US007837736B2

(12) **United States Patent**
Bonutti

(10) **Patent No.:** **US 7,837,736 B2**
(45) **Date of Patent:** **Nov. 23, 2010**

(54) **MINIMALLY INVASIVE SURGICAL SYSTEMS AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 361 days.

(21) Appl. No.: **11/928,898**

(22) Filed: **Oct. 30, 2007**

(65) **Prior Publication Data**

US 2008/0147075 A1 Jun. 19, 2008

Related U.S. Application Data

(63) Continuation of application No. 10/681,526, filed on Oct. 8, 2003, now Pat. No. 7,635,390, which is a continuation of application No. 10/191,751, filed on Jul. 8, 2002, now Pat. No. 7,104,996, which is a continuation-in-part of application No. 09/976,396, filed on Oct. 11, 2001, now Pat. No. 6,770,078, and a continuation-in-part of application No. 09/941,185, filed on Aug. 28, 2001, now Pat. No. 6,702,821, and a continuation-in-part of application No. 09/566,070, filed on May 5, 2000, now Pat. No. 6,575,982, and a continuation-in-part of application No. 09/737,380, filed on Dec. 15, 2000, now Pat. No. 6,503,267, and a continuation-in-part of application No. 09/569,020, filed on May 11, 2000, now Pat. No. 6,423,063, and a continuation-in-part of application No. 09/483,676, filed on Jan. 14, 2000, now Pat. No. 6,468,289, and a continuation-in-part of application No. 09/798,870, filed on Mar. 1, 2001, now Pat. No. 6,503,277, and a continuation-in-part of application No. 09/526,949, filed on Mar. 16, 2000, now Pat. No. 6,620,181, and a continuation-in-part of application No. 09/789,621, filed on Feb. 21, 2001, now Pat. No. 6,635,073.

(51) **Int. Cl.**
A61F 2/38 (2006.01)

(52) **U.S. Cl.** **623/20.14**; 623/20.15

(58) **Field of Classification Search** 623/20.14, 623/20.15, 20.29, 20.28, 20.26, 20.27, 20.3, 623/20.32, 20.33, 20.18, 20.19, 20.21–20.31, 623/901
See application file for complete search history.

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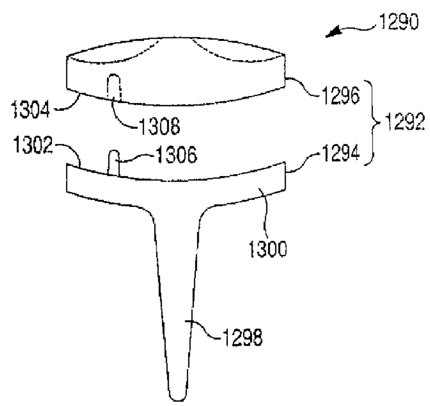

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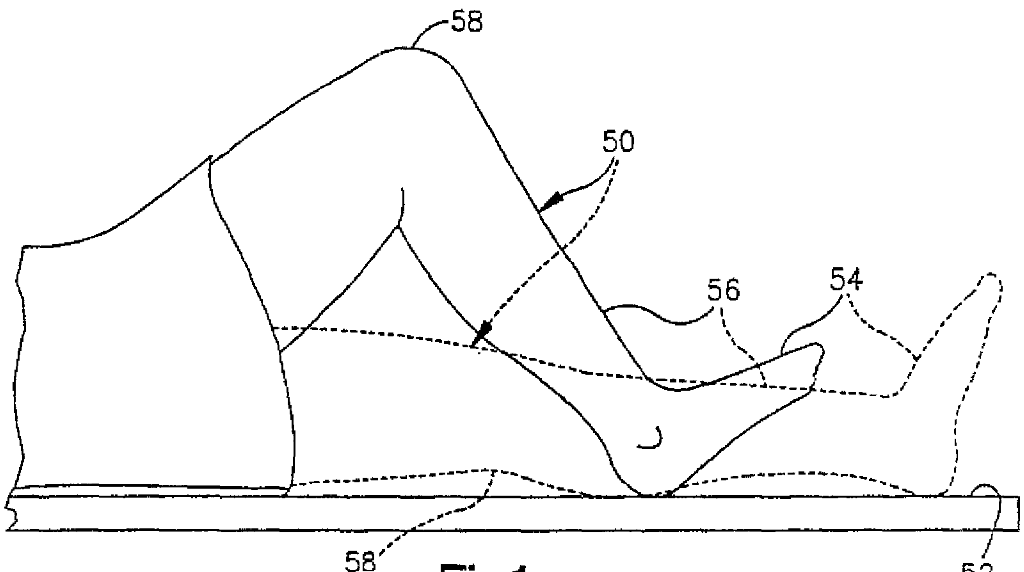
(57) **ABSTRACT**

A method is provided for performing a total knee arthroplasty. The method includes making a primary incision near a knee joint of a patient and resecting medial and lateral condyles of the femur of the leg to create at least one femoral cut surface. The resecting step is performed without dislocating the knee joint. The method also includes balancing various ligament tensions to obtain desired tension and moving a femoral component of a total knee implant through the primary incision. The method further includes positioning the femoral component with respect to the at least one femoral cut surface.

40 Claims, 37 Drawing Sheets



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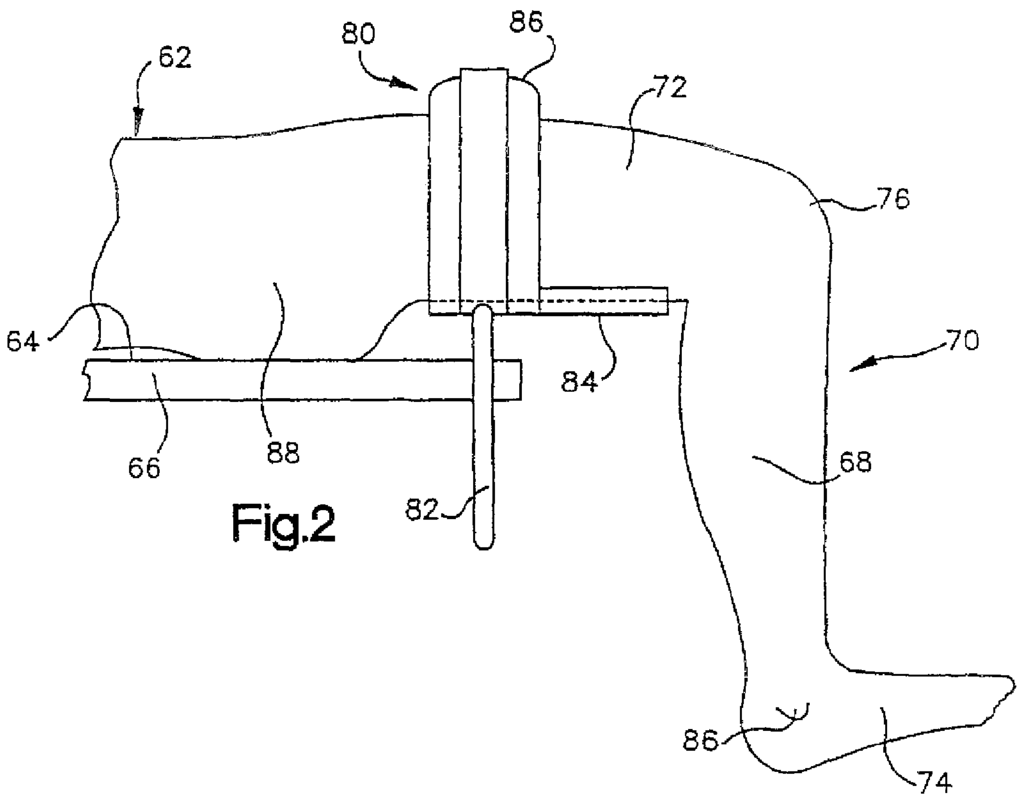

Fig.2

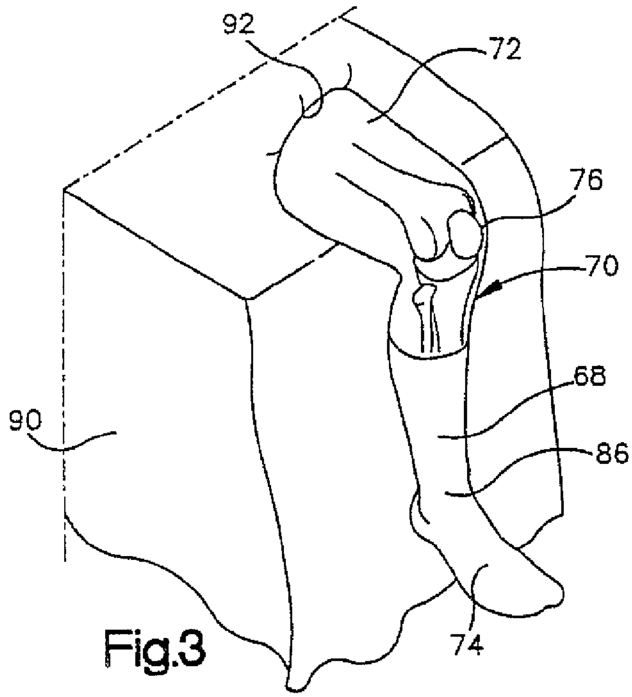
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Fig.3

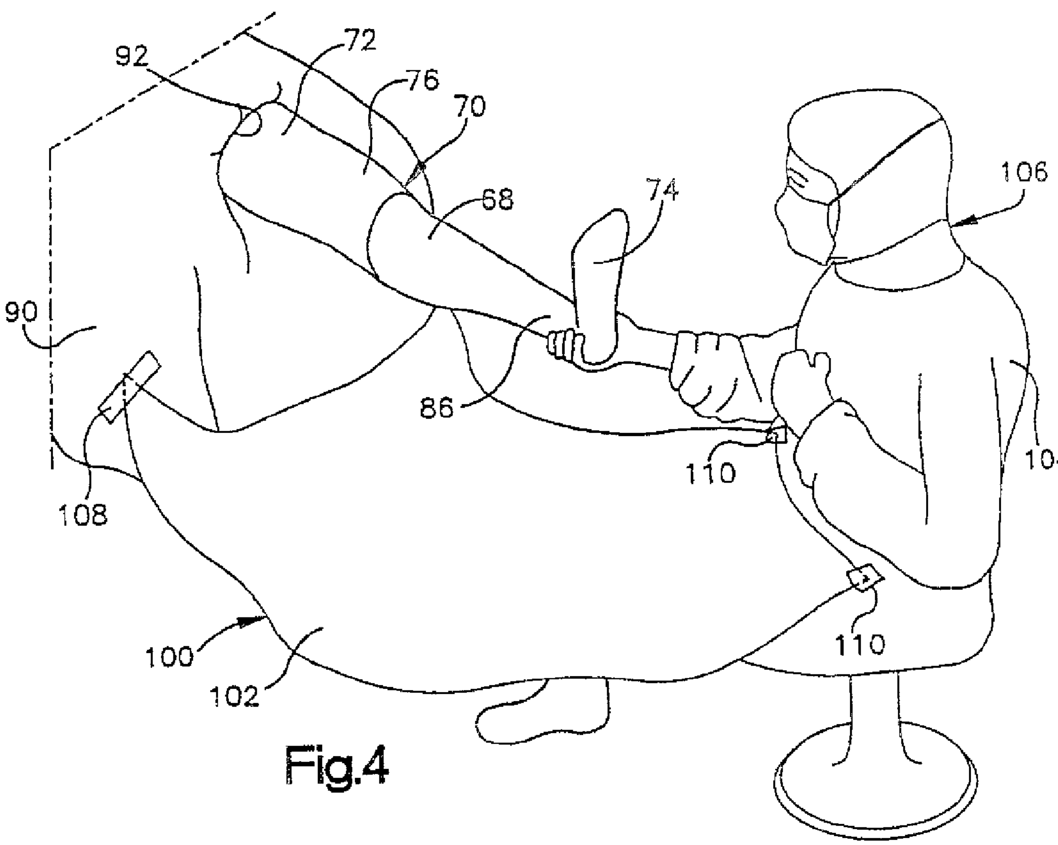
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Fig.4

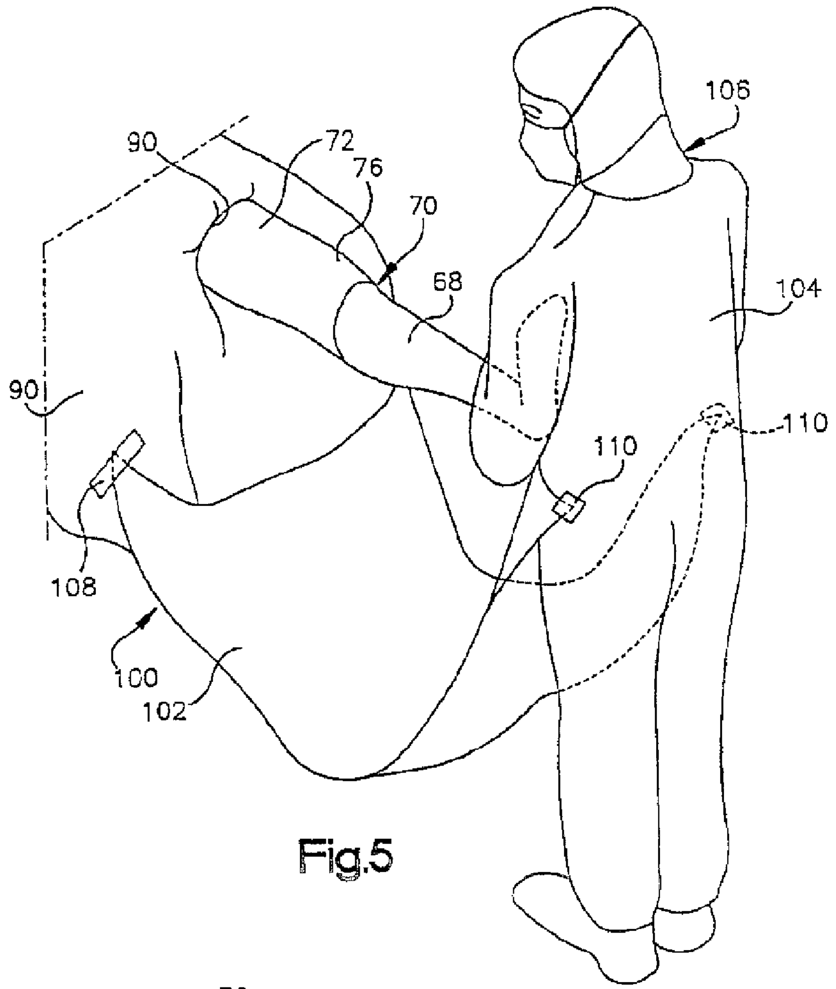


Fig.5

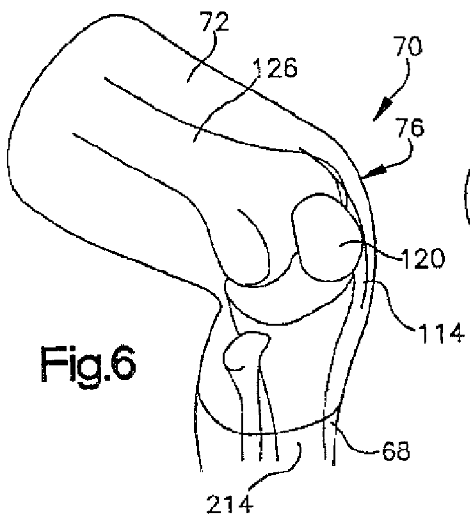


Fig.6

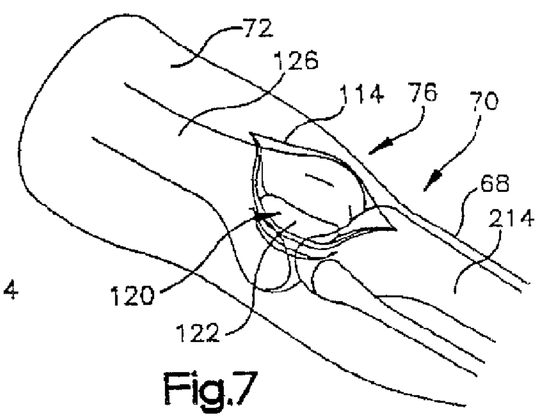
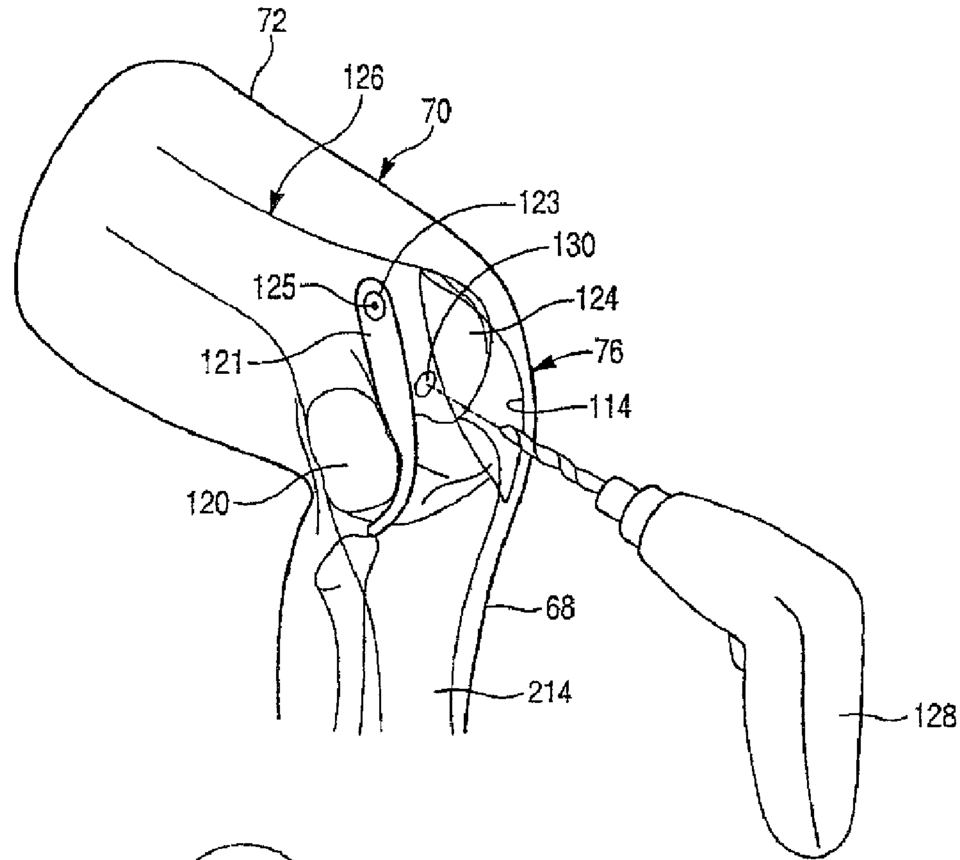


Fig.7

Fig. 8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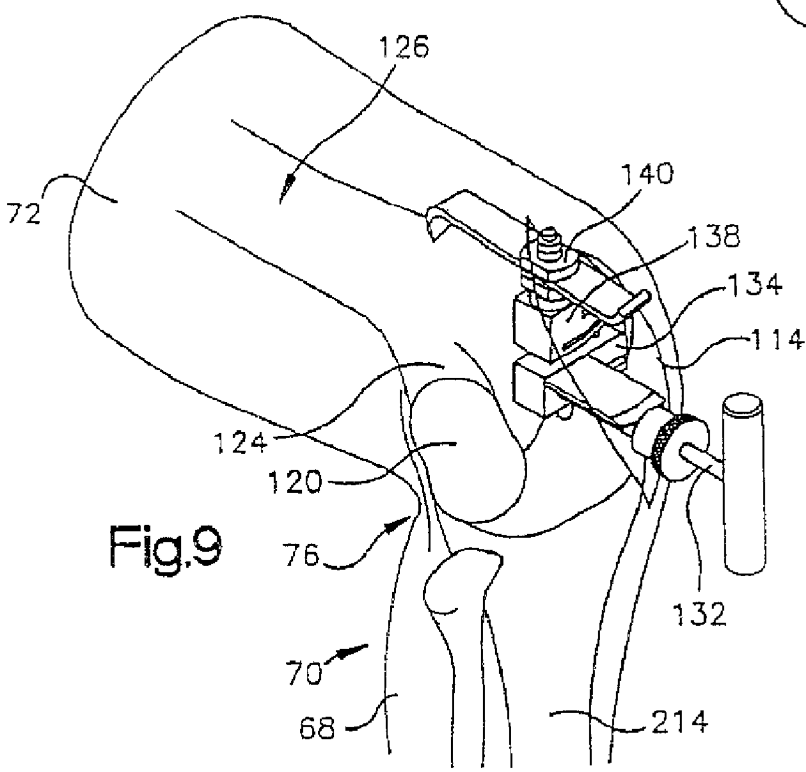
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Fig.9

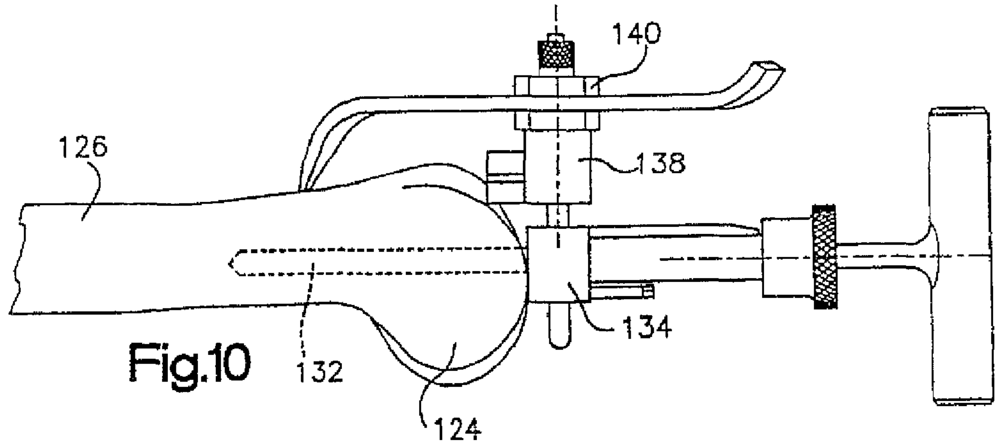

Fig.10

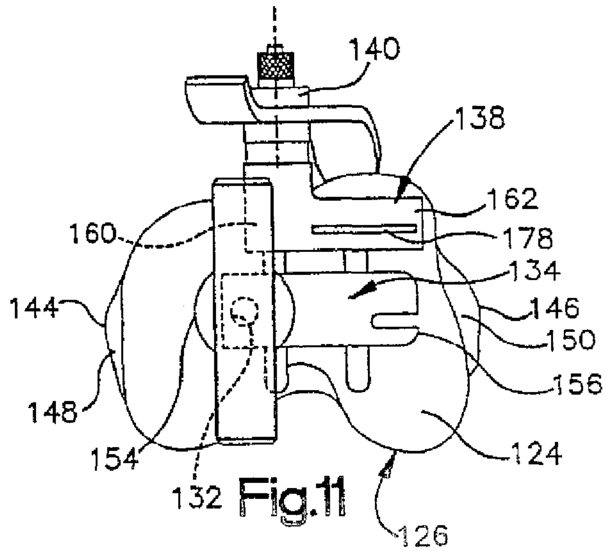

Fig.11

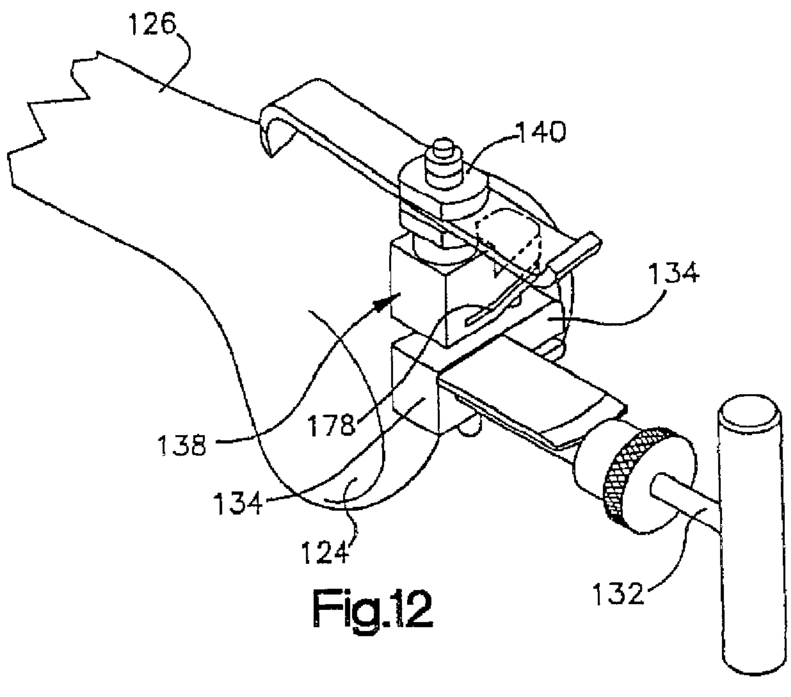

Fig.12

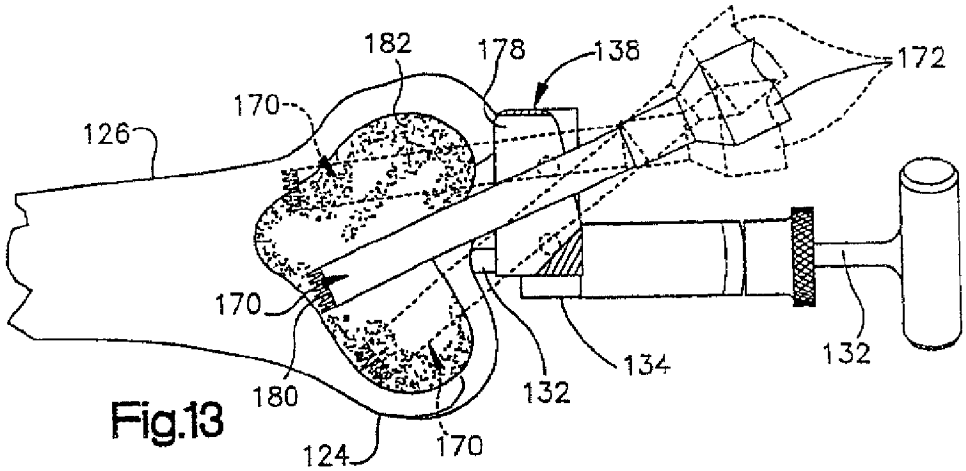

Fig.13

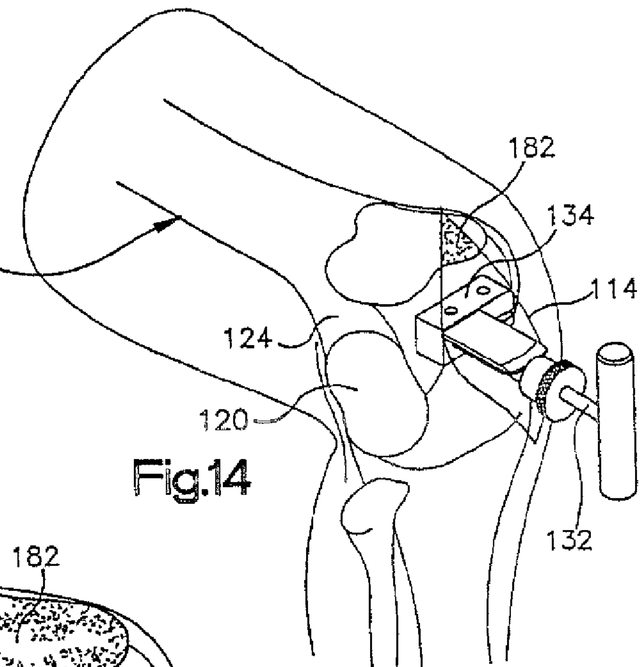

Fig.14

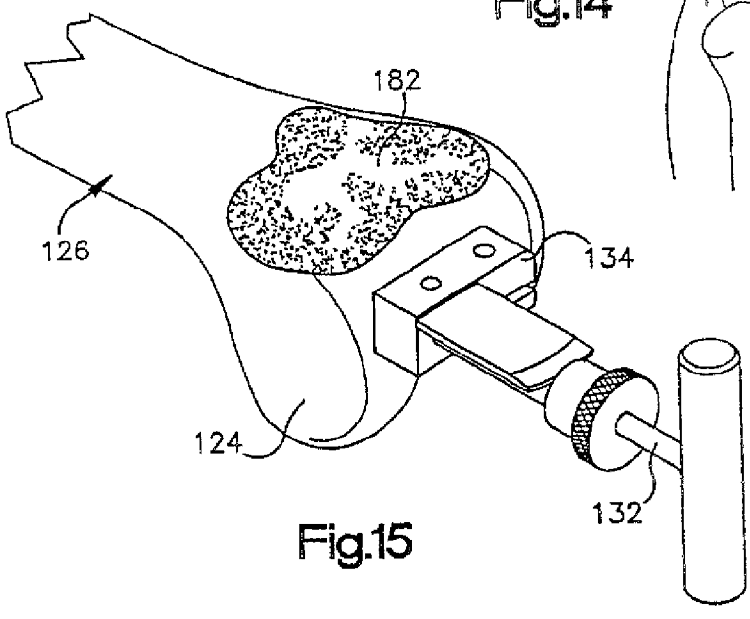

Fig.15

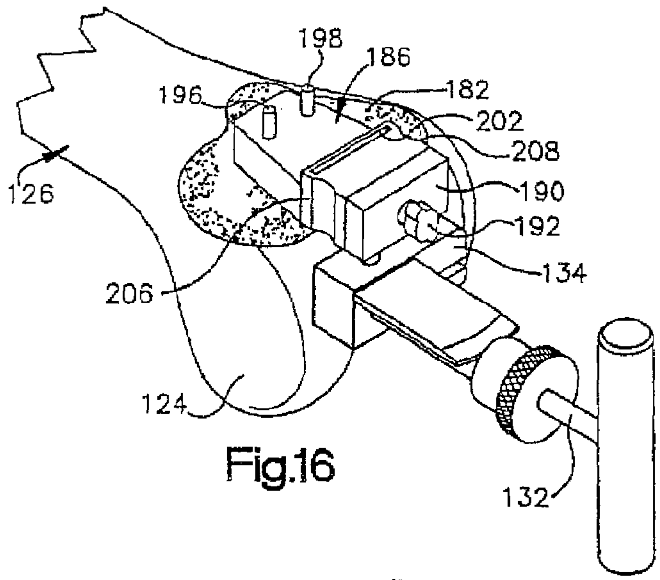

Fig.16

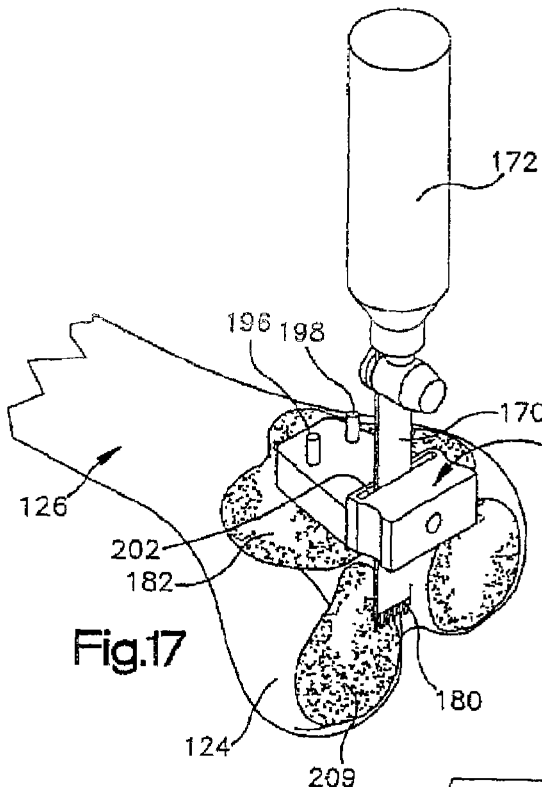

Fig.17

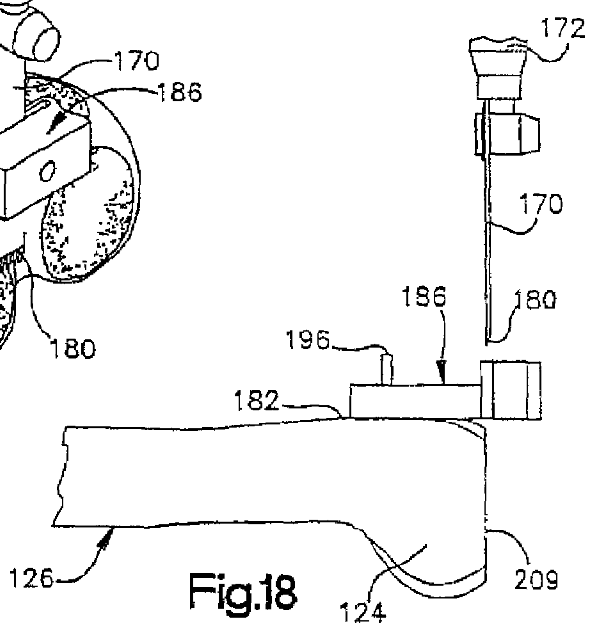

Fig.18

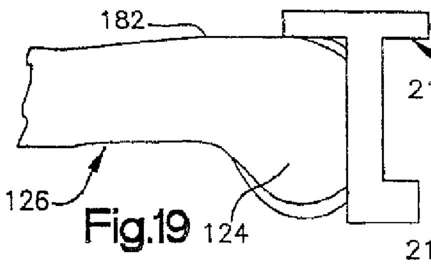

Fig.19

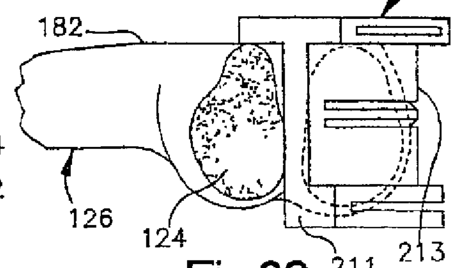

Fig.20

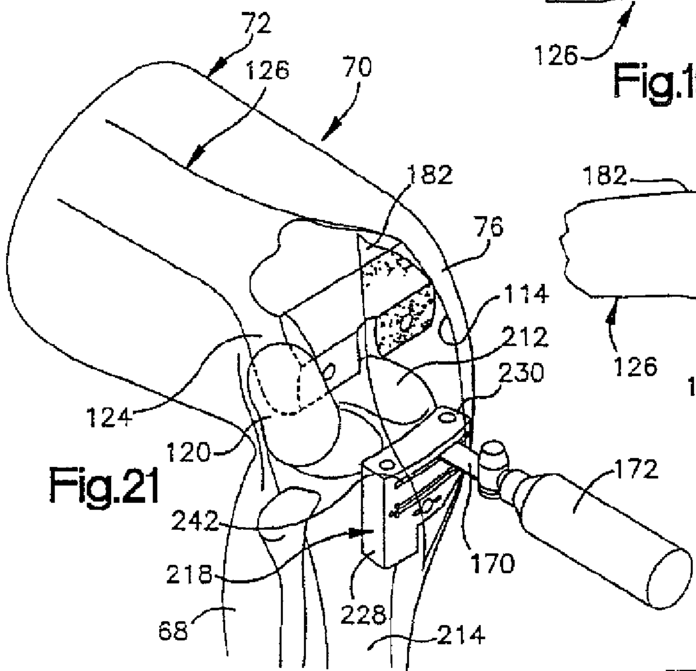

Fig.21

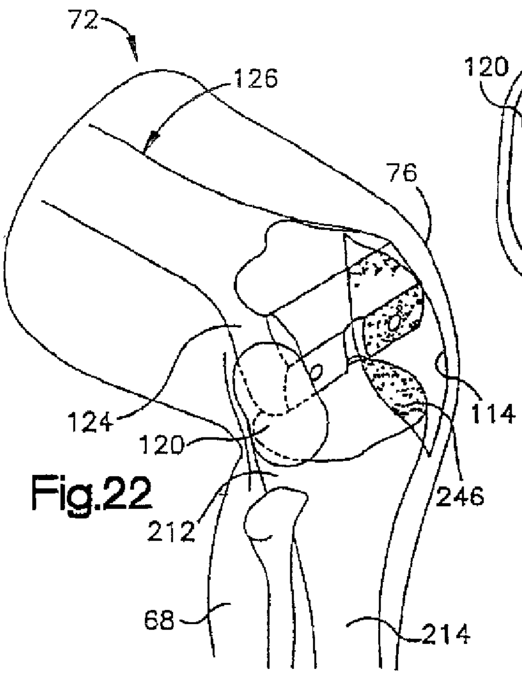

Fig.22

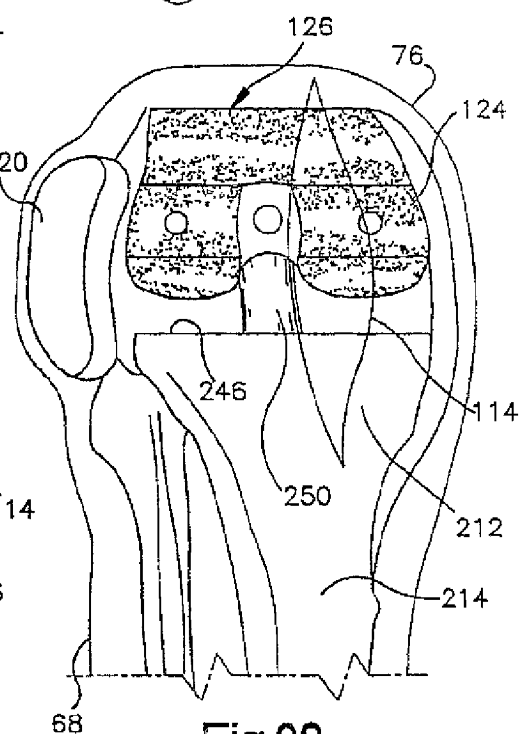

Fig.23

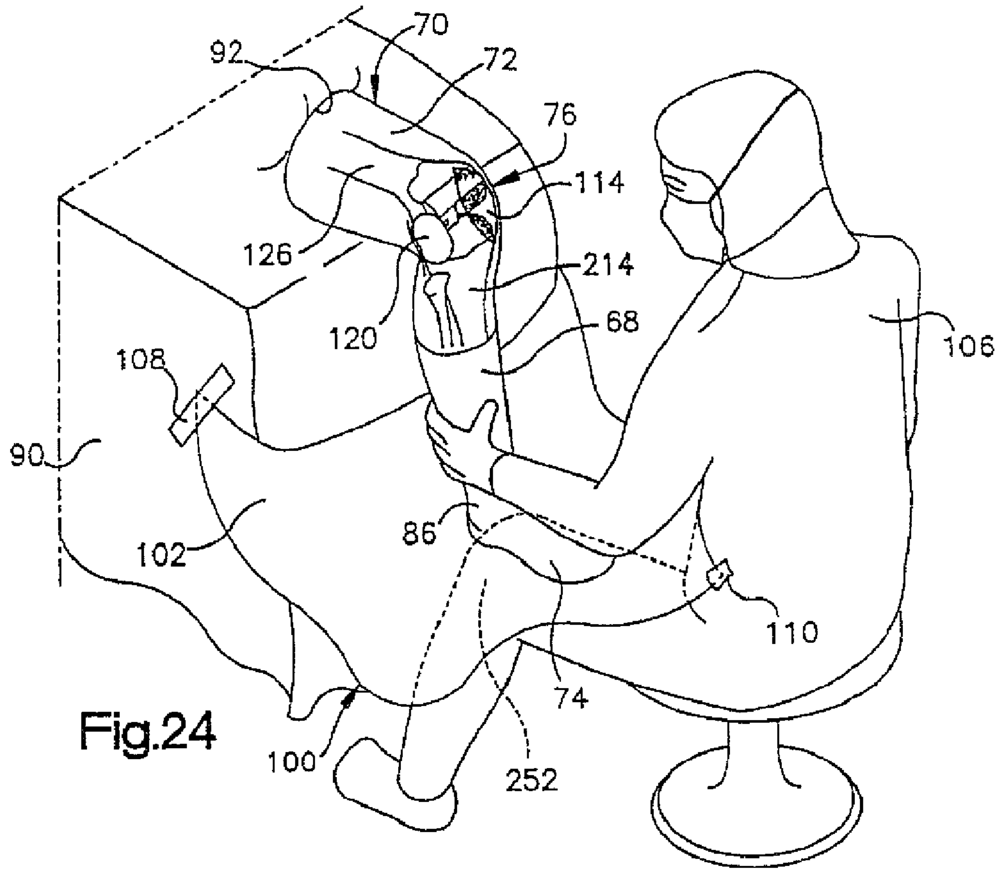
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Fig.24

