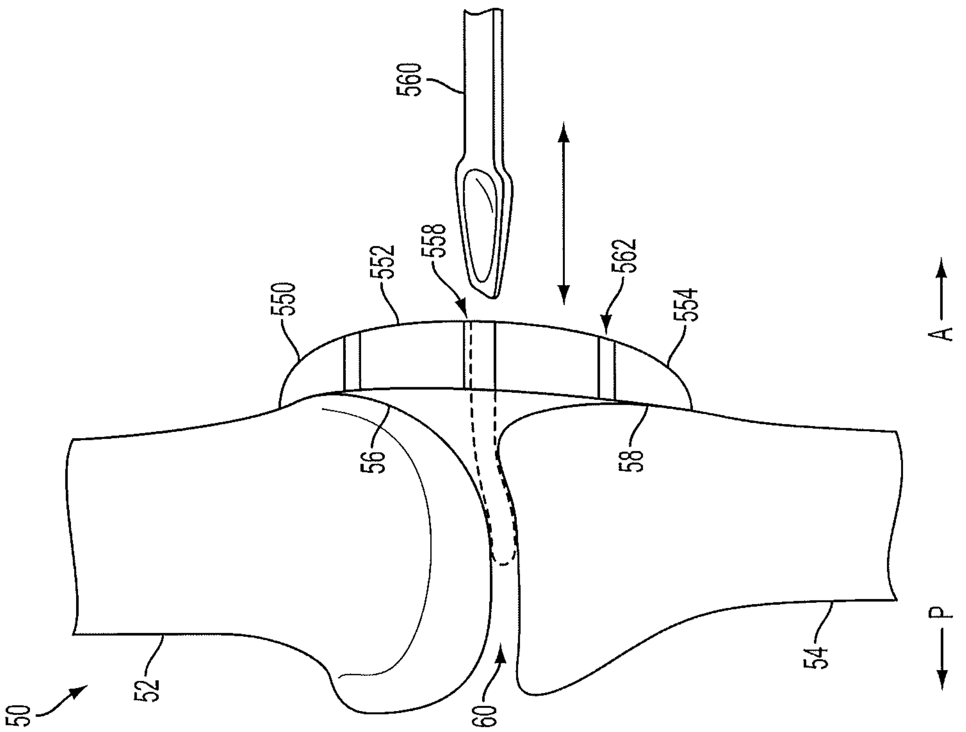

50
52
56
58
60
54
550
552
558
562
554
560
A
P

FIG. 20

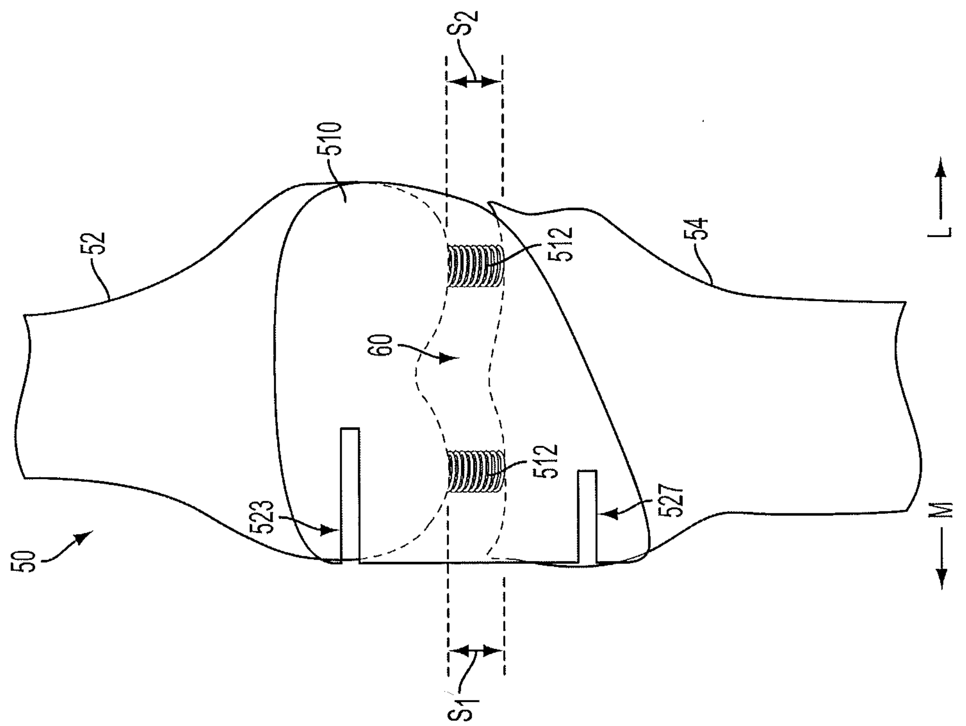

50
52
510
512
512
60
523
527
54
S2
S1
L
M

FIG. 19

