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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A61F 2/38

A1

(11) International Publication Number: **WO 00/13616**

(43) International Publication Date: 16 March 2000 (16.03.00)

(21) International Application Number: PCT/US99/19344

(22) International Filing Date: 24 August 1999 (24.08.99)

(30) Priority Data:
09/148,110 4 September 1998 (04.09.98) US

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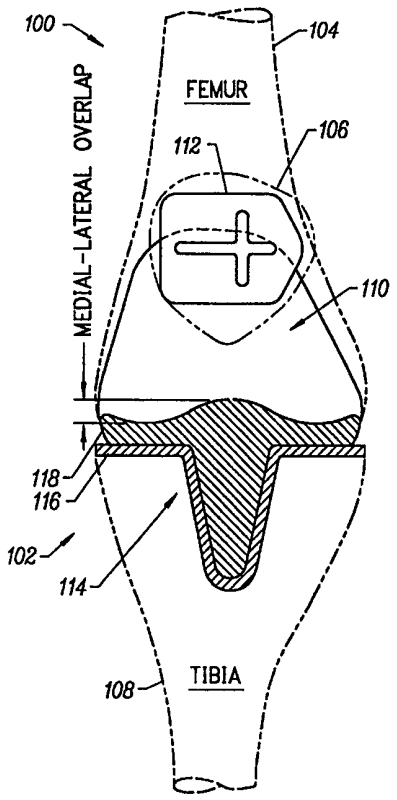
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: MODULAR KNEE IMPLANT SYSTEM

(57) Abstract

A trochlear implant (130) for a prosthetic knee, a prosthetic knee system (100), and a method for using the prosthetic knee system are disclosed. The trochlear implant mounts to the knee end of a femur (104), and cooperates with a patellar implant (112) mounted on the back side of a patella. The patellar implant is a component of a prosthesis including a femoral implant for replacing the knee end of the femur. The trochlear implant has an articulation surface shaped to slidably receive a portion of the patellar implant. The articulation surface is substantially similar in shape to a portion of a surface of the femoral implant such that the patellar implant is capable of being used with the femoral implant and the trochlear implant.



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MODULAR KNEE IMPLANT SYSTEM

BRIEF DESCRIPTION OF THE INVENTION

The present invention relates in general to a modular knee implant system for a prosthetic joint, and more particularly to a system including a trochlear implant.

BACKGROUND OF THE INVENTION

A knee joint connects three bones: the femur (thigh bone), the tibia (leg bone), and the patella (knee cap). Either through disease, injury, or pre-mature wear from mal-alignment, the knee joint can be damaged, and all or portions of the damaged joint surfaces may need to be replaced with a prosthetic implant. The most common prosthetic knee implant is referred to as a "total knee replacement" system because all knee joint surfaces are replaced. Typically the total knee replacement system includes a patellar implant, a femoral implant and a tibial implant.

Different portions of the knee are referred to as compartments. For example, each condyle (rounded end of the femur) is a separate compartment. Other prosthetic implants, called "unicompartmental" replacements, can be used when only the medial (toward the body's midline) compartment or the lateral (away from the body's midline) compartment of the femoral-tibial surface needs to be replaced. The unicompartmental replacement systems have femoral and tibial implants but do not include a patellar implant. Currently available unicompartmental implant systems are designed to be modular and work with their total knee counterparts from the same manufacturer with respect to using the same instruments and same bone contour. When these unicompartmental implant systems need to be replaced with a total knee system, both the femoral and tibial implants must be removed.

Less frequently, the surface of the knee joint compartment between the patella and the groove on the front of the femur (trochlea) requires replacement. Several prosthetic implants are available which replace this part of the knee joint and are called "total patello-femoral" prostheses or implants. Typically the total patello-femoral prostheses have a patellar implant that is installed on the patella and another implant which replaces at least a portion of the femur that contacts the patella.

However, there is no total patello-femoral implant system which is modular with any total knee system. Therefore, if a total patello-femoral prosthesis has been implanted, and because of further deterioration of the knee, the patello-femoral implant must be replaced during a second operation possibly years later, then the entire patellar component of the implant must be removed even though it is functioning well. Each time a prosthetic component is removed and replaced with another, there is inevitable bone damage or bone loss which makes the second implantation more difficult and less successful.

A prothesis system which does not require replacement of the patella implant when replacing the patello-femoral prothesis with a total knee prosthesis is desirable. In particular, a trochlear implant which is applied to the surface of the trochlear groove of the femur and which cooperates with the components of the selected total knee implant is desirable.

OBJECTS AND SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a prosthesis system which does not require replacement of the patella implant when replacing the trochlear implant with a full femoral implant.

It is another object of the present invention to provide a trochlear implant which cooperates with the components of the selected total knee implant system.

A more general object of the present invention is to provide a trochlear implant for a prosthetic joint that reduces the amount of bone removed for the implant.

It is yet another object of the present invention to provide a modular joint replacement system having interchangeable components.

In summary the present invention provides a prosthetic knee of the type which includes a femoral implant and a patellar implant. The femoral implant and patellar

implant have bearing surfaces that slidably engage the femoral implant with the patellar implant when the femoral implant and patellar implant move relatively. A trochlear implant has an articulation surface shaped to slidably receive a portion of the bearing surface of the patellar implant. The articulation surface is substantially similar in shape to a portion of the bearing surface of the femoral implant such that the patellar implant is usable with the femoral implant and the trochlear implant.

The present invention also provides a trochlear implant for use in a prosthetic knee. The trochlear implant mounts to the knee end of a femur and cooperates with a patellar implant mounted to the back side of a patella. The patellar implant is a component of a prosthesis system including a femoral implant for replacing the knee end of the femur. The trochlear implant has an articulation surface shaped to slidably receive a portion of the patellar implant. The articulation surface is substantially similar in shape to a portion of a surface of the femoral implant such that the patellar implant is capable of being used with the femoral implant and the trochlear implant.

In addition, the present invention provides a method of knee replacement using a prosthetic knee system. A trochlear implant and a patellar implant are provided. The patellar implant cooperates with the trochlear implant and a femoral implant. The trochlear implant has an articulation surface shaped to slidably receive a portion of the patellar implant. The articulation surface is substantially similar in shape to a portion of a load bearing surface of a femoral implant. The patellar implant is installed in a patella in a knee. The trochlear implant is installed in the trochlear groove in a knee-end of a femur bone.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be clearly understood from a reading of the following description in conjunction with the accompanying drawings.

FIGURE 1 is a front view of an installed total knee prosthesis.

FIGURE 2 is a side view of the installed total knee prosthesis of Figure 1.