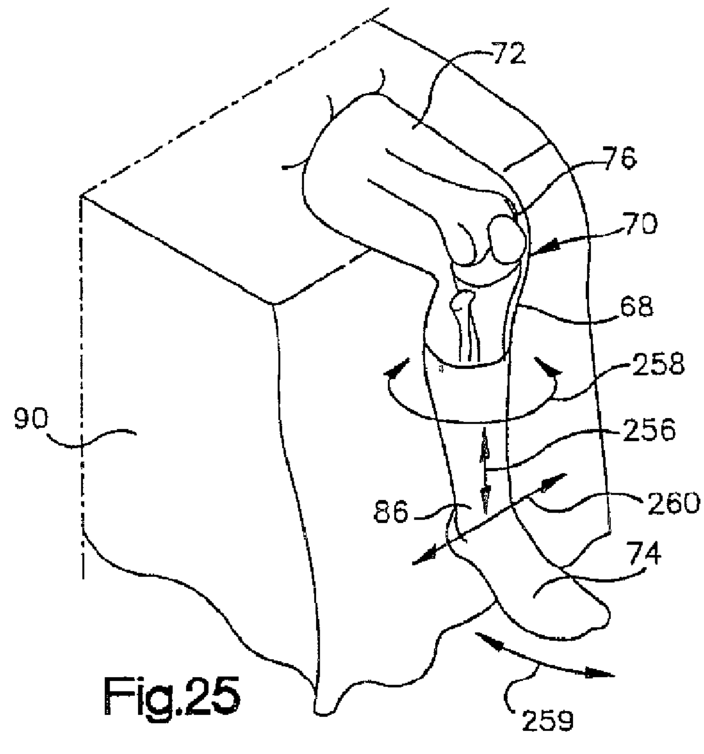
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Fig.25

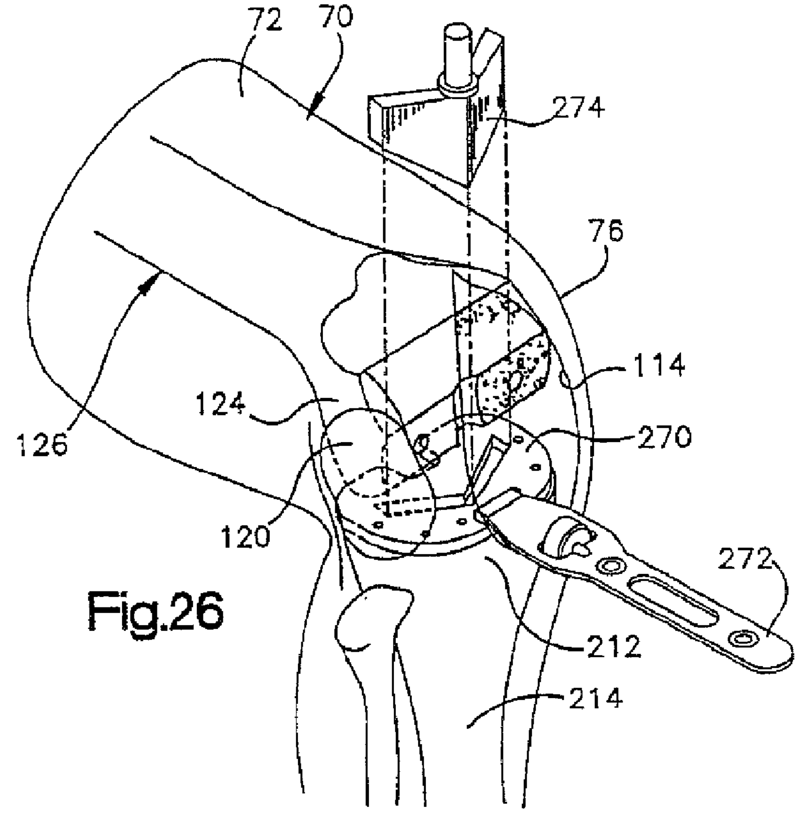
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Fig.26

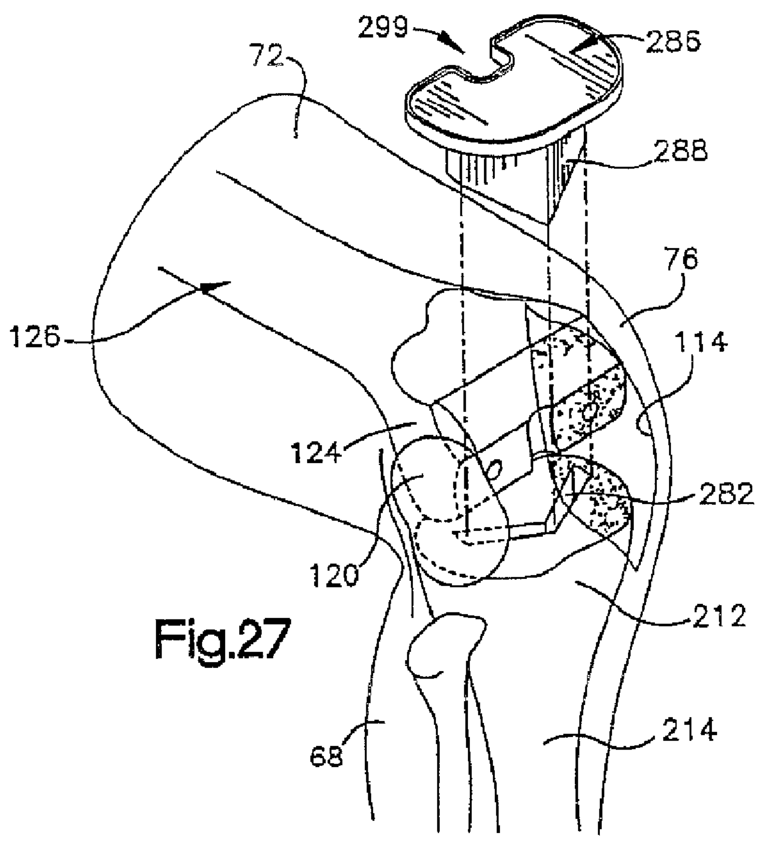
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Fig.27

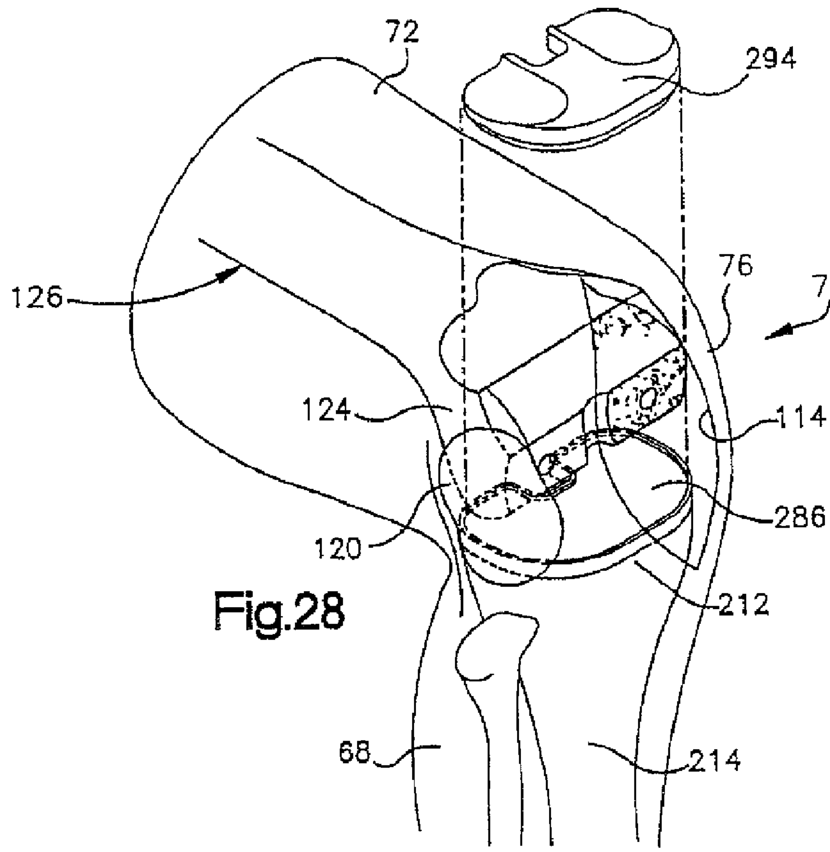
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Fig.28

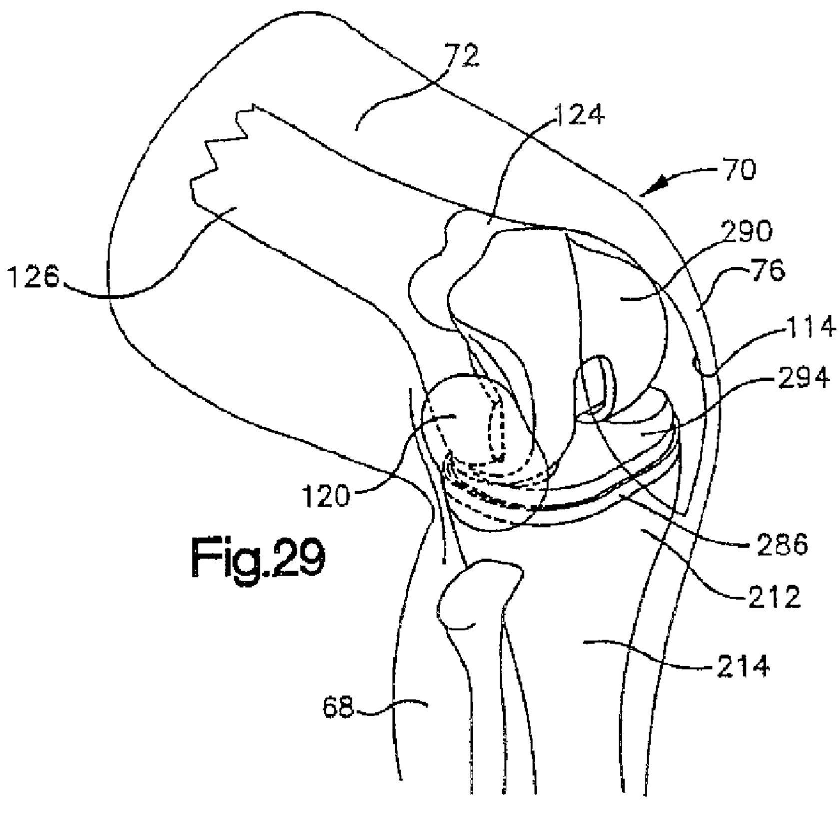
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Fig.29

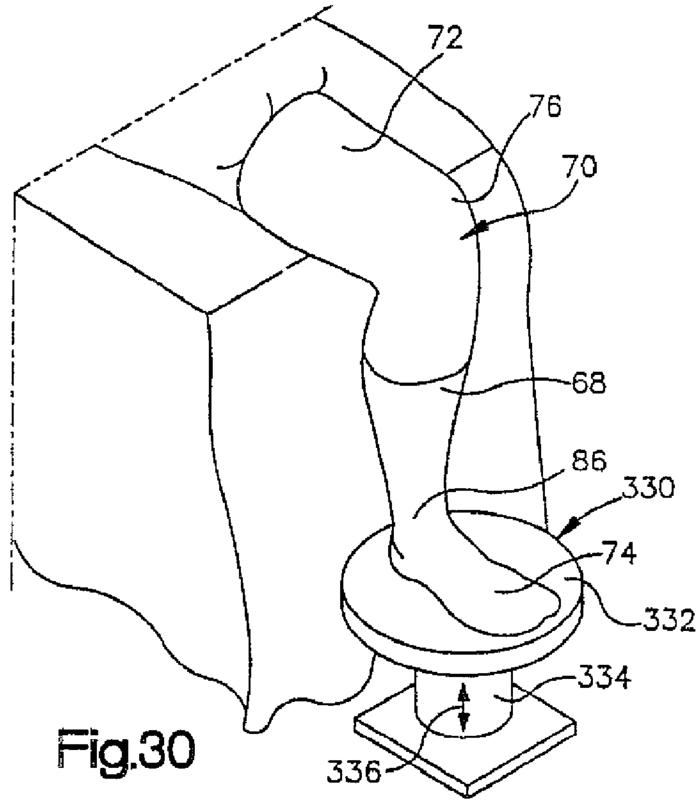

Fig.30

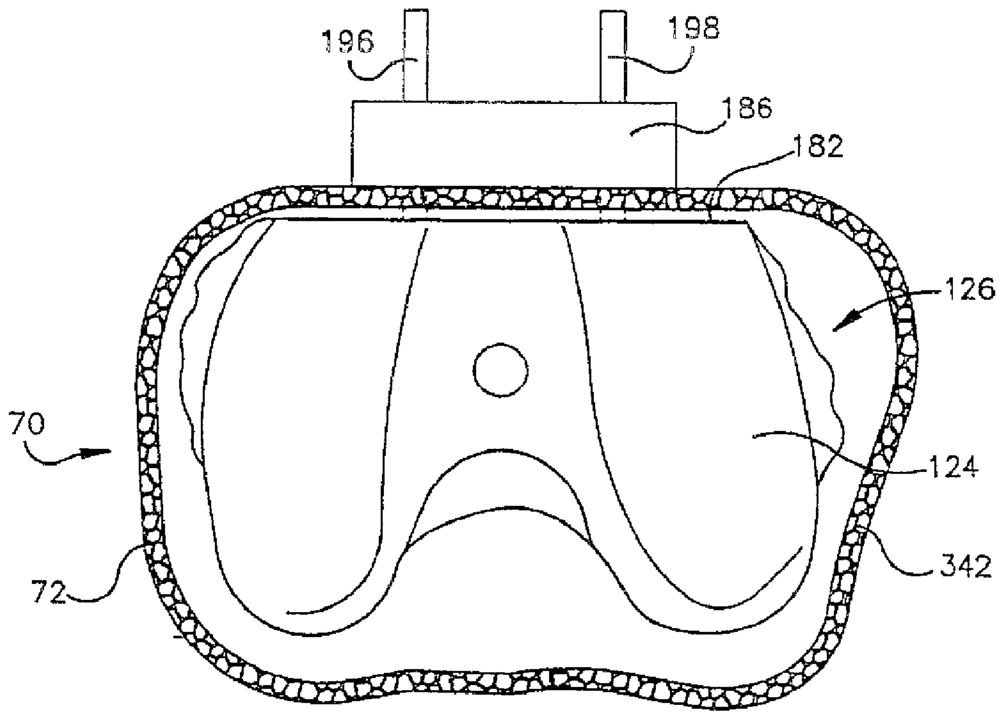

Fig.31

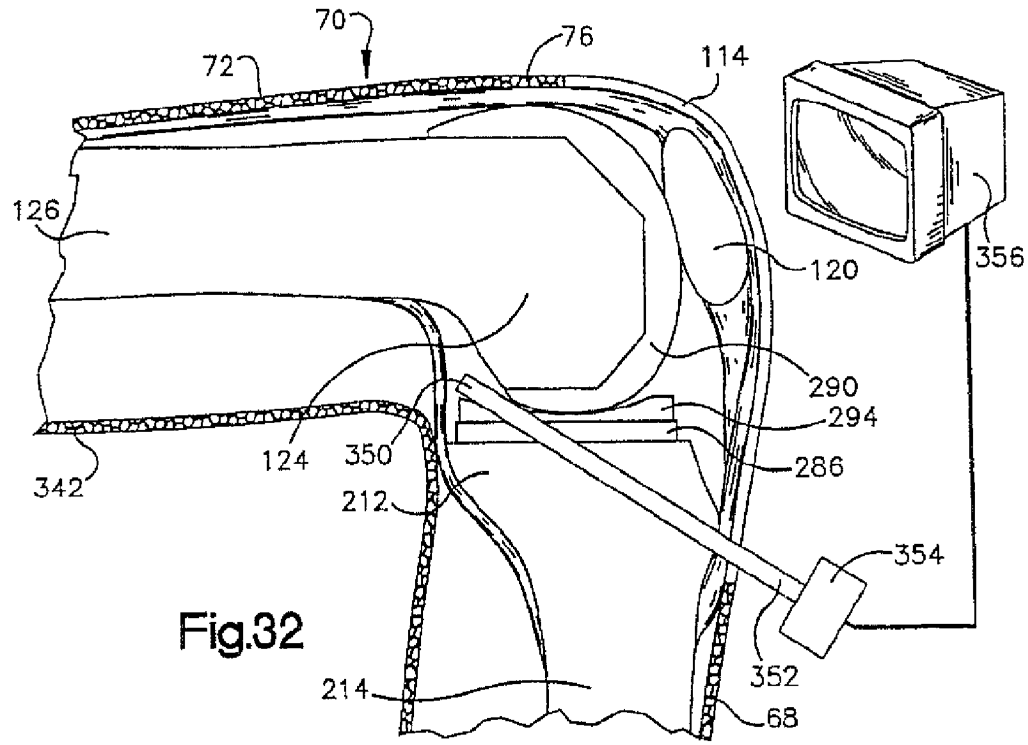
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Fig.32

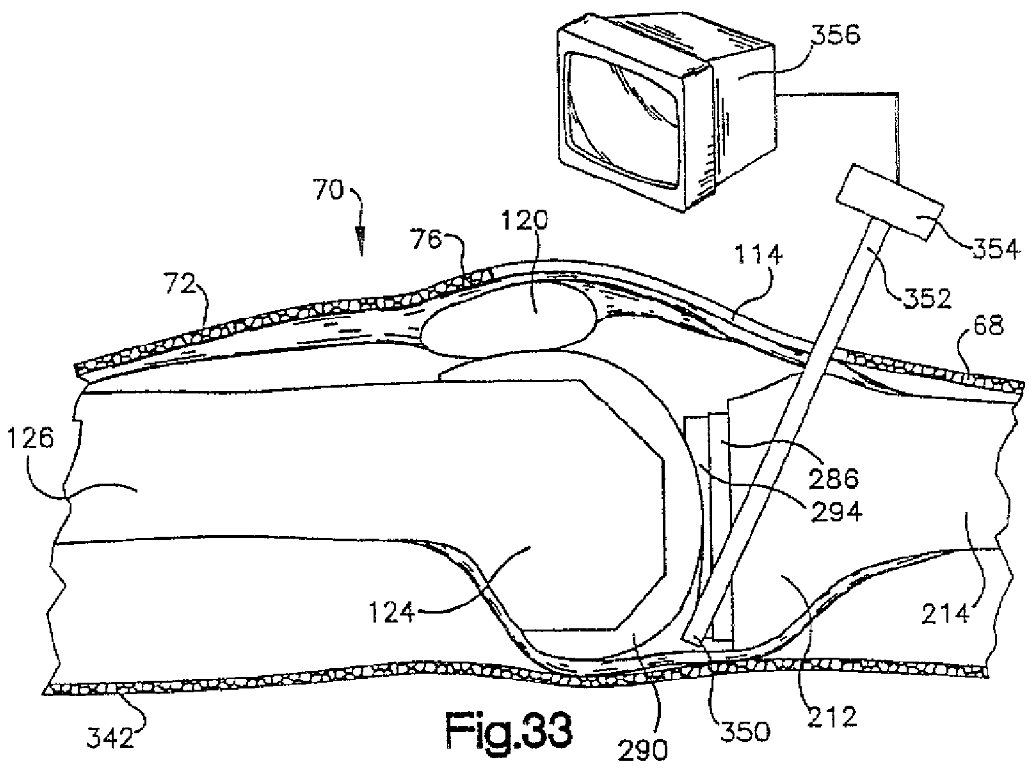
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Fig.33

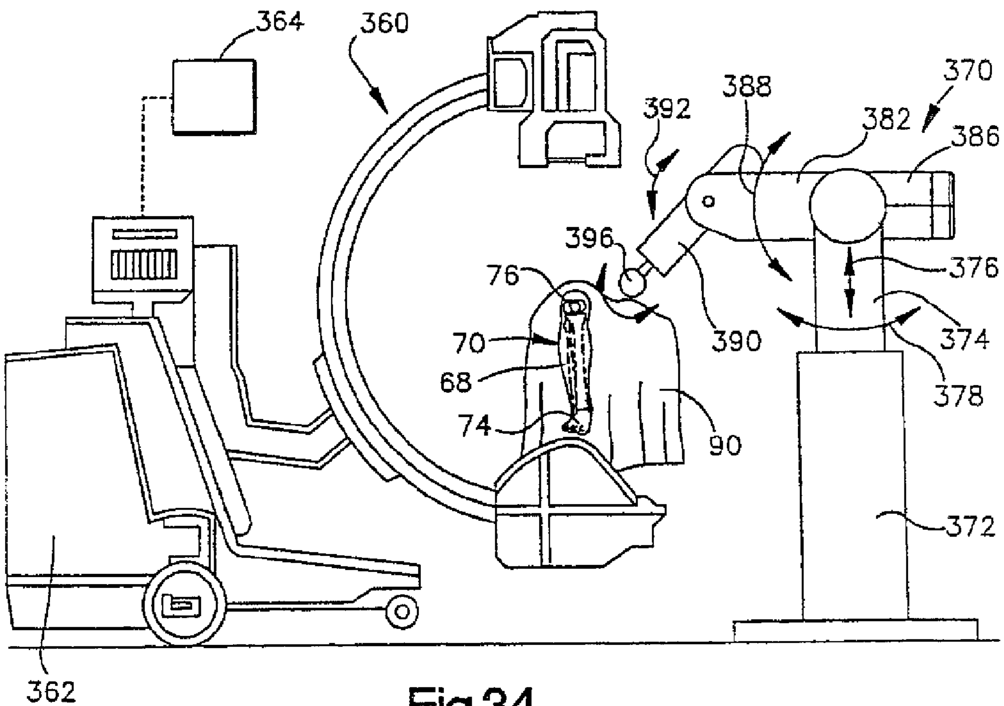
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Fig.34

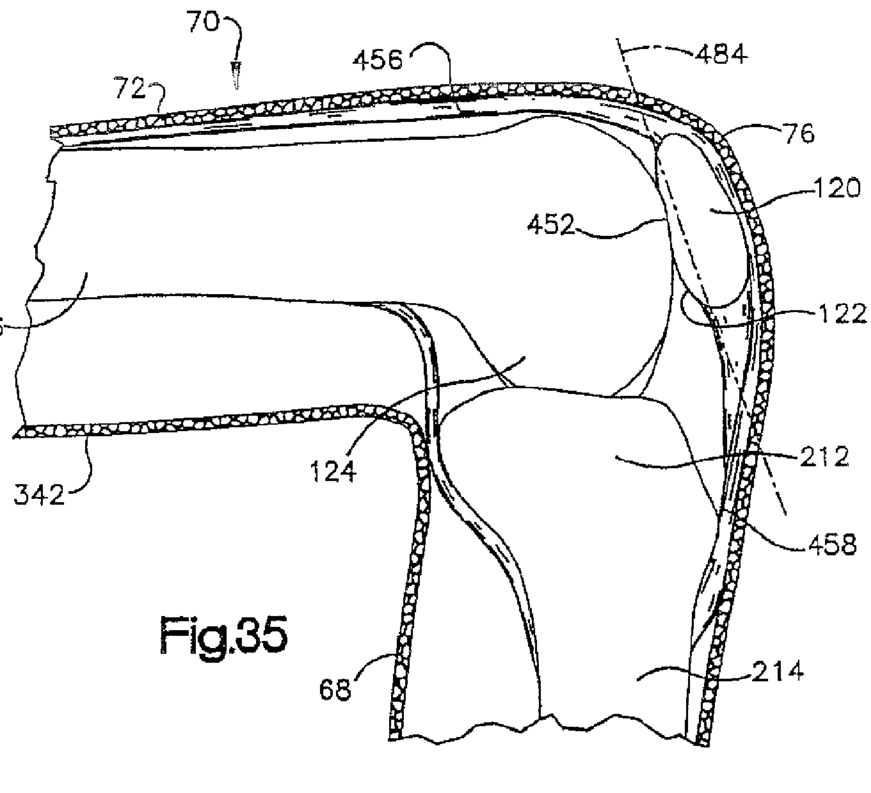
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Fig.35