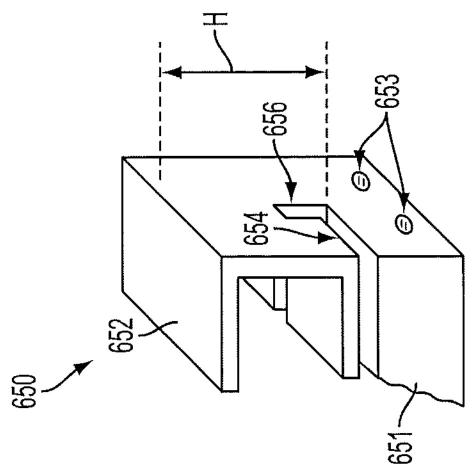


FIG. 23

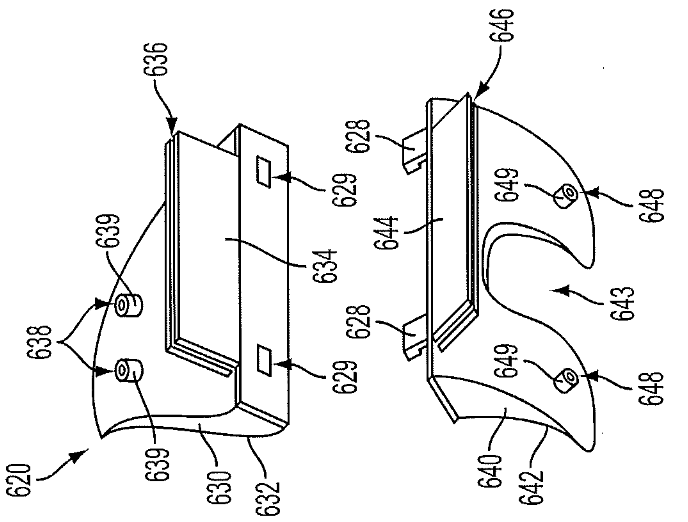


FIG. 22

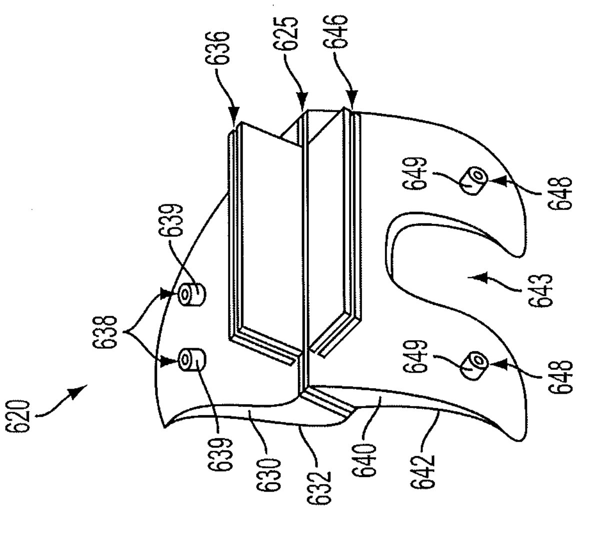


FIG. 21

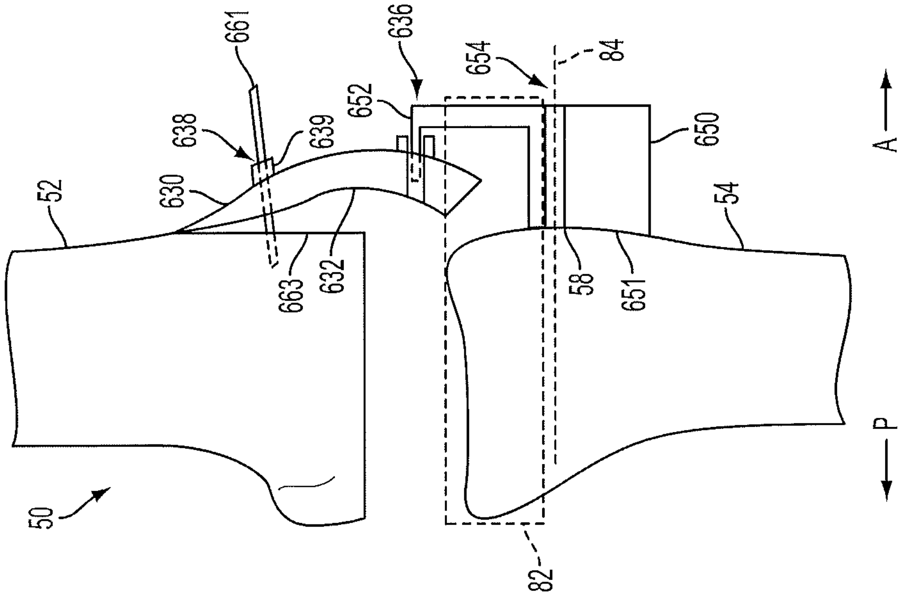

661
638
639
636
652
654