FIGURE 3 is an exploded front view of the components of the prosthetic knee implant system of the present invention.

FIGURE 4 is a perspective view of one embodiment of the trochlear implant of Figure 3 installed in a human knee.

FIGURE 5 is a perspective view of an embodiment of trochlear implant of the present invention suitable for installation in a left knee.

FIGURE 6 is a side view of the trochlear implant of Figure 5.

FIGURE 7 is a bottom view of the trochlear implant of Figure 5.

FIGURE 8 is a front view of the trochlear implant of Figure 5 installed in a human knee.

FIGURE 9 is a side view of the trochlear implant of Figure 5 installed in the human knee.

FIGURE 10 is a diagram of a common generation curve used in a preferred embodiment of the trochlear implant of Figure 3.

FIGURE 11 is a diagram showing the rotation of the common generation curve of Figure 10 to generate the segments of surfaces of revolution that define the shape of the articulation surface of the trochlear implant and that define the shape of the femoral load bearing surface of a femoral implant, and that also define the shape of a load bearing surface of the patellar implant.

FIGURE 12 is a bottom view of the trochlear implant of Figure 5 showing the angles used to taper the peripheral edges.

FIGURE 13 is an exploded view of a second prosthetic knee system using another embodiment of the trochlear implant of the present invention.

FIGURE 14 is an exploded view of a third prosthetic knee system using yet another embodiment of the trochlear implant of the present invention.

FIGURE 15 is an exploded view of a fourth prosthetic knee system using another alternative embodiment of the trochlear implant of the present invention.

FIGURE 16 is a flowchart of a method of knee replacement using the components of the prosthetic knee system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In Figure 1, a prosthetic knee implant 100 suitable for use with the present invention is installed in a human knee 102. The knee 102 has a femur 104, a patella 106 and a tibia 108. The prosthetic knee 100 includes a femoral implant 110, a patellar implant 112 and an optional tibial implant 114. The tibial implant 114 has a tibial platform component 116 and a tibial bearing component 118.

The patellar implant 112 is shaped to mate with the femoral implant 110. The tibial implant 114, and in particular the tibial bearing component 118, is shaped to mate with the femoral implant 110. The femoral implant 110 is shaped to slidably receive the patellar implant 112 and the tibial implant 114.

Figure 2 is a side view of the installed prosthetic knee of Figure 1 and also shows a tendon 120 that attaches the muscles to the patella 106. The femoral implant 110 and the patellar implant 112 have bearing surfaces, 122 and 124, respectively. When the femoral implant and patella implant move relative to each other, the bearing surfaces 122 and 124 allow the femoral implant 110 and patella implant 112 to slidably engage. The tibial implant 114 also has a bearing surface 126 that slidably engages another portion of the femoral bearing surface 122 when the femur 104 and tibia 108 move relative to each other.

As shown in Figure 3, the prosthetic knee system of the present invention includes a femoral implant 110, a patellar implant 112 and a trochlear implant 130. The trochlear implant 130 has an articulation surface 132 shaped to slidably receive a portion of the bearing surface 124 of the patellar implant 112. The patellar implant 112 has an apex 134 that aligns with a longitudinal axis 136 forming a trochlear groove in both the femoral implant 110 and the trochlear implant 130.

A noteworthy aspect of the invention is that the articulation surface 132 of the trochlear implant 130 is substantially similar in shape to a portion of the femoral bearing surface 122 of the femoral implant 110. Therefore, the patellar implant 112 is usable with both the femoral implant 110 and the trochlear implant 130. When a patient's remaining joint surface deteriorates to the point where the physician needs to replace the trochlear implant 130 with the femoral implant 110, the patient's patella is not subjected to additional bone loss and trauma because the existing patellar implant 112 is usable with the new femoral implant 110.

Fundamental differences among knee prostheses are found in the nature of the articulation or bearing surfaces. There are two basic types of articulation surfaces: those surfaces with theoretical line or point contact (referred to as incongruent contact), and those surfaces with area contact (referred to as congruent contact). Those surfaces with congruent contact more closely resemble the human body.

In a preferred embodiment, the articulation surface 138 of the trochlear implant 130 has a shape that substantially congruently engages the patellar implant 112. In an alternate embodiment, the articulation surface 132 of the trochlear implant 130 is shaped to provide substantially point contact with the patellar implant 112. In another alternate embodiment, the articulation surface 132 of the trochlear implant 130 is shaped to provide substantially line contact with the patellar implant 112. In other embodiments, the articulation surface 132 of the trochlear implant 130 is shaped to provide a combination of congruent and line contact with the patellar implant 112.

In one embodiment, the trochlear implant 130 is asymmetrical about the longitudinal axis 136 for installation in either a right knee or a left knee. In Figure 3, the trochlear implant 130 is for installation in a right knee. In an alternate embodiment, the trochlear implant 130 symmetrical about the longitudinal axis and can be installed in either the right knee or the left knee.

In a preferred embodiment, the bearing surface of the femoral implant 110, the bearing surface of the patellar implant 112 and the articulation surface of the trochlear implant 130 are aligned to and are generated by a common generation curve 138, Figure 3. Alternately, the articulation surface of the trochlear implant 130 is shaped to receive and engage a substantially spherical, dome-shaped patellar implant 130.

The trochlear implant 130 may be made of cast cobalt-chrome-molybdenum and the articulation surface 132 is polished. Alternately, the trochlear implant 130 is made of cobalt-chrome, stainless steel or other suitable metal alloy. In another alternative embodiment, the trochlear implant 130 is made of a ceramic. In yet another embodiment, the trochlear implant 130 is made of titanium. In another alternate embodiment, a surface treatment is applied to harden and/or smooth the articulation surface of the trochlear implant 130. In particular, a trochlear implant 130 made of titanium is treated to harden and smooth the articulation surface.

The trochlear implant 130 is installed in the trochlear groove between the condyles 142 of a knee-end of a femur 104 in a human knee 100, Figure 4. In this embodiment, the trochlear implant 130 does not contact the tibia 108 or a tibial implant. In an alternate embodiment, the trochlear implant 130 can contact the tibia 108 or the tibial implant.

Referring to Figures 5, 6 and 7, a peripheral edge 152 defines and forms the articulation surface 132 and a back surface 154. In Figure 7, the back surface 154 has a cement retaining rim 156 extending along a portion of the back surface 154 and portion of the peripheral edge 152. Three fixation pins 158 project from the back surface 154. In one embodiment, the back surface 154 is textured. Alternately, the back surface 154 has a porous coating. In an alternate embodiment, no cement retaining rim 156 is provided. In another alternate embodiment, no fixation pins are provided. In yet another alternate embodiment, any number, such as one, two, or more than three, fixation pins 158 project from the back surface 154. Alternately the trochlear implant 130 is fixed to the femur using screws.