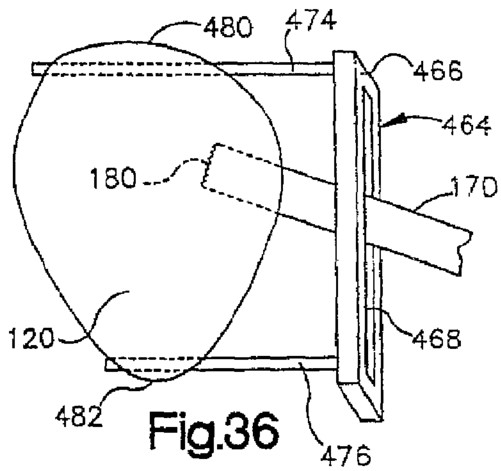

Fig.36

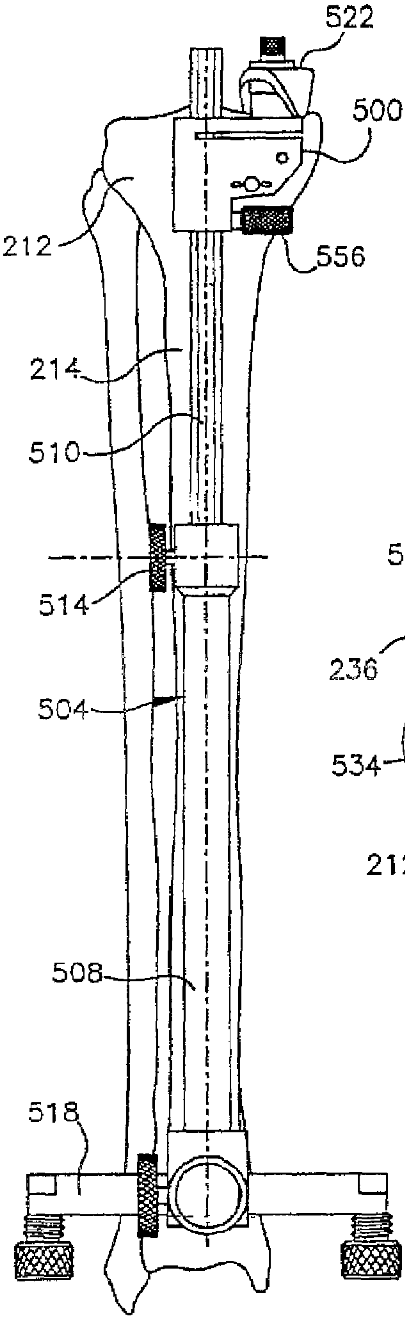

Fig.37

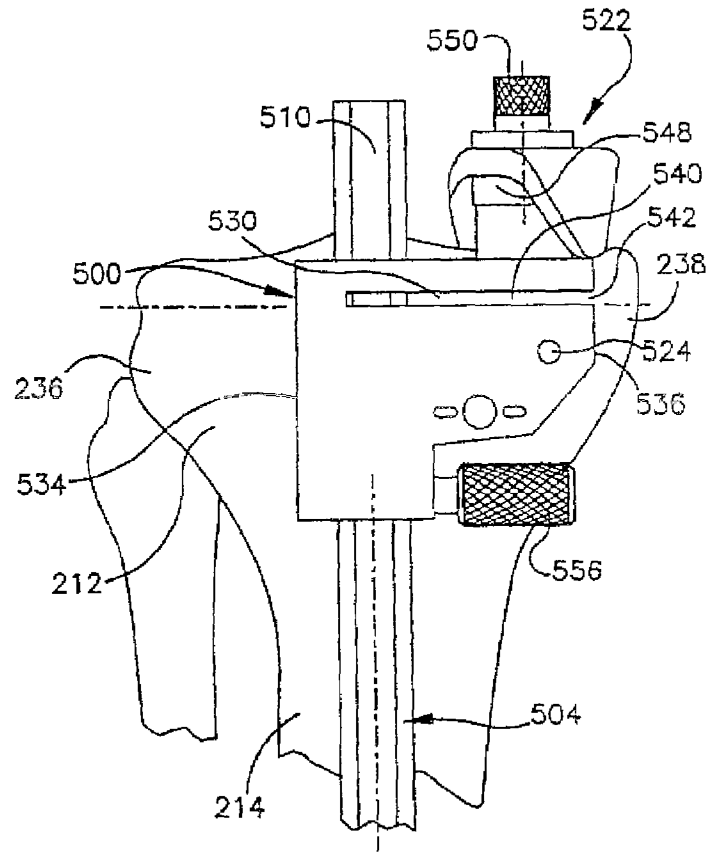

Fig.38

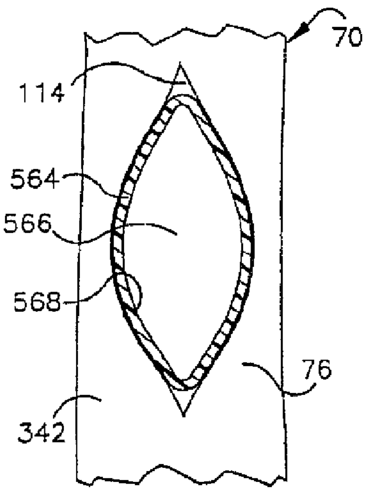

Fig.39

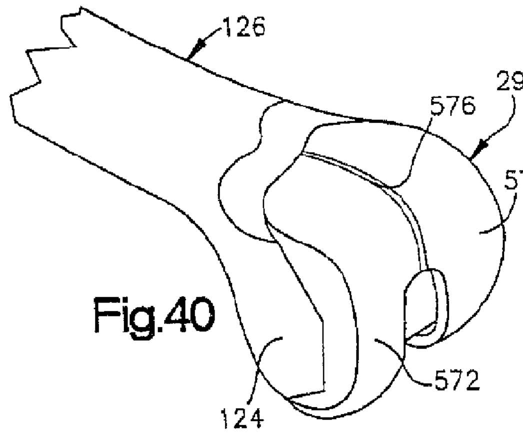

Fig.40

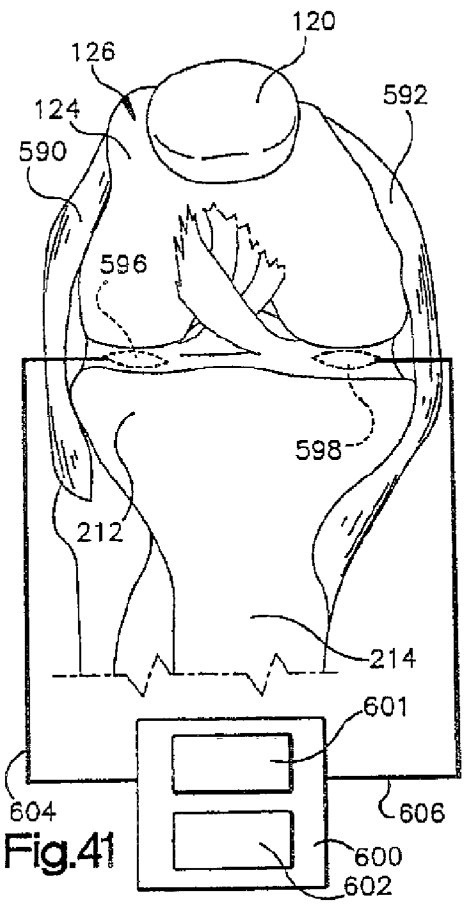

Fig.41

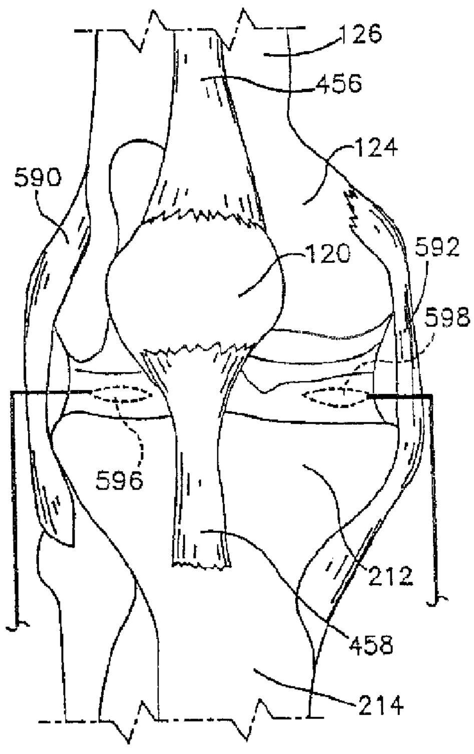

Fig.42

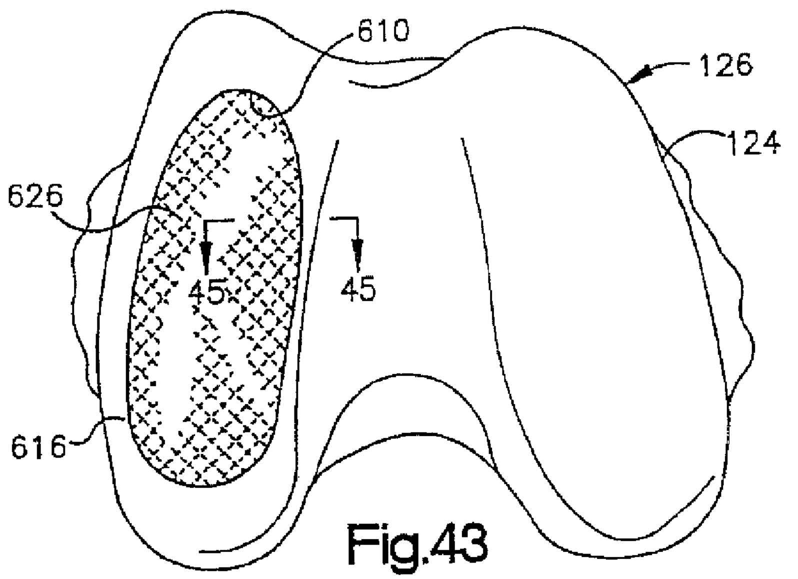

Fig.43

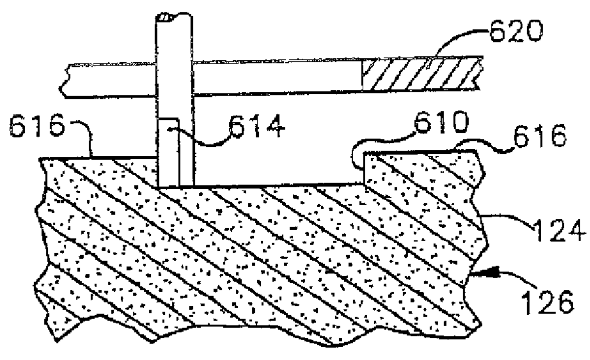

Fig.44

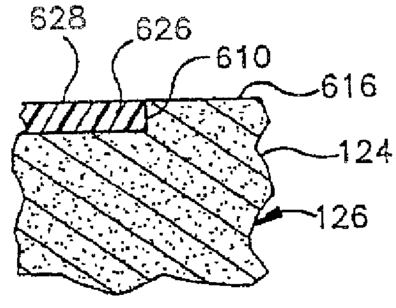

Fig.45

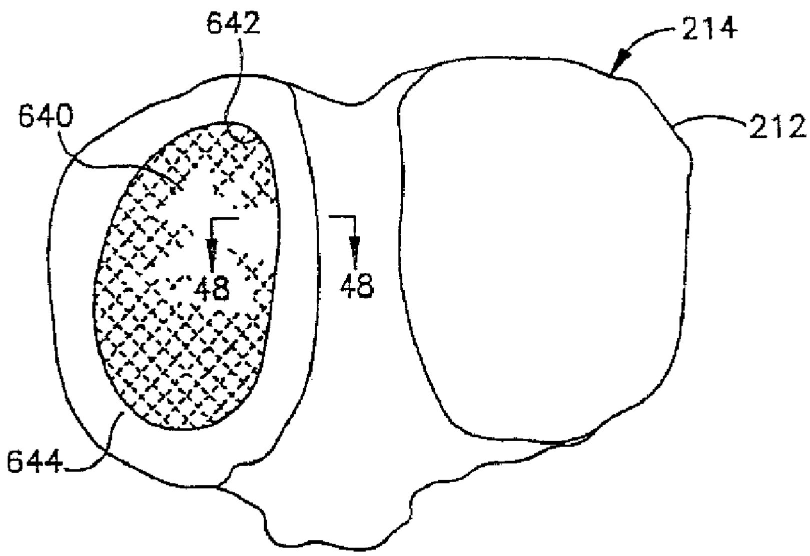

Fig.46

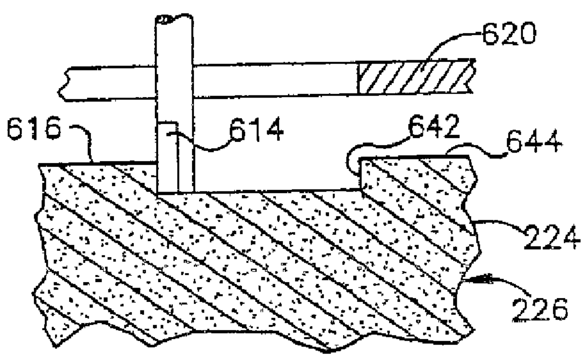

Fig.47

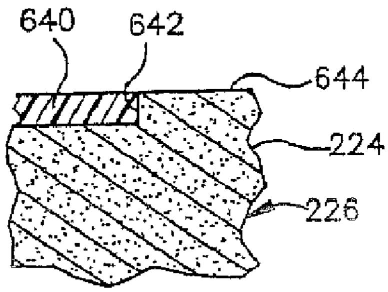

Fig.48

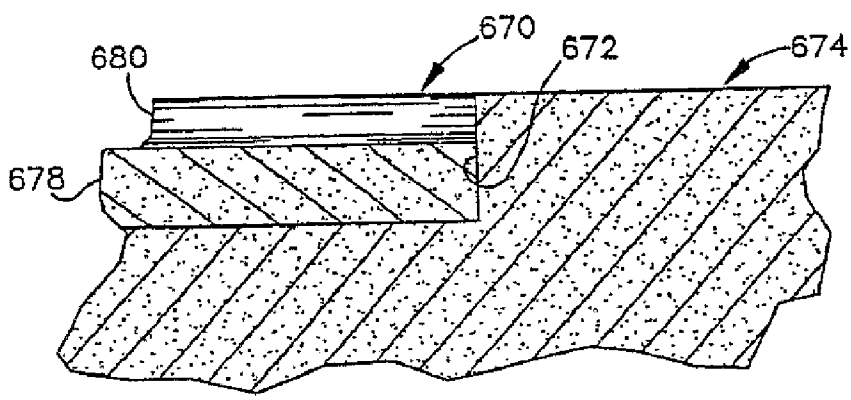

Fig.49

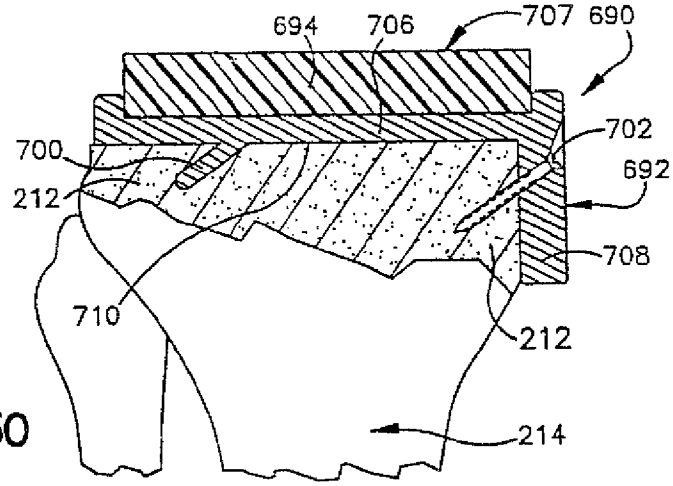

Fig.50

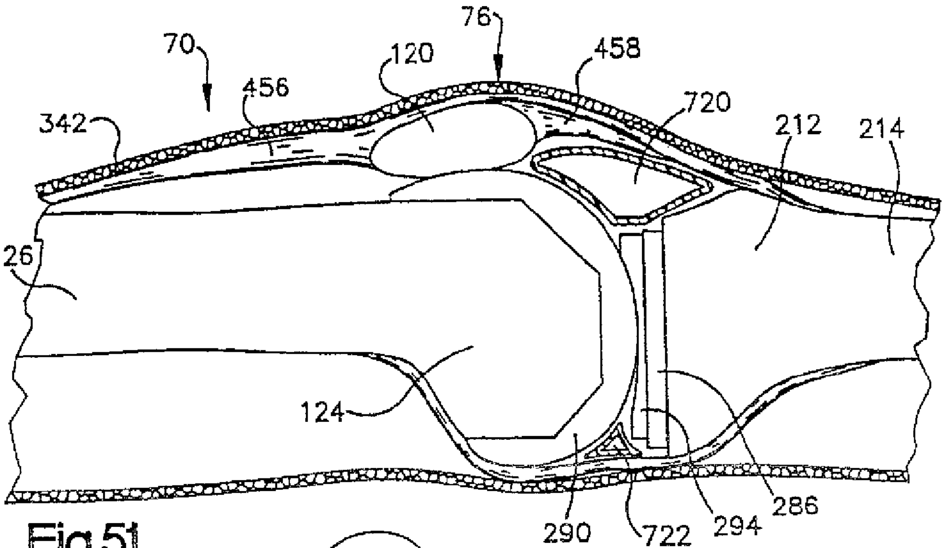

Fig.51

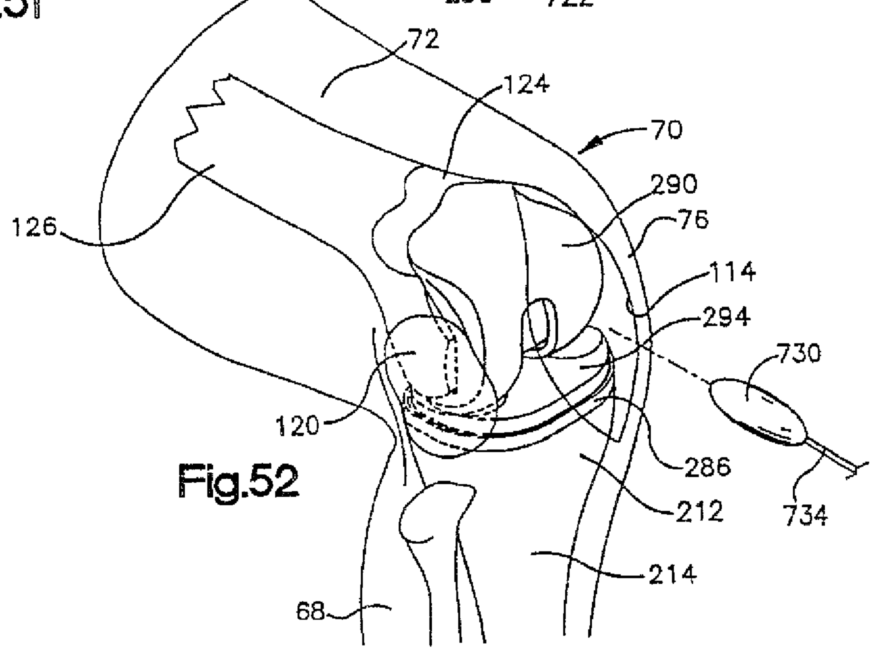

Fig.52

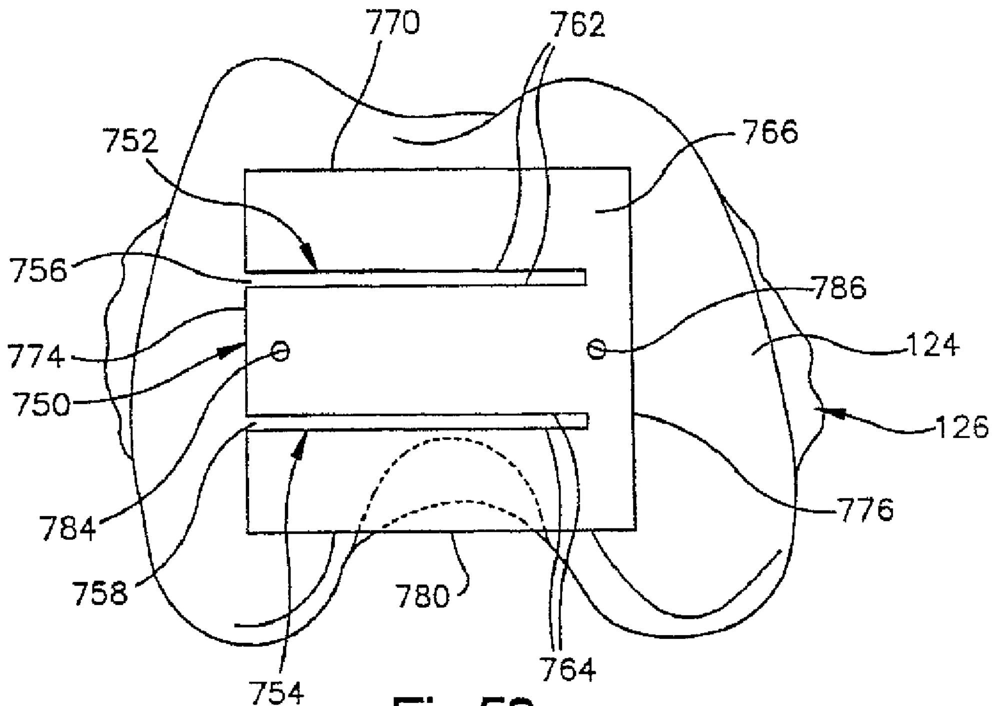
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Fig.53

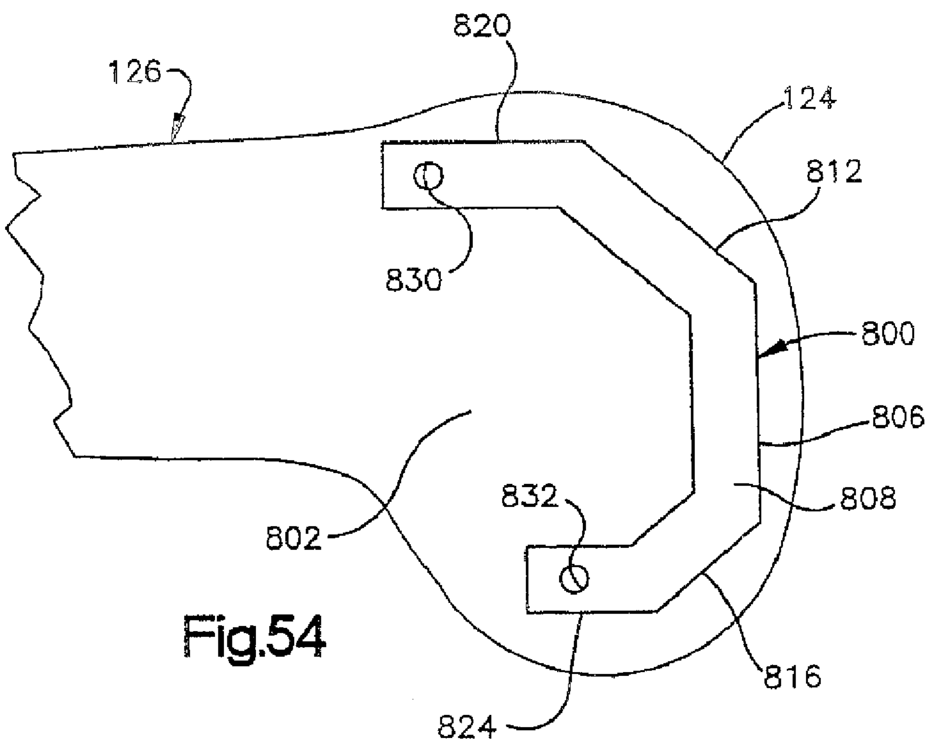
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Fig.54

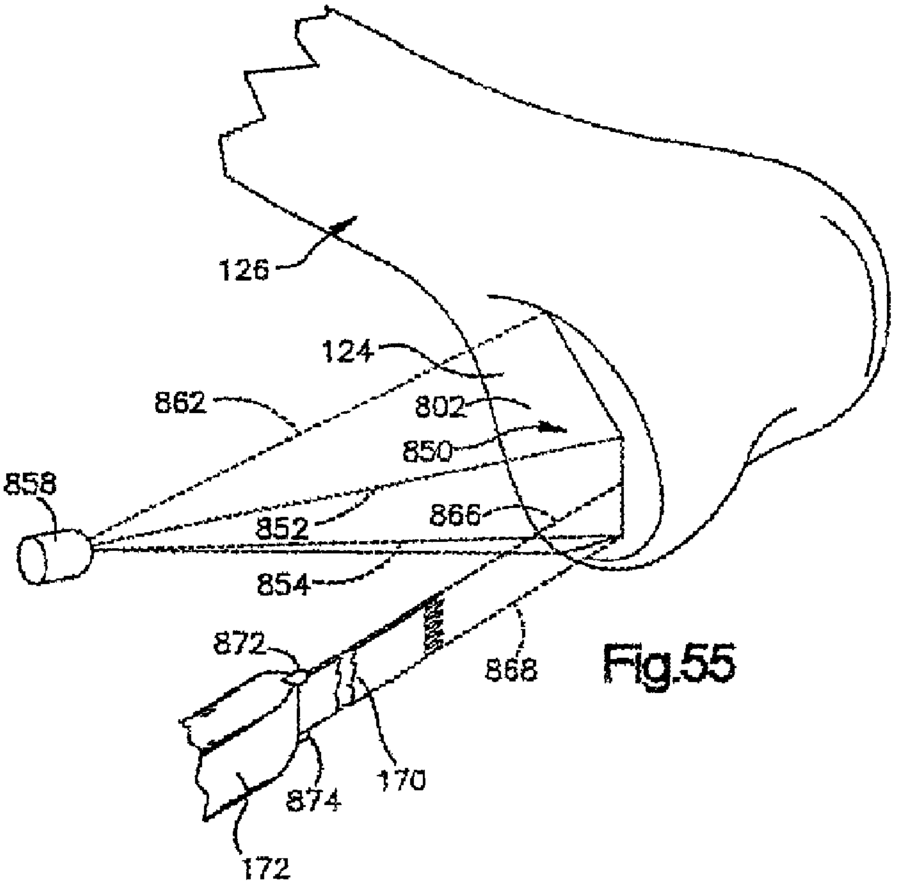
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Fig.55

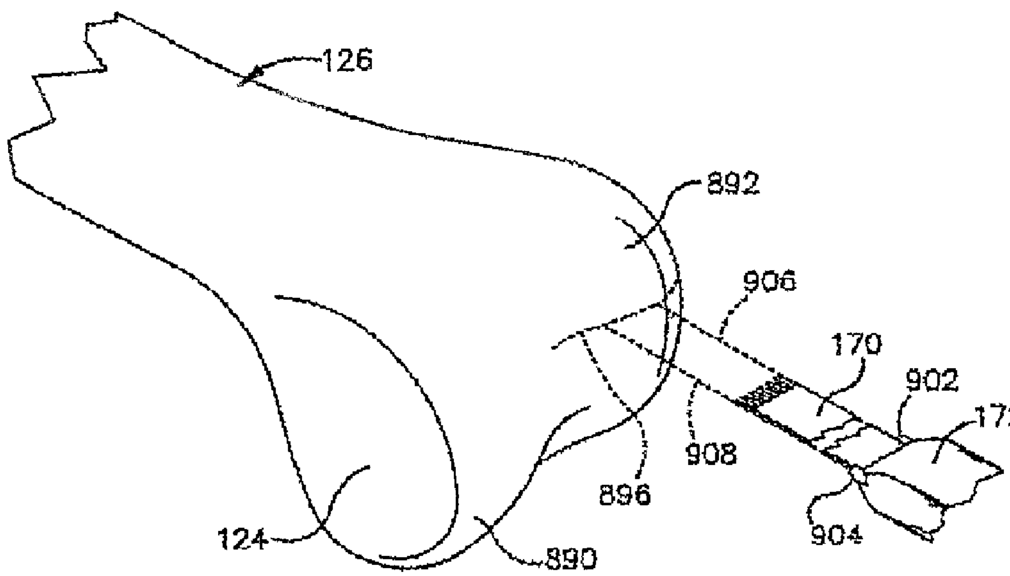
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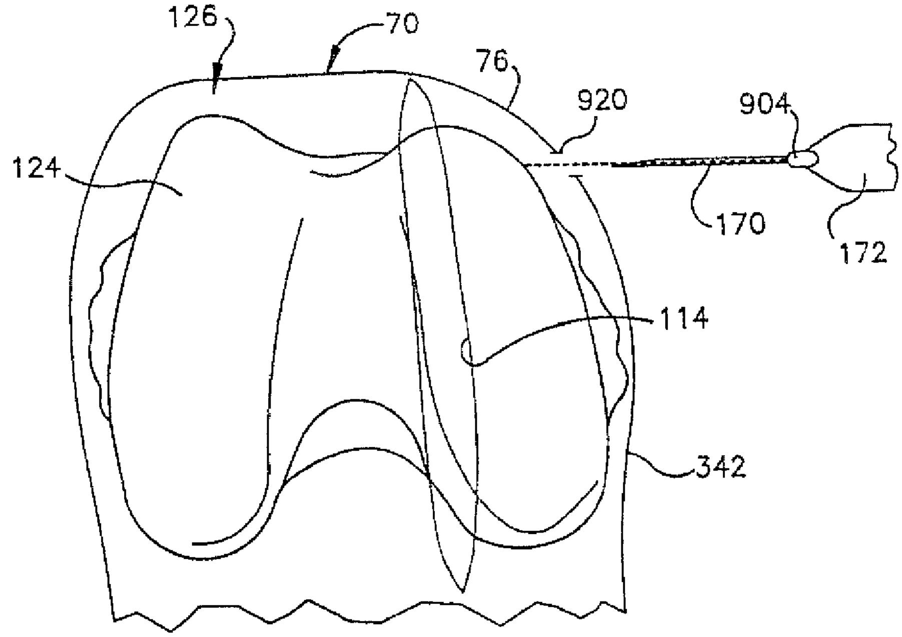
Fig.56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342

Fig.57

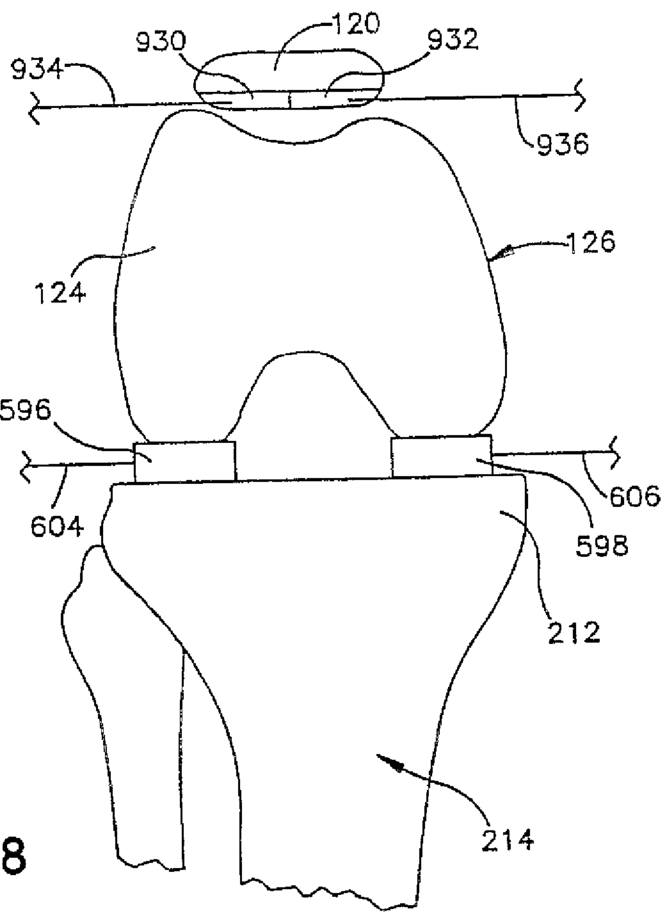
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Fig.58

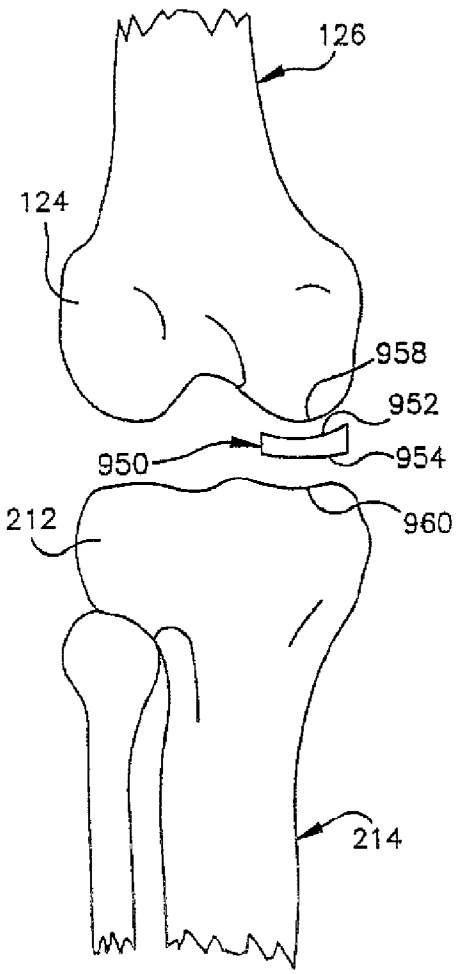

Fig.59

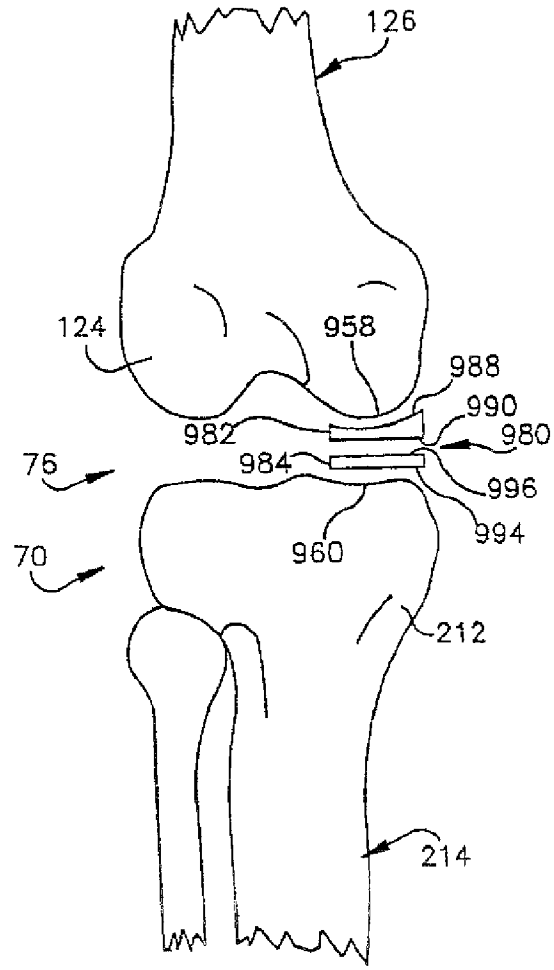

Fig.61

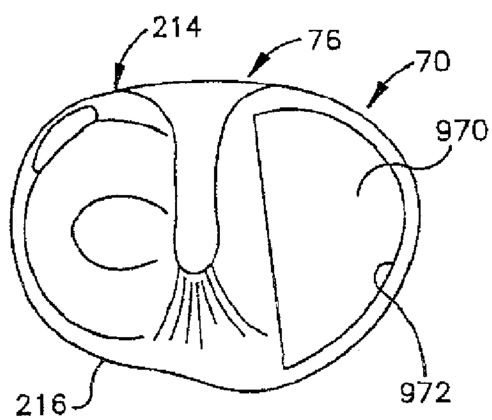

Fig.60

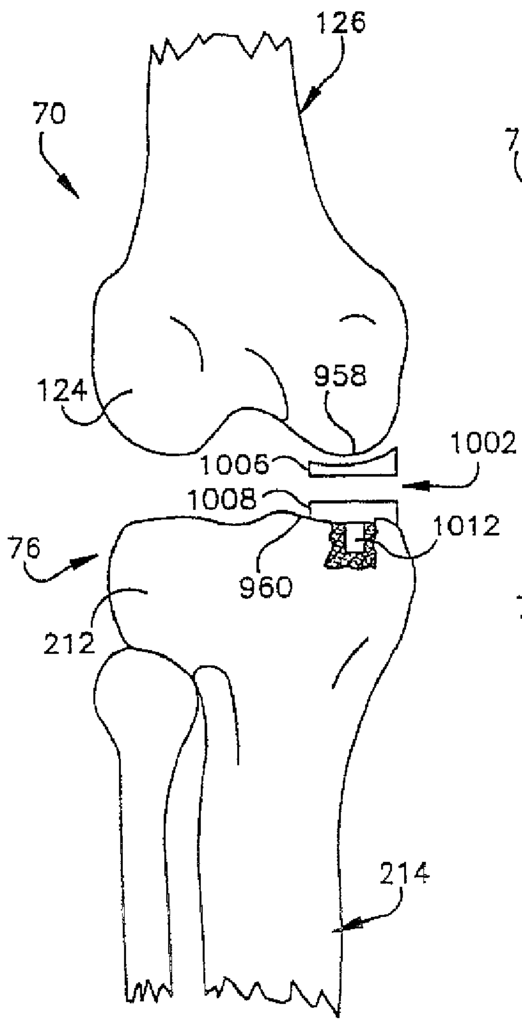
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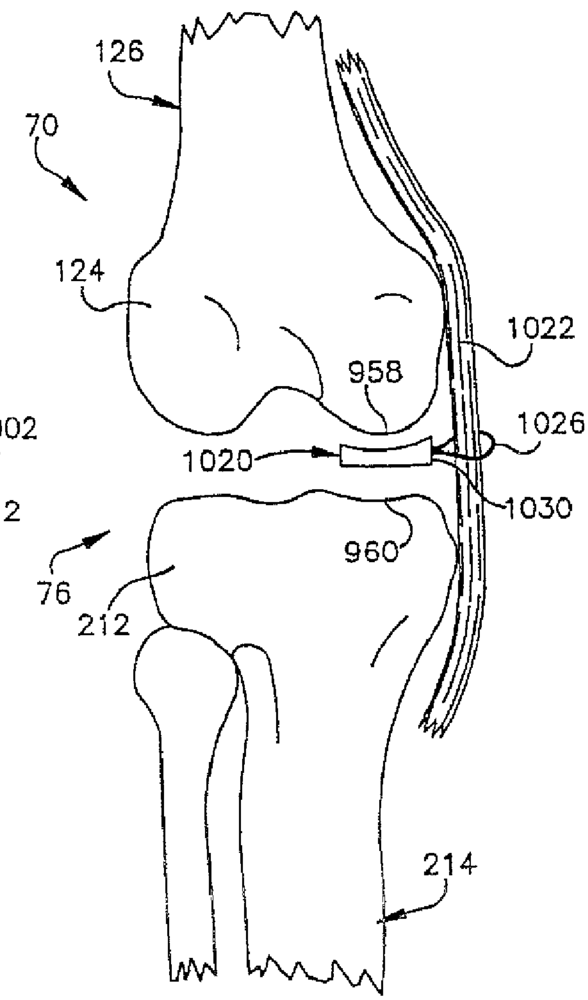
Fig.62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214

Fig.63

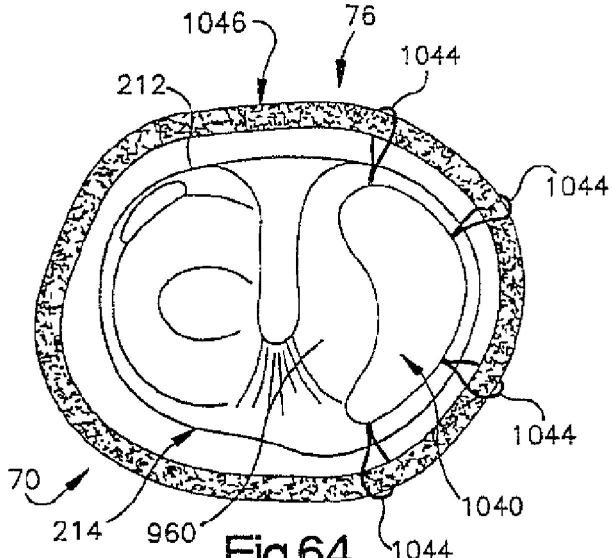

Fig.64

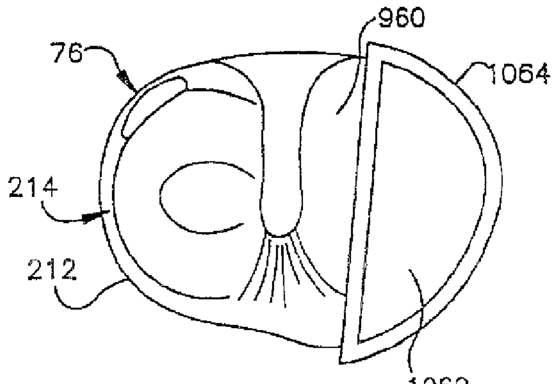

Fig.65

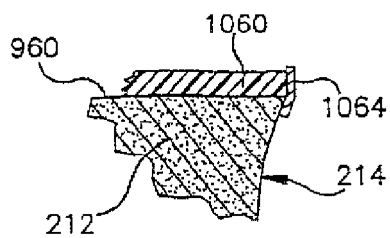

Fig.66

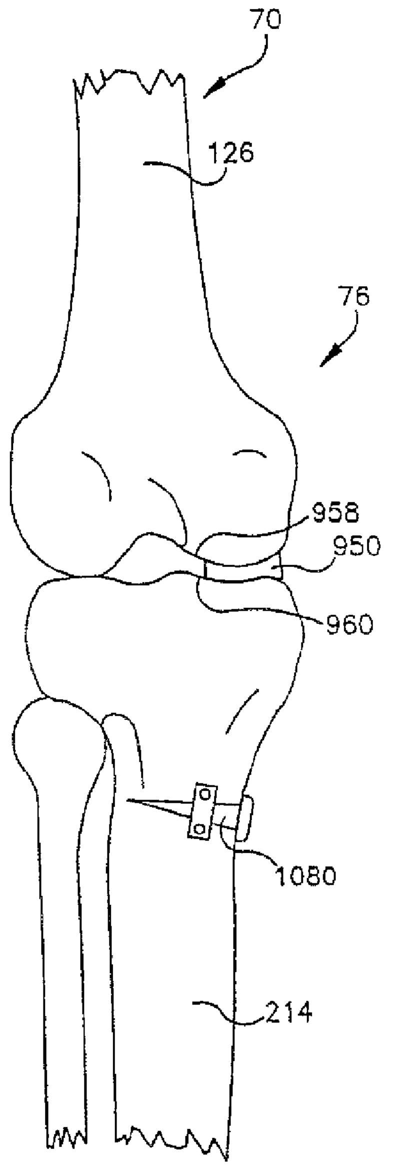

Fig.67

Fig. 68

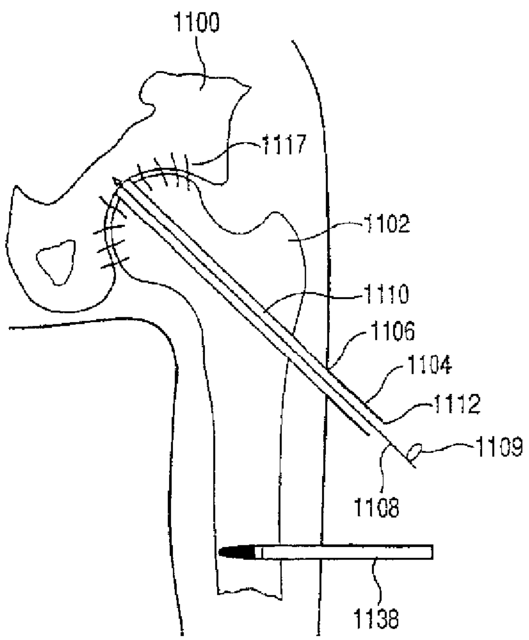

Fig. 69

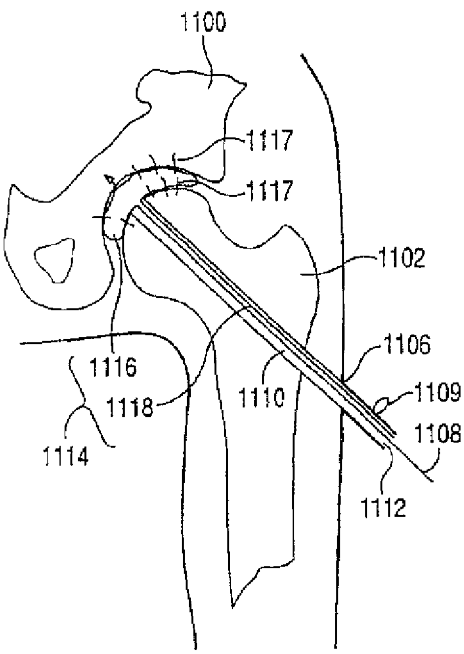

Fig. 70A

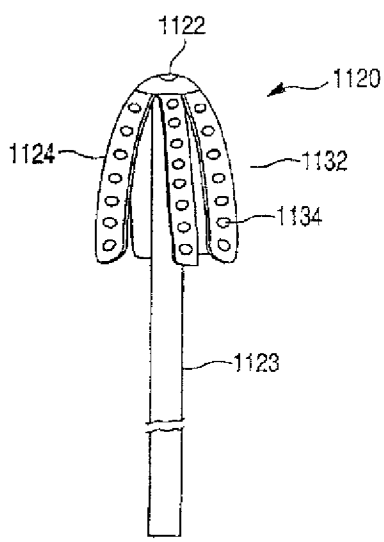

Fig. 70B

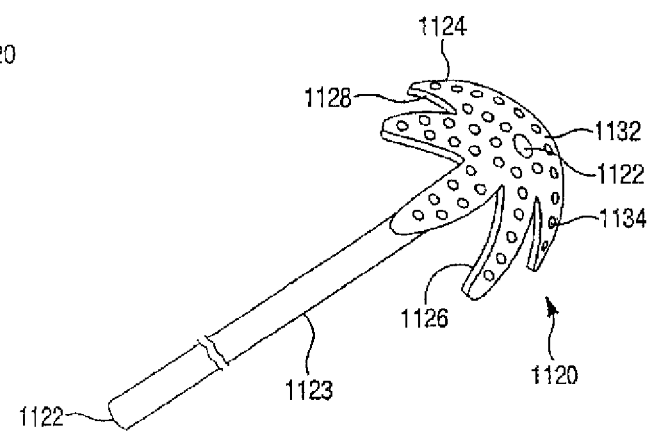

Fig. 71

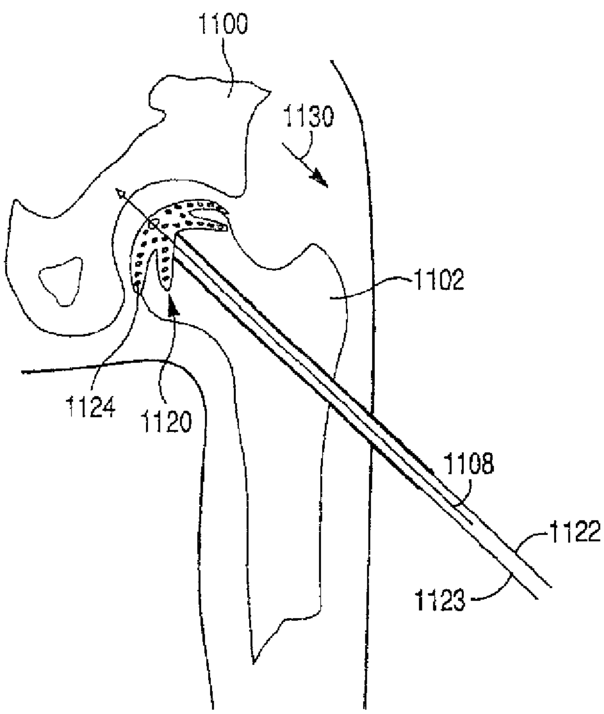
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Fig. 72