84
630
52
650
54
A
P
663
632
58
651
50
82

FIG. 25

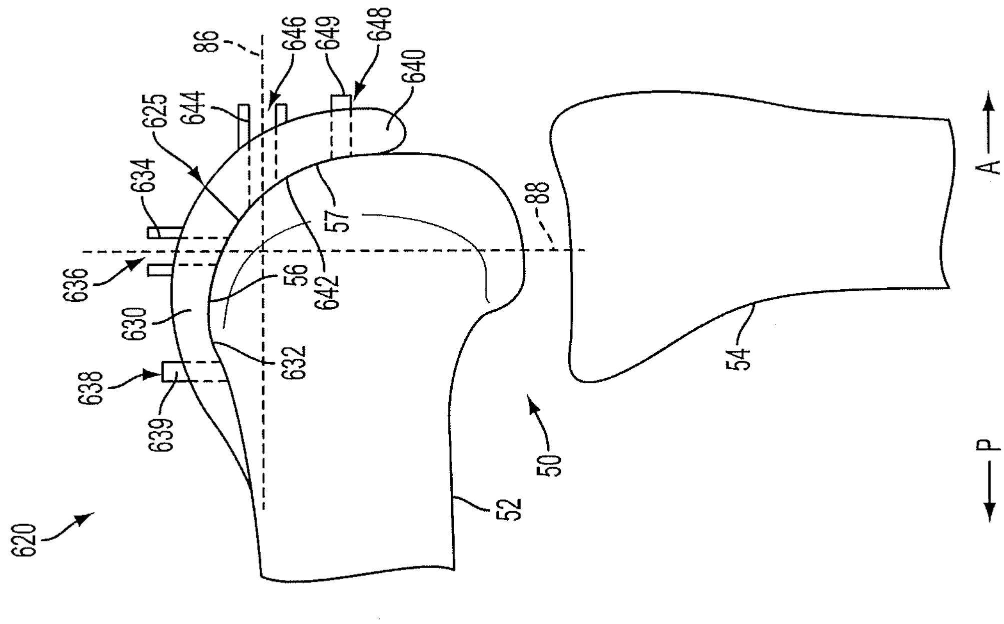

86
646
649
648
640
625
644
634
88
636
56
57
642
630
632
638
639
54
A
P
50
52
620

FIG. 24