In Figures 8 and 9, the trochlear implant 130 of the present invention is shown in a human knee with the patellar implant 112. The trochlear implant 130 contacts the patellar implant 112 for a range of knee motion. Primary and secondary load bearing regions, 162 and 164, respectively, on the patellar implant 112 engage primary and secondary load bearing regions, 166 and 168, respectively, of the articulation region 132 of the trochlear implant 130 to produce substantially anatomical patella-femoral articulation. As shown in Figure 9, at full extension of the leg and knee, the primary load bearing region 162 of the patellar implant 112 lifts off the primary load bearing region 166 of the trochlear implant 130, and the secondary load bearing region 164 of the patellar implant 112 slidably engages the secondary load bearing region 168 of the trochlear implant 130. In contrast, at moderate and full flexion, the primary load bearing region 162 of the patellar implant 112 slidably engages the primary load bearing region 166 of the trochlear implant 130.

In an alternate embodiment, at the extremes of knee motion, either when the knee is very straight or when the knee is extremely bent, the patellar implant 112 does not contact the trochlear implant 130. Preferably, the patellar implant 112 slidably engages the trochlear implant 130 from an angle of about 20° when the knee is almost straight to an angle of about 110° when the knee is bent.

Figure 10 shows the common generation curve 138 that is used to generate the shapes of the articulation and load bearing surfaces of the trochlear implant, femoral implant, patellar implant and tibial implant in a preferred embodiment of the present invention. The formation of the load bearing surfaces of the femur, patellar and tibial

implants is described in detail in U.S. Patent 4,470,158 to Pappas et al. which is incorporated herein by reference.

The primary and secondary load bearing regions of the articulation and load bearing surfaces are formed as surfaces of revolution and their shape is defined or generated by the common generation curve F 138. The shape of the load bearing or articulation surfaces is defined by rotating the common generation curve F 138 through a predetermined angle about the generating axis 172 at the same major generating radii D1 and D2 where D1 and D2 are equal to each other and also equal to a predefined radius. The peak 174 of the common generation curve F 138 forms the apex 134 (Figure 3) of the patellar implant and the longitudinal axis 136 (Figure 3) of the femoral implant and the trochlear implant.

Figure 11 shows the segments S1 and S2 of the load bearing regions of the load bearing surface and articulation surface of the femoral implant and trochlear implant of the present invention, respectively. Segment S1 forms the secondary load bearing region 164, 168 (Figure 9). Segment S2 forms the primary load bearing regions 162, 166 (Figure 9) of the patellar implant and trochlear implant, respectively.

In particular, to generate the articulation region of the trochlear implant. The common generating curve 138 is rotated at an angle of $\theta 1$, equal to 0°, at a radial distance from generating axis C1 at ∞. In other words, the common generating curve 138 is substantially parallel to the line L1 for a distance of S1 or .314 inches. Tangent to line L1, the common generating curve 138 is rotated about generating axis C2 for an angle of $\theta 2$ at a radial distance of R2. In one embodiment, $\theta 2$ and R2 equal about 90° and 1.388 inches, respectively. The shape of the trochlear implant ends at line L2.

The load bearing regions of the patellar implant and femoral implant are generated in a similar manner. For the femoral implant, segment S1 is formed substantially parallel to the line L1 for a distance of .612 inches, and segment S2 is formed for an angle $\theta 2$ of 107. 75° with R2 equal to 1.388 inches. Therefore, the trochlear implant load bearing regions 148, 146 (Figure 9) formed with segments S1 and S2, respectively, substantially match the load bearing regions S1 and S2 of the femoral implant.

Referring to Figure 12, the trochlear implant 130 is tapered. To taper the trochlear implant 130, a portion of the common generation curve 138 is used and

peripheral side edges 176, 178 of the trochlear implant 130 are formed at predetermined angles θ3 and θ4 with respect to the longitudinal axis 136. In one embodiment, the predetermined angles θ3 and θ4 are substantially equal to about 20° and 30°, respectively. In an alternate embodiment, θ3 and θ4 are the same.

Figure 13 shows a second prosthetic knee system, such as the Johnson & Johnson "PRIMARY CRUCIATE-SUBSTITUTING" (P.F.C.) modular total knee system, with a second embodiment of the trochlear implant 182 of the present invention. A patellar implant 184 is usable with either the femoral implant 186 or the trochlear implant 182.

Figure 14 shows a third prosthetic knee system, such as the Intermedics "NATURAL-KNEE," with a third embodiment of the trochlear implant 188 of the present invention. A patellar implant 190 is usable with either a femoral implant 192 or the trochlear implant 188.

Figure 15 shows a fourth prosthetic knee system, such as the Zimmer "Insall/Burstein (I/B) II" modular knee system, with a fourth embodiment of the trochlear implant 194 of the present invention. A patellar implant 196 is usable with either a femoral implant 198 or the trochlear implant 194.

In Figure 16, a flowchart of an embodiment of a method of knee replacement using the components of the prosthetic knee system is shown. In step 202, a trochlear implant of the present invention is provided, and in step 204, a patellar implant suitable for use with the present invention is also provided. In step 206, the patellar implant is installed in a patella in a knee. In step 208, the trochlear implant is installed in the trochlear groove in a knee-end of a femur bone.

When a patient's remaining joint surface deteriorates to the point where the trochlear implant needs to be replaced, in step 210 a femoral implant suitable for use with the trochlear implant is provided. The shape of the articulation surface of the trochlear implant and the shape of the load bearing surface of the femoral implant are substantially similar. In step 212, the trochlear implant is removed, and in step 214 the existing patellar implant is left in place in the patella. In an alternate embodiment, the patellar implant has a detachable load bearing surface, however, even in such patellar implants, the portion of the patellar implant that is attached to the patella bone remains in place.

In step 216, the surgeon installs the femoral implant in the knee-end of the femur bone. If the tibia portion of the knee also needs to be replaced, a tibial implant is also provided in step 218, and installed in step 220.

Thus, there has been provided a prosthetic knee system that allows the same patellar implant to be used with both a trochlear implant and a femoral implant. Therefore, when a patient's remaining joint surface deteriorates to the point where the physician needs to replace the trochlear implant with the femoral implant, the patient's patella is not subjected to additional bone loss and trauma because the existing installed patella implant is usable with the new femoral implant.

While the invention has been described in detail and with reference to specific examples, it will be apparent to one skilled in the art that various trochlear implant shapes can be made without departing from the spirit and scope of the present invention.