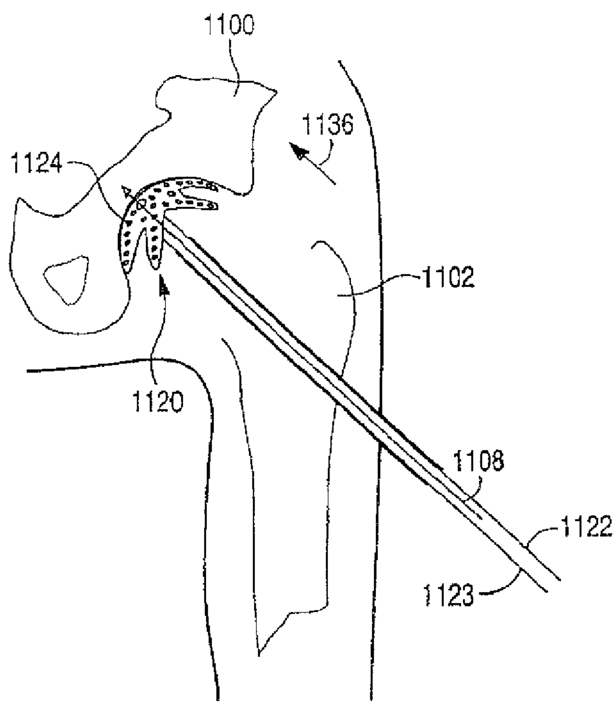
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Fig. 73

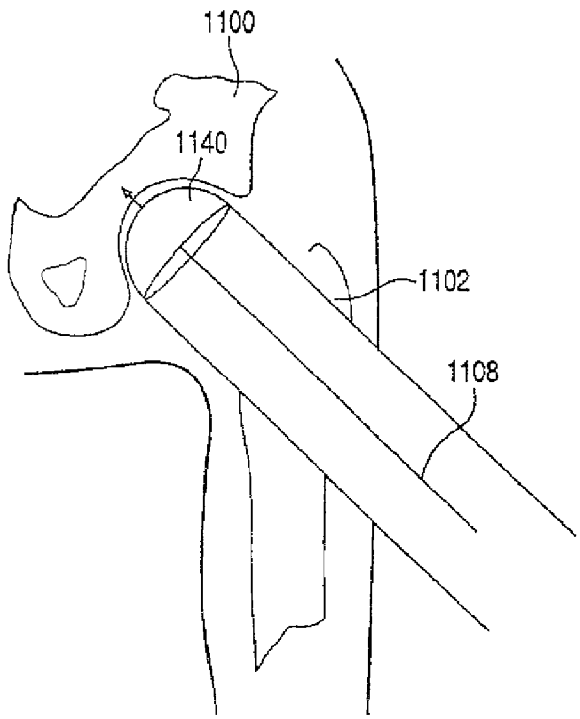

Fig. 74A

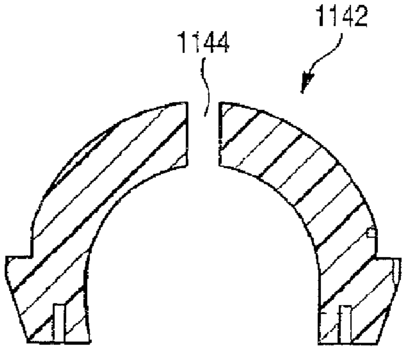

Fig. 74B

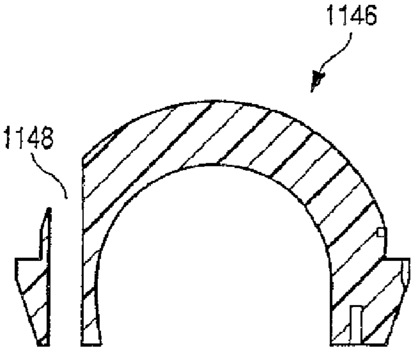

Fig. 75

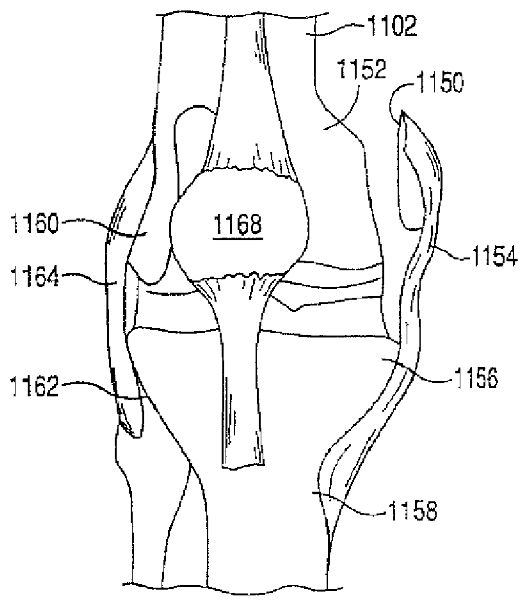

Fig. 76

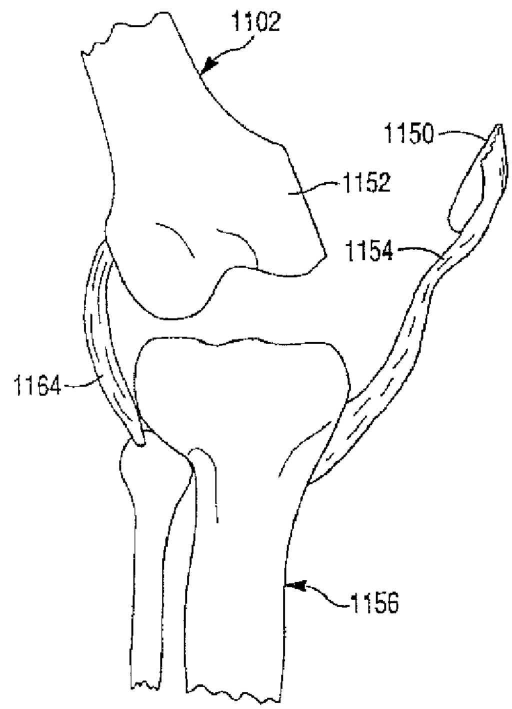

Fig. 77

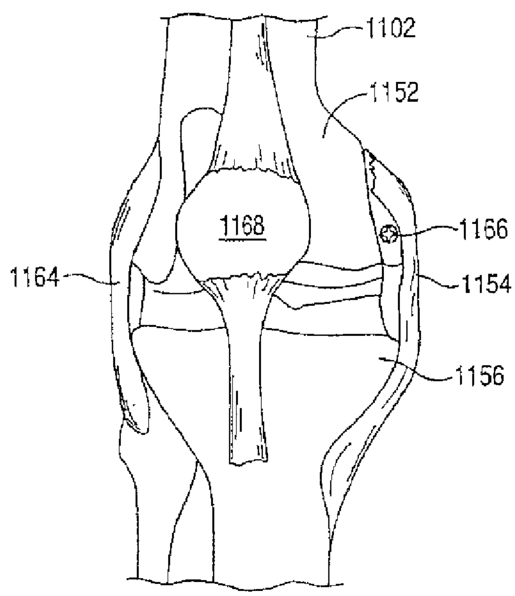

Fig. 78

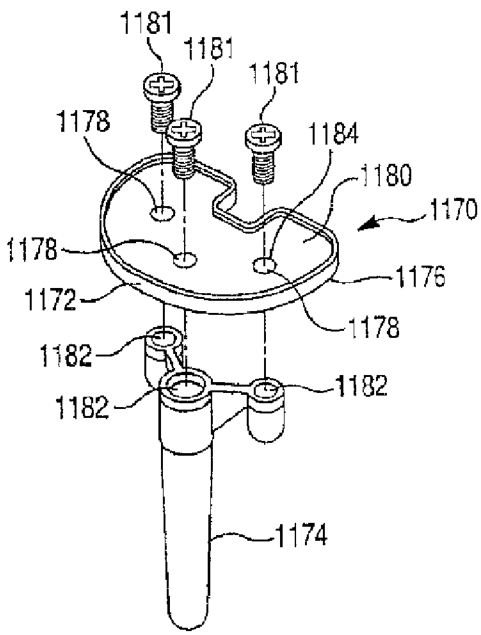

Fig. 79

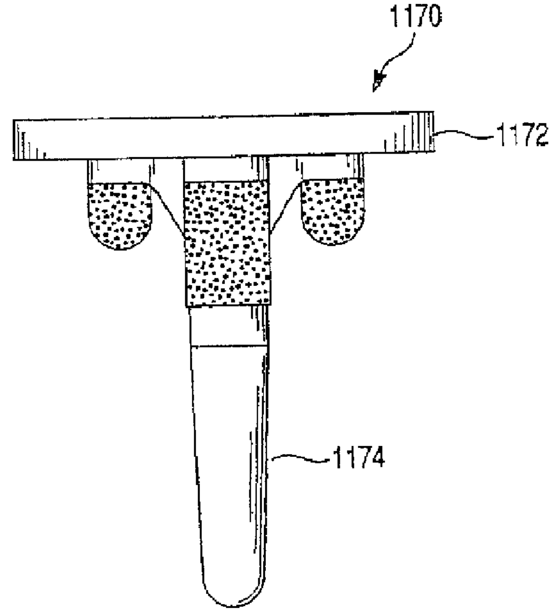

Fig. 80

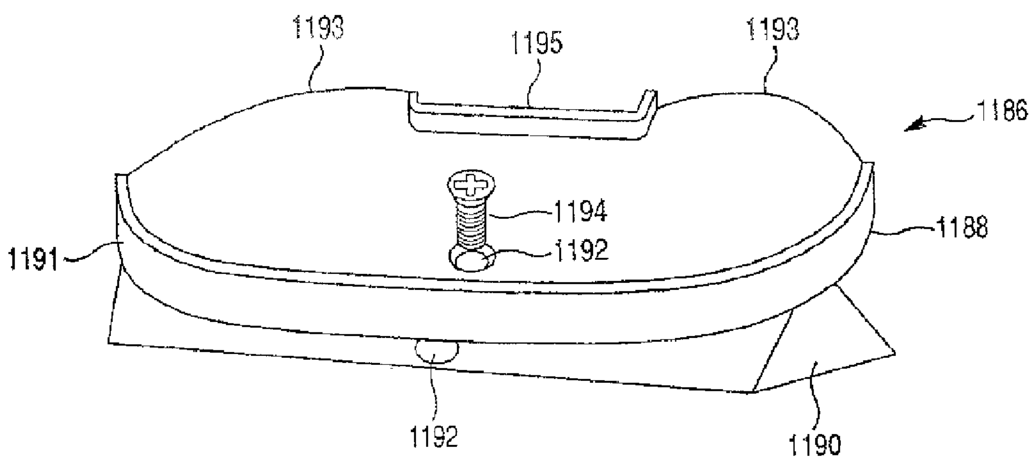

Fig. 81

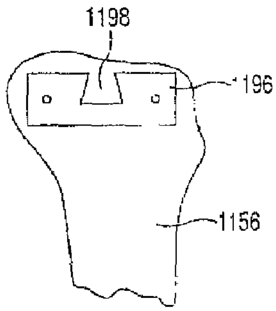

Fig. 82

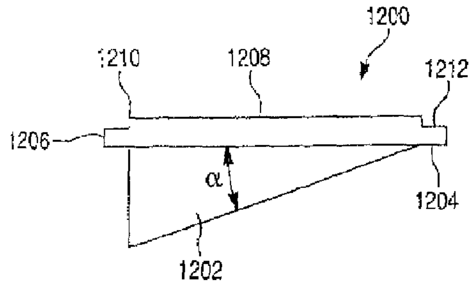

Fig. 83

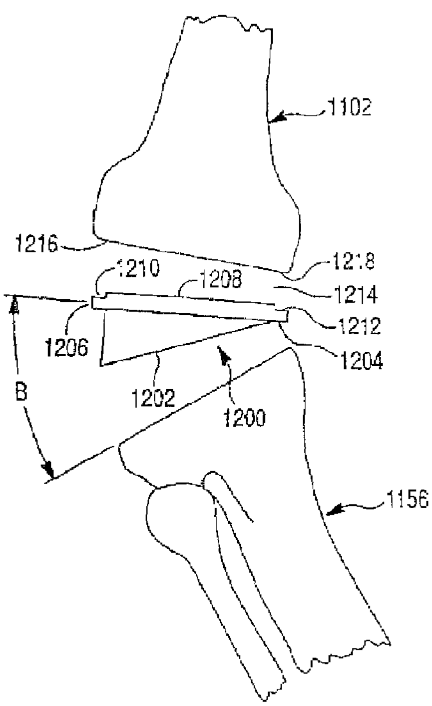

Fig. 84

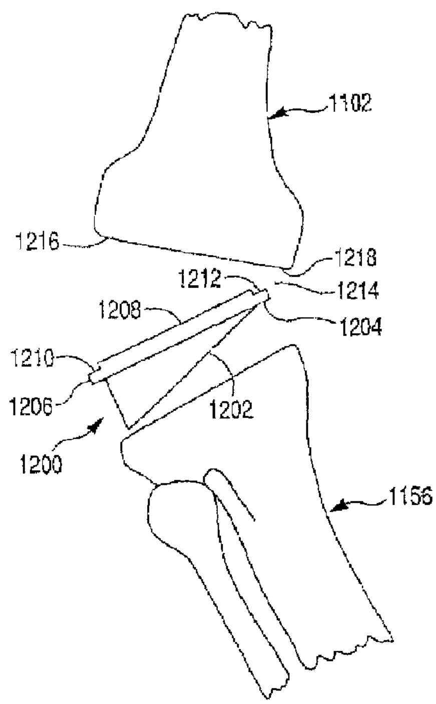

Fig. 85

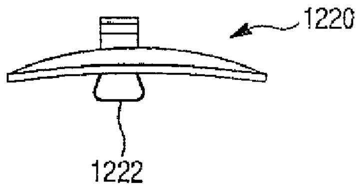

Fig. 86

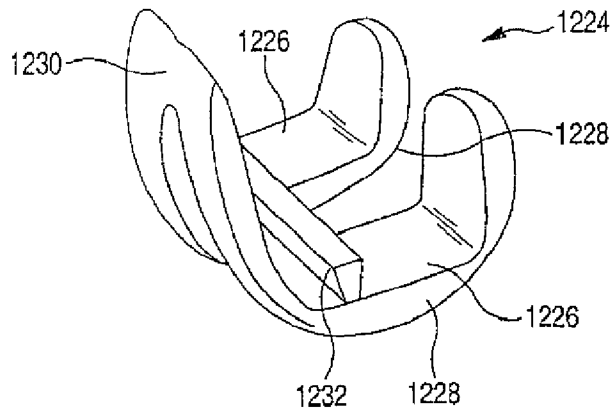

Fig. 87

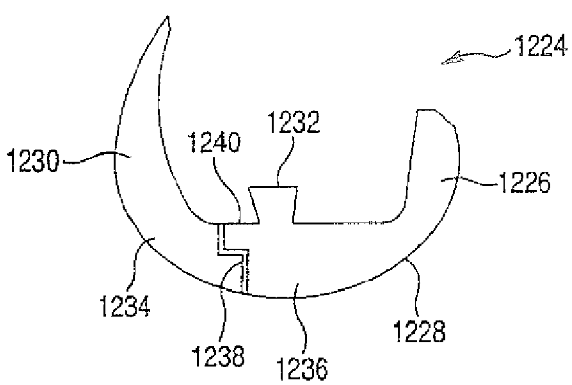

Fig. 88

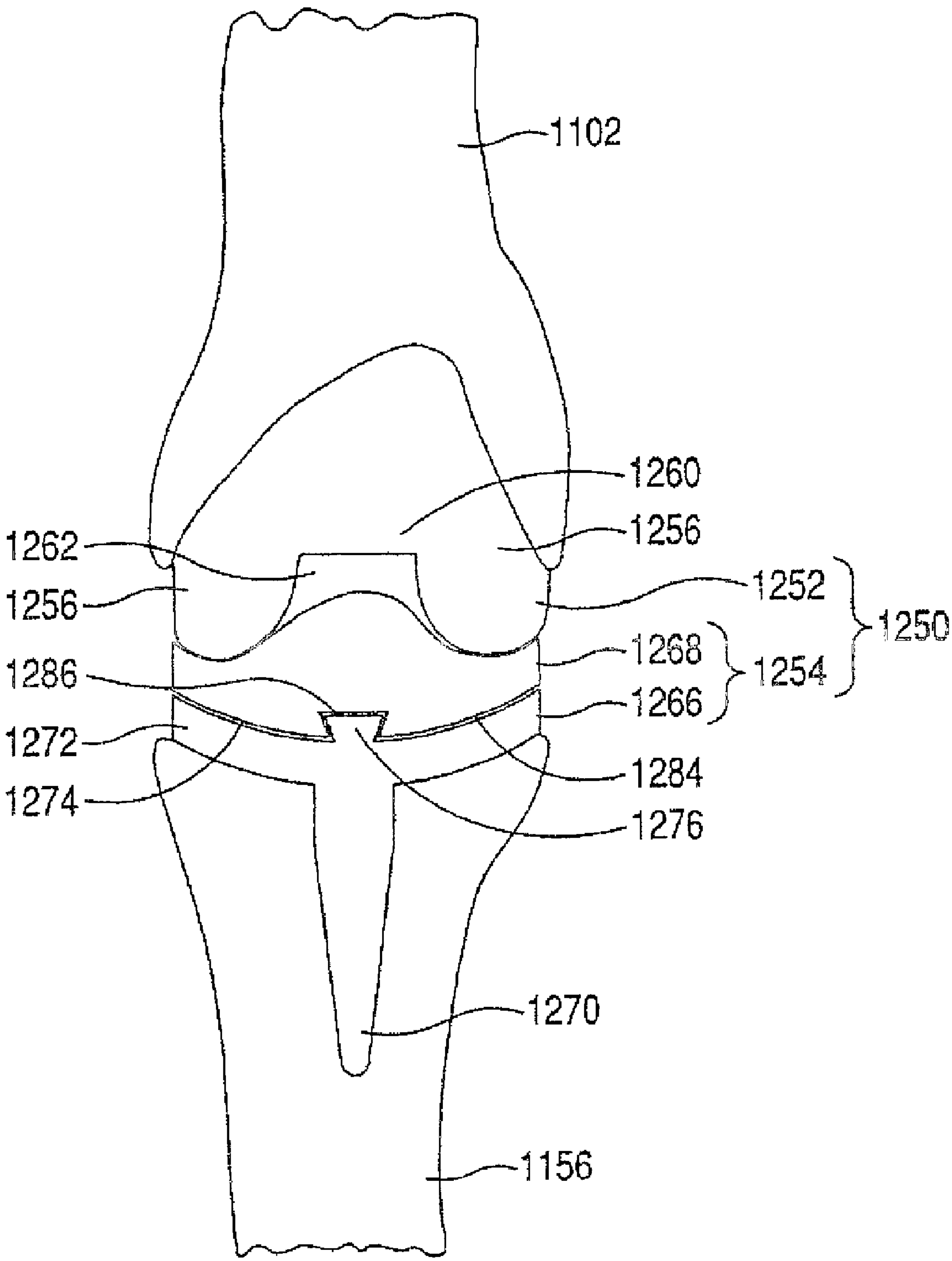
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Fig. 89

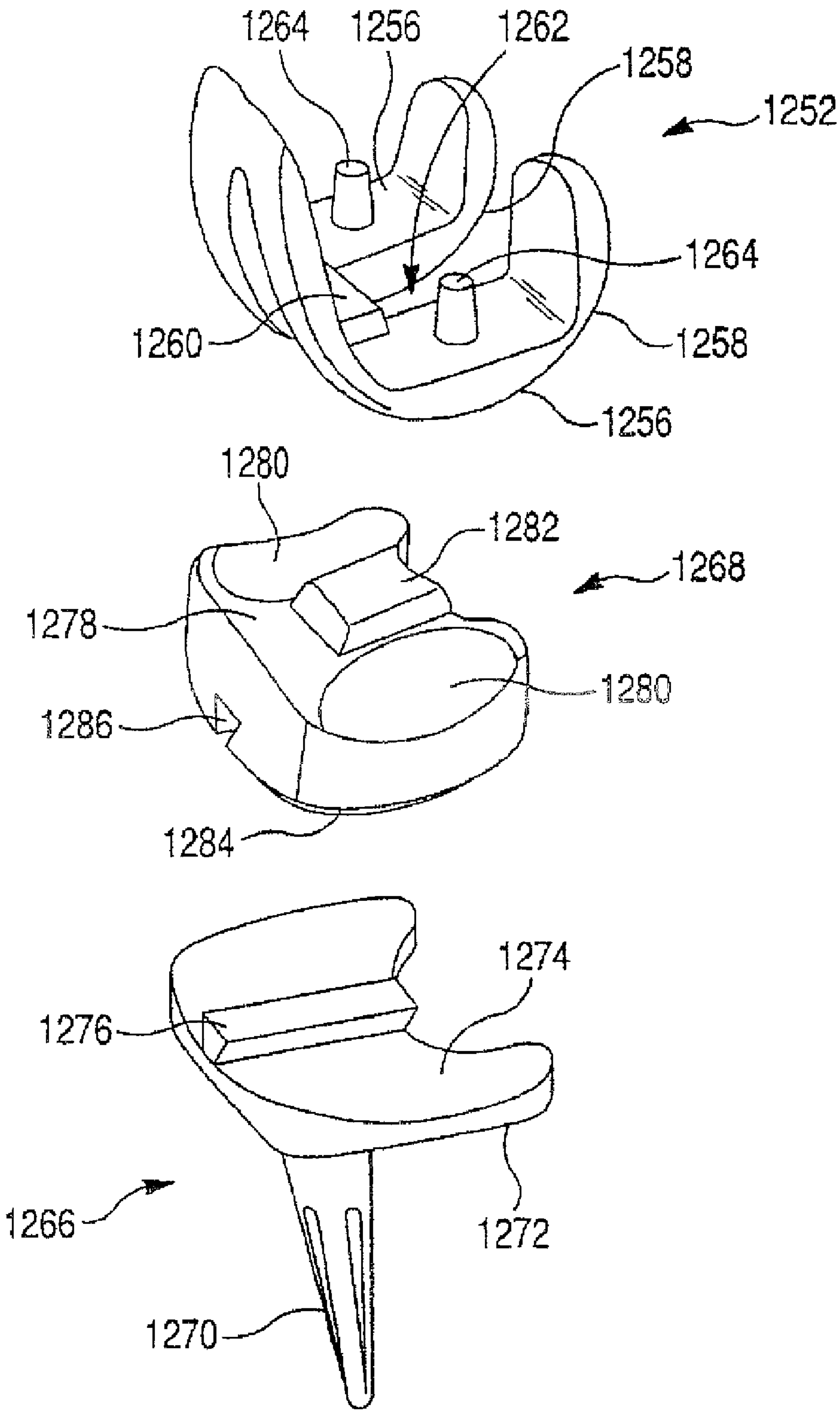
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Fig. 90

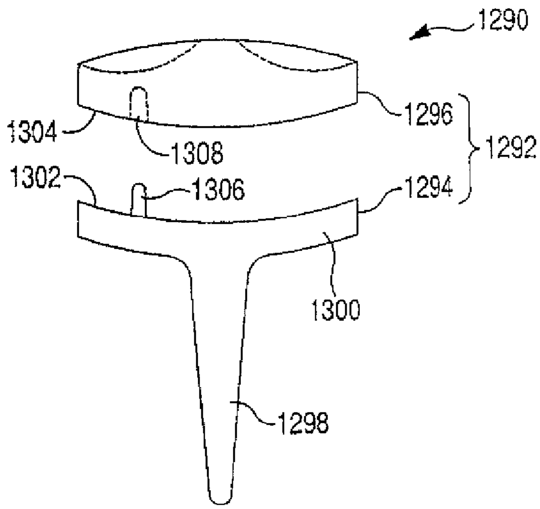


Fig. 91

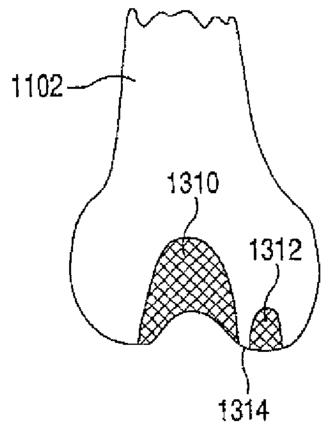


Fig. 92

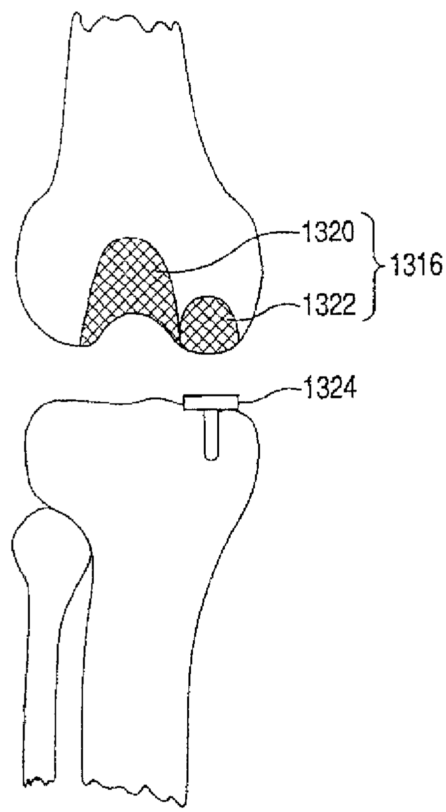


Fig. 93

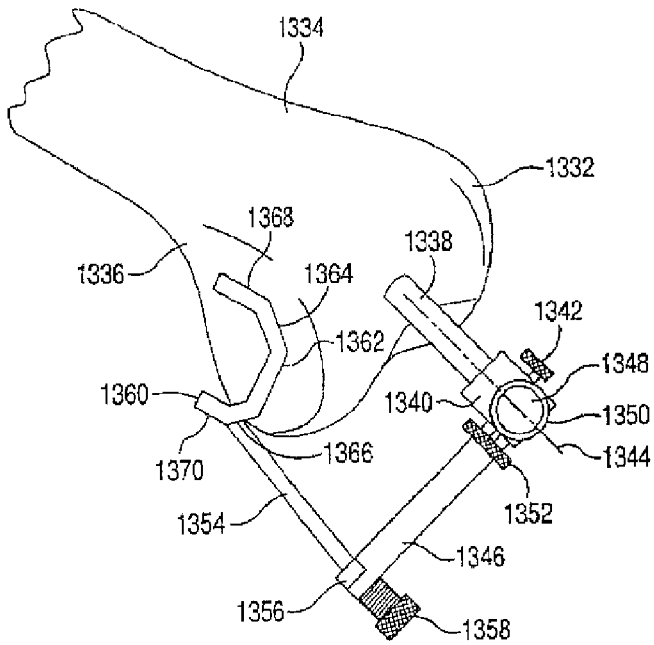


Fig. 95

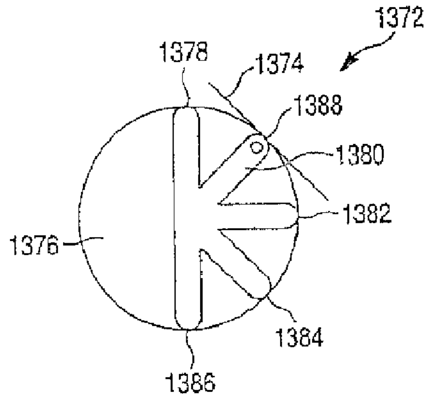


Fig. 94

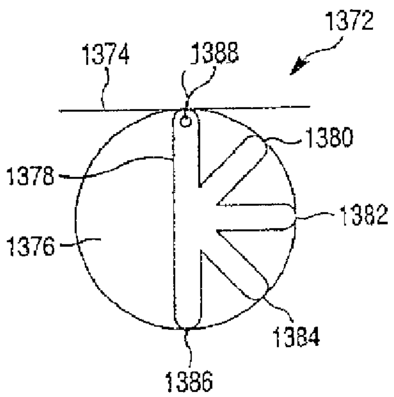


Fig. 96

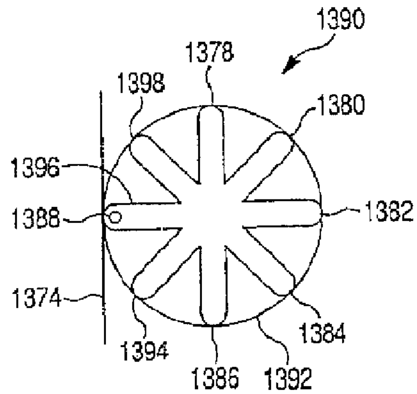


Fig. 97

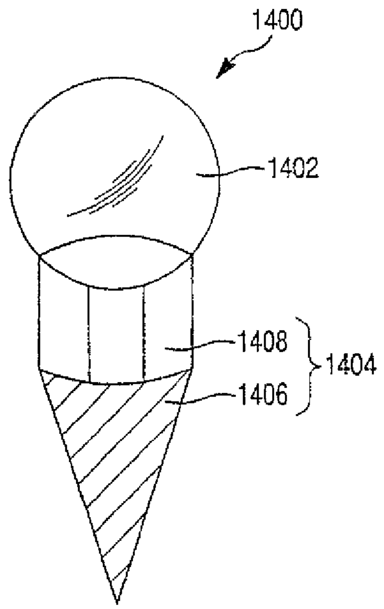


Fig. 99

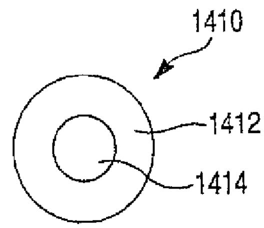


Fig. 98

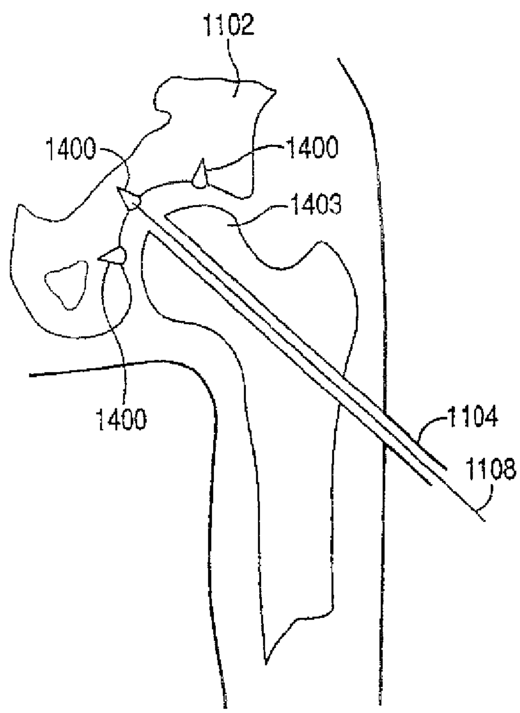
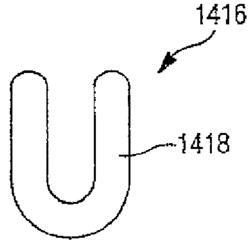


Fig. 100



MINIMALLY INVASIVE SURGICAL SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 10/681,526 filed Oct. 8, 2003 now U.S. Pat. No. 7,635,390. U.S. patent application Ser. No. 10/681,526 is a continuation of U.S. patent application Ser. No. 10/191,751 filed Jul. 8, 2002, now U.S. Pat. No. 7,104,996. U.S. patent application Ser. No. 10/191,751 is a continuation-in-part of U.S. patent application Ser. No. 09/976,396 filed Oct. 11, 2001, now U.S. Pat. No. 6,770,078. U.S. patent application Ser. No. 10/191,751 is also continuation-in-part of U.S. patent application Ser. No. 09/941,185 filed Aug. 28, 2001, now U.S. Pat. No. 6,702,821. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/566,070 filed May 5, 2000, now U.S. Pat. No. 6,575,982. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/737,380 filed Dec. 15, 2000, now U.S. Pat. No. 6,503,267. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/569,020 filed May 11, 2000, now U.S. Pat. No. 6,423,063. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/483,676 filed Jan. 14, 2000, now U.S. Pat. No. 6,468,289. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/798,870 filed Mar. 1, 2001, now U.S. Pat. No. 6,503,277. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/526,949 filed on Mar. 16, 2000, now U.S. Pat. No. 6,620,181. U.S. patent application Ser. No. 10/191,751 is also a continuation-in-part of U.S. patent application Ser. No. 09/789,621 filed Feb. 21, 2001, now U.S. Pat. No. 6,635,073.

BACKGROUND OF THE INVENTION

The present invention relates to a new and improved method of performing surgery, and instruments, implants, and other surgical implements that can be used in surgery. The surgery may be of any desired type. The surgery may be performed on joints in a patient's body. The surgery may be performed on any desired joint in a patient's body. Regardless of the type of surgery to be performed, a limited incision may advantageously be utilized.

In some embodiments, this specification relates to limited incision partial or total knee joint replacements and revisions and is the result of a continuation of work which was previously performed in conjunction with the subject matter of U.S. Pat. No. 5,514,143. This specification also contains subject matter which relates to U.S. Pat. Nos. 5,163,949; 5,269,785; 5,549,683; 5,662,710; 5,667,520; 5,961,499; 6,059,817; and 6,099,531. Although this specification refers to knee joints, it should be understood that the subject matter of this application is also applicable to joints in many different portions of a patient's body, for example a shoulder, spine, arm, hand, hip or foot of a patient.

During a total or partial knee replacement or revision, an incision is made in a knee portion of a leg of the patient to obtain access to the knee joint. The incision is relatively long to enable instrumentation, such as a femoral alignment guide, anterior resection guide, distal resection guide, femoral cutting guide, and femoral anterior, posterior and chamfer resection guide to be positioned relative to a distal end portion of

the femur. In addition, the incision must be relatively large to enable a tibial resection guide to be positioned relative to the proximal end portion of the tibia.

With known procedures of total or partial knee replacement, the incision in the knee portion of the patient is made with the leg of the patient extended (straight) while the patient is lying on his or her back. At this time, the extended leg of the patient is disposed along and rests on a patient support surface. After the incision has been made in the knee portion of the leg of the patient, the leg is flexed and a foot connected with the leg moves along the patient support surface. The knee portion of the flexed leg of the patient is disposed above the patient support surface. This results in the soft tissue in the knee being compressed against the back of the knee joint. This makes it very difficult to access posterior soft tissue to remove bone spurs (ostified), meniscus, posterior capsule, ligaments in the back of the joint, and/or any residual soft tissue or connective tissue that is blocking further flexion.

After the incision has been made and while the leg is flexed with the foot above the patient support surface, the surgeon cannot view arteries, nerves and veins which are sitting just posterior to the knee capsule. Therefore, a surgeon may be very reluctant, or at least very careful, of inserting instruments into the back of the knee joint to remove tissue. This may result in osteophytes, bone spurs and similar types of posterior soft tissue being left in place.