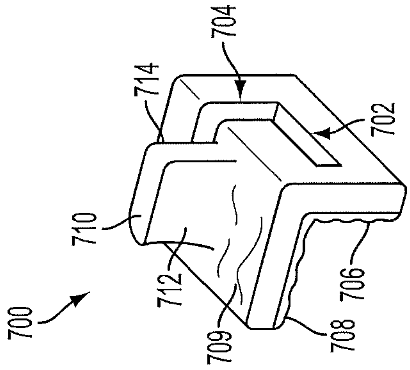

700
704
714
702
710
712
709
708
706

FIG. 27

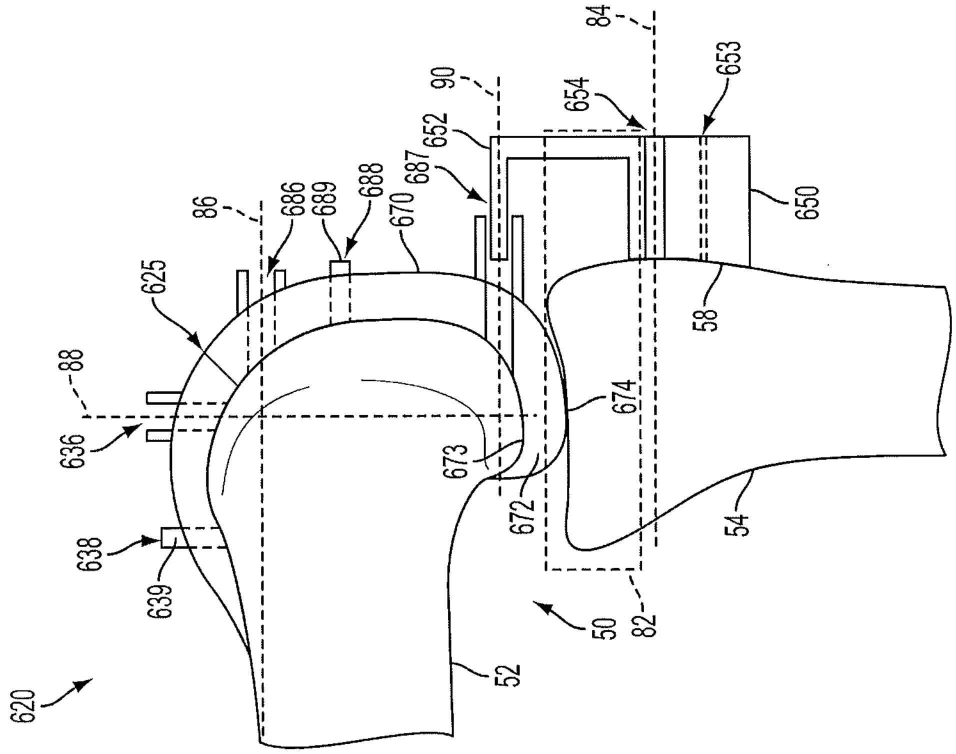

620
625
636
638
639
88
86
686
689
688
670
687
652
90
654
653
84
650
58
674
673
672
54
52
50
82