What is claimed is:

1. In a prosthetic knee of the type which includes a femoral implant and a patellar implant, said femoral implant and said patellar implant having bearing surfaces, said bearing surfaces for slidably engaging said femoral implant with said patellar implant when said femoral implant and said patellar implant relatively move, the improvement comprising:

a trochlear implant having an articulation surface shaped to slidably receive a portion of the bearing surface of said patellar implant, said articulation surface being substantially similar in shape to a portion of the bearing surface of said femoral implant such that said patellar implant is usable with said femoral implant and said trochlear implant.

2. The prosthetic knee of claim 1 wherein said articulation surface has a shape substantially similar to at least a portion of the bearing surface of the femoral implant.

3. The prosthetic knee of claim 1 wherein said articulation surface of said trochlear implant is defined by rotating a common generation curve through a predetermined angle about a predetermined generating axis.

4. The prosthetic knee of claim 1 wherein said articulation surface of said trochlear implant is a compound surface having a first lateral surface generated by moving said common generation curve for a first predetermined distance, said first lateral surface being laterally joined to a second lateral surface generated by rotating said common generation curve with a second radius for a predetermined angle.

5. A trochlear implant mountable to the knee end of a femur and cooperable with a patellar implant mounted to the back portion of a patella, the patellar implant being a component of a prosthesis including a femoral implant for replacing the knee end of the femur, said trochlear implant having an articulation surface shaped to slidably receive a portion of the patellar implant, said articulation surface being substantially similar in shape to a portion of a surface of the femoral implant such that the patellar implant is capable of being used with the femoral implant and said trochlear implant.

6. The trochlear implant of claim 5 wherein said articulation surface has a groove for engaging the patellar implant.

7. The trochlear implant of claim 5 wherein said articulation surface provides substantially congruent engagement with the patellar implant.

8. The trochlear implant of claim 5 wherein said articulation surface provides substantially point contact with the patellar implant.

9. The trochlear implant of claim 5 wherein said articulation surface provides substantially line contact with the patellar implant.

10. The trochlear implant of claim 5 wherein said trochlear implant is symmetrical about a longitudinal axis for installation in either of a right knee and a left knee.

11. The trochlear implant of claim 5 wherein said trochlear implant is asymmetrical about a longitudinal axis for installation in only one of a right knee and a left knee.

12. The trochlear implant of claim 5 wherein said trochlear implant is made of cobalt-chrome-molybdenum.

13. The trochlear implant of claim 5, further comprising:

a back surface and a peripheral edge forming said articulation surface and a back surface; and

said back surface including a cement retaining rim extending along at least a portion of the back surface and at least a portion of said side edge.

14. The trochlear implant of claim 5, further comprising:

a back surface and sides; and

at least one fixation pin projecting from said back surface.

15. The trochlear implant of claim 5 wherein said articulation surface is a compound surface having a first surface that is laterally connected to a second surface, said compound surface being generated by a common generation curve, said first surface being generated by moving the common generation curve for a first predetermined distance, said second surface being generated by rotating said common generation curve at a predetermined radius for a predetermined angle.

16. A prosthetic knee system, comprising:

a patellar implant shaped to correspond to a femoral implant; and

a trochlear implant shaped to receive said patellar implant, said trochlear implant having an articulation surface shaped to slidably receive a portion of said patellar implant, said articulation surface being substantially similar in shape to a portion of a surface of the femoral implant such that said patellar implant is usable with the femoral implant and said trochlear implant.

17. The prosthetic knee system of claim 16, further comprising:

a tibial implant having a tibial articulation surface shaped to slidably receive said femoral implant, said tibial articulation surface slidably engaging a portion of said femoral articulation surface of said femoral implant.

18. The trochlear implant of claim 16 wherein said patellar implant contacts said trochlear implant when the knee is almost straight at an angle of about 20° to an angle of about 110° when the knee is bent.

19. A method for knee replacement comprising the steps of:

providing a trochlear implant;

providing a patellar implant cooperable with a femoral implant and said trochlear implant, said trochlear implant having an articulation surface shaped to slidably receive a portion of said patellar implant, said articulation surface being substantially similar in shape to a portion of a surface of the femoral implant;

installing said patellar implant in a patella in a knee; and

installing said trochlear implant in a knee-end of a femur bone.

20. The method for knee replacement of claim 19, further comprising the steps of:

providing said femoral implant;

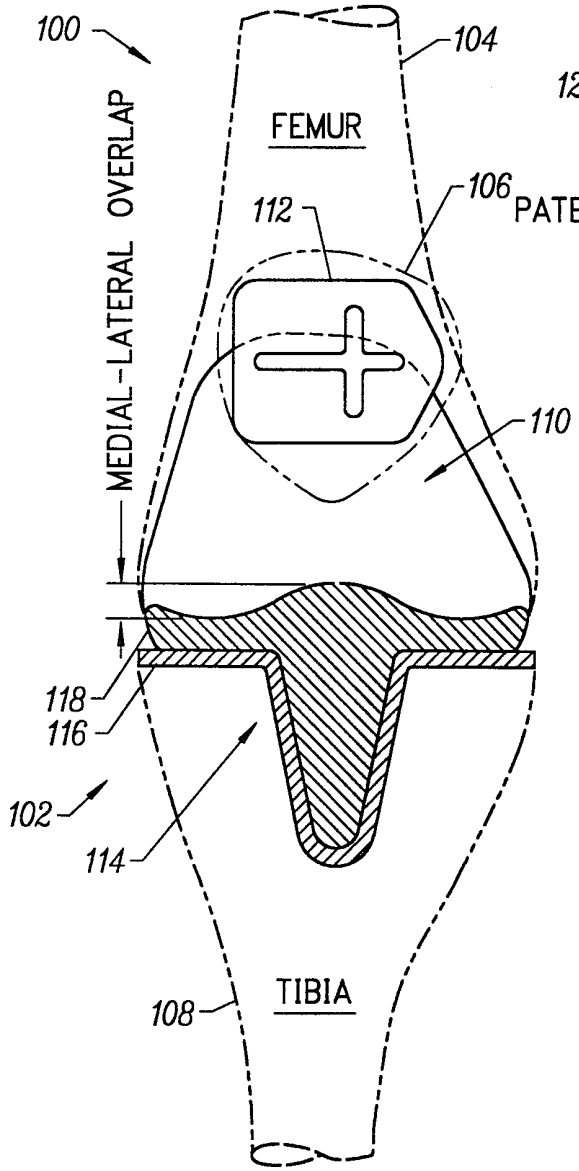
removing said trochlear implant;

leaving said patellar implant in the patella; and

installing said femoral implant in the knee-end of the femur bone.