With known techniques, the patella is commonly everted from its normal position. When the patella is everted, the inner side of the patella is exposed and faces outward away from end portions of the femur and tibia. The outer side of the everted patella faces inward toward the end portions of the femur and the tibia. Moving the everted patella to one side of end portions of the femur and tibia tends to increase the size of the incision which must be made in the knee portion of the patient's leg.

After implants have been positioned in the knee portion of the patient's leg, it is common to check for flexion and extension balancing of ligaments by flexing and extending the knee portion with the foot above the support surface. If the ligaments are too tight medially or laterally, they can be released to obtain the desired tension. However, the checking of ligament balance by flexing and extending the leg of the patient, ignores rotational balancing of ligaments. Since the femoral implant is movable relative to the tibial implant, the stability of the knee joint is dependent upon balancing of the ligaments in flexion, extension, and rotation.

SUMMARY OF THE INVENTION

The present invention relates to a new and improved method and apparatus for use in performing any desired type of surgery on a joint in a patient's body. The joint may advantageously be a knee joint. However, the method and apparatus may be used in association with surgery on other joints in a patient's body. There are many different features of the present invention which may used either together or separately in association with many different types of surgery. Although features of the present invention may be used with many different surgical procedures, the invention is described herein in conjunction with surgery on a joint in a patient's body.

One of the features of the present invention relates to the making of a limited incision. The limited incision may be in any desired portion of a patient's body. For example, the limited incision may be in a knee portion of a leg of a patient. The limited incision may be made while a lower portion of the leg of the patient is extending downward from the upper portion of the leg of the patient. At this time, a foot connected with the lower portion of the leg of the patient may be below a surface on which the patient is supported. The limited incision may be made while the lower portion of the leg of the patient is suspended from the upper portion of the leg or while the lower portion of the leg and/or the foot of the patient are held by a support device. After the incision has been made, any one of many surgical procedures may be undertaken.

It is believed that in certain circumstances, it may be desired to have a main incision of limited length and a secondary incision of even smaller length. The secondary incision may be a portal or stab wound. A cutting tool may be moved through the secondary incision. An implant may be moved through the main incision.

Once the incision has been made, a patella in a knee portion of the patient may be offset to one side of its normal position. When the patella is offset, an inner side of the patella faces inward toward the end portions of a femur and tibia. If desired, the patella can be cut and realigned in situ, with minimal or no subluxation. Additionally, the cutting and/or realignment can be done while the knee is in flexion, which is the natural position, rather than extension.

Although any one of many known surgical procedures may be undertaken through the limited incision, down sized instrumentation for use in the making of cuts in a femur and/or tibia may be moved through or part way through the incision. The down sized instrumentation may be smaller than implants to be positioned in the knee portion of the patient. The down sized instrumentation may have opposite ends which are spaced apart by a distance which is less than the distance between lateral and medial epicondyles on a femur or tibia in the leg of the patient.

It is contemplated that the down sized instrumentation may have cutting tool guide surfaces of reduced length. The length of the cutting tool guide surfaces may be less than the length of a cut to be made on a bone. A cut on a bone in the patient may be completed using previously cut surfaces as a guide for the cutting tool.

It is contemplated that at least some, if not all, cuts on a bone may be made using light or other electromagnetic radiation, such as infrared radiation, directed onto the bone as a guide. The light directed onto the bone may be in the form of a three dimensional image. The light directed onto the bone may be a beam along which a cutting or milling tool is moved into engagement with the bone.

There are several different orders in which cuts may be made on bones in the knee portion of the leg of the patient. It is believed that it may be advantageous to make the patellar and tibial cuts before making the femoral cuts.

There are many different reasons to check ligament balancing in a knee portion of the leg of a patient. Ligament balancing may be checked while the knee portion of the leg of the patient is flexed and the foot of the patient is below the support surface on which the patient is disposed. Flexion and extension balancing of ligaments may be checked by varying the extent of flexion of the knee portion of the leg of the patient. In addition, rotational stability of the ligaments may be checked by rotating the lower portion of the leg of the patient about its central axis. Balancing of ligaments may also be checked by moving the foot of the patient sideways, rotating the lower portion of the leg of the patient, and/or moving the foot anteriorly or posteriorly.

It is believed that it may be advantageous to utilize an endoscope or a similar apparatus to examine portions of the patient's body which are spaced from the incision. It is also contemplated that images of the knee portion of the patient's leg may be obtained by using any one of many known image generating devices other than an endoscope. The images may be obtained while the patient's leg is stationary or in motion. The images may be obtained to assist a surgeon in conducting any desired type of surgery.

Balancing of the ligaments in the knee portion of a patient's leg may be facilitated by the positioning of one or more transducers between tendons, ligaments, and/or bones in the knee portion. One transducer may be positioned relative to a medial side of a knee joint. Another transducer may be positioned relative to a lateral side of the knee joint. During bending of the knee joint, the output from the transducers will vary as a function of variations in tension forces in the ligaments. This enables the tension forces in ligaments in opposite sides of the knee portion to be compared to facilitate balancing of the ligaments.

Patellar tracking may be checked by the positioning of one or more transducers between the patella and the distal end portion of the femur. If desired, one transducer may be placed between a medial portion of the patella and the distal end portion of the femur. A second transducer may be placed between a lateral portion of the patella and the distal end portion of the femur. Output signals from a transducer will vary as a function of variations in force transmitted between the patella and femur during bending of the leg.

The articular surface on the patella may be repaired. The defective original articular surface on the patella may be removed by cutting the patella while an inner side of the patella faces toward a distal end portion of a femur. The step of cutting the patella may be performed while the patella is disposed in situ and is urged toward the distal end portion of the femur by connective tissue. An implant may then be positioned on the patella.

It is contemplated that the size of the incision in the knee or other portion of the patient may be minimized by conducting surgery through a cannula. The cannula may be expandable. To facilitate moving of an implant through the cannula, the implant may be formed in two or more portions. The portions of the implant may be interconnected when the portions of the implant have been positioned in the patient's body. Although the implants disclosed herein are associated with a patient's knee, it should be understood that the implants may be positioned at any desired location in a patient's body.

An implant may be positioned in a recess formed in a bone in a patient. The implant may contain biological resurfacing and/or bone growth promoting materials. The implant may contain mesenchymal cells and/or tissue inductive factors. Alternatively, the implant may be formed of one or more materials which do not enable bone to grow into the implant.

In accordance with one of the features of the present invention, body tissue may be moved or stretched by a device which is expandable. The expandable device may be biodegradable so that it can be left in a patient's body. The expandable device may be expanded to move and/or stretch body tissue and increase a range of motion of a joint. The expandable device may be used to stretch body tissue in which an incision is to be made.

An improved drape system is provided to maintain a sterile field between a surgeon and a patient during movement of the surgeon relative to the patient. The improved drape system includes a drape which extends between the surgeon and a drape for the patient. During surgery on a knee portion of a leg of a patient, the drape system extends beneath a foot portion of the leg of a patient. It is contemplated that the drape system will be utilized during many different types of operations other than surgery on a leg of a patient.

An implant may be movable relative to both a femur and a tibia in a leg of a patient during bending of the leg. The implant may include a single member which is disposed between and engaged by end portions of both the femur and tibia. Alternatively, the implant may include a plurality of members which are disposed in engagement with each other. If desired, one of the members of the plurality of members may be secured to a bone and engaged by a member which is not secured to a bone. The implant may be secured to soft tissue in the knee portion of the patient's leg.

There are many different features to the present invention. It is contemplated that these features may be used together or separately. It is also contemplated that the features may be utilized in association with joints in a patient's body other than a knee joint. For example, features of the present invention may be used in association with surgery on vertebral joints or glenoid joints. However, it is believed that many of the features may be advantageously utilized together during the performance of surgery on a patient's knee. However, the invention should not be limited to any particular combination of features or to surgery on any particular joint in a patient's body. It is contemplated that features of the present invention will be used in association with surgery which is not performed on a joint in a patient's body.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of the invention will become more apparent upon a consideration of the following description taken in connection with the accompanying drawings wherein:

FIG. **1** is a schematic illustration depicting extended and flexed positions of a patient's leg during performance of knee surgery in a known manner;

FIG. **2** is a schematic illustration depicting the manner in which a leg support is used to support an upper portion of a leg of a patient above a support surface on which the patient is disposed in a supine orientation during performance of knee surgery;

FIG. **3** is a schematic illustration depicting the patient's leg after a portion of a drape system has been positioned over the patient, the leg being shown in a flexed condition with the foot below the patient support surface and with an upper portion of the leg supported by the leg support of FIG. **2**;

FIG. **4** is a schematic illustration of the patient's leg of FIGS. **2** and **3** in an extended condition and of the drape system which extends between a surgeon and the patient;

FIG. **5** is a schematic illustration depicting the manner in which the drape system of FIG. **4** maintains a sterile field during movement of the surgeon relative to the patient;

FIG. **6** is a schematic illustration depicting the manner in which an incision is made in the knee portion of the leg of the patient when the leg is in the position illustrated in FIGS. **2** and **3**;

FIG. **7** is a schematic illustration depicting the manner in which the incision is expanded and a patella is everted with the leg of the patient extended;

FIG. **8** is a schematic illustration depicting the manner in which a drill is utilized to form a passage in a femur in the upper portion of the leg of the patient with the leg in the position illustrated in FIGS. **2** and **3** and the patella offset from its normal position;

FIG. **9** is a schematic illustration of the positioning of a femoral alignment guide in the hole formed by the drill of FIG. **8** with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **10** is a schematic illustration depicting the position of an anterior resection guide and a stylus relative to the femoral alignment guide of FIG. **9** before an anterior femur cut has been made with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **11** is a schematic illustration, taken generally along the line **11-11** of FIG. **10**, further illustrating the relationship of the anterior resection guide and stylus to the distal end portion of the femur;

FIG. **12** is a schematic illustration further illustrating the relationship of the anterior resection guide and stylus to the distal end portion of the femur;

FIG. **13** is a schematic illustration depicting the manner in which a cutting tool is moved along a guide surface on the anterior resection guide during making of an anterior femur cut with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **14** is a schematic illustration depicting the relationship of the femoral alignment guide to the femur after making of the anterior femur cut of FIG. **13**, the anterior resection guide and stylus being removed from the femoral alignment guide, and the leg of the patient being in the position illustrated in FIGS. **2** and **3**;

FIG. **15** is a schematic illustration of the anterior femur cut and femoral alignment guide of FIG. **14**;

FIG. **16** is a schematic illustration depicting the manner in which the femoral alignment guide is utilized to position a distal resection guide relative to the distal end portion of the femur after making of the anterior femur cut and with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **17** is a schematic illustration depicting the manner in which a distal femur cut is made with a cutting tool after the femoral alignment guide has been removed, the leg of the patient being in the position illustrated in FIGS. **2** and **3**;

FIG. **18** is a schematic illustration depicting the relationship of the cutting tool and distal resection guide of FIG. **17** to the femur;

FIG. **19** is a schematic illustration depicting the manner in which a femoral cutting guide is positioned on the distal end portion of the femur with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **20** is a schematic illustration further depicting the relationship of the femoral cutting guide to the distal end portion of the femur;

FIG. **21** is a schematic illustration depicting the relationship of a tibial resection guide to the proximal end portion of a tibia in the lower portion of the patient's leg after making the femoral cuts and with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **22** is a schematic illustration of the distal end portion of the femur and the proximal end portion of the tibia after making the femoral and tibial cuts with the leg of the patient in the position illustrated in FIGS. **2** and **3** and the patella offset to one side of the incision;

FIG. **23** is a schematic illustration further depicting the femoral and tibial cuts of FIG. **22**;

FIG. **24** is a schematic illustration depicting the manner in which force is applied against the bottom of the patient's foot by a surgeon's knee with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **25** is a schematic illustration depicting the various directions in which the lower portion of the patient's leg can be moved relative to the upper portion of the patient's leg to expose portions of the bone at the incision in the knee portion of the patient's leg and to check ligament balancing;

FIG. **26** is a schematic illustration depicting the manner in which a tibial punch is positioned relative to a tibial base plate with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **27** is a schematic illustration depicting completed preparation of the tibia for a tibial tray implant with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **28** is a schematic illustration depicting positioning of a tibial bearing insert in the tibial tray of FIG. **27** with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **29** is a schematic illustration depicting femoral and tibial implants with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **30** is a schematic illustration of an apparatus which may be utilized to move the lower portion of a patient's leg relative to the upper portion of a patient's leg when the patient's leg is in the position illustrated in FIGS. **2** and **3**;

FIG. **31** is a schematic illustration depicting the manner in which a distal resection guide is connected with a patient's femur by pins which extend through the guide and through skin in the upper portion of the patient's leg into the femur with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **32** is a schematic illustration depicting the manner in which an endoscope may be inserted through an incision in a patient's knee to inspect portions of the patient's knee which are remote from the incision with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **33** is a schematic illustration similar to FIG. **32**, depicting the manner in which the endoscope may be inserted through the incision in the patient's knee with the leg of the patient extended;

FIG. **34** is a schematic illustration depicting the manner in which an imaging apparatus may be utilized to generate images of a portion of the patient's leg and the manner in which a robot may be utilized to position cutting tools or other devices relative to the patient's leg with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **35** is a schematic illustration depicting the relationship of a cut line to a patella in a knee of the leg of the patient with the leg in the position illustrated in FIGS. **2** and **3** and with the patella in the normal position;

FIG. **36** is a schematic illustration depicting the manner in which a cutting tool is moved relative to a guide member to cut the patella of FIG. **35** while the patella is disposed in situ;

FIG. **37** is a schematic illustration depicting the manner in which a tibial alignment shaft and a tibial resection guide are positioned relative to a tibia in a lower portion of a leg of the patient with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **38** is an enlarged fragmentary view of a portion of FIG. **37** and illustrating the construction of the tibial resection guide;

FIG. **39** is a schematic illustration depicting the relationship between an expandable cannula and an incision in the knee portion of one leg of the patient with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **40** is a schematic illustration depicting the relationship between two separate portions of an implant which are interconnected within the patient's body;

FIG. **41** is a schematic illustration depicting the relationship of transducers to a flexed knee joint of a patient when the leg of the patient is in the position illustrated in FIGS. **2** and **3**;

FIG. **42** is a schematic illustration, generally similar to FIG. **41**, illustrating the relationship of the transducers to the knee joint when the leg of the patient is extended;

FIG. **43** is a schematic illustration of a distal end portion of a femur in a leg of a patient with the leg in the position illustrated in FIGS. **2** and **3** and illustrating the relationship of an implant to a recess in the end portion of the femur;

FIG. **44** is a schematic sectional view depicting the manner in which a cutting tool is used to form a recess in the end portion of the femur of FIG. **43** with the leg of the patient in the position illustrated in FIGS. **2** and **3**;

FIG. **45** is a schematic sectional view, taken generally along the line **45-45** of FIG. **43** further illustrating the relationship of the implant to the recess;

FIG. **46** is a schematic end view of a proximal end portion of a tibia in a leg of a patient, with the leg in the position illustrated in FIGS. **2** and **3**, illustrating the relationship of an implant to a recess in the end portion of the tibia;

FIG. **47** is a schematic sectional view depicting the manner in which a cutting tool is used to form the recess in the end portion of the tibia of FIG. **46**;

FIG. **48** is a schematic sectional view, taken generally along the line **48-48** of FIG. **46**, further illustrating the relationship of the implant to the recess;

FIG. **49** is a schematic sectional view illustrating the relationship of another implant to a recess in a bone in a patient's body;

FIG. **50** is a schematic illustration depicting the relationship between a tibial implant and a tibia in the leg of the patient;

FIG. **51** is a schematic illustration depicting the relationship of expandable devices to the knee portion of a patient's leg;

FIG. **52** is a schematic illustration depicting the manner in which an expandable device may be positioned relative to a knee portion of a patient's leg with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **53** is a schematic illustration depicting the manner in which a femoral cutting guide may be mounted on a distal end of a femur in a patient's leg with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **54** is a schematic illustration of the manner in which a femoral cutting guide may be mounted on a side surface of a femur in a patient's leg with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **55** is a schematic illustration depicting the manner in which light is directed onto a distal end portion of a femur with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **56** is a schematic illustration depicting the manner in which light is used to guide movement of a cutting tool relative to a distal end portion of a femur with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **57** is a schematic illustration depicting the manner in which a cutting tool is moved relative to a secondary incision with a knee portion of a patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **58** is schematic illustration depicting the relationship of transducers to a patella and distal end portion of a femur with the patient's leg in the position illustrated in FIGS. **2** and **3**;

FIG. **59** is a schematic illustration depicting the relationship between a movable implant, a distal end portion of a femur, and a proximal end portion of a tibia in a knee portion of a leg of a patient;

FIG. **60** is a plan view of a proximal end portion of a tibia depicting the manner in which an implant may be inlaid into a tibia;

FIG. **61** is a schematic illustration, generally similar to FIG. **59**, depicting the relationship between a movable implant formed by a plurality of members, a distal end portion of a femur, and a proximal end portion of a tibia in a knee portion of a leg of a patient;

FIG. **62** is a schematic illustration, generally similar to FIGS. **59** and **61**, depicting the relationship between an implant formed by a movable member and a fixed member, a distal end portion of a femur, and a proximal end portion of a tibia in a knee portion of a leg of a patient;

FIG. **63** is a schematic illustration, generally similar to FIG. **59**, depicting the manner in which an implant is connected with a ligament in a knee portion of a patient's leg;

FIG. **64** is a schematic illustration, generally similar to FIG. **60**, depicting the manner in which an implant is connected with a joint capsule in a knee portion of a patient's leg;

FIG. **65** is a schematic illustration, generally similar to FIG. **60**, depicting the manner in which a retainer holds moldable implant material in place on a proximal end portion of a tibia in the knee portion of a leg of the patient;

FIG. **66** is a fragmentary sectional view, taken generally along the line **66-66** of FIG. **65** further illustrating the manner in which the retainer holds moldable implant material;

FIG. **67** is a schematic illustration depicting the manner in which an implant is provided in a knee portion of a leg of a patient to correct defects in a joint and in which an osteotomy wedge is provided to correct defects in bone alignment;

FIG. **68** is a schematic view of the hip region with a guide wire and cannula inserted;

FIG. **69** is a schematic view of the hip region with an inflatable device inserted;

FIG. **70**A is a side view of a bone removing instrument according to the present invention in a retracted state;

FIG. **70**B is a perspective view of the bone removing instrument of FIG. **70**A in an expanded state;

FIG. **71** is a schematic view of the hip region with the bone remover of FIG. **70**B inserted and removing the femoral head;

FIG. **72** is a schematic view of the hip region with the bone remover of FIG. **70**B inserted and removing the acetabulum;

FIG. **73** is a schematic view of the hip region with a backing of an acetabular component being implanted;

FIG. **74**A is a sectional view of one embodiment of a liner for an acetabular component;

FIG. **74**B is a sectional view of another embodiment of a liner for an acetabular component;

FIG. **75** is a schematic illustration of a knee joint with an osteotomy performed;

FIG. **76** is a schematic illustration of the access created by the osteotomy of the knee joint of FIG. **75** with the patella not shown for clarity;

FIG. **77** is a schematic illustration of the knee joint of FIG. **75** with the osteotomy repaired;

FIG. **78** is an exploded view of a modular tibial component;

FIG. **79** is a schematic illustration of the modular tibial component of FIG. **78** assembled;

FIG. **80** is a schematic illustration of a tibial component;

FIG. **81** is a schematic illustration of a tibial side-cutting jig for the tibial component of FIG. **80**;

FIG. **82** is a front view of a tibial component;

FIG. **83** is a schematic illustration of the tibial component of FIG. **82** being implanted;

FIG. **84** is another schematic illustration of the tibial component of FIG. **82** being implanted;

FIG. **85** is a side view of a patellar implant;

FIG. **86** is a schematic illustration of a femoral component;

FIG. **87** is a section illustration of the femoral component of FIG. **86**;

FIG. **88** is a schematic illustration of a knee implant;

FIG. **89** is an exploded perspective illustration of the total knee implant of FIG. **88**;

FIG. **90** is a schematic illustration of a tibial component of a knee implant;

FIG. **91** is a schematic illustration of a bicompartment femoral implant;

FIG. **92** is a schematic illustration of a bicompartment femoral implant and a unilateral tibial implant;

FIG. **93** is a schematic illustration depicting the manner in which an adjustable femoral cutting jig may be mounted on a distal end of a femur in a patient's leg;

FIG. **94** is a schematic illustration of a femoral cutting guide having a single cutting guide surface;

FIG. **95** is a schematic illustration of the femoral cutting guide of FIG. **94** with the cutting guide surface in a different position;

FIG. **96** is a schematic illustration of another embodiment of a femoral cutting guide having a single cutting guide surface;

FIG. **97** is a schematic illustration of an implant having a reduced articulating surface area;

FIG. **98** is a schematic illustration showing a number of the implants of FIG. **97** implanted in an acetabulum;

FIG. **99** is a schematic illustration of another implant having a reduced articulating surface area; and

FIG. **100** is a schematic illustration of another implant having a reduced articulating surface area.

DESCRIPTION OF SPECIFIC PREFERRED EMBODIMENTS OF THE INVENTION

Known Method of Performing Surgery on a Patient's Knee

During the performance of surgery using known methods, a patient is supported on an operating table or other support surface **52** (FIG. **1**). When a leg **50** of the patient is in the extended position illustrated in dashed lines in FIG. **1**, a foot **54** connected with a lower portion **56** of the leg **50** is disposed above the support surface **52**. During an operation on a knee portion **58** of the leg **50**, the knee portion is raised and lowered relative to the support surface as the leg **50** is flexed and extended. However, the foot **54** is always disposed above the support surface **54** and may be supported by the support surface throughout the operation.

During this known operating procedure, an incision is made in the knee portion **58** of the leg **50** when the leg is in the extended position illustrated in dashed lines in FIG. **1**. At this time, the foot **54** of the patient may rest on the support surface **52** or be disposed in a foot support located above the support surface. Once an incision has been formed in the knee portion **58**, the leg **50** may be flexed or bent to the position illustrated in solid lines in FIG. **1**.

As the knee portion **58** is bent, the leg **50** is flexed and compresses the soft tissue of the knee portion **58** against the back of the knee joint. This makes it very difficult to access the posterior of the knee portion **58** to remove bone spurs (osteophytes), the meniscus, the posterior capsule, and/or any residual soft tissue or bone that is blocking further flexion. The catching or pinching of soft tissue in the posterior aspect of the knee portion **58** may prevent further flexion and limits the range of motion. In addition, arteries, nerves and veins are sitting just posterior of the knee joint.

Due to the lack of access to the posterior of the knee portion **58**, a surgeon may be very reluctant or, at least, very careful about inserting instruments blindly into the back of the knee joint to remove tissue. This may result in osteophytes, bone spurs and similar types of posterior soft tissue being left in place.

Cuts are made on a femur and tibia with the leg **50** in the bent or flexed condition, illustrated in FIG. **1**. This results in the distal end portion of the femur and the proximal end portion of the tibia in the leg **50** being pressed together adjacent to the cuts. This interferes with ligament balancing. The relatively large incision which is necessary to accommodate known instrumentation systems increases time required for the patient to recover from the operation.

Preparation for Operation

It is contemplated that various features and/or combinations of features of the present invention will be utilized during surgery on different portions of a patient's body, such as a head, trunk or limbs of a patient. Although at least some of the features of the present invention are believed particularly advantageous when utilized in association with surgery on any one of the many joints in a patient's body, it is believed that the various features and/or combination of the features of the present invention are particularly advantageous when utilized in conjunction with surgery on a knee portion of a leg of a patient. It should be understood that the various features of the present invention may be use separately or in any desired combination of features.

Surgery on the knee portion of the patient may relate to any one of many different aspects of the knee portion, such as ligaments, tendons, articular surfaces, and/or total or partial knee replacements or revisions. Although the disclosure herein frequently refers to one particular type of knee operation, that is, a total knee replacement, features of the invention may be utilized with any desired type of surgery. It is believed that it will be apparent to a person having a knowledge of knee surgery how various features of the invention may be utilized with either a full or partial knee replacement. Therefore, there has been only minimal mention herein of how the features of the invention are applicable to partial knee replacements.

When knee surgery is to be performed in accordance with one of the features of the present invention, the patient **62** (FIG. **2**) is disposed on a support surface **64** of an operating table **66**. If desired, a patient support surface **64** other than an operating table could be used to support the patient. A lower portion **68** of a leg **70** extends downward from an upper portion **72** of the leg **70**. A foot **74** connected with the lower portion **68** of the leg **70** is disposed below the support surface **64**. The leg **70** is flexed so that a knee portion **76** of the leg is bent.

In accordance with another of the features of the present invention, the upper portion **72** of the leg **70** can be supported above the support surface **64** by a leg support **80** (FIG. **2**). The leg support **80** includes a stand or base section **82** which is connected with the operating table **66**. The leg support **80** includes a base **84** which is connected with an upper end portion of the stand **82**. The base **84** is engaged by and supports the upper portion **72** of the leg **70**.

A generally annular thigh holder **86** extends around the upper portion **72** of the leg **70** of the patient and is connected with the base **84** and stand **82**. The base **84** has a portion which extends along the posterior side of the upper portion **72** of the leg **70** of the patient. The base **84** supports the upper portion **72** of the leg **70** above and spaced from the support surface **64**. However, the upper portion **72** of the leg **70** could be disposed in engagement with the support surface **64** if desired.

The leg support **80** supports the leg **70** of the patient with a hip **88** of the patient hyperflexed at an angle of twenty to thirty degrees throughout the operation on the knee portion **76**. The leg support **80** may have a known commercial construction or may have a construction similar to that disclosed in U.S. Pat. Nos. 4,373,709 or 6,012,456. If desired, a tourniquet may be combined with the leg support **80** in a manner similar to that provided in known leg supports or in a manner similar to that disclosed in U.S. Pat. No. 4,457,302.

In accordance with another feature of the invention, the lower portion **68** (FIG. **3**) of the leg **70** is suspended from the upper portion **72** of the leg. This enables the foot **74** and ankle portion **86** of the leg **70** of the patient to be freely moved in any direction or a combination of directions. Thus, the foot **74** and ankle portion **86** of the leg **70** of the patient can be moved anteriorly or upward (as viewed in FIG. **3**) to decrease the extent of flexion of the knee portion **72** or even to extend or straighten the leg **70**.

Alternatively, the foot **74** and ankle portion **86** may be moved posteriorly toward the operating table **66**, from the position illustrated in FIG. **3**, to hyperflex the knee portion **72** of the leg of a patient. The foot **74** may be moved sidewardly, that is in either a lateral or medial direction. In addition, the foot **74** may be rotated about the longitudinal central axis of the lower portion **68** of the leg **70**.

It is contemplated that the foot **74** and ankle portion **86** may be simultaneously moved in a plurality of the directions previously mentioned. If desired, the upper portion **72** of the leg **70** of the patient may be supported on a separate section of the operating table **66**, in a manner similar to the disclosure in U.S. Pat. No. 5,007,912.

After a drape **90** has been positioned over the patient **62** and the operating table **66**, in the manner illustrated in FIG. **3**, the leg **70** extends out of the drape. The drape **90** may be connected with the leg support **80** and have an opening **92** (FIGS. **3** and **4**) through which the leg of the patient extends. This enables the leg **70** of a patient to be moved between the extended position illustrated in FIG. **4** and a hyperflexed position in which the foot **74** is disposed posteriorly from the position illustrated in FIG. **3**.

When the leg **70** is in a hyperflexed condition, the included angle between the upper and lower portions **72** and **68** of the leg **70** is less than ninety degrees. The leg **70** may be flexed from the extended position of FIG. **4** to a hyperflexed position by manually moving the foot **74** and an ankle portion **96** of the leg **70** relative to the operating table **66** (FIG. **2**) while the upper portion **72** of the leg is held by the leg support **80**. When the leg **70** is hyperflexed, a portion of the foot **74** may be disposed beneath the operating table **66** (FIG. **2**).

An improved drapery system **100** (FIG. **4**) includes the drape **90** and a drape **102** connected with a gown **104** on a surgeon **106**. The illustrated drape **102** is formed separately from the drape **90** and gown **104**. However, the drape **102** may be integrally formed as one piece with the drape **90**. Alternatively, the drape **102** may be integrally formed as one piece with the gown **104**. If formed integral, drape **90**, drape **102**, and/or gown **104** can be provided with a quick release mechanism, such as serrated edges, to allow surgeon **106** to rapidly tear away. Thus, drapery system **100** allows the patient to be a sterile field directly or modularly attached to the surgeon and/or an assistant.

Regardless of whether separate or integral, drape **90** and/or drape **102** can include attachments for surgical instruments such as suction, Bovie, arthroscopic equipment, etc. Drape **102** can have a large pouch to collect all fluid, body parts, blood, etc. so they do not drain all over the floor and are collected in an easily disposable fashion. In this regard, drape **102** can include a drain, with or without active suction, to remove fluid and other debris.

Drape **90** could be adhesive drape with a Betadine adhesive or a clear plastic adhesive, either with or without antimicrobial agents impregnated, which covers the skin surrounding the operative field. Drape **90** could be a two layer drape with a larger drape below which sticks to the patient or is loosely attached to the patient and a narrower surgical field drape above for two layer draping.

In the embodiment illustrated in FIG. **4**, the drape **102** is formed separately from the gown **104** and the drape **90**. The drape **102** is connected to the drape **90** by suitable clamps **108**. The drape **102** is connected with the waist of the surgeon **106** by clamps **110** to the gown **104**. Rather than utilizing clamps **108** to interconnect the drapes **90** and **102**, the drapes could be interconnected by VELCRO, ties, or other known devices. Of course, similar devices could be utilized to connect the drape **102** with the gown **104** of the surgeon **106**. The connection mechanism can be chosen such that, if surgeon **106** needs to change position with respect to the patient, the connection mechanism allows re-attachment of gown **104** to various locations of drape **102**.

The improved drapery system **100** maintains a sterile field between the leg **70** and the surgeon **106** during movement of the surgeon relative to the patient **62**. Thus, when the surgeon is in a seated position (FIG. **4**) the drapery system **100** provides a sterile field which extends from the surgeon to the space beneath and adjacent to the leg **70**. When the surgeon stands (FIG. **5**) the drapery system **100** continues to maintain a sterile field between the surgeon and the patient. This enables the surgeon **106** to move the leg **70** of a patient during an operation without contaminating the sterile field. The draping system **100** enables the sterile field to be maintained when the patient's leg is moved between the extended position of FIGS. **4** and **5** and a hyperflexed position in which the foot **74** of the patient is disposed beneath the operating table **66**.

During movement of the surgeon **106** relative to the patient, for example, between the seated position of FIG. **4** and the standing position of FIG. **5**, the drape **102** moves with the surgeon and maintains a sterile field. Thus, when the surgeon **106** moves toward and away from the patient, the end portion of the drape **102** connected with the surgeon also moves toward and away from the patient. As the surgeon moves toward the patient, a portion of the drape **102** between the surgeon **106** and patient is lowered. As the surgeon moves away from the patient, the portion of the drape **102** between the surgeon and patient is raised. The foot **74** connected with the leg **70** of the patient is always above the drape **102** during movement of the surgeon **106**.

Drape **102** and/or drape **90** has flexibility and could be provided with flexed sections or may have a large redundant area which would go down to the surgeon's knees or to the floor to maintain the sterile field. By typical sterile technique, anything below the waist level of the surgeon or the support surface is considered un-sterile. However, with drapery system **100**, if drape **102** happens to drop down to the floor, it creates a contiguous sterile field and therefore, the surgeon could retrieve dropped objects from the floor if it is contained within drape **102** or drape **90**. This could save a significant amount of money by eliminating the need to dispose of (or re-sterilize) fallen surgical instruments or implants.

Although the drapery system **100** has been illustrated in FIGS. **3**-**5** in association with a patient's leg **70**, the drapery system may be used in association with surgery on any desired portion of a patient's body. For example, the drapery system **100** could be used to maintain a sterile field between a surgeon and patient during surgery on a trunk portion of a patient's body. Alternatively, the drapery system **100** could be used to maintain a sterile field during surgery on a head or arm portion of a patient's body.

Drapery system **100** can use disposable drapes or can be re-sterilizable, either in its entirety or portions thereof. Additionally, known current drape technology can be incorporated into drapery system **100**. This includes the use of disposable independent drapes, ¾ sheet, disposable adherent drapes, U-drapes, disposable adhesive drapes, Betadine drapes, VELCRO attached drapes, snap, plastic snap drapes, single piece drapes, multi-drapes, two layer drapes, clear plastic drapes, independent or attached to drapes, one piece drapes with stretchable segment for extremities, arthroscopic drapes, shoulder drapes which incorporate U-drapes, square drapes, etc.

In another embodiment, drapes **90**, **102** could be configured to create a mobile field. Specifically, the drapes can be made to have a surgeon's helmet attached to it and part of gown **104** attached to it so that the surgeon would literally walk into the drape system, his hands and his face would go into the drape to create a mobile surgical field attached to the patient to create even more of a sterile field. The drapery system could have laminar flow system connected to it to create sterile air coming in and then a suction coming out so it could have unidirectional airflow to further sterilize the field.

The drape system could have a tent, a cover over the top of this to create a mobile surgical field so that this could be done in emergency setting such as a military field or otherwise outdoors. Because the drape system can be provided with an attachment for flowing air in and out, maintaining extremely sterile air, the drape system could also be used for organ or tissue harvesting, such as bone harvesting under an emergency situation. The drape system could have the surgeon's gown, face mask, sterilizable hood all attached as part of it. It could be unrolled as one sterile pack adhering to the patient and rolling outward and the surgeon simply walks into the drape as does the assistant. When the procedure is complete, simply roll up the drape and throw it away, thereby maintaining all potential biohazards.

The drape could have a sterile flap where instruments could be passed through and/or a simple opening where the assistant could deliver instruments required through this field or the drape could be a flat open sheet where the assistant could bring the instruments on top of the sterile surgical field. There also may be a separate attachment for the circulating nurse.

As previously noted, drape **90** and/or drape **102** may also include an abbreviated gown **104** simply with the arms, front portion of the gown. This abbreviated gown could be a portion of drape **90**, **102** so the draping system need not extend fully down to the floor. Rather, the abbreviated gown would have arm holes so that the surgeon can put his arms through the holes and the nurse would put gloves on him once they are sterilized. A provision can be made so that at least one person has an independently moveable surgical gown.

Incision

In accordance with another feature of the present invention, a limited incision **114** (FIG. **6**) is formed in the knee portion **76** of the leg **70**. The incision **114** is made just medial to the patella **120**. However, the incision **114** could be disposed laterally of the patella **120**. Although the length of the incision **114** may vary depending upon the circumstances, the incision **114** will usually have a length of between about seven (**7**) and about thirteen (13) centimeters. However, even smaller incisions may be made when circumstances permit.

In one embodiment, the incision is made when the knee portion **76** of the leg is flexed and the lower portion **68** of the leg extends downward from the upper portion **72** of the leg in the manner illustrated in FIGS. **2** and **3**. At this time, the upper portion **72** of the leg **70** is supported above the support surface **64** by the leg support **80** (FIG. **2**). The lower portion **68** of the leg **70** is suspended from the upper portion **72** of the leg (FIGS. **2** and **3**).

When the knee portion **76** of the leg **70** is flexed so that the lower portion **68** of the leg is suspended at an angle of approximately ninety degrees relative to the upper portion **72** (FIGS. **2** and **3**), the incision **114** (FIG. **6**) may have a length of approximately ten (10) centimeters. When the leg **70** is straightened from the flexed condition of FIGS. **2** and **3** to the extended condition of FIGS. **4** and **5**, the length of the incision **114** may decrease by between ten and thirty percent. Thus, in one specific instance, an incision **114** had a length of approximately eleven (11) centimeters when the leg **70** was in the flexed condition of FIGS. **2**, **3** and **6** and a length of slightly less than ten (10) centimeters when the leg was in the extended condition of FIG. **5**. By making the incision **114** with the leg in a flexed condition (FIGS. **2**, **3**, and **6**) and operating on the leg **70** with the leg in a flexed condition, the overall length of the incision can be reduced from the length of incisions which have previously been made in the leg when it is in the extended condition.

The benefits of having a smaller incision include improved cosmetic results, improved rehab, less dissection of muscle and soft tissue, and preservation of the quadriceps mechanism.

It is preferred to have the incision **114** located adjacent to the medial edge of the patella **120**, in the manner illustrated schematically in FIG. **6**. However, the incision **114** could be located adjacent to the lateral edge of the patella **120** if desired. Alternatively, the incision **114** could be disposed midway between lateral and medial edges of the patella **120**. By moving the incision **114** laterally or medially away from the midline of the knee, less stress is placed on incision **114** compared to a midline incision.