FIG. 26

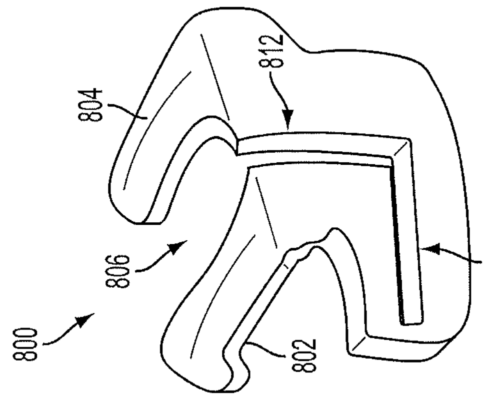


FIG. 29

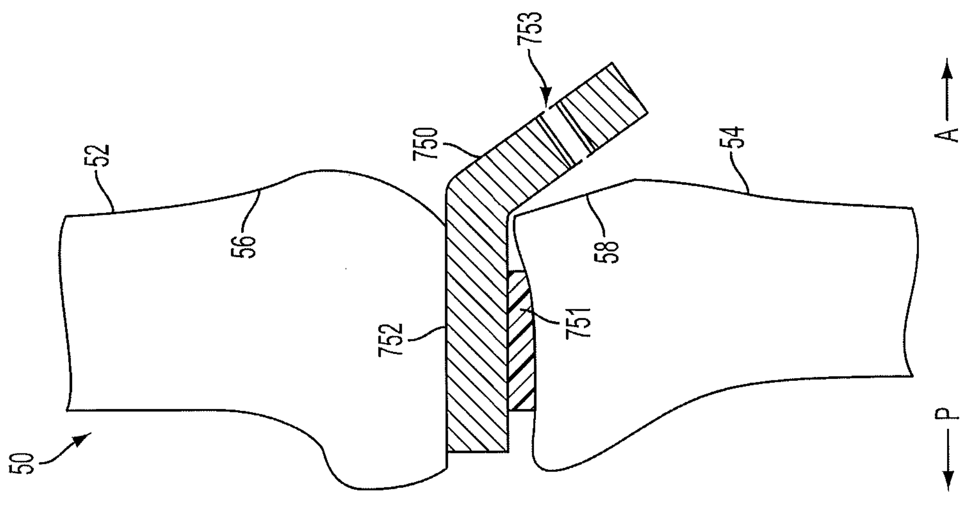


FIG. 28

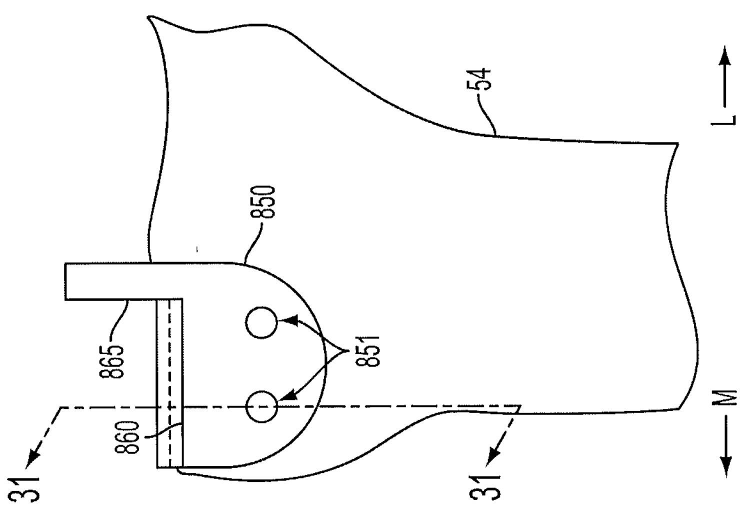


FIG. 30

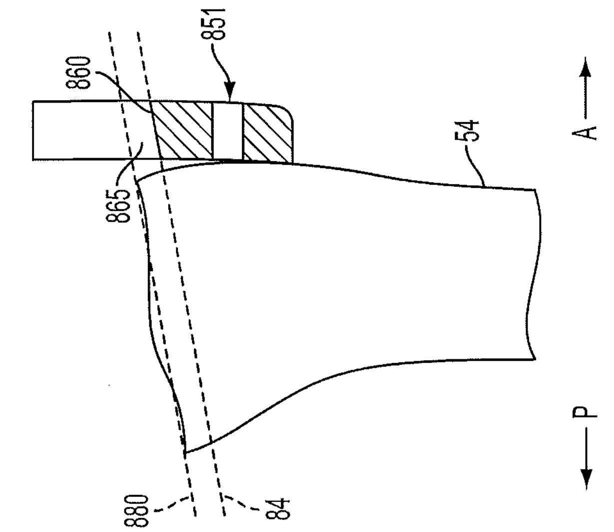


FIG. 31