21. The method for knee replacement of claim 20, further comprising the step of providing a tibial implant shaped to mate with the femoral implant in a knee-end of a tibia, wherein said femoral implant is shaped to receive said patellar implant and said tibial implant; and

installing said tibial implant.


100
104
FEMUR
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112
PATELLA
MEDIAL-LATERAL OVERLAP
110
118
116
102
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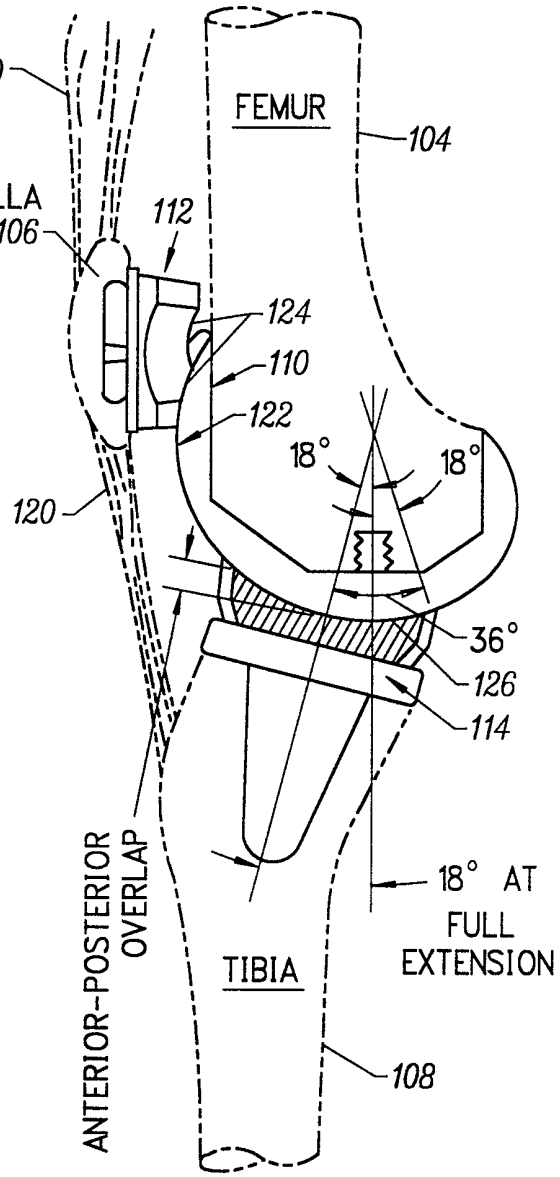
TIBIA

FIG. 1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124
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114
ANTERIOR-POSTERIOR OVERLAP
18° AT FULL EXTENSION
TIBIA
108