Although it is desired to minimize the length of the incision **114**, it is contemplated that the incision may have a length of approximately twice the length of the patella. It may be desired to have the incision **114** extend from a proximal end of the tibia in the leg **70** to the epicondylar notch on the distal end portion of the femur in the leg **70**. The length and location of the incision **114** may vary depending on the size of the implants to be positioned in the knee portion **76** and the location at which the implants are to be positioned. It is believed that it may be desired to have the incision **114** be smaller than the implants even though the implants must move through the incision. The visoelastic nature of the body tissue and mobility of the incision **114** enables the implants to be larger than the incision and still move through the incision.

A straight incision **114** has been illustrated in FIG. **6**. However, the incision **114** could have a different configuration if desired. For example, the incision **114** could have an L-shaped configuration. The incision **114** could be skewed at an acute angle to a longitudinal central axis of the patella **120**. If desired, the incision **114** could have a configuration matching the configuration of either the lateral or medial edge of the patella **120**.

Immediately after the incision **114** is formed, the leg **70** may be moved from the flexed condition of FIGS. **2** and **3** to the extended condition of FIG. **5**. While the leg **70** is in the extended condition, the incision **114** (FIG. **7**) is elastically expanded using suitable retractors. The incision **114** can also be expanded while the leg is in the flexed condition. The retractors apply force against the visoelastic body tissue of the knee portion **76**. The retractors have a construction similar to that disclosed in U.S. Pat. No. 5,308,349. Alternatively, a pneumatic retractor, such as is disclosed in U.S. patent application Ser. No. 09/526,949 filed on Mar. 16, 2000 by Peter M. Bonutti may be utilized to expand the incision.

After the incision **114** has been elastically expanded, a patella **120** and tissue on the lateral side of the incision may be everted in a manner illustrated in FIG. **7**. Thus, the patella **120** is moved from the normal orientation of FIG. **6** to the everted or flipped orientation of FIG. **7**, preferably while the leg **70** of the patient is in the extended orientation of FIG. **7**. At this time, the inner side **122** of the patella **120** is facing outward away from other bones in the knee portion **76**. The outer side of the everted patella **120** is facing inward toward other bones in the knee portion **76**. This enables the inner side **122** of the patella **120** to be examined.

In order to enable a relatively small incision **114** to be used for operating on bones in the knee portion **76** of the leg **70** of the patient, the patella **120** is returned back to its normal position with the inner side **122** of the patella facing inward and the outer side of the patella facing outward. As this occurs, the opening at the incision **114** contracts. The retractors are then utilized to apply force against opposite sides of the incision **114**. As this occurs, the visoelastic body tissue is extended, the opening at the incision **114** is again expanded, and the patella **120** is pushed to the lateral side of the knee portion **76**. This moves the patella **120** to a location offset to one side of the incision **114** in a manner illustrated in FIG. **8**. The leg **70** is then flexed to the orientation shown in FIGS. **2** and **3**.

If desired, the foregoing step of inverting the patella **120** may be omitted. The patella **120** may be left in orientations in which the inner side **122** of the patella faces inward throughout the operation. If this is done, the inner side **122** of the patella **120** may be inspected by tilting the patella from its normal orientation and/or using viewing devices, such as an endoscope. Regardless of how the inner side **122** of the patella **120** is inspected, moving the patella to the offset position of FIG. **8**, with the inner side **122** facing inward, facilitates utilization of an incision **114** having a limited length. It is contemplated that many different surgical procedures could be conducted on the knee portion **76** with the patella **120** in the offset position of FIG. **8**. Furthermore, avoiding eversion of the patella **120** significantly reduces stress on the quadriceps/tendon complex. Applicant has found that the stress on the complex is at least 20% less compared to a procedure with eversion, thereby decreasing the risks of tearing, damage, and strain.

As shown in FIG. **8**, a retractor **121** can be used to offset patella **120** and/or maintain patella **120** in the offset position. In an exemplary embodiment, retractor **121** is approximately 2-3 mm thick. Retractor **121** also holds soft tissue away to expose the bone. Accordingly, retractor **121** can include at least one hole **123** for receiving a pin **125** to secure retractor **121** to bone or other body tissue. Alternatively, a suture or wire can be threaded through hole **123** to secure retractor **121** to tissue. In another embodiment, retractor **121** includes a sharp end to hold retractor **121** to the tissue.

Retractor **121** can be made out of any suitable material, such as metallic materials typically used for surgical instruments. If retractor **121** is made of a polymer, it is contemplated that retractor **121** could be disposable. If this is done, retractor **121** may be partially or entirely formed of relatively inexpensive polymeric materials. As previously disclosed, the disposable retractors could be sharpened at one end like a Homan. Such a disposable retractor could be made of a polymer such as polyethylene, which may be malleable to a degree. Thus, the disposable retractor could be deformed to a desired shape to expose the joint as required and possibly pin the tissue directly through the malleable portion of the retractor to hold the soft tissue out of the way while one is working on the bone. This would allow enhanced exposure through a smaller incision, visualizing it through flexion and extension.

The retractors could also be a composite with some metal and some plastic with a portion of the device, flexible, malleable and locking into bone to keep the tissue out of the way while one is working on the bone. Additionally, it is contemplated that the retractors could also be heated and malleable intraoperatively. The retractors could be made of a biodegradable material and be left in position to maintain a soft tissue sleeve or exposure so as to minimize scarring the joint. Regardless of the material, the retractors could have ribs or a roughened surface to grip the tissue. The retractors could also be coupled with a balloon retractor (discussed below).

Femoral Procedure

Expansion of the incision **114** with the retractors exposes a distal end portion **124** (FIG. **8**) of a femur **126** in the upper portion **72** of the leg **70**. The incision **114** is movable relative to the distal end portion **124** of the femur **126** to maximize exposure of the femur through the limited length of the incision. The femur **126** is then cut to receive an implant. Although either intramedullary or extramedullary instrumentation can be utilized, intramedullary instrumentation is used in an exemplary embodiment during cutting of the femur **126**. Therefore, a drill **128** is utilized to access the intramedullary canal or marrow cavity in the femur **126**.

The drill **128** is utilized to form a hole **130** in the center of the intercondylar notch in the distal end portion **124** of the femur **126** in a known manner. The drill **128** is used to form the hole **130** while the leg **70** is in the orientation illustrated in FIGS. **2** and **3**. The patella **120** is in the offset position illustrated in FIG. **8**. At this time, the inner side **122** (FIG. **7**) of the patella faces toward the femur **126**.

An epicondylar reference guide (not shown) engages the hole in the distal end portion **124** of the femur **126** to enable a line parallel to an epicondylar axis peaks of the medial and lateral condyles to be inscribed on the distal end portion **124** of the femur **126**. At this time, the leg **70** is in the orientation illustrated in FIGS. **2**, **3**, **8** and **9**. A shaft **132** (FIGS. **9**, **10**, **11** and **12**) of a femoral alignment guide **134** is then inserted into the intermedullary opening **130**.

The femoral alignment guide **134** is then aligned with the epicondylar line which extends parallel to the epicondylar axis through the peaks of the lateral and medial condyles on the distal end portion **124** of the femur **126**. The femoral alignment guide **134** is utilized to support an anterior resection guide **138** and stylus **140** (FIGS. **10**, **11** and **12**) on the distal end portion **124** of the femur **126** in the upper portion **72** of the leg **70** of the patient. Although only the femur **126** is illustrated in FIGS. **10**, **11** and **12**, it should be understood that the leg **70** is in the orientation illustrated in FIGS. **2** and **3**. The upper portion **72** of the leg **70** us supported by the leg support **80**.

In accordance with one of the features of the present invention, the instrumentation is down sized to enable the size of the incision **114** (FIG. **9**) to be minimized. The downsized instrumentation has a transverse dimension which is smaller than a transverse dimension of an implant to be placed in the knee portion **76** (FIG. **9**). Thus, the femoral alignment guide **134** and anterior resection guide **138** have transverse dimensions, perpendicular to a longitudinal central axis of the femur **126**, which are smaller than transverse dimensions of a femoral implant **290**, tibial bearing insert **294**, and a tibial tray **286** (FIG. **29**) in a direction perpendicular to the longitudinal central axis of the femur **126** (FIG. **9**).

The instrumentation extends from a center portion of the femur **126** toward one side of the femur (FIG. **11**). In the particular operation illustrated schematically in FIGS. **7-12**, the incision **114** is offset to the medial side of the patella **120**. Therefore, the instrumentation is offset to the medial side of the femur **126**. However, if the incision **114** were offset to the lateral side of the patella **120**, the instrumentation would be offset to the lateral side of the femur **126**. If the incision **114** were centrally disposed relative to the femur **126**, the instrumentation would be centrally disposed relative to the femur. Thus, the instrumentation is in general alignment with the incision **114** and extends only part way across the distal end portion **124** of the femur **126**.

The femoral alignment guide **134** (FIGS. **10**, **11** and **12**) and anterior resection guide **138** have opposite ends which are spaced apart by distance which is less than a distance between epicondyles **148** and **150** on the distal end portion **124** of the femur **126**. The distance between opposite ends **154** and **156** of the femoral alignment guide **134** is less than two thirds (⅔) of the distance between tips **144** and **146** of the lateral and medial epicondyles **148** and **150**. Similarly, a distance between an end **160** and an opposite end **162** of the anterior resection guide **138** is less than two thirds (⅔) of the distance between the tips **144** and **146** of the lateral and medial epicondyles **148** and **150**.

The distance between opposite ends of a known femoral alignment guide and the distance between opposite ends of a known anterior resection guide are approximately the same as or greater than the distance between the tips **144** and **146** of the lateral and medial condyles **148** and **150**. The distance between opposite ends of the known femoral alignment guide and the distance between opposite ends of the known anterior resection guide are greater than the transverse dimensions of the femoral and tibial implants **286**, **290** and **294** (FIG. **29**). This known anterior resection guide and femoral alignment guide are commercially available from Howmedica Osteonics of 359 Veterans Boulevard, Rutherford, N.J. under the designation "Scorpio" (trademark) Single Axis Total Knee System.

The incision **114** must be large enough to enable the femoral alignment guide **134** and the anterior resection guide **138** to pass through the incision. By reducing the size of the femoral alignment guide **134** and anterior resection guide **138**, the size of the incision **114** can be reduced. Of course, reducing the size of the incision **118** reduces damage to body tissue of the patient **62**. The femoral alignment guide **134** and the anterior resection guide **138** may be larger than the incision **114**. This is because the incision **114** can be resiliently stretched and/or moved relative to the femur **126** to enable the femoral alignment guide **134** and anterior resection guide **138** to move through the incision.

The distance between opposite ends **154** and **156** of the femoral alignment guide **134** is less than the distance which a femoral implant extends across the distal end portion **124** of the femur **126**. Similarly, the distance between opposite ends **160** and **162** of the anterior resection guide **138** is less than the distance which the femoral implant extends across the distal end portion **124** of the femur **126**. The femoral alignment guide **134** and the anterior resection guide **138** both extend medially from a center portion of the femur **126**. However, if the incision **114** were offset laterally of the patella **120**, the femoral alignment guide **134** and the anterior resection guide **138** would extend laterally from the center portion of the femur **126**. Similarly, if the incision **114** was centered relative to the patella **120**, the femoral alignment guide **134** and anterior resection guide **138** would be centered relative to the femur **126**.

If leg **70** is positioned as shown in FIGS. **2** and **3**, positioning of the femoral alignment guide **134** and anterior resection guide **138** on the distal end portion **124** of the femur **126** is facilitated by distracting the knee joint under the influence of the weight of the lower portion **68** of the patient's leg and the foot **74**. Thus, when the femoral alignment guide **134** and anterior resection guide **138** are positioned on the distal end portion **124** of the femur **126**, the lower portion **68** of the leg **70** can be suspended from the upper portion **72** of the leg. At this time, the foot **74** is below the level of the support surface **64** (FIG. **2**) on which the patient is disposed in a supine orientation. The upper portion **72** of the patient's leg **70** is supported above the support surface **64** by the leg support **80** (FIG. **2**).

By distracting the knee joint under the influence of the weight of the lower portion **68** of the leg of the patient, the distal end portion **124** of the femur **126** is exposed through the relatively small incision **114** (FIG. **9**). Exposure of the distal end portion **124** of the femur **126** at the limited incision **114** is promoted by moving the lower portion **68** of the leg **70** and the incision relative to the femur. In addition, exposure of the distal end portion **124** of the femur **126** is promoted by having the patella **120** offset to the lateral side of its normal position. The inner side **122** of the patella **120** faces inward toward the distal end portion **124** of the femur **126** so that the skin on the knee portion **76** is not excessively stretched by everting the patella.

In accordance with another feature of the present invention, the instrumentation is at least partially positioned between the distal end portion **124** of the femur **126** and body tissue of the knee portion **76** (FIG. **9**). To enable the size of the incision **114** to be minimized, the instrumentation is moved laterally of the incision so that a portion of the instrumentation moves between the knee capsule and the end portion **124** of the femur **126**. This results in a portion of the instrumentation being exposed at the incision **114** and a laterally extending portion of the instrumentation being concealed by body tissue. For example, the end **154** (FIG. **11**) of the femoral alignment guide **134** and/or the end **160** of the anterior resection guide **138** are overlaid by body tissue adjacent to the lateral edge portion of the incision **114**. The body tissue which overlies portions of the instrumentation may include skin, the knee capsule, and connective and soft tissues.

With prior art instrumentation, the soft tissue must be completely dissected so that the distal end portion **124** of the femur **126** is fully exposed. In contrast, the instrumentation of the present invention can be at least partially positioned between the distal end portion **124** of the femur **126** and body tissue of the knee portion **76** (FIG. **9**). As discussed in more detail below, the soft tissue can be lifted or otherwise retracted. This minimizes the need for dissection.

When the femoral alignment guide **134** and anterior resection guide **138** are connected with the femur **126**, central axis of the femoral alignment guide and anterior resection guide are medially offset from the central axis of the femur. Thus, the central axis of the femur **216** extends through a lateral portion, that is, left portion as viewed in FIG. **11**, of the femoral alignment guide **134**. The anterior resection guide **138** is almost entirely offset to the right (as viewed in FIG. **11**) of the central axis of the femur **126**. The incision **114** is disposed along a medial edge, that is, a right edge as viewed in FIG. **6**, of the patella **120** when the patella is in its normal or initial position.

By having both the incision **114** and the instrumentation medially offset relative to the femur **126**, the central portion of the instrumentation is exposed at the incision. Thus, the medial edge of the incision overlaps the medial end **156** of the femoral alignment guide **134** and the medial end **162** of the anterior resection guide **138**. Similarly, the lateral edge of the incision **114** overlaps the lateral end **154** of the femoral alignment guide **134** and the lateral end **160** of the anterior resection guide **138**.

In view of the foregoing, it can be seen that the leg **70** (FIG. **3**) of the patient **62** (FIG. **2**) is maintained in the position illustrated in FIGS. **2** and **3** with the foot **74** of the patient below the support surface **64** upon which the patient is supported in a supine position during forming of the incision **114** in the knee portion **76** of the leg **70**. The upper portion **72** of the patient's leg **70** is supported above the support surface **64** by the leg support **80** (FIG. **2**). In addition, the leg of the patient is maintained in the position illustrated in FIGS. **2** and **3** during connection of the femoral alignment guide **134** and anterior resection guide **138** with the distal end portion **124** of the femur **126**.

Once the femoral alignment guide **134** and anterior resection guide **138** have been mounted on the distal end portion **124** of the femur **126**, an anterior cut is made in the manner illustrated in FIG. **13**. During the anterior cut, a blade **170** of a saw **172** is utilized to make a cut across anterior portions of the lateral and medial condyles. The saw blade **170** is moved along guide surface **178** (FIGS. **11** and **12**) on the anterior resection guide **138**.

The guide surface **178** extends only part way across of the end portion **124** of the femur **126** (FIGS. **11** and **13**). The guide surface **178** does not extend across the lateral portion of the end portion **124** of the femur **126**. This at least partially results from the fact that the incision **114** (FIG. **6**) is offset in a medial direction from the center of the knee portion **76**. The incision **114** extends along the medial edge portion of the patella **120** when the patella is in its normal, that is, initial, position. In addition, the large majority of the anterior resection guide **138** extends medially from the central axis of the shaft **132** of the femoral alignment guide **134** (FIG. **11**). By having the anterior resection guide disposed in an overlying relationship with the medial portion of the end portion **124** of the femur **126** (FIGS. **11** and **13**), the size of the incision **114** can be reduced.

When anterior portions of the lateral and medial condyles **148** and **150** (FIGS. **10**, **11** and **12**) on the distal end portion **124** of the femur **126** are to be cut with the saw **172**, the blade **170** is pivoted sideways (FIG. **13**) so that the cutting end of the blade has an arcuate component of movement. The cutting end of the blade **170** will move along a straight path during part of the movement of the blade along the guide surface **178**. However, when the blade **170** reaches the ends of the guide surface **178**, the saw **172** is pivoted to pivot the blade and move the cutting end of the blade along a path having an arcuate configuration. This results in a generally fan shaped cut which extends only part way across the anterior side of the lateral and medial condyles on the end portion **124** of the femur.

The saw blade may have teeth along opposite longitudinally extending edges. The saw blade **170** and saw **172** are of the oscillating type. However, a reciprocating type saw and blade may be utilized if desired. Additionally and as later described, a milling device and associated guides can be used.

Due to the limited length of the anterior resection guide **138**, the saw blade **170** is moved along the guide surface **178** to only partially complete the anterior skim cut on the end portion **124** of the femur **126**. The guide surface **178** is offset to the medial side of the central axis of femur **126** (FIG. **11**). Therefore, the saw blade can only partially form the lateral portion of the anterior skim cut while the saw blade engages the guide surface **178**. The anterior resection guide **138** can then disconnected from the femoral alignment guide **134** (FIGS. **14** and **15**) and the anterior femur cut is completed.

During completion of the anterior femur (skim) cut, previously cut surfaces on the end portion **124** of the femur **126** can be used to guide the saw blade **170** (FIG. **13**). Thus, an initial portion of the anterior skim cut is made on the distal end portion **124** of the femur **126** while the saw blade **170** is moved along one or more guide surfaces on the anterior resection guide **138**. After the anterior resection guide **138** has been disconnected from the femoral alignment guide **134**, the saw blade **170** is positioned in engagement with the cut surfaces on the distal end portion **124** of the femur **126**. This is accomplished by inserting the saw blade **170** into a slot or saw kerf formed in the distal end portion **124** of the femur during the initial portion of the anterior skim cut.

The saw blade **170** is then moved along the previously cut surfaces on the distal end portion of the femur **126** to guide the saw blade during completion of the anterior skim cut. Utilizing cut surfaces formed during an initial portion of the anterior skim cut to guide the saw blade **170** enables the size of the anterior resection guide **138** to be minimized. Although the illustrated saw blade **170** has teeth **180** at only one end, the saw blade could also have teeth along opposite longitudinally extending edges.

By utilizing the anterior resection guide **138** to guide movement of the saw blade **170** during only an initial portion of forming the anterior skim cut on the distal end portion **124** of the femur **126**, the overall length of the anterior resection guide, that is, the distance between the ends **160** and **162** (FIG. **11**) of the anterior resection guide can be limited to a distance which is less than the distance between the epicondyles **148** and **150**. Specifically, the distance between the ends **160** and **162** of the anterior resection guide **138** is less than two thirds (⅔) of the distance between the tips **144** and **146** of lateral and medial epicondyles **148** and **150** on the distal end portion **124** of the femur **126**. By limiting the length of the anterior resection guide **138**, the size of the incision **114** can be minimized.

It is contemplated that the initial portion of the anterior skim cut could be made with a first cutting tool and the anterior skim cut completed with a second cutting tool. The initial portion of the anterior skim cut may be made with relatively small oscillating saw blade. The final portion of the anterior skim cut may be made with a larger reciprocating saw blade. Alternatively, a small milling cutter could be used to make the initial portion of the anterior skim cut. The final portion of the skim cut could be made with a relatively long milling cutter or saw blade. It may be desired to make the initial portion of the anterior skim cut with a chisel and to complete the anterior skim cut with either a saw blade or a milling cutter.

The illustrated anterior resection guide **138** has a slot which forms the guide surface **178**. This results in the saw blade **170** being captured so that the saw blade is restrained against both up and down movement (as viewed in FIG. **11**) relative to the anterior resection guide **138**. However, in order to reduce the size of the anterior resection guide **138**, the slot could be eliminated and the saw blade **170** moved along a flat outer side of the anterior resection guide.

During making of the anterior skim cut, with and without the anterior resection guide **138**, body tissue (FIG. **9**) overlies at least portions of the lateral and medial condyles being cut. This is due to the relatively short extent of the incision **114**. Thus, the saw blade **170** and the portion of the femur **126** being cut by the saw blade are both at least partially enclosed by body tissue overlying the femur during making of the anterior skim cut. During making of the anterior skim cut, the incision **114** is moved relative to the femur **126** to provide clearance for the saw blade.

After the anterior portion of the lateral and medial epicondyles have been cut away and the anterior resection guide **138** removed, a flat anterior cut surface **182** (FIGS. **14** and **15**) is disposed on the distal end portion **124** of the femur **126**. The anterior skim cut is made on the distal end portion **124** of the femur **126** with the patella **120** offset to one side of the incision **118** (FIG. **14**). The inner side of the patella **120** faces toward the distal end portion **124** of the femur **126** when the patella is in the offset position of FIGS. **9** and **14**.

The flat anterior cut surface **182** (FIG. **15**) extends parallel to the epicondylar axis. The maximum width of the anterior cut surface **182**, as measured parallel to the epicondylar axis, is greater than the distance between opposite ends **154** and **156** (FIG. **11**) of the femoral alignment guide **134**. Similarly, the maximum width of the anterior cut surface **182** (FIG. **15**), as measured parallel to the epicondylar axis, is greater than the distance between opposite ends **160** and **162** (FIG. **11**) of the anterior resection guide **138**. The anterior cut surface **182** is at least partially covered by body tissue which encloses the distal end portion of the femur **126** (FIG. **14**).

During making of the anterior skim cut, the patient **62** (FIG. **2**) is supported in a supine position on the support surface **64**. The upper portion **72** of the leg **70** is disposed above the support surface on the leg support **80**. The lower portion **68** of the leg **70** extends downward from the support surface **64**. The foot **74** (FIG. **3**) of the patient is disposed below the support surface.

Throughout the making of the anterior skim cut and the formation of the flat anterior cut surface **182** (FIGS. **14** and **15**) on the distal end portion **124** of the femur **126**, the lower portion **68** of the leg **70** can be suspended from the upper portion **72** of the leg in the manner illustrated in FIG. **3**. This results in the knee portion **76** of the leg **70** being distracted by the combined weight of the lower portion **68** of the leg and the foot **74**. At this time, the lower portion **68** of the leg **70** dangles from the upper portion **72** of the leg. If desired, a holder could be provided to engage either the foot **74** and/or the lower portion **68** of the leg **70** to maintain the foot **74** and lower portion **68** of the leg in a desired position relative to the support surface **64**.

Once the anterior skim cut has been completed, a distal resection guide **186** is positioned relative to the flat anterior skim cut surface **182** (FIG. **16**). To position the distal resection guide **186** relative to the cut surface **182**, a resection guide stand **190** is mounted on the femoral alignment guide **134** in the manner illustrated in FIG. **16**. The distal resection guide **186** is connected with the resection guide stand **190** by rotating a locking knob **192**. The distal resection guide **186** and resection guide stand **190** may be magnetized to assure correct assembly. Since the femoral alignment guide **134** is medially offset relative to the distal end portion **124** of the femur **126**, the distal resection guide **186** is also medially offset relative to the distal end portion of the femur.

When the distal resection guide **186** is to be connected with the resection guide stand **190**, the distal resection guide is moved between the anterior skim cut surface **182** and body tissue overlying the anterior skim cut surface (FIG. **14**). Thus, due to the limited extent of the incision **114**, skin and other body tissues are disposed over the anterior skim cut surface **182**. The distal resection guide **186** slides between the anterior skim cut surface **182** and the body tissue overlying the anterior skim cut surface. A lower (as viewed in FIGS. **16**, **17** and **18**) major side of the distal resection guide **186** engages the anterior skim cut surface **182**. The opposite or upper (as viewed in FIGS. **16**, **17** and **18**) major side of the distal resection guide **186** is engaged by the body tissue overlying the anterior skim cut surface **182** (FIG. **14**). The surgeon moves the incision **114** and/or the lower portion **68** of the leg **70** relative to the distal end portion of the femur **126** to facilitate movement of the distal resection guide **186** onto the anterior skim cut surface **182**.

Once the distal resection guide **186** has been positioned in the desired location on the flat anterior cut surface **182**, the distal resection guide **186** is secured in place with pins **196** and **198** (FIG. **16**). At this time, body tissue overlies the portion of the distal resection guide **186** spaced from the distal end of the femur. The distal resection guide **186** is medially offset from a central portion of the femur **126** and is aligned with the incision **114**. The incision **114** (FIG. **14**) is moved relative to the distal end portion **124** of the femur **216** to enable the pins **196** and **198** to be forced into the distal end portion of the femur.

The femoral alignment guide **134** and resection guide stand **190** are then separated from the distal end portion **124** of the femur **126** (FIGS. **17** and **18**). As this is done, the resection guide stand **190** (FIG. **16**) is separated from the distal resection guide **186**. Separation of the resection guide stand **190** from the distal resection guide **186** is accomplished by rotating the knob **192** and moving the resection guide stand **190** upward (as viewed in FIG. **16**) to disconnect the guide stand **190** from the femoral alignment guide **134**. The intramedullary rod **132** and femoral alignment guide **134** are then removed from the femur **126**. The distance between opposite ends **206** and **208** of the distal resection guide **186** is less than two thirds (⅔) of the distance between tips **144** and **146** (FIG. **11**) of the lateral and medial epicondyles **148** and **150**.

The distal resection guide **186**, like the anterior resection guide **138**, is down sized to enable the distal resection guide to move into the knee portion **76** of the patient's leg **70** through a relatively small incision **114**. To enable the distal resection guide **186** to move into the incision through a relatively small incision **114**, opposite ends **206** and **208** (FIG. **16**) of the distal resection guide **186** are spaced apart by a distance which is less than the distance between the lateral and medial epicondyles **148** and **150** (FIG. **11**) on the distal end portion **124** of the femur **126**. The distance between opposite ends **206** and **208** of the distal resection guide **186** is less than the distance which a femoral implant extends across the distal end portion **124** of the femur **126**.

The distal resection guide **186** is offset medially relative to the distal end portion **124** of the femur **126**. The incision **114** is also medially offset relative to the distal end portion **124** of the femur **126**. This results in the central portion of the guide surface **202** being exposed through the incision **114**. The lateral and medial edges of the incision **114** overlap opposite ends **206** and **208** of the distal resection guide **186**. The incision **114** also overlaps the anterior side, that is, the upper side as viewed in FIG. **16**, of the distal resection guide. During cutting with the saw blade **170** (FIGS. **17** and **18**), the incision **114** is elastically expanded with suitable retractors.

During making of the distal femoral cut, the saw blade **170** moves along the guide surface **202** (FIG. **17**) on the distal resection guide **186**. The guide surface **202** on the down sized distal resection guide **186** has a length which is less than a transverse dimension of a cut to be made in the distal end portion **124** of the femur **126**. The saw **172** may be pivoted, in a manner illustrated schematically in FIG. **13**, adjacent to opposite ends of the guide surface **202**. This moves the cutting end of the saw blade **170** along an arcuate path to form a generally fan shaped distal femoral cut. The saw **172** may be either a reciprocating or oscillating saw.

Due to the reduced size of the distal resection guide **186**, the saw blade **170** (FIGS. **17** and **18**) is ineffective to complete the distal femoral cut while the saw blade is in engagement with the guide surface **202** (FIGS. **16** and **17**). Therefore, after an initial portion of the distal cut has been made by moving the saw blade **170** along the guide surface **202**, the distal resection guide **186** is disconnected from the distal end portion **124** of the femur **126** and the distal femoral cut is completed.

During completion of the distal femoral cut, surfaces formed during the initial portion of the distal femoral cut are effective to guide the saw blade **170**. The saw blade **170** (FIGS. **17** and **18**) is moved into the saw kerf or slot formed during the initial portion of the distal femoral cut. As the saw blade **170** extends the initial portion of the distal femoral cut, the saw blade slides along cut surfaces formed during the initial portion of the distal femoral cut. Thus, cut surfaces formed during movement of the saw blade **170** along the guide surface **202** are utilized to guide movement of the saw blade during completion of the distal femoral cut.

The initial portion of the distal femoral cut may be made with a first cutting tool and the final portion of the distal femoral cut may be made with a second cutting. For example, the initial portion of the distal femoral cut may be made with a relatively small oscillating saw blade which can be readily inserted through the incision **114** into engagement with the distal resection guide **186**. The final portion of the distal femoral cut may be made with a larger saw blade which may be of the reciprocating type. It is contemplated that the initial and/or final portion of the distal femoral cut may be made with a milling cutter. It is also contemplated that a chisel may be used to make the initial and/or final portion of the distal femoral cut.

When the distal femoral cut is completed, a flat distal end surface **209** extends across the distal end of the femur **126** (FIG. **17**). The distal end surface **209** extends perpendicular to the anterior cut surface **182**. The maximum width of the distal end surface **209**, as measured parallel to the anterior cur surface **182** and epicondylar axis, is greater than the distance between opposite ends **206** and **208** of the distal resection guide **186**. The trochlear groove of the femur extends through the distal end surface **209**.

The distal femoral cut can be formed with the patella **120** (FIG. **14**) offset to one side of the incision **114** and with the inner side **122** of the patella facing toward the distal end portion **124** of the femur **126**. In addition, the leg **70** of the patient can be in the orientation illustrated in FIGS. **2** and **3** with the foot **74** and lower portion **68** of the leg suspended from the upper portion **72** of the leg. The upper portion **72** of the leg is supported above the support surface **64** by the leg support **80**.

A femoral cutting guide **210** (FIGS. **19** and **20**) is then positioned on the distal end portion **124** of the femur **126** and utilized to make femoral anterior, posterior and chamfer cuts in a known manner. The femoral cutting guide **210** is connected with the distal end portion **124** of the femur **126** by two pins (not shown) in a known manner. The femoral cutting guide **210** is down sized so that it has opposite ends which are spaced apart by distance which is less than a distance between the lateral and medial epicondyles **148** and **150** (FIG. **11**) on the distal end portion **124** of the femur **126**. The femoral cutting guide **210** is offset in a medial direction from the center of the femur **126** (FIG. **20**). The medially offset position of the femoral cutting guide **210** is the result of the medially offset position of the incision **114** (FIG. **6**).

The initial portion of the femoral anterior, posterior and chamfer cuts are made by moving the saw blade **170** or other cutting tool along guide surfaces on the femoral cutting guide. Due to the relatively small size of the femoral cutting guide, the cuts cannot be completed while moving the saw blade **170** or other cutting tool along guide surfaces on the femoral cutting guide. Therefore, the femoral cutting guide **210** is separated from the distal end portion **124** of the femur **126** and the cuts are completed while guiding movement of the saw blade **170** or other cutting tool with cut surfaces formed during the making of the initial portions of the femoral anterior, posterior and chamfer cuts. When the femoral anterior, posterior and chamfer cuts are completed, the distal end portion **124** of the femur **126** will have the known configuration illustrated in FIGS. **22** and **23**.

The femoral cutting guide **210** (FIGS. **19** and **20**) may have the same construction as a femoral cutting guide which is commercially available from Howmedica Osteonics of 359 Veterans Boulevard, Rutherford, N.J. The femoral cutting guide may have the construction disclosed in U.S. Pat. Nos. 5,282,803 or 5,749,876. However, it is preferred to down size the known femoral cutting guides to have a distance between opposite ends which is less than two thirds (⅔) of the distance between tips **144** and **146** (FIG. **11**) of medial and lateral condyles **148** and **150** on the distal end portion **124** of the femur **126**. This enables the femoral cutting guide **210** to move through the incision **114**.

Since the femoral cutting guide **210** is down sized, initial portions of the femoral anterior, posterior and chamfer cuts are made while guiding a saw blade or other cutting tool with the femoral cutting guide. These cuts are subsequently completed utilizing previously cut surfaces to guide the saw blade **170**. To complete a cut in this manner, the saw blade **170** or other cutting tool is moved along the previously cut surfaces to guide the saw blade as the cuts are extended.

During the making of the initial portions of the anterior, posterior and chamfer cuts with the femoral cutting guide **210** and the subsequent completion of the cuts without the femoral cutting guide, the knee portion **76** of the leg **70** of the patient can be distracted by the weight of the lower portion **68** and foot **74** of the leg. Thus, the lower portion **68** and foot **74** of the leg **70** are suspended from the upper portion **72** of the leg in a manner illustrated in FIGS. **2** and **3** during the making of the femoral anterior, posterior and chamfer resections. The upper portion **72** of the patient's leg **70** is supported above the support surface **64** by the leg support **80** (FIG. **2**).

By distracting the knee joint during the making of the femoral anterior, posterior and chamfer cuts, access to the distal end portion **124** of the femur **126** is promoted and the making of the cuts is facilitated. Access to the distal end portion **124** of the femur **126** is also promoted by moving the suspended lower portion **68** of the leg **70** relative to the distal end portion of the femur. The incision **114** may be moved relative to the distal end portion **124** of the femur **126** by applying force to body tissue adjacent to the incision.

Tibial Procedure

As was the case for femoral preparation, the tibial procedure can be performed with the leg **70** in the position shown in FIGS. **2** and **3**. Since the knee portion **76** of the leg **70** is distracted, a proximal end portion **212** (FIG. **21**) of a tibia **214** is separated from the distal end portion **124** of the femur **126**. The foot **74** (FIG. **3**) may be moved posteriorly to hyperflex the knee portion **76**. This facilitates viewing of the proximal end portion **212** of the tibia **214** through the relatively small incision **114**.

When the knee portion **76** (FIG. **2**) is hyperflexed, the angle between the upper portion **72** and the lower portion **68** of the patient's leg **70** is less than ninety (90) degrees. At this time, the foot **74** is disposed posteriorly of the position illustrated in FIG. **2**. This results in the proximal end portion **212** (FIG. **21**) of the tibia **214** being moved anteriorly relative to the distal end portion **124** of the femur **126**. The distal end portion **212** of the tibia **214** can then be viewed through limited incision **114**. Even though the incision **114** has a relatively short length, it is possible to move the incision relative to the proximal end portion **212** of the tibia **214**. Therefore, the entire or at least almost the entire, proximal end surface of the tibia **214** can be viewed through the incision **214**.

It is contemplated that an external tibial alignment guide (not shown) will be utilized to align a tibial resection guide **218** (FIG. **21**) with the proximal end portion **212** of the tibia **214**. The tibial alignment guide has a known construction and may be similar or the same as is commercially available from Howmedica Osteonics of 359 Veterans Boulevard, Rutherford, N.J. Alternatively, the tibial alignment guide may have the construction disclosed in U.S. Pat. Nos. 5,578,039; or 5,282,803.

Once the tibial resection guide **218** (FIG. **21**) has been aligned with and secured to the proximal end portion **212** of the tibia **214**, the external tibial alignment guide (not shown) is disconnected from the tibial resection guide **218**. The tibial resection guide **218** is secured to the proximal end portion **212** of the tibia **214** by suitable pins.

In accordance with one of the features of the present invention, the tibial resection guide **218** is relatively small so that it can be moved through a relatively small incision **114** into engagement with the proximal end portion **212** of the tibia **214**. To facilitate moving of the tibial resection guide **218** through a relatively small incision **114**, the tibial resection guide **218** is smaller than implants **286** (FIG. **27**) and **294** (FIG. **28**) to be positioned on the proximal end portion **212** of the tibia **214**. The tibial resection guide **218** has a distance between opposite ends **228** and **230** (FIG. **21**) which is less than two thirds (⅔) of the distance between tips of lateral and medial epicondyles on the tibia **214**. Similarly, the distance between the ends **228** and **230** of the tibial resection guide **218** is less than two thirds (⅔) of the distance between tips **144** and **146** (FIG. **11**) of the lateral and medial condyles **148** and **150** on the femur **126**.

During positioning of the external tibial alignment guide and the tibial resection guide **218** (FIG. **21**) relative to the tibia **214** in the leg **70** of the patient, the leg **70** can be supported in the manner illustrated in FIGS. **2** and **3**. Thus, the upper portion **72** (FIG. **2**) of the leg **70** is supported above the support surface **64** by the leg support **80**. The lower portion **68** of the leg **70** is suspended from the upper portion **72** of the leg. The foot **74** (FIG. **3**) connected with the lower portion **68** of the leg **70** is disposed below to support surface **64** (FIG. **2**).

During positioning of the tibial resection guide **218** on the proximal end portion **212** of the tibia **214**, the tibial resection guide is moved between the proximal end portion of the tibia and body tissue overlying the proximal end portion of the tibia. The tibial resection guide **218** is positioned relative to the proximal end portion **212** of the tibia **214** while the incision **114** is resiliently expanded. The incision **114** is expanded by applying force against opposite sides of the incision with suitable retractors. The retractors may have a construction similar to the construction disclosed in U.S. Pat. No. 5,308,349. Alternatively, a pneumatic retractor, such as is disclosed in U.S. patent application Ser. No. 09/526,949 filed Mar. 16, 2000 by Peter M. Bonutti may be used to expand the incision **114**.