FIG. 2

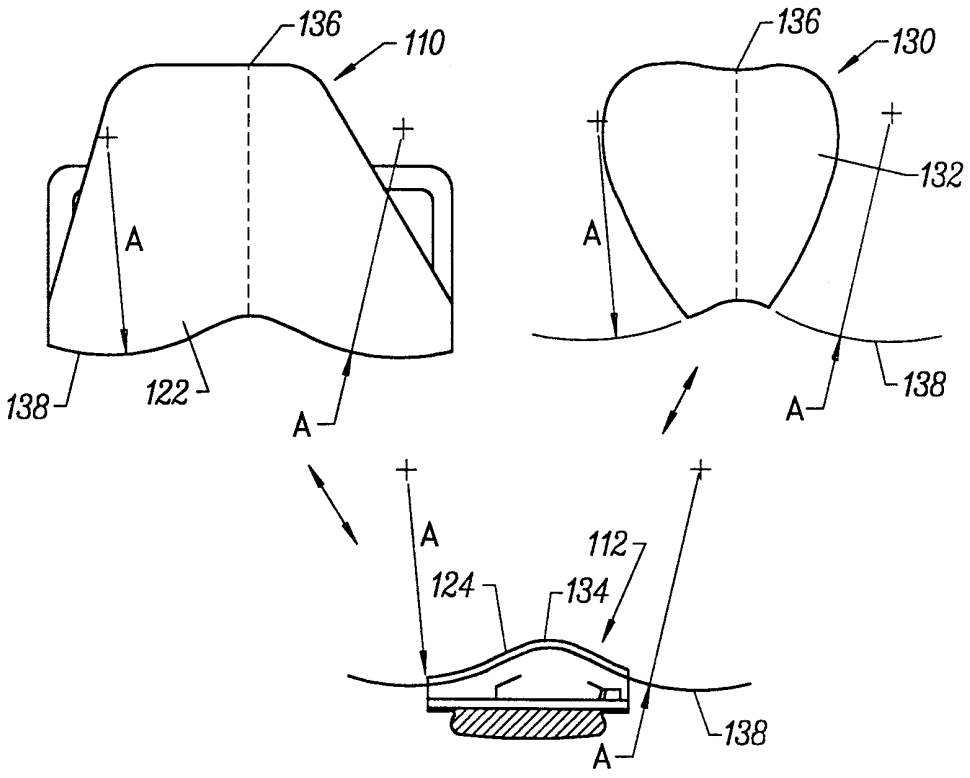

FIG. 3

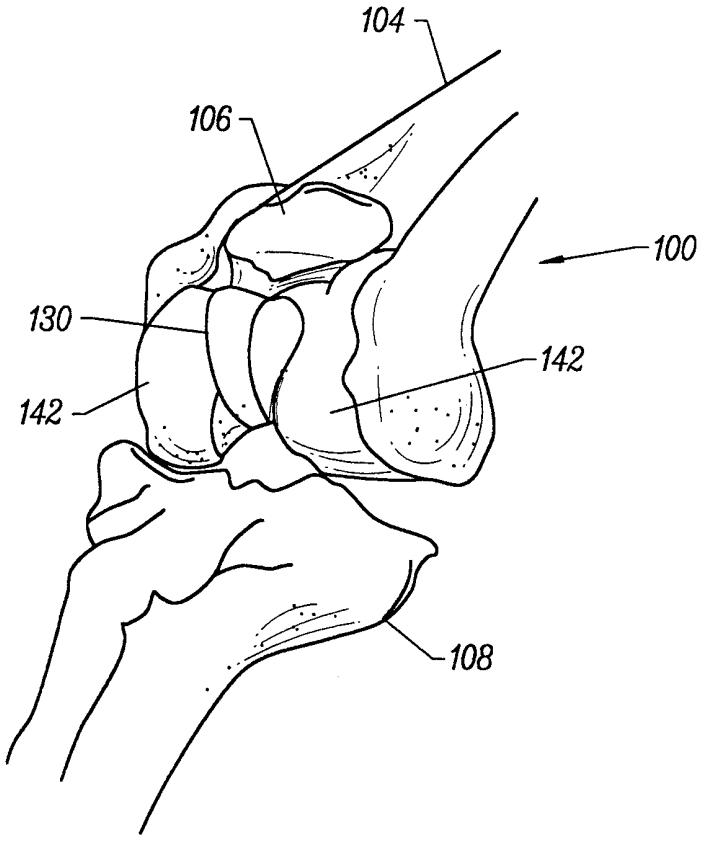

FIG. 4

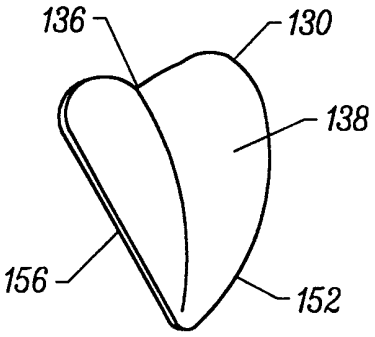

FIG. 5

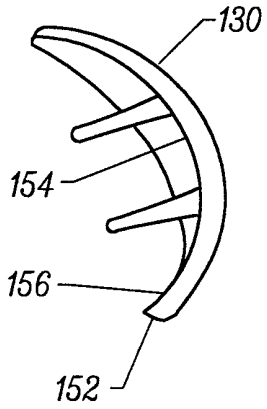

FIG. 6

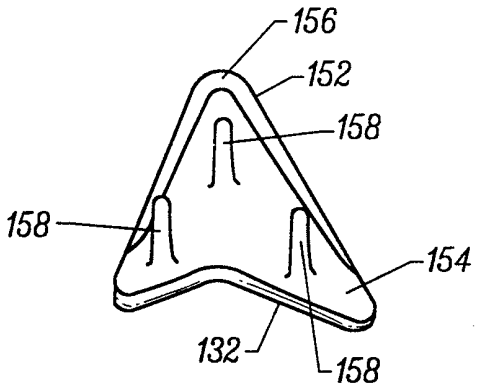

FIG. 7

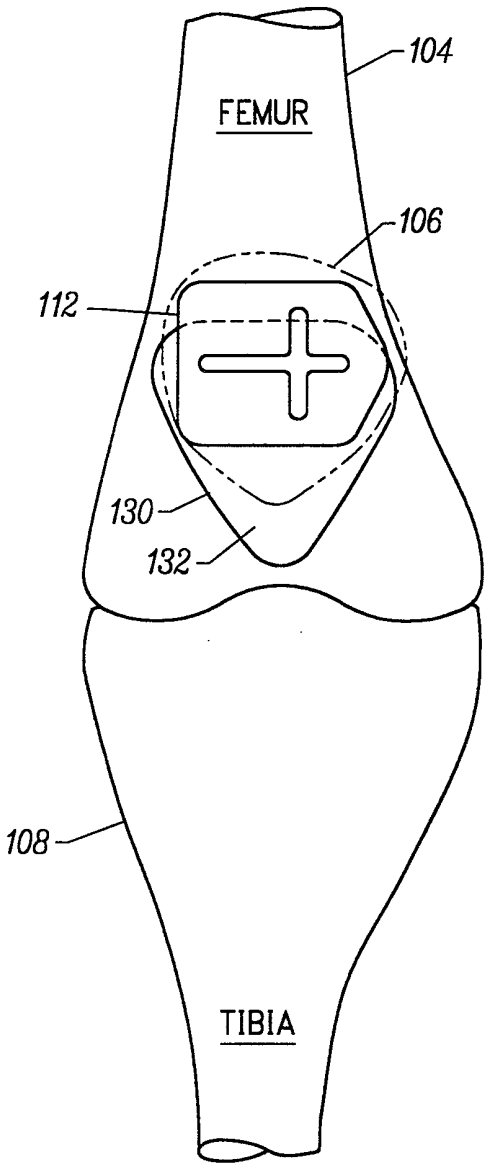
104
FEMUR
106
112
130
132
108
TIBIA

FIG. 8

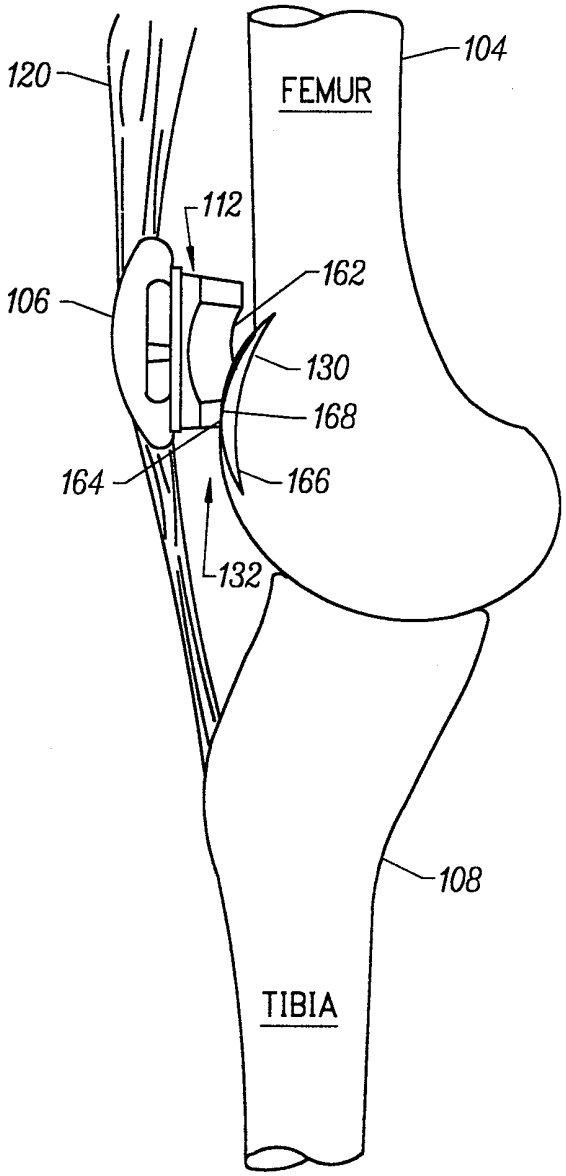
120
104
FEMUR
112
106
162
130
168
164
166
132
108
TIBIA