The tibial resection guide **218** is slid inferiorly, that is, downward (as viewed in FIG. **21**) between the proximal end portion **212** of the tibia **214** and body tissue adjacent to the proximal end of the tibia. The tibial resection guide **218** is then connected to the proximal end portion **212** of the tibia **214** with suitable pins. Once the resection guide **218** has been connected with the tibia **214**, the force applied against opposite sides of the incision **114** by retractors is interrupted and the incision contracts. As this occurs, the body tissue moves over the lower (as viewed in FIG. **21**) portion of the tibial resection guide **218** to further enclose the tibial resection guide.

The tibial resection guide **218** is medially offset relative to the proximal end portion **212** of the tibia **214**. This is because the incision **114** is medially offset relative to the proximal end portion **212** of the tibia **214**. The incision **114** extends from the proximal end portion **212** of the tibia **214** to the superior portion of the trochlear groove in the distal end portion **124** of the femur **126**. As was previously mentioned, the incision **114** and the instrumentation may be laterally offset relative to the femur **126** and the tibia **214**.

Once the tibial resection guide **218** (FIG. **21**) has been mounted on a proximal end portion **212** of the tibia **214**, a proximal tibial cut is made. The proximal tibial cut is made by moving the blade **170** of the saw **172** along a guide surface **242** on the tibial resection guide **218** (FIG. **21**). When the saw blade reaches an end portion of the tibial guide surface **242**, the saw **172** is pivoted to move the saw blade **170** in the manner illustrated schematically in FIG. **16**. This pivotal movement results in the cutting end portion of the saw blade **170** having an arcuate component of movement. This results in a generally fan shaped cut being formed in the proximal end portion **212** of the tibia **214**.

Due to the reduced size of the tibial resection guide **218** to facilitate movement of the tibial resection guide through the incision **114**, the saw **172** can only form an initial portion of the proximal tibial cut as the saw blade **170** moves along the guide surface **242** of the tibial resection guide **218**. To complete the proximal tibial resection cut, the tibial resection guide **218** is disconnected from the tibia **214**.

Once the tibial resection guide **218** has been separated from the tibia **214**, the saw blade **170** is inserted into the slit or kerf made by the saw blade during the initial portion of the proximal tibial cut. The cut surfaces which were formed during an initial portion of making the proximal tibial cut on the tibia **214** are then used to guide the saw blade **170** during completion of the proximal tibial cut. Thus, the saw blade **170** is moved along surfaces formed during the making of the initial portion of the proximal tibial cut to guide movement of the saw blade during completion of the proximal tibial cut.

It is contemplated that different cutting tools may be utilized to make the initial and final portions of the proximal tibial cut. Thus, the saw blade **170** used to make the initial portion of the tibial cut may be a relatively small oscillating blade and the saw blade used to make the final portion of the tibial cut may be a relatively long reciprocating blade. Alternatively, the initial and/or final portion of the tibial cut may be made with a milling cutter. If desired, a chisel could be utilized to make the initial portion of the tibial cut. The incision **114** may be expanded with suitable retractors during making of the tibial cut. The retractors may have any desired construction, including the construction disclosed in U.S. Pat. No. 5,308,349. Ligaments and other body tissue adjacent to the proximal end portion **212** of the tibia **214** may be shielded with suitable surgical instruments during making of the tibial cut.

Upon completion of the proximal tibial cut on the proximal end portion **212** of the tibia **214**, a flat proximal tibia cut surface **246** (FIG. **22**) is exposed on the proximal end portion **212** of the tibia **214** through the incision **114**. The flat cut surface **246** has a maximum width, as measured along an axis extending parallel to an axis extending through central axes of the collateral ligaments, which is greater than the distance between opposite ends **228** and **230** of the tibial resection guide **218**. The distal end portion **124** of the femur **126** is also exposed through the incision **118**.

In order to increase exposure of the proximal end portion **212** of the tibia **214** at the incision **218**, the foot **74** and lower portion **68** of the leg **70** (FIG. **24**) can be moved posteriorly toward the operating table **66** (FIG. **2**) to hyperflex the knee portion **76** of the patient's leg **70** during the making of the proximal tibial cut. When the knee portion **76** of the leg **70** is hyperflexed, the ankle **86** is moved from a position either extending through or anterior of a vertical plane extending perpendicular to a longitudinal central axis of the upper portion **72** of the patient's leg **70** to a position disposed posteriorly of the vertical plane. Thus, as viewed in FIGS. **2** and **24**, the ankle **86** is moved toward the left. As this occurs, an angle between a longitudinal central axis of the upper portion **72** of the patient's leg and the longitudinal central axis of the lower portion **68** of the patient's leg is decreased to an angle of less than ninety degrees.

Hyperflexing the patient's leg **70** moves the proximal end portion **212** (FIGS. **22** and **23**) of the tibia **214** anteriorly away from the distal end portion **124** of the femur **126**. At this time, the knee portion **76** of the patient's leg is distracted under the influence of the weight of the lower portion **68** of the patient's leg and the foot **74** connected with the lower portion of the patient's leg. If desired, a force pulling the lower portion of the patient's leg downward (as viewed in FIG. **3**) may be applied to the patient's leg to further increase the distraction of the knee portion **76** of the leg and the extent of exposure of the proximal end portion **212** of the tibia **214**.

By hyperflexing the knee portion **76** of the patient's leg **70** and applying a downward (as viewed in FIG. **3**) force against the lower portion **68** of the patient's leg, the proximal end portion **212** of the tibia **214** is delivered anteriorly that is, toward the surgeon **106** (FIG. **24**). Application of a downward force against the lower portion **68** of the patient's leg is effective to open the space between the proximal end portion **212** of the tibia **214** and the distal end portion **124** of the femur **126** to the maximum extent permitted by the tendons and ligaments, that is, fibrous connective tissue, interconnecting the femur and tibia.

This enables the posterior cruciate ligament **250** (FIG. **23**) to be checked. In addition, access is provided to the posterior side of the knee portion **76** of the leg **70**. The surgeon **106** (FIG. **24**) can manually feel the posterior portion of the knee joint. There is sufficient space between the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** to enable the surgeon **106** to visually and tactilely check the posterior of the knee portion **76** of the patient's leg **70**.

Access to the posterior portion of the knee enables osteophytes, bone spurs and similar types of posterior soft tissue to be removed. This enables tissue which could block further flexion of the knee portion **76** to be removed. In addition, it is possible to check the collateral ligaments and other fibrous connective tissue associated with the knee.

At this time, the lower portion **68** of the leg **70** (FIGS. **23** and **24**) is suspended from the upper portion **72** of the leg. Therefore, the lower portion **68** of the leg **70** hangs from the upper portion **72**. The foot **74** may be supported on the surgeon's knee **252** (FIG. **24**) or other surface. The foot **74** is free to move in any direction relative to the knee portion **76**. By raising or lowering his or her knee **252**, the surgeon **106** can move the tibia **214** relative to the femur **126** and vary the space between the distal end of the femur and the proximal end of the tibia.

By varying force indicated by arrows **256** (FIG. **25**), the vertical extent of space between the proximal end portion **212** of the tibia **214** and the distal end portion **124** of the femur **126** (FIGS. **22** and **23**) can be either increased or decreased. The force **256** is varied by raising and lowering the surgeon's knee **252**. Increasing the space between the proximal end portion **212** of the tibia **214** and the distal end portion **124** the femur **126** maximizes access to the posterior of the knee portion **76**.

By moving the lower portion **68** of the leg **70** upward, the ligaments and other connective tissue between the tibia **214** and femur **126** are relaxed. This enables the lower portion **68** of the leg **70** to be rotated about its longitudinal central axis, in a manner indicated by arrows **258** in FIG. **25**. Rotational movement of the lower portion **68** of the leg **70** about its central axis enables the surgeon to check the collateral ligaments and the resistance encountered to rotation of the lower portion **68** of the leg relative to the upper portion **72**.

In addition, the foot **74** can be pivoted in a clockwise direction (as viewed in FIG. **25**) about the knee portion **76**, in the manner indicated by arrow **259** in FIG. **25**, to increase the extent of flexion of the knee portion **76**. Alternatively, the foot **74** can be pivoted in a counterclockwise direction about the knee portion **76** to decrease the extent of flexion of the leg **70**.

The lower portion **68** of the leg **70** can also be moved sidewise, in the manner indicated by the arrow **260** in FIG. **25**. When the lower portion **68** of the leg **70** is moved in the manner indicated by the arrow **260**, the lower portion of the leg is moved along a path extending through lateral and medial surfaces of the foot **74** and the lower portion **68** of the leg **70**. This enables the ligaments and other fibrous connective tissue in the leg to be checked for a range of movement. Although the incision **114** has not been shown in FIG. **25**, it should be understood that the lower portion **68** of the leg **70** can be moved in the directions indicated by the arrows in FIG. **25** when the knee portion **76** is in the condition illustrated in FIGS. **22** and **23**.

The illustrated instrumentation can be formed of a metal which enables the instrumentation to be sterilized and reused. For example, the instrumentation could be formed of stainless steel. However, known metal instruments are relatively heavy and bulky. This substantially increases transportation expense.

It is contemplated that it may be desired to use the instrumentation once and then dispose of the instrumentation. If this is done, the instrumentation may be partially or entirely formed of relatively inexpensive polymeric materials. Thus, the femoral resection guide **134**, anterior resection guide **138**, distal resection guide **186**, femoral cutting guide **210**, and/or tibial resection guide **218** could be formed of inexpensive polymeric materials. If this was done, the guides could be used once and disposed of without being sterilized. In addition, the polymeric guides would weigh substantially less than metal guides.

Implants

After the distal end portion **124** of the femur **126** has been prepared and the proximal end portion **212** of the tibia **214** is prepared to receive implants (FIGS. **22** and **23**) and prior to insertion of the implants, any necessary work on the patella **120** may be undertaken. During work on the patella, the leg **70** of the patient may be extended and the patella **120** may be everted or flipped to the position illustrated in FIG. **7**. The inner side or articular surface **122** of the patella **120** faces outward and is exposed. Known surgical techniques are then utilized to cut the patella **120** and position an implant on the patella in a known manner. This may be accomplished utilizing any one of many known devices and procedures, such as the devices and procedures disclosed in U.S. Pat. Nos. 4,565,192; 5,520,692; 5,667,512; 5,716,360; and/or 6,159,246. If desired any necessary work on the patella **120** may be undertaken after the femoral and tibial implants have been installed.

As an alternative to the above-described procedure in which patella **120** is everted or flipped to the position illustrated in FIG. **7**, patella **120** can be resurfaced or otherwise worked upon while maintained in a substantially non-everted, anatomic position. U.S. Pat. No. 6,174,314 B1, the contents of which are incorporated herein by reference, discloses instrumentation and methods for in situ resurfacing of a patella.

Additionally, U.S. Pat. No. 5,163,949 and progeny, such as U.S. Pat. Nos. 6,358,266 B1, 6,277,136 B1, and 6,187,023 B1, discloses various embodiments of retractors and method of dissecting tissue. These embodiments include fluid operated retractors, mechanical retractors, and combinations thereof. The retractors and methods disclosed in this line of patents, which is incorporated herein by reference, can be used for patella procedures and/or visualization while the patella is maintained in a substantially non-everted, anatomic position.

Once the femoral and tibial cuts have been made and the patella repaired, femoral and tibial implants are installed in the knee portion of the leg **70**. Prior to permanently mounting of the implants in the knee portion **76** of the leg **70**, trials are conducted, in a known manner, with provisional femoral and tibial implants. The provisional femoral and tibial implants are releasably positioned relative to the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**. As discussed in more detail below, the provisional implants (and/or instrumentation) can be made disposable and can be combined with the cutting guides or other instrumentation so that separate, dedicated provisional implants are not required.

The provisional implants are intended to aid the surgeon **106** in assessment of the function and balance of the various ligaments. The trials enable the surgeon **106** to observe the relationship of the provisional femoral and tibial implants relative to each other during flexion and extension of the knee portion **76** of the leg **70**. In one embodiment, the lower portion **68** of the leg **70** is suspended from the upper portion **72** of the leg (FIGS. **2** and **3**) during the trials with the provisional implants. Therefore, the lower portion of the leg **68** can be freely moved relative to the upper portion of the leg to check ligament balancing with the provisional implants. Since the lower portion of the leg **68** is suspended, it is possible to check for flexion and extension balancing of the ligaments and to check for rotational stability and rotational balancing of the ligaments during the trials with provisional implants. The lower portion **68** of the leg **70** can be moved with a combination of flexion or extension, rotation and sidewise movement.

The trials also enable the surgeon to check the manner in which the provisional implants interact with each other during flexion, extension, rotation, and sidewise movement. The manner in which the provisional femoral and tibial implants move relative to each other during combined bending and rotational movement of a patient's leg **70** enables a surgeon to check for the occurrence of excessive space or other undesirable situations between the provisional implants. During trials with provisional implants, the range of motion of the knee joint can be checked in both flexion/extension and rotation.

Utilizing known surgical techniques, it is very difficult, if not impossible, to check for both flexion/extension balancing, rotational balancing, and sidewise balancing during trials with provisional implants. With rotational balancing, the ligaments are balanced through multiple planes. When both flexion/extension and rotation are being checked, the surgeon can locate defects and improve the stability of the knee joint. The surgeon can assess the posterior cruciate ligament, collateral ligament balancing, and posterior capsule balancing. The surgeon can proceed with flexion/extension balancing of ligaments and rotational balancing of the ligaments. This enables the leg **70** to be examined throughout its range of motion during trials with provisional implants.

During an operation on the patient's leg **70**, the surgeon can apply upward force against the foot of the patient by resting the foot **74** on the surgeon's knee **252** (FIG. **24**) and raising the knee of the surgeon. Of course, when the foot **74** is to be lowered, the surgeon can lower the knee **252** upon which the foot **74** of the patient is resting. Alternatively, a pneumatic piston can be utilized to raise and lower the foot **74** of the patient.

Throughout the operation on the patient's knee **76**, the upper portion **72** of the patient's leg **70** is supported above the support surface **64** by the leg support **80**. This causes the hip of the patient to be hyperflexed by between 20 degrees and 40 degrees. Flexing of the hip by 20 degrees to 40 degrees improves rotational positioning and alignment. It also enhances the ability of the surgeon to hyperflex the knee portion **76** or to extend the knee portion during surgery. In addition, having the upper portion **72** of the patient's leg supported above the support surface **64** by the leg support **80** improves suspension of the lower portion **68** of the leg from the upper portion **72** of the leg. It is believed that the combination of suspending the lower portion **68** of the leg **70** and having the upper portion **72** of the leg supported above the support surface **64** by the leg support **80** will enhance the ability of a surgeon to check ligament balancing in flexion/extension, and rotation during trials during which provisional femoral and tibial components are temporarily connected with the distal end portion **124** of the femur **126** and with the proximal end portion **212** of the tibia **214**.

During a portion of the trials, the patella **120** may be in the normal position relative to the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**. Therefore, during trials, it is possible to check tracking of the patella relative to the provisional femoral implant. This is done in order to prevent any possible interference of the patella **120** with the movement of the knee through its range of motion.

To install the trial femoral and tibial components, the proximal end portion **212** of the tibia **214** is prepared to receive the trial tibial implant. This is accomplished by positioning a tibial trial base plate **270** on the proximal end portion **212** of the tibia **214** (FIG. **26**). An alignment handle **272** is connected with the tibial trial base plate **270** to facilitate positioning of the tibial trial base plate relative to the proximal end portion **214** of the tibia.

The trial femoral implant (not shown) is then placed on the distal end portion **124** of the femur. This may be done in a known manner using a femoral impactor/extractor. A trial tibial bearing insert (not shown) is then mounted on the tibial trial base plate **270** in a known manner. Once this has been done, the trial provisional implants are used during conducting of trials with flexion/extension and rotational movements of the lower portion **68** of the patient's leg. When the trials are completed, the trial provisional implants are removed in a known manner.

After completion of the trials, the tibial trial base plate **270** is pinned to the proximal end portion **214** of the tibia. A tibial punch **274** (FIG. **26**) is positioned in a tibial punch tower (not shown) which is assembled onto the tibial trial base plate **270**. The tibial punch **274** is advanced relative to the tibial punch tower by impacting a mallet against the tibial punch. The foot **74** rests against the knee **252** of the surgeon during pounding of the tibial punch **274** into the tibia **214**. This results in the impaction forces being transmitted to the surgeon's knee **252** rather than to ligaments interconnecting the femur **126** and tibia **214**.

Once the tibial punch **274** has been advanced until it is fully seated on the base plate, the punch is removed. The tibial trial base plate **270** is then removed from the proximal end portion **214** of the tibia. Once the tibial trial base plate **270** has been removed, an opening **282** (FIG. **27**) formed in the proximal end portion **212** of the tibia **214** is exposed. The opening **282** has a configuration corresponding to the configuration of the tibial punch **274**.

A tibial tray **286** (FIG. **27**) forms a base portion of a tibial implant. The tibial tray **286** has a keel **288** with a configuration corresponding to the configuration of the tibial punch **274** (FIG. **26**) and the opening **282** (FIG. **27**) formed in the tibia **214**. The keel **288** (FIG. **27**) of the tibial tray **286** is covered with a suitable cement prior to being inserted into the opening **282**. If desired, the cement may be omitted.

A tibial component impactor/extractor may be used to insert the tibial tray **286** into the opening **282**. Once the tibial tray **286** has been mounted on the proximal end portion **212** (FIG. **28**) of the tibia **214**, a femoral component **290** (FIG. **29**) is mounted on the distal end portion **124** of the femur **126**. A known femoral impactor/extractor may be used to position the femoral component **290** on the distal end portion of the femur. The femoral component **290** may be provided with or without an intramedullary stem. Cement may or may not be used in association with the femoral component **290**. Once the femoral component **290** has been mounted on the distal end portion **124** of the femur **126**, a tibial bearing insert **294** (FIGS. **28** and **29**) is positioned in the tibial tray.

The femoral and tibial implants **286**, **290**, and **294** may have any one of many known constructions. For example, the femoral and tibial implants could have the construction of a knee replacement which is commercially available from Howmedica Osteonics of 359 Veterans Boulevard, Rutherford, N.J. under the designation of "Scorpio" (trademark) total knee. Rather than being a total replacement, the femoral and tibial implants could be for a partial knee replacement. Thus, the femoral and tibial implants **286**, **290** and **294** could have a construction which is the same as is illustrated in U.S. Pat. No. 5,514,143. The femoral and tibial implants **286**, **290** and **294** may be of either the cemented type or the cementless types.

Once the femoral component **290** has been positioned on the femur **126** and the tibial tray **286** and bearing insert **294** positioned on the tibia **214**, ligament balancing is again conducted. The ligament balancing includes a check of stability of the joint in flexion, extension, and rotation. The ligament balancing check is performed with the lower portion **68** of the leg **70** suspended from the upper portion **72** of the leg. The upper portion **72** of the leg **70** is held above the support surface **64** (FIG. **2**) by the leg support **80** during the ligament balancing.

Since the lower portion **68** of the leg **70** is suspended from the upper portion **72**, in the manner illustrated in FIGS. **2**, **3** and **25**, the surgeon has a more natural feel of the true ligamentous structure. This is because tissues are not squashed or bunched in the back of the knee portion **76**. Since the lower portion **68** of the leg **70** is suspended from the upper portion **72** of the leg, the joint **76** is distracted without having the lower portion **68** of the leg jammed back against the upper portion **72** of the leg. With the leg suspended, a surgeon can view the tibial bearing insert **294** (FIG. **29**) and the femoral component **290** to determine how the femoral and the tibial implants cooperate with each other and the ligaments, tendons, joint capsule and other tissues.

The knee portion **76** may be flexed and extended, by moving the lower portion of the leg **70** along the path indicated by arrow **259** in FIG. **25**. In addition, the lower portion **68** of the leg **70** may be moved sideways, that is, laterally and/or medially, as indicated by arrow **260** in FIG. **25**, to check for the occurrence of slight openings between the tibial bearing insert **294** (FIG. **29**) and femoral component **290**. The lower portion **68** of the leg can also be rotated about its longitudinal central axis, in the manner indicated by the arrow **258** in FIG. **25**. By simultaneously applying a combination of rotational, sideward, and flexion or extension motion to the lower portion **68** of the leg **70**, the surgeon can view the interaction between the tibial bearing insert **294** (FIG. **29**) and femoral component **290** through the entire range of movement of the leg **70**, including movement having rotational components.

By manually feeling resistance to flexion, rotational and/or sideward movement of the lower portion **68** of the patient's leg **70** (FIG. **25**), the surgeon can check the balancing of ligaments and other tissues in the knee portion **76** of the leg. In addition, the surgeon can check the manner in which relative movement occurs between the tibial bearing insert **294** and femoral component **290** (FIG. **29**). If a check of the rotational alignment of the femoral and tibial implants indicates that they are misaligned, the surgeon can change the rotational positions of the implants. If the ligaments are too tight medially or laterally, the surgeon can release the ligaments to the extent necessary. Ligaments which are too loose can be tightened. Since the lower portion **68** of the leg **70** is suspended, the surgeon can feel the effects of any ligamentous imbalance and take corrective action.

In contrast to the present invention, the majority of knee arthroplasties are done with the leg in a fixed position. Surgeons do not flex and extend through progressive intervals. As the above discussion illustrates, one aspect of the present invention involves controlling the position of the joint so that when the surgeon wants to work on the quadriceps mechanism the knee is in full extension. Similarly, when the surgeon wants to work on the tibia then he may be in more flexion, more toward 90-100°. The controlled positioning can be done in a leg alignment jig which allows reproducible holding positions that can be adjusted as desired. As previously noted, this can be achieved with electric motor, pneumatics, mechanical, or simple ratchets built on to a table, but allow precise positioning of the leg while surgeon goes from flexion to extension. There are existing leg holders, but these are very crude. Most surgeons simply use a sandbag and hold the leg in one position. This position is not precisely controlled, and therefore, somewhat variable. The soft tissue sleeve and relaxation is critical as one goes from flexion to extension, is more relaxed depending on which portion of the joint you want to expose, varying from flexion to extension. Certainly, quadriceps mechanism is the most relaxed in full extension, tighter against the femur in flexion. The tibia exposure may be improved in flexion, but controlling the specific amount of flexion/extension, locking this into position while the cuts are being performed sequentially and precisely is of significant value.

A portion of the foregoing check of ligamentous balancing may be performed with the patella **120** offset to one side of the incision **114**, in the manner illustrated in FIG. **29**. This enables the surgeon to have a clear view of the tibial bearing insert **294** and femoral component **290** through the open incision **114**. After conducting a complete check of the ligamentous balancing with the patella **120** offset to one side of its natural position, the patella can be moved back to its natural position.

When the patella **120** is moved back to its natural position, the incision **114** closes so that there is little or no exposure of the tibial bearing insert **294** and femoral component **290** to the view of the surgeon. However, the surgeon **106** can move the lower portion **68** of the leg **70** with flexion/extension motion, indicated by the arrow **259** in FIG. **25**, and/or rotational motion, indicated by the arrows **258**, or sideways motion indicated by arrows **260**. During this motion of the lower portion **68** of the leg **70**, the surgeon can check the manner in which the patella **120** interacts with the tibial and femoral implants and other tissues in the knee portion **76** of the patient's leg. By providing combinations of the foregoing rotational and flexion/extension motion of the lower portion of the leg **70**, the manner in which the patella **120**, with or without an implant thereon, tracks relative to the tibial and femoral implants can be readily checked.

In the foregoing description, the patella **120** was repaired after making the femoral and tibial cuts and before trials. However, it is contemplated that the patella **120** may be repaired after trials and after installation of the implants **286**, **290** and **294**. Of course, the patella **120** may not need to be repaired and will be maintained in its original condition.

It is contemplated that fluid operated devices may be utilized to release ligaments or other tissue. The fluid operated devices may be utilized to apply force to tissue to move tissue relative to a bone, to expand the tissue, or to lengthen the tissue. For example, a balloon or bladder may be placed between tissue at the posterior of the knee portion **76** prior to mounting of the implants **286**, **290** and **294**. The balloon may be inflated with gas or the bladder filled with liquid to move tissue relative to the distal end portion **124** of the femur **126** and relative to the proximal end portion **212** of the tibia **214**. The balloon or bladder may be used to move tissue before or after making of the femoral and/or tibial cuts. The balloon or bladder may be used to move tissue before or after the trial implants are positioned in the knee portion **76**. The balloon or bladder may be used to move tissue before or after the implants **286**, **290** and **294** are positioned in the knee portion **76**.

The balloon or bladder may be formed of biodegradable or non-biodegradable material. If the balloon or bladder is formed of biodegradable material, it may be left in the knee portion during and after closing of the incision **114**. Of course, the biodegradable balloon or bladder will eventually be absorbed by the patient's body. In this regard, a narcotic or other medicament may be incorporated in the material in the balloon or the fluid used to expand the balloon. This provides a gradual time release of the medicament as the balloon degrades. Regardless of whether the device is biodegradable, capsular tightening and capsular tissue can be expanded or stretched. In the device is left in postoperatively, the balloon or bladder provides for hemostasis and maintenance of the soft tissue sleeve to improve flexion/extension.

It is contemplated that fluid operated retractors, expanders, and/or dissectors may be used to retract, expand or dissect body tissue. For example, retractors having a construction similar to any one of the constructions disclosed in U.S. Pat. No. 5,197,971 may be utilized to release tissue at locations spaced from the incision **114**. When tissue is to be released at locations where there is limited accessibility from the incision **114**, a device similar to any one of the devices disclosed in U.S. Pat. No. 5,295,994 may be utilized. It is believed that devices similar to those disclosed in U.S. patent application

Ser. No. 09/526,949 filed Mar. 16, 2000 may be used in ways similar to those disclosed therein to move and/or release body tissue.

While the lower portion **68** of the leg **70** is suspended from the upper portion **72** of the leg and while the upper portion of the leg is held above the support surface **64** by the leg support **80**, the incision **114** in the knee portion **76** of the leg **70** is closed. Prior to closing of the incision **114**, the incision is thoroughly drained. Tissues in the knee portion **78** are then interconnected using a suture or other suitable devices. The soft tissues are closed in a normal layered fashion.

Review

With the exception of the procedure on the patella **120** (FIG. **7**), all of the foregoing procedures may be performed with the leg **70** of the patient in the orientation illustrated in FIGS. **2**, **3** and **25**. Thus, with the exception of procedures on the patella **120**, all of the foregoing procedures may be conducted with the lower portion **68** of the leg **70** suspended from the upper portion **72** of the leg.

The incision **114** (FIG. **7**) was made in the knee portion **76** of the leg **70** with the lower portion **68** of the leg suspended. Similarly, the incision **114** in the knee portion of the leg **70** was closed with the lower portion **68** of the leg suspended from the upper portion **72** of the leg. Thus, from the making of the incision **114** in the knee portion **76** of the leg **70** through the closing of the incision, the lower portion **68** of the leg is almost continuously extended downward from the upper portion **72** of the leg and the foot **74** was below the support surface **64**. In addition, the upper portion **72** of the leg was supported above the support surface **64** by the leg support **80**. Only during everting of the patella **120** (FIG. **7**) and resecting of the patella to receive an implant was the leg **70** of the patient in an extended or straightened orientation. However, the leg **70** of the patient could be extended or straightened at any time the surgeon desires during the foregoing procedure.

Throughout the entire procedure, the drapery system **100** (FIGS. **4** and **5**) maintained a sterile field between the surgeon **106** and the patient. As the surgeon moved between seated and standing positions and moved toward or away from the patient, the drape **102** would rise or fall. Thus, when the surgeon **106** moves from the seated position of FIG. **4** to the standing position of FIG. **5**, the drape **102** tends to rise upward with the surgeon. Similarly, when the surgeon moves from the standing position of FIG. **5** back to the seated position of FIG. **4**, the drape **102** tends to move downward. The drape **102** will tend to move upward as the surgeon moves away from the leg **70** of the patient and will tend to move downward as the surgeon moves toward the leg **70** of the patient. Although it is preferred to use the drapery system **100** illustrated in FIGS. **4** and **5** and the various other embodiments described in connection with these figures, it is contemplated that a different drapery system could be utilized if desired.

It is believed that it will be particularly advantageous to utilize down sized instrumentation in performing the foregoing procedures on the knee portion **76** of the patient. The femoral alignment guide **134** (FIGS. **10-15**), anterior resection guide **138** (FIGS. **10-13**), resection guide stand **190** (FIG. **16**), distal resection guide **186** (FIGS. **16-18**), and tibial resection guide **218** (FIG. **21**) all have sizes which are two thirds (⅔) of their normal sizes or smaller. However, the various down sized instrumentation components of FIGS. **9-21** can be utilized in their normal manner and have generally known constructions. Thus, the instrumentation of FIGS. **9-21**, with the exception of being down sized, is generally similar to known instrumentation which is commercially available from Howmedica Osteonics Corp. of Rutherford, N.J. under the trademark "Scorpio" single access total knee system.

As was previously mentioned, it is contemplated that extramedullary and/or intramedullary instrumentation could be utilized if desired. Although it is believed that it may be preferred to use instrumentation which is anteriorly based, it is contemplated that posteriorly based instrumentation systems could be used if desired. Additionally and as described below, lateral or medial based instrumentation could be used if desired. The present invention also envisions combinations of these various instrumentations.

In the foregoing description, the saw **172** and blade **170** (FIG. **15**) were utilized to make cuts in various bones in the knee portion **76** of the leg **70** of the patient. The saw **172** and blade **170** may be of either the oscillating or reciprocating type. However, it is contemplated that other known cutting instruments could be utilized. For example, a milling device could be utilized to form at least some of the cuts. Alternatively, a laser or ultrasonic cutter could be utilized in making some of the cuts. It is believed that it may be particularly advantageous to utilize a laser or ultrasonic cutter to initiate the formation of a cut and then to utilize a saw or other device to complete the cut.

It is contemplated that either extramedullary or intramedullary instrumentation having a construction which is different than the illustrated construction could be utilized. For example, the anterior resection guide **138** FIGS. **10**, **11** and **12** has a guide surface **178** which is formed by a slot through which the saw blade extends. If desired, the guide surface **178** could be provided on an end face without providing for capturing or holding of the saw blade **170** in a slot.

The instrumentation may be entirely or partially formed of light weight polymeric materials which are relatively inexpensive. A femoral cutting guide **210** has a size which corresponds to the size of the specific femoral component **290** which is to be installed on the distal end portion **124** of a femur **126**. An inexpensive femoral cutting guide **210**, formed of polymeric material, may be packaged along with a femoral component **290** of the same size. After the femoral component **290** is installed, the femoral cutting guide **210** may be discarded. This would minimize investment in instrumentation and would tend to reduce the cost of handling and/or sterilizing cutting guides. The result would be a reduction in cost to the patient.

It is contemplated that the use of guide members, corresponding to the anterior resection guide **138** of FIG. **11**, the distal resection guide **186** of FIG. **16**, and the tibial resection guide **218** of FIG. **21** could be eliminated if desired. If this was done, positioning of a saw blade or other cutting device could be provided in a different manner. For example, light forming a three dimensional image, such as a hologram, could be projected onto the distal end portion **124** of the femur **126**. The three dimensional image would have lines which would be visible on the surface of the end portion **124** of the femur **126**. The saw cut would be formed along these lines. Alternatively, robot type devices having computer controls could be utilized to form the cuts without using guide members.

It is contemplated that emitters, receivers, and/or reflectors of computer navigation systems could be pinned or otherwise attached onto the femur **126** and tibia **214** to provide cutting positions and to facilitate ligament balancing through relatively small incisions. The computer navigation system may utilize three or four separate registers which have optical feedback to a central unit. The computer navigation system may utilize electromagnetic or photo-optical feedback.

It is contemplated that various known structures could be utilized in association with the leg **70** of the patient during performing of one or more of the procedures described herein. For example, the apparatus disclosed in U.S. Pat. No. 5,514,143 could be connected with the leg **70** of the patient and used to control flexion and extension of the leg. Since the apparatus disclosed in U.S. Pat. No. 5,514,143 includes separate femoral and tibial sections, it is believed that this apparatus may be particularly well adapted for use with the leg of the patient in the orientation illustrated in FIGS. **2**, **3** and **25**. This apparatus does not interfere with distraction of the knee portion **76** and can accommodate flexion and extension of the leg **70** of the patient.

The foregoing description has primarily referred to a full knee replacement. However, it is contemplated that the apparatus and procedures disclosed herein may be utilized in association with a revision or partial knee replacement. For example, the method and apparatus disclosed herein could be utilized in association with a unicompartmental knee replacement of the type disclosed in the aforementioned U.S. Pat. No. 5,514,143. The method and apparatus disclosed herein could be utilized in association with a revision of a previously installed full or partial knee replacement. It is also contemplated that the procedures disclosed herein and apparatus similar to the apparatus disclosed herein may be utilized with many different types of joints. For example, the procedures and apparatus may be utilized in association with a joint in an arm, shoulder, spine or hip of a patient.

Support Assembly

In accordance with one of the features of the invention, a support assembly **330** (FIG. **30**) is provided for the lower portion **68** of the leg **70** of the patient. Rather than support the foot **74** of the patient on the knee **252** of the surgeon (FIG. **24**), as previously described herein, the support assembly **330** may be utilized. The support assembly **330** includes a flat surface **332** which engages the foot of the patient. A pneumatically actuated piston and cylinder assembly **334** is operable to raise and lower the foot **74** of the patient in the manner indicated schematically by an arrow **336** in FIG. **31**. Mechanisms other than pneumatics, such as a motor, could be used to control piston and cylinder assembly **334**.

When the knee portion **76** of the leg **70** is to be distracted, the piston and cylinder assembly is operated to lower the surface **332** and foot **74** of the patient. As this occurs, the weight transferred from the foot **74** of the patient to the support surface decreases until the support surface **332** is below and spaced from the foot **74**. Similarly, when the extent of distraction of the knee portion **76** is to be decreased, the piston and cylinder assembly **334** is operated to raise the support surface **332** and foot **74** of the patient.

By providing a flat support surface **332**, the lower portion **68** of the leg of the patient may be rotated about its longitudinal central axis relative to the upper portion **72** of the leg of the patient when the support assembly **330** is being utilized to at least partially support the lower portion **68** of the leg of the patient. However, it is contemplated that a foot holder could be provided in place of the flat surface **332**. The foot holder would have the advantage of being able to hold the foot **74** of the patient in a desired orientation relative to the upper portion **72** of the leg **70** of the patient. The foot holder could be constructed so as to have a pneumatically (or other) actuated drive to rotate the foot **74** about the longitudinal central axis of the leg **70** and/or lower portion **68** of the leg **70** of the patient.

The support surface **332** is raised and lowered by operation of the piston and cylinder assembly **334**. Therefore, operation of the piston and cylinder assembly **334** is effective to move the lower portion **68** of the leg **70** of the patient in the directions of the arrow **256** in FIG. **25**. It is contemplated that a drive assembly could be connected with the support surface **332** to rotate the support surfaces about a vertical axis. The drive assembly may include a rack and pinion drive arrangement or a worm and wheel drive arrangement. By rotating the support surface **332** about a vertical axis relative to the piston and cylinder assembly **334**, movement of the lower portion **68** of the leg **70** in the directions of the arrow **258** in FIG. **25** would be facilitated.

Percutaneous Instrumentation Mounting

In accordance with another feature of the invention, it is contemplated that the size of the incision **114** may be reduced by connecting one or more of the guide members with one or more bones through the skin of the patient. For example, the anterior resection guide **138** (FIGS. **10** and **11**), distal resection guide **186** (FIG. **16**), femoral cutting guide **210** (FIGS. **19** and **20**), and/or tibial resection guide **218** (FIG. **21**) could be mounted on the outside of the leg **70** and connected with bone in either the upper portion **72** or the lower portion **68** of the leg **70** of the patient. This would minimize or even eliminate the necessity of moving the guide through the incision **114** into engagement with the bone. It would also minimize or even eliminate the necessity of sizing the incision **114** so as to accommodate the guide.

For example, the distal resection guide **186** (FIGS. **16-18**) is illustrated schematically in FIG. **31** as being mounted outside of the upper portion **72** of the leg **70** of the patient. The distal resection guide **186** is illustrated in FIG. **31** as being disposed in engagement with an outer surface of skin **342** which encloses the distal end portion **124** of the femur **126**. The distal resection guide **186** is mounted directly outward of the flat anterior cut surface **182** formed on the distal end portion **124** of the femur **126**. The skin **342** and other body tissue extends between the distal resection guide **186** and the distal end portion **124** of the femur **126**.

The distal resection guide **186** is connected with the femur **126** by the pins **196** and **198**. The pins **196** and **198** extend through the distal resection guide **186** and the skin **342** into the femur **126**. The pins **196** and **198** extend through the flat anterior cut surface **182** into the femur **126** and hold the distal resection guide **186** against movement relative to the femur **126**.