FIG. 9

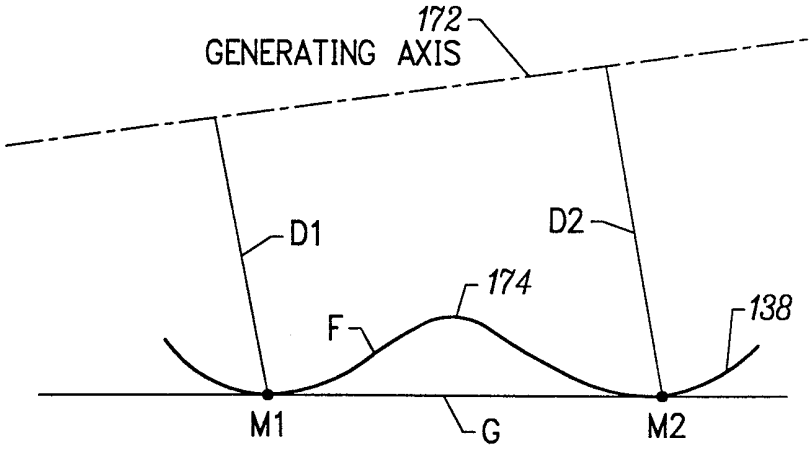

FIG. 10

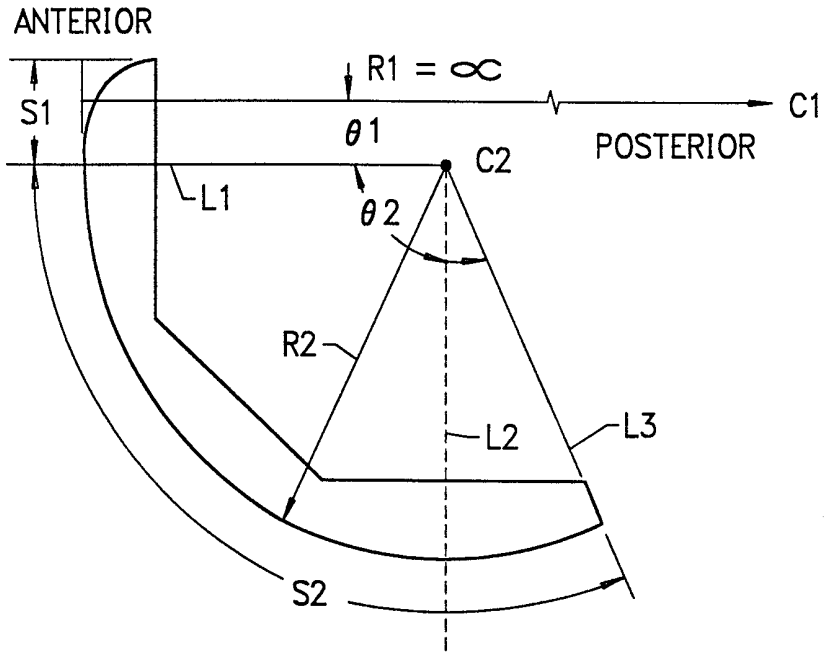

FIG. 11

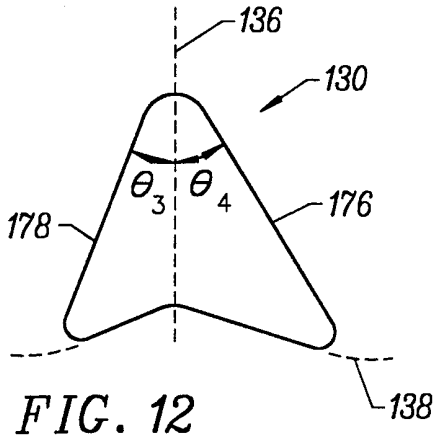

FIG. 12

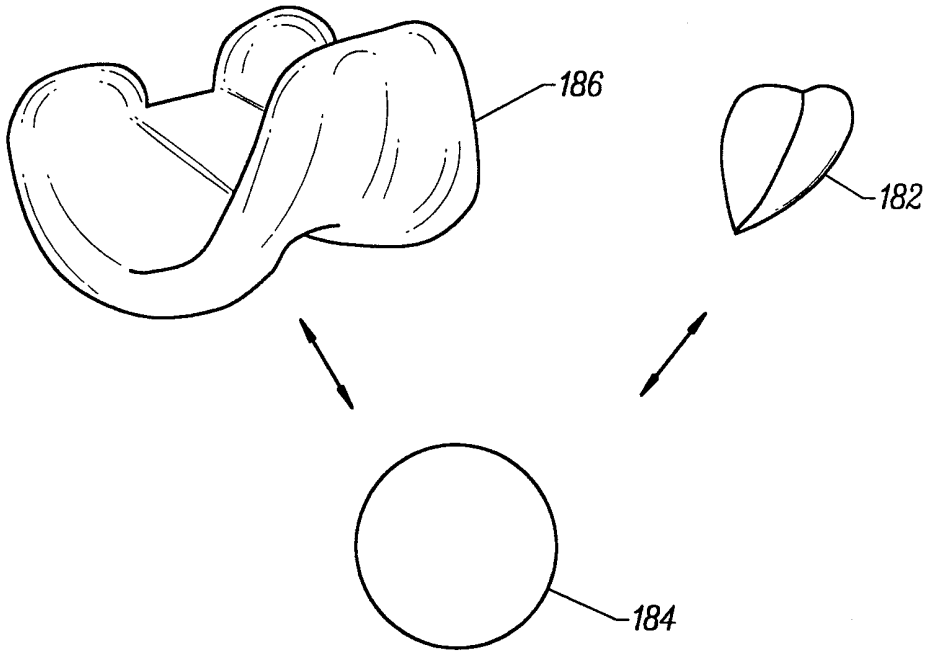

FIG. 13

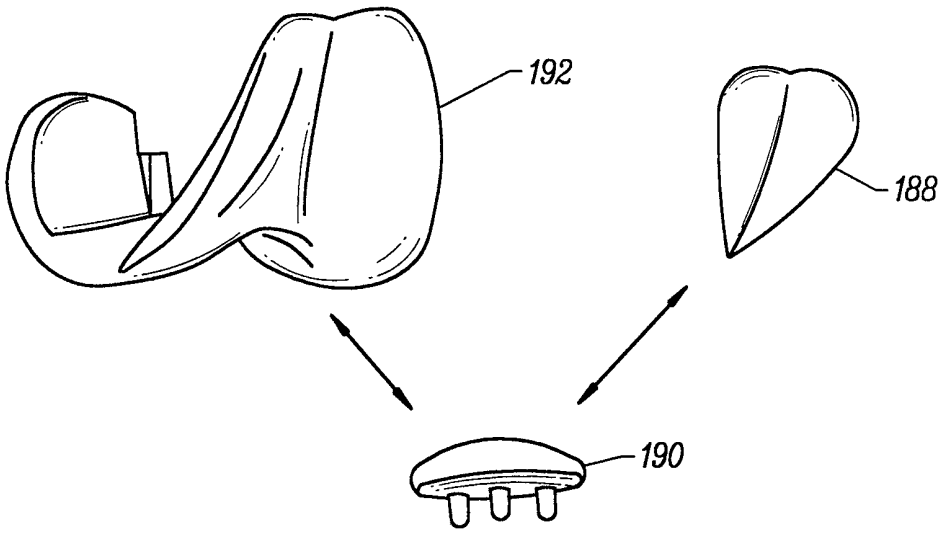

FIG. 14

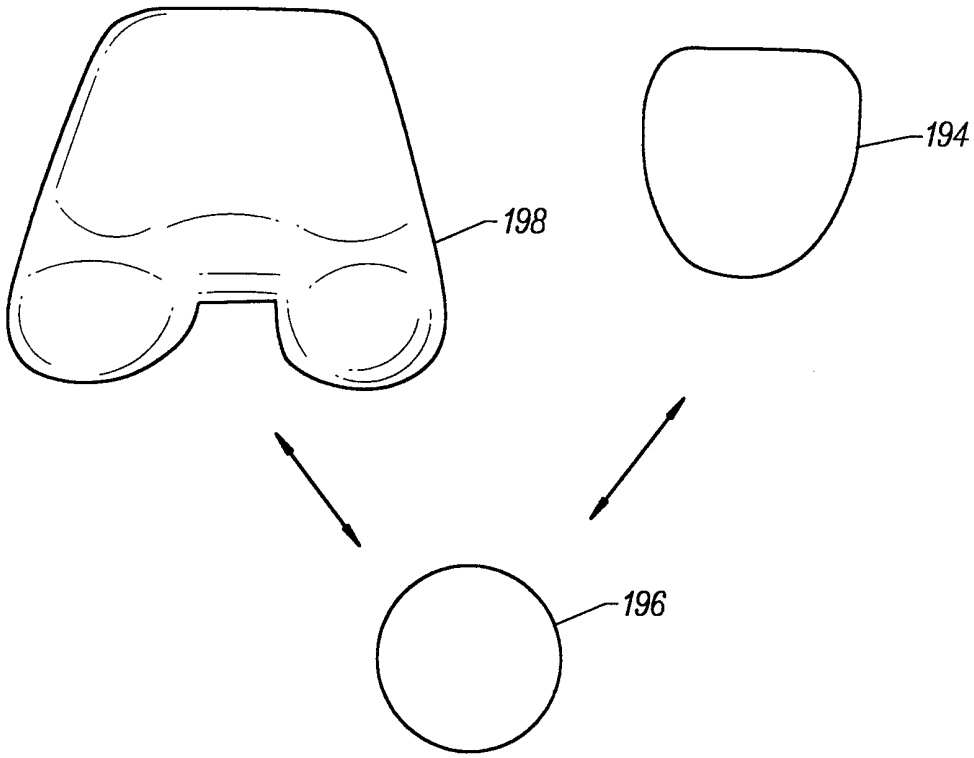

FIG. 15

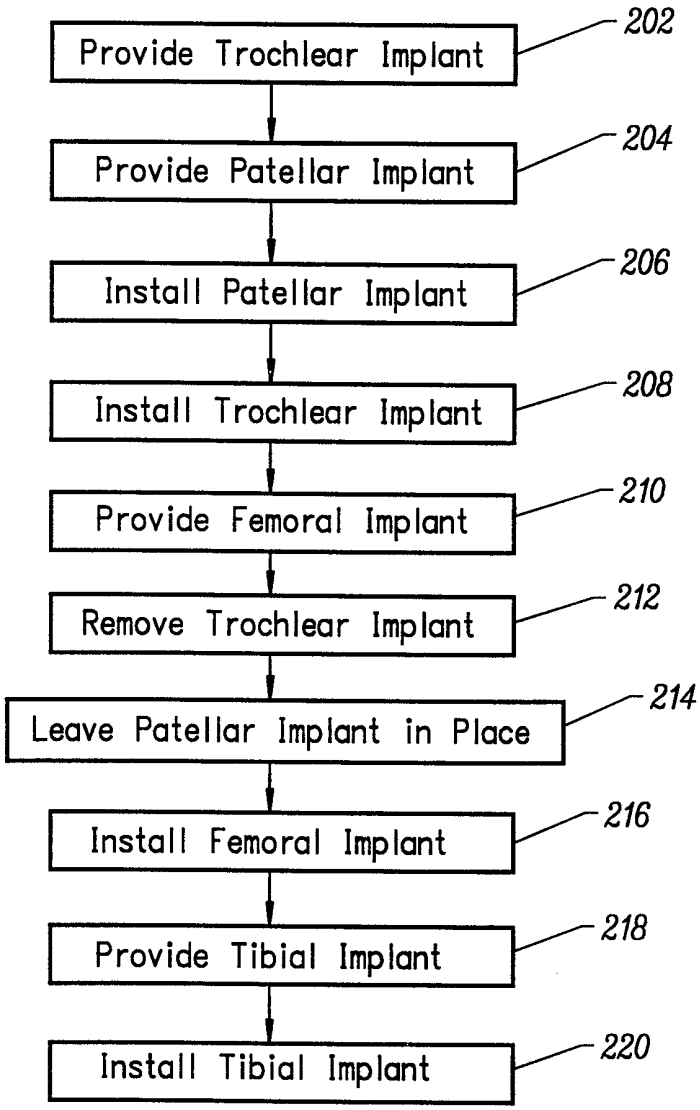
Provide Trochlear Implant
202
Provide Patellar Implant
204
Install Patellar Implant
206
Install Trochlear Implant
208
Provide Femoral Implant
210
Remove Trochlear Implant
212
Leave Patellar Implant in Place
214
Install Femoral Implant
216
Provide Tibial Implant
218
Install Tibial Implant
220

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/19344

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61F 2/38
US CL :623/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 623/20

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 5,871,539 A (PAPPAS) 16 February 1999, all figures, especially Figs. 1-3.	1-4, 16-20
X	US 3,878,566 A (BECHTOL) 22 April 1975, all figures, especially Figs. 6-9.	16-18

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 05 OCTOBER 1999	Date of mailing of the international search report 17 NOV 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer BRUCE E. SNOW Telephone No. (703) 308-3255

Form PCT/ISA/210 (second sheet)(July 1992)★