Although a distal resection guide **186** has been illustrated in FIG. **31**, it is contemplated that an anterior resection guide, corresponding to the anterior resection guide **138** of FIG. **11** could be mounted in a similar manner. If this were done, the anterior resection guide **138** would have a generally L-shaped configuration with a body portion which would extend along the outer surface of the skin **342** (FIG. **31**). Pins, corresponding to the pins **196** and **198** of FIG. **31**, would extend through the relatively long body portion of the generally L-shaped anterior resection guide **138**, through the skin **342** and into the femur **126**.

The short leg of the L-shaped anterior resection guide **138** would be positioned adjacent to the distal end portion **124** of the femur **126**. The short leg of the anterior resection guide would have a guide surface aligned with the distal end portion **124** of the femur **126** at a location corresponding to the location where the flat anterior cut surface **182** is to be formed. This guide surface could be of the slot or capture type illustrated in FIG. **14**. Alternatively, the guide surface could be formed on a flat end face of the anterior resection guide. This would result in elimination of the slot commonly utilized to capture a saw blade or other cutting instrument. By having a portion of the anterior resection guide disposed outside of the incision **114** and connected with the femur **126** through the skin **342**, the size of the incision **114** tends to be minimized.

In addition to the aforementioned guides associated with the femur **126**, it is contemplated that a guide associated with the tibia **214** (FIG. **21**) could be connected with the tibia by pins extending through the skin **342**. For example, the tibial resection guide **218** could be placed in abutting engagement with skin which overlies the proximal end portion **212** of the tibia **214**. Suitable pins would extend through the tibial resection guide **218** (FIG. **21**) and through the skin **342** (FIG. **31**) into engagement with the distal end portion **212** of the tibia. Although it may be preferred to provide a tibial guide surface **242** of the slot type illustrated in FIG. **22**, it is contemplated that only a single guide surface could be provided on a flat end portion of the tibial resection guide if desired.

Inspection

It is contemplated that at various times during the performance of the foregoing procedures, it may be desired to inspect locations remote from the incision **114**. Thus, it may be desired to visually ascertain the condition of soft tissue in the posterior of the knee portion **76**. In addition, it may be desired to visually check the condition of the collateral ligaments or soft tissue adjacent to the ligaments. The inspections may be conducted before or after the making of femoral and tibial cuts, before or after trials, and/or before or after installation of the implants **286**, **290** and **294**.

In accordance with another feature of the invention, locations remote from the limited incision may be visually inspected. To inspect locations remote from the incision **114**, a leading end portion **350** (FIG. **32**) of an endoscope **352** can be inserted through the incision **114** and moved to the posterior of the knee portion **76**. Alternatively, the leading end portion **350** of the endoscope **352** can be inserted through a smaller stab wound incision. A camera **354** transmits an image to a monitor **356**. The surgeon **106** can then view images of the posterior of the knee portion **76** transmitted through the endoscope **352**. The upper portion **72** of the leg **70** is supported by the leg support **80**. The leg **70** is shown in FIG. **32** in the same position illustrated in FIGS. **2** and **3**.

In order to provide the surgeon **106** with information as to how the femoral and tibial implants **286**, **290** and **294** interact with tissues in the knee portion **76**, the leg **70** of the patient may be bent between the flexed condition of FIG. **32** and the extended condition of FIG. **33**. In addition, the lower portion **68** of the leg **70** may be rotated about its longitudinal central axis, in the manner indicated by the arrow **258** in FIG. **25**. During bending of the knee portion **76**, the surgeon views images of the posterior knee portion transmitted through the endoscope **352** to the monitor **356**. This enables the surgeon to detect any present or potential interference of tissue in the knee portion **76** with the full range of motion of the knee portion. During relative movement between the femur **126** and tibia **214**, the surgeon can view the manner in which the femoral and tibial implants interact with each other and the tissue in the joint capsule.

It is contemplated that the end portion **350** of the endoscope **352** will be moved so as to enable the surgeon **106** to view the collateral ligaments, particularly the ligament on the lateral side of the knee portion **76**, during bending of the knee portion. Although the endoscope **352** is illustrated in FIGS. **32** and **33** as being utilized after the femoral and tibial implants **286**, **290** and **294** have been connected with the femur **126** and tibia **214**, it is contemplated that the endiscope will be utilized prior to cutting of the femur and tibia, after cutting of the femur and tibia and prior to trials, after trials, and/or during trials.

It is contemplated that the endoscope **352** may be inserted into the knee portion **76** of the patient at a location other than through the incision **114**. Thus, if desired, a separate, very small portal or puncture type incision could be formed in the knee portion **76** of the leg of the patient at a location adjacent to a location where it is desired to visually inspect the knee portion of the patient. Although it is believed that it will be desired to inspect the knee portion **76** of the patient while there is relative movement between the femur **126** and tibia **214**, it should be understood that the endoscope **352** could be utilized to inspect the knee portion **76** while the femur **126** and tibia **214** are stationary relative to each other.

Although an endoscope **352** is illustrated in FIGS. **32** and **33**, it is contemplated that other known devices could be utilized to inspect knee portion **76**. Thus any desired fiber optic type instruments may be utilized to inspect the knee portion **76**. For example any of the known instruments associated with arthroscopic surgery could be utilized to inspect the knee portion **76**.

Generation of Images and Robotic Device

In accordance with another feature of the invention, during performance of surgery on a knee portion **76** of a patient's leg **70** (FIG. **34**), a known C-arm fluoroscope **360** or other imaging system is utilized to generate images of the knee portion **76** of the leg **70** during movement of the lower portion **68** of the leg relative to the upper portion of the leg. Images are transmitted in any fashion from the C-arm fluoroscope **360** to a control unit **362**. Video images are transmitted from the control unit **362** to a video screen **364** which is viewable by the surgeon **106** during surgery on the knee portion **76** of the leg **70**. A continuous display of images is projected in rapid succession on the screen illustrating the knee portion **76** of the leg **70** when the lower portion **68** of the leg is in various positions relative to the upper portion of the leg.

Thus, during flexion and/or extension of the leg **70**, video images are transmitted to the screen **364** to enable a surgeon to view images of the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** during bending of the knee portion. The video display of images may be undertaken prior to forming of the incision **114** to enable the surgeon to view the manner in which components of the knee portion **76** interact prior to surgery. After the incision **114** has been made, the images provided on the video screen **364** enable the surgeon to visually determine the relationship between the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** after the patella **120** has been moved to an offset position and prior to initiating any cuts on the bones in the patient's leg **70**.

After cuts have been made on the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** in the manner previously explained, the lower portion **68** of the patient's leg can be moved relative to the upper portion **72** of the patient's leg. The images provided on the video screen **364** will enable a surgeon to better understand the relationship between the femur, tibia, and ligaments in the patient's leg during preliminary checking of ligament balancing after the distal end portion **124** of the femur **126** has been cut and after the proximal end portion **212** of the tibia **214** has been cut.

During trials when trial tibial and femoral components have been temporarily connected with the femur **126** and tibia **214**, the images provided at the video screen **364** will enable the surgeon to better evaluate the interaction between the trial components and body tissue in the knee portion **76** of the patient's leg **70**. Once the trials have been completed and the femoral and tibial implants **286**, **290** and **294** positioned on the femur **126** and tibia **214**, the images provided at the video screen **364** will enable the surgeon to evaluate the relationship between the femoral and tibial implants.

During ligamentous balancing, images provided at the video screen **364** will indicate to the surgeon whether or not there is any undesired relative movement between the femoral and tibial implants. It is contemplated that the images be transmitted from the control unit **362** to the video screen **364** during movement of the lower portion **68** of the patient's leg **70** in any one or a combination of the directions indicated by the arrows **256**, **258**, **259** and **260** in FIG. **25**. Once the surgeon, with the assistance of images provided at the video screen **364**, is satisfied that the femoral and tibial implants **286**, **290** and **294** have been correctly positioned in the knee portion **76** of the patient's leg **70**, the incision **114** is closed.

The general construction and mode of operation of the C-arm fluoroscope **360** (FIG. **34**) and control unit **362** is the same as is disclosed in U.S. Pat. Nos. 5,099,859; 5,772,594; 6,118,845 and/or 6,198,794. However, it is contemplated that other known image generating devices could be utilized in place of the fluoroscope if desired. For example, an image generating device similar to a magnetic resonance imaging unit (MRI) could be utilized.

In accordance with still another feature of the invention, a robot **370** (FIG. **34**) is provided to perform cutting and/or implant placement operations on the knee portion **76** in the leg **70** of a patient. The robot **370** includes a base **372**. A support column **374** is moveable vertically relative to the base **372**, in a manner indicated by arrows **376** in FIG. **34**. In addition, the support column **374** is rotatable about coincident longitudinal central axes of the base **372** and support column in a manner indicated schematically by arrows **378** in FIG. **32**. A main arm **382** is pivotally attached to an upper end portion of the support column **374**. Motors and controls **386** are connected with the main arm **382**. The main arm is pivotal relative to the support column **374** in the manner indicated by arrows **388** in FIG. **34**.

A secondary arm **390** is pivotally mounted on an outer end portion of the main arm **382**. The secondary arm **390** is pivotal relative to the main arm **382** in the manner indicated by arrows **392**. A mounting section **396** is rotatable about a longitudinal central axis of the secondary arm **390** and has a mounting flange which is rotatable about an axis which extends perpendicular to the longitudinal central axis of the secondary arm **390**.

It is contemplated that a cutting tool, such as the saw **172**, may be mounted on the mounting section **396**. Controls for the robot **370** effect movement of the saw relative to the distal end portion **124** of the femur **126** to form the anterior cut surface **182** on the femur and to form a distal end cut on the femur. In addition, the robot **370** moves the saw to form chamfer cuts on the distal end portion **124** of the femur **126**.

The robot **370** may also be utilized to move the saw to make the cuts to form the proximal end portion **212** of the tibia **214**. Thus, the robot may be utilized to form the proximal tibial cut surface **246** (FIG. **22**).

By using the robot **370** to move the saw to form the cuts on the distal end portion **124** of the femur **126** and on the proximal end portion **212** of the tibia **214**, the need for instrumentation, such as the femoral alignment guide **134** and anterior resection guide **138** of FIG. **11**, the distal resection guide **186** of FIGS. **16** and **18**, and the tibial resection guide **218**, is eliminated. Controls for the robot **370** are connected with the C-arm fluoroscope **360** to enable the position of the saw relative to the femur and tibia to be viewed by the surgeon during an operation.

The robot **370** may have any one of many different constructions. Specifically, it is contemplated that the robot **370** may have the same construction as is disclosed in U.S. Pat. No. 5,154,717. Alternatively, the robot **370** could have the construction disclosed in U.S. patent application Ser. No. 09/789,621 filed Feb. 21, 2001 by Peter M. Bonutti. However, it should be understood that other known robots could be utilized if desired. For example, a robot similar to the known "Robo Doc"™ could be utilized.

It is contemplated that a computer navigation system may be used with the robot **370** to guide movement of a cutting tool, such as a saw or milling cutter, relative to the tibia and femur in the leg **70** of the patient. Two or more locating devices are connected with the distal end portion **124** of the femur **126**. In addition, two or more locating devices are connected to the proximal end portion of the tibia **214**. The locating devices cooperate with motors and computer controls **386** for the robot **370** to provide the robot with information as to the position of the mounting section **396** and cutting tool relative to the femur **126** and tibia **214**.

The locating devices may be of the reflective or energy emitting type or energy receiving type. For example, three reflectors may be pinned onto the distal end portion **124** of the femur **126**. Similarly, three reflectors may be pinned onto the proximal end portion **212** of the tibia **214**. Light transmitted from the robot **370** to the reflectors on the femur and tibia is reflected back to photo cells on the robot to enable the robot to determine the positions of the femur and tibia. Rather than using reflectors, energy emitting devices may be pinned onto the femur **126** and tibia **214**. The energy emitting devices may emit either light or radio waves.

The above-described image guided surgery system is merely intended to be representative of the type of system that can be used with the present invention. However, it should be understood that other known image guided surgery systems, both in conjunction and independent of robotic systems, could be utilized if desired. Examples of commercially available systems include systems the Z-KAT (Hollywood, Fla.) suites, the MEDIVISION system (Oberdorf, Switzerland), the STEALTH NAVIGATOR system (Louisville, Colo.), and the ORTHOPILOT System (Tuttlingen, Gemany).

It should also be understood that the robot **370** could have any one of many different constructions. It is also contemplated that the robot **370** could interact with a surgeon and patient in many different ways. For example, the robot could have a plurality of articulate arms which are controlled by the surgeon. Images provided by the fluoroscope **360** would enable the surgeon to control the articulate arms. Locating devices connected with the femur and tibia are visible to the surgeon in images provided by the fluoroscope **360**. Computer controls which respond to the locating devices provide information to the surgeon about cutting tools and/or other instruments being moved by the articulate arms. The surgeon operated controls, the articulate arms, and the fluoroscope or other imaging device may cooperate in the manner disclosed in U.S. Pat. Nos. 6,063,095 and 6,102,850 if desired.

It is believed that it may be desired to use a hologram to provide a three-dimensional optical image of cuts to be made. The three-dimensional image would be projected onto the end portion **124** of the femur **126** and/or onto the end portion **212** of the tibia **214**. The three-dimensional image may be lines indicating where the femur **126** and/or tibia **214** are to be cut.

The three dimensional image would allow a surgeon **106** to visually monitor operation of the robot **370** during the making of cuts. If there was even a small discrepancy, the surgeon **106** could interrupt operation of the robot and take corrective action. It is believed that the projecting of a three-dimensional image onto surfaces to be cut will be particularly advantageous when a robotic system which has surgeon operated articulate arms is utilized. The projection of a hologram generated three-dimensional image would enable a surgeon to visually determine whether or not a robotic system, similar to the system disclosed in U.S. Pat. Nos. 6,063,095 or 6,102,850, is being operated properly.

Patellar Resection

In the foregoing description, the patella **120** was everted or flipped from its normal position to a position in which an inner side **122** of the patella faces outward (FIG. **7**). The patella **120** was then cut while it was in the everted position. A patellar implant was then mounted on the patella **120** in a known manner. The patella **120** was then returned to its normal position with the inner side of the patella facing inward toward the distal end portion **124** of the femur **126**. This is a well known manner of performing surgery on a patella to install a patellar implant.

In accordance with one of the features of the present invention and as discussed above, it is contemplated that the patella **120** will be cut and an implant positioned on the patella while the patella remains in a substantially normal position relative to the femur **126**. When the patella **120** is in its normal position relative to the femur **126** (FIG. **35**), an inner side **122** of the patella **120** is disposed adjacent to the distal end portion **124** of the femur **126**. The patella **120** is urged toward the trochlear groove **452** in the distal end portion **124** of the femur **126** by the patellar tendon **456** and the patellar ligament **458**. The patellar tendon **456** connects the patella **120** with the quadriceps femoris muscle. The patellar ligament **458** connects the patella **120** with the tibia **214**. The patellar tendon **456** and patellar ligament **458** may be referred to as fibrous connective tissue.

While the patella **120** is in the normal position illustrated in FIG. **35**, a guide assembly **464** (FIG. **36**) is positioned relative to the patella. The guide assembly **464** includes a main section **466** (FIG. **36**) with a slot **468** having guide surfaces along which a blade **170** of a saw **172** is moved. The main section **466** of the guide assembly **464** is positioned relative to the patella **120** by a pair of parallel arms **474** and **476**.

The arm **474** extends through the medially offset incision **114** and under the superior aspect **480** of the in situ patella **120**. The arm **476** extends through the incision **114** and under the inferior aspect **482** of the in situ patella **120**. By positioning the arm **474** under the upper end portion **480** of the patella and the arm **476** under the lower end portion **482** of the patella **120**, the guide surfaces in the slot **468** are accurately aligned with the patella **120** while the patella is in its normal position relative to the femur **126** and tibia **214** (FIG. **35**).

While the in situ patella **120** is urged toward the distal end portion **124** of the femur **126** by the patellar tendon **456** and the patellar ligament **458** (fibrous connective tissue), the saw **170** or other cutting tool cuts along a plane **484** (FIG. **35**) to form a flat surface on the inside of the patella **120**. A relatively thin layer on which the inner side **122** of the patella is disposed, is then removed from the patella **120**. A patellar prosthesis or implant is then mounted on the cut surface on the inside of the patella while the patella remains in its normal position. A suitable cement can be utilized to connect the implant with the patella. In addition, one or more projections may be provided on the inside of the implant to interconnect the implant and the patella in a known manner.

The guide assembly **464** can include inflatable bladders as an adjunct or replacement for arms **474** and **476**. These bladders would elevate the patella **120** to obtain access to inner side **122**. In this regard, U.S. Pat. No. 5,163,949 and progeny, such as U.S. Pat. Nos. 6,358,266 B1, 6,277,136 B1, and 6,187,023 B1, discloses various embodiments of retractors and method of dissecting tissue. These embodiments include fluid operated retractors, mechanical retractors, and combinations thereof. The retractors and methods disclosed in this line of patents, which is incorporated herein by reference, can be used for patella procedures and/or visualization while the patella is maintained in a substantially non-everted, anatomic position.

If desired, the patella **120** may be repaired before making cuts on the femur **126** and tibia **214**. Thus, immediately after making the incision **114**, the patella **120** may be cut while it is disposed in its normal position. An implant may then be mounted on the patella **120**. The surgically repaired patella **120** may then be moved to the offset position of FIG. **8**. The femoral and tibial cuts may then be made in the manner previously explained in association with FIGS. **8-25** and the tibial and femoral implants **286**, **290** and **294** mounted on the femur **126** and tibia **214** (FIGS. **27-29**) while the previously repaired patella is in the offset position.

Extramedullary Tibial Instrumentation

When a tibial resection guide **500** (FIGS. **37** and **38**) or the tibial resection guide **218** (FIG. **21**) is to be positioned relative to the proximal end portion **212** of the tibia **214**, an external tibial alignment guide **504** (FIG. **37**) may be used to position the tibial resection guide relative to the tibia **214**. The external tibial alignment guide **504** is disposed outside of the patient's leg **70** and extends along the lower portion **68** of the patient's leg. If desired, the patient's leg can be in the position illustrated in FIGS. **2**, **3**, and **25**.

The external tibial alignment guide **504** (FIG. **37**) includes a hollow distal shaft **508**. A proximal shaft **510** is telescopically received in the distal shaft **508**. When the proximal shaft **510** has been extended for a desired distance from the distal shaft **508**, a vertical adjustment knob **514** is tightened to hold the proximal shaft **510** against movement relative to the distal shaft **508**.

The foot or lower end portion of the hollow distal shaft **508** is connected with the mid-point between the palpable medial and lateral malleoli by a spring clamp **518**. The spring clamp **518** is aligned with the second metatarsal and grips the outside of the ankle portion **86** (FIG. **25**) of the patient's leg **70**. The proximal shaft **510** (FIG. **37**) of the external tibial alignment guide **504** is aligned with the medial third of the tibial tubercle. This results in the external tibial alignment guide **504** being positioned along the outside of the patient's leg with the longitudinal axis of the external tibial alignment guide **504** extending parallel to a longitudinal central axis of the tibia **214**.

A stylus **522** (FIG. **38**) is mounted on the tibial resection guide **500**. The stylus **522** engages the proximal end portion **212** of the tibia to position the tibial resection guide **500** relative to the tibia. The tibial resection guide **500** is connected to the proximal end portion **212** of the tibia by a single pin **524** (FIG. **38**) which extends through the tibial resection guide **500** into engagement with the proximal end portion **212** of the tibia **214**. The external tibial alignment guide **504** and the stylus **522** cooperate with the tibial resection guide **500** and pin **524** to hold the tibial resection guide against rotation.

Although the tibial resection guide **500** has been shown in FIG. **38** as being connected directly to the proximal end portion **212** of the tibia **214**, the tibial resection guide could be connected with proximal end portion **212** of the tibia **214** in different manner. Thus, in FIG. **38**, the posterior facing side of the tibial resection guide **500** is disposed in abutting engagement with the proximal end portion **212** of the tibia **214**. However, the posterior facing side of the tibial resection guide **500** could be positioned in engagement with skin which encloses the proximal end portion **212** of the tibia **214** in order to minimize the overall length of the incision **114**. This would result in the pin **524** extending through the tibial resection guide and through the skin and other tissue overlying the proximal end portion **212** of the tibia **214** into engagement with the proximal end portion of the tibia. The manner in which the tibial resection guide would be mounted on the tibia, would be similar to that disclosed in FIG. **31** for the distal resection guide **186**. However, the tibial resection guide **500** is secured in place by a single pin **524**, by the external tibial alignment guide **504**, and, to some extent at least, the stylus **522**.

The tibial resection guide **500** is medially offset from the external tibial alignment guide **504**. This is because the incision **114** (FIG. **6**) is disposed adjacent to the medial edge portion of the patella **120**. If desired, the incision **114** could be disposed adjacent to the lateral side of the patella **120**. If this was done, the tibial resection guide **500** would be laterally offset from the external tibial alignment guide **504**. Regardless of which direction the tibial resection guide **500** is offset, a portion of the tibial resection guide may be disposed beneath body tissue to minimize the size of the incision **114**.

In accordance with a feature of the apparatus of FIGS. **37** and **38**, the external tibial alignment guide **504** is maintained in position on the tibia **214** during cutting of the proximal end portion **212** of the tibia **214** in a manner similar to that illustrated in FIG. **21**. Maintaining the tibial alignment guide **504** in place during cutting of the proximal end portion **212** of the tibia **214**, enables the tibial alignment guide to be utilized to position the tibial resection guide **500** relative to the tibia **214**. This enables the tibial resection guide **500** to be connected to the tibia **214** by only the single pin **524**. In the past, a plurality of pins have been utilized to connect the tibial resection guide **500** with the tibia **214** in a manner similar to the disclosures in U.S. Pat. Nos. 5,234,433 and 5,643,272. It should be understood that the tibial alignment guide **504** and a tibial resection guide, similar to the tibial resection guide **500**, may be utilized during performance of a partial knee replacement in the manner disclosed in the aforementioned U.S. Pat. No. 5,234,433.

Since, the external tibial alignment guide **504** is maintained in position during cutting of the tibia, the saw blade **170** or other cutting tool must be angled around the proximal shaft **510** of the external tibial alignment guide **504** as the proximal end portion **212** of the tibia **214** is cut. During movement of the saw blade **170** (FIGS. **13** and **21**) along the guide surface **530** (FIG. **38**), only an initial portion of the cut in the proximal end portion **212** of the tibia is made. This is because the proximal shaft **510** of the external tibial alignment guide **504** partially blocks the saw blade **170**. In addition, the tibial resection guide **500** is down sized.

Opposite ends **534** and **536** of the tibial resection guide **500** are space apart by a distance less than two thirds (⅔) of the distance between tips of lateral and medial epicondyles **236** and **238** (FIG. **38**) on the proximal end portion **212** of the tibia **214**. Therefore, after an initial portion of the cut across the proximal end portion **212** of the tibia **214** has been made while moving the saw blade **170** along the guide surface **530**, the tibial resection guide **500** and external tibial alignment guide **504** are disconnected from the tibia **214**. The tibial cut is then completed.

During completion of the tibial cut, the guide surface **530** on the resection guide **500** is not in position to guide the saw blade **170**. Therefore, cut surfaces formed during the making of the initial portions of the tibial cut are utilized to guide the saw blade. When the tibial cut is to be completed the saw blade **170** is inserted into a slot or kerf formed in the distal end portion **212** of the tibia **214** by the saw blade **170** as it moved along the guide surface **530** and made the initial portion of the tibial cut. During completion of the tibial cut, the cut surfaces which were formed on the proximal end portion **212** of the tibia **214** during the initial portion of the tibial cut are used to guide movement of the saw blade.

The tibial resection guide **218** of FIG. **21** has a guide surface **242** formed by a closed ended slot. The tibial resection guide **500** of FIG. **38** has a guide surface **530** formed by an open ended slot. Thus, the tibial resection guide **500** includes a slot **540** which has an open end **542**. The open end **542** of the slot **540** facilitates movement of the saw blade **170** along the slot and angling of the saw blade relative to the slot to maximize the extent of the initial portion of the tibial cut. Thus, the extent of the tibial cut formed during movement of the saw blade along the guide surface **530** on the tibial resection guide **500** is maximized by forming the slot **540** with the open end **542** so that the saw blade can be angled at the open end **542** of the slot.

The tibial resection guide **500** may be used with a first cutting tool during making of the initial portion of the tibial cut. A second cutting tool may be used to complete the tibial cut. For example, a relatively small blade **170** of an oscillating saw **172** may be used to make the initial portion of the tibial cut. A relatively long blade of a reciprocating saw may be used to complete the tibial cut. If desired, a chisel and/or milling cutter could be used to make the initial portion and/or final portion of the tibial cut.

It is contemplated that it may be desired to set the tibial resection guide **500** (FIG. **37**) for any one of a plurality of different resection levels. Thus, the tibial resection guide **500** could be set to make a tibial cut at a distance of two millimeters from a location on the proximal end portion **212** of the tibia **214** which is engaged by the stylus **522**. Alternatively, the tibial resection guide **500** could be utilized to make a cut at a distance of eight millimeters from the location where the stylus **522** engages the proximal end portion **212** of the tibia **214**. Of course, the greater the distance at which the tibial cut is made from the location where the stylus **522** engages the proximal end portion **212** of the tibia **214**, the greater will be the thickness of a layer of bone removed from the distal end portion **212** of the tibia **214**.

To facilitate movement of the tibial resection guide **500** between various depths, the stylus **522** includes a drive assembly **548** (FIG. **38**). The drive assembly **548** is actuated by rotating a knob **550** on the stylus. Rotation of the knob **550** through a predetermined distance, that is, one complete revolution, will cause the drive assembly **548** to move the tibial resection guide **500** for a predetermined distance along the proximal shaft **510** of the external tibial alignment guide **504**. Thus, rotation of the knob **550** for one complete revolution in a clockwise direction, viewed from above, is effective to move the tibial resection guide **500** through a distance of two millimeters downwards along the proximal shaft **510** of the external tibial alignment guide. Of course, this would increase the depth of the tibial cut by a distance of two millimeters. Similarly, rotating the knob **550** through two complete revolutions is effective to actuate the drive assembly

548 to move the tibial resection guide 500 downward (as viewed in FIG. 39) along the proximal shaft 510 of the external tibial alignment guide 504 through a distance of four millimeters.

The drive assembly 548 includes an externally threaded member which is connected with the knob 550. An internally threaded member is connected with the tibial resection guide 500. The internally threaded member engages the externally threaded member and is held against axial and rotational movement relative to the tibial resection guide 500.

After the tibial resection guide 500 has been moved to a desired position relative to the proximal end portion 212 of the tibia 214, a locking knob 556 is rotated to actuate a lock screw to hold the tibial resection guide 500 against movement along the proximal shaft 510 of the external tibial alignment guide 504. The pin 524 is then inserted through the tibial resection guide 500 into the proximal end portion 212 of the tibia 214.

Rather than moving the tibial resection guide 500 along the proximal shaft 510 of the external alignment guide 504 under the influence of force transmitted from the knob 550 through the drive assembly 548 to the tibial resection guide, the drive assembly could be connected with the knob 556. For example, the knob 556 could be connected with a pinion gear of a rack and pinion drive arrangement. The rack portion of the drive arrangement could be mounted on the proximal shaft 510. If this was done, rotation of the knob 556 would cause the rack and pinion gear set to move the tibial resection guide along the proximal shaft 510 through a distance which is a function of the extent of rotation of the knob 556. The stylus 552 would be connected to the tibial resection guide 500 and would engage the proximal end of the tibia 214 to indicate when the tibial resection guide 500 had moved to a desired position relative to proximal end portion 212 of the tibia.

It is contemplated that the stylus 522 could be eliminated if desired. The tibial resection guide 500 could be positioned by sliding a thin member, such as a blade, beneath tissue overlying the proximal end portion 212 of the femur 214. A reference surface on the tibial resection guide 500 would then be moved into engagement with the blade or other thin member. The reference surface may be disposed on the upper (as viewed in FIG. 38) end of the tibial resection guide 500 or may be disposed in a slot in the tibial resection guide. The reference surface may also be utilized to guide movement of a saw or other cutting tool.

If desired a hook or sickle shaped locating member could be extended from the tibial resection guide 500 to position the tibial resection guide relative to the proximal end portion 212 of the tibia 214. When the incision 114 and tibial resection guide 500 are medially offset relative to the tibia 214, the locating member would extend along the medial side of the proximal end portion 212 of the tibia. This would enable the stylus 522 to be eliminated.

It is contemplated that retractors may be mounted on the proximal shaft 510 of the external tibial alignment guide 504. The retractors engage opposite sides of the incision. The retractors are effective to expand the incision 114 and/or maintain the incision in a desired position relative to the proximal end portion 212 of the tibia 214.

Cannula

In accordance with another feature of the invention, access to the interior of the knee portion 76 of the leg 70 may be obtained through a cannula 564 (FIG. 39). The cannula 564 is inserted into the incision 114. If desired, the patient's leg 70 can be in the position shown in FIGS. 2, 3 and 25. The upper portion of the patient's leg is supported by the leg support 80.

The incision 114 is formed with a relatively short length in the manner previously described herein. The cannula 564 has an initial size, illustrated in FIG. 39, which stretches the viscoelastic material of tissues forming the knee portion 76 of the leg 70. Therefore, initial insertion of the cannula 564 into the incision 114 is effective to expand the incision.

Compact cutting tools, similar to those utilized for arthroscopic, endoscopic, or fiber optic assisted surgery may be at least partially moved through a passage 566 (FIG. 39) formed by an inner side 568 of the cannula 564. The cutting tools may have a construction similar to the construction illustrated in U.S. Pat. Nos. 5,540,695 or 5,609,603. Alternatively, the cutting tools may have a construction similar to the construction disclosed in U.S. patent application Ser. No. 09/483,676 filed Jan. 14, 2000 by Peter M. Bonutti and having a disclosure which corresponds to U.S. Pat. No. 5,269,785.

The cannula 564 is advantageously expandable to further stretch the viscoelastic tissue of the knee portion 76. Of course, expanding the cannula 564 increases the size of the passage 566 to enable a relatively large object to pass through the passage. Thus, the cannula 564 may be expanded to facilitate movement of the implants 286, 290 and 294 through the cannula. The leg 70 is in the position shown in FIGS. 2, 3 and 24 during expansion of the cannula and movement of objects through the passage 566.

It is contemplated that the expandable cannula 564 may have many different known constructions. The illustrated cannula 564 is formed of elastomeric material and has the same construction as is disclosed in U.S. patent application Ser. No. 08/470,142 filed Jun. 6, 1995 by Peter M. Bonutti, et al. and having a disclosure which corresponds to the disclosure in U.S. Pat. No. 5,961,499. It should be understood that the cannula 564 could have a different construction, for example, a construction similar to the constructions disclosed in U.S. Pat. Nos. 3,811,449 or 5,183,464.

The cannula 564 can be expanded in many different ways other than under the influence of force transmitted directly to the cannula from an object moving through the cannula. For example, the cannula may be expanded by force transmitted from an implant 286, 290 and/or 294 to the cannula. The cannula 564 may be expanded by inserting tubular members into the cannula. Alternatively, fluid pressure could be used to expand the cannula 564 in the manner disclosed in the aforementioned Bonutti, et al. patent application Ser. No. 08/470,142 filed Jun. 6, 1995.

Rather than being expanded by inserting the expandable cannula 564 into the incision 114, the incision may be expanded by utilizing pneumatic retractors. The pneumatic retractors may have a construction similar to the construction disclosed in U.S. Pat. No. 5,163,949. By utilizing the expandable cannula 564 or the expandable pneumatic retractors, force can be applied against opposite sides of the incision 114 to stretch the viscoelastic material disposed adjacent to opposite sides of the incision. This will result in the relatively small incision 114 being expanded to accommodate relatively large surgical instruments and/or implants.

Although a single incision 114 is illustrated in FIG. 39, it is contemplated that a plurality of incisions could be provided. Thus, a small incision may be spaced from the incision 114 to enable a cutting tool to be moved into the knee portion 76 along a path which is spaced from and may be transverse to a path along which a cutting tool is moved through the incision 114. A second cannula, which is smaller than the cannula 564, may be utilized with the second incision.

Implant with Interconnectable Portions

In order to enable surgery on a knee portion **76** of a patient's leg **70** to be conducted through an incision **114** of relatively small size, the implant may advantageously be formed in two or more portions (FIG. **40**). The portions of the implant are sequentially moved through the incision **114** into engagement with the distal end portion **124** of the femur **126** and/or the proximal end portion **212** of the tibia **214**. It is believed that having the implant formed as two or more portions will facilitate movement of the implant through the cannula **564** (FIG. **39**).

As the portions of the implant are sequentially moved through the incision **114**, they are positioned in engagement with one or more of the bones, that is, the femur **126** and/or the tibia **214** in the leg **70** of a patient. After the plurality of portions of the implant have been moved through the incision **114** and positioned in engagement with the femur **126** and/or tibia **214**, the portions of the implant are interconnected to form a unitary implant. If desired, the portions of the implant are moved through the incision **114** and interconnected while the leg of the patient is in the position illustrated in FIGS. **2**, **3** and **25**.

It is contemplated that the portions of the implant may be interconnected, while they are disposed in the patient's body and in engagement with either the femur **126** and/or tibia **214**, in many different ways. For example, the portions of the implant may be bonded together to form a one piece implant. The portions of the implant may be bonded together by the application of energy in anyone of many different forms to a joint between portions of the implant. For example, ultrasonic energy could be applied to the implant. Alternatively, heat could be directly applied to the implant. If desired, a laser could be utilized to effect bonding of separate portions of the implant together.

It is also contemplated that the separate portions of the implant could be mechanically interconnected. This could be done with a fastener which extends between portions of the implant. Alternatively, a retainer member such as a rod or bar could extend between portions of the implant. Regardless of how the portions of the implant are interconnected, the portions of the implant are interconnected after they have been moved into the patient's body.

In the embodiment of the invention illustrated in FIG. **40**, the femoral component **290** of an implant is formed as two separate portions **572** and **574**. The portion **572** of the implant **290** is moved through the incision **114** into engagement with the distal end portion **124** of the femur **126**. Thereafter, the portion **574** of the implant **290** is moved through the incision **114** into engagement with the distal end portion **124** of the femur **126**. After the two portions **572** and **574** of the femoral component **290** of the implant have been positioned in abutting engagement with the femur **126**, the two portions of the implant are interconnected at a joint **576** between the two portions of the implant. If desired, the portions **572** and **574** of the femoral component **290** of the implant may be moved through the cannula **564** of FIG. **39**.

The specific implant **290** illustrated in FIG. **40** has portions formed of a polymeric material which may be either a polymer or a co-polymer. The material of the two portions **572** and **574** of the implant **290** are heated at the joint **576** while the two portions of the implant are disposed in the patient's body in engagement with the femur **126**. As this occurs, the material forming the two portions **572** and **574** of the implant **290** is heated to a temperature within its transition temperature range and becomes tacky without changing its overall configuration. The two portions **572** and **574** of the implant **290** may be heated by the direct or indirect application of heat. The indirect application of heat may include applying ultrasonic energy to the implant.

The heated material of the two portions **572** and **574** of the implant **290** are then pressed together at the joint **576** to form a bond between the two portions of the implant. As this occurs, there is a fusing of the material of the portion **572** of the implant **290** with the material **574** of the implant. This fusing together of the two portions **572** and **574** occur in the patient's body and results in the formation of a one-piece unitary implant **290**.

Rather than being formed of a polymeric material, it is contemplated that the two portions **572** and **574** of the implant could be formed of metal and have a polymeric layer on a side of the metal toward the femur **126**. This would result in the layer of polymeric material being disposed in engagement with the distal end portion **124** of the femur **126** and the metal forming the femoral component **290** facing toward the tibia **214** for engagement with the tibial bearing insert **294** (FIG. **32**). With such a construction, the application of energy to the two portions **572** and **574** of the implant would result in a heating of the layer of polymeric material on the inside of the layer of metal. The heated polymeric materials on the two portions **572** and **574** bond together at the joint **576** in a manner previously described.

When the two portions **572** and **574** of the femoral implant **290** are to be interconnected by fusing together sections of polymeric material which form the portions **572** and **574** of the implant or sections of polymeric material which are disposed on layers of metal forming part of the portions **572** and **574** of the implant **290** to be interconnected, it is contemplated that they may be interconnected in many different ways. One way in which polymeric material on the portions **572** and **574** of the femoral implant **290** may be interconnected is the same as is disclosed in U.S. patent application Ser. No. 09/737,380 filed Dec. 15, 2000 by Peter M. Bonutti, et al. This patent application contains a disclosure which corresponds to the disclosure in U.S. Pat. No. 6,059,817.

The two portions **572** and **574** of the implant **290** (FIG. **40**) may be formed of only metal. If this is done, the two portions **572** and **574** of the implant may be mechanically interconnected. For example, a screw could extend from the portion **574** of the implant **270** to the portion **572** of the implant while the two implants are in engagement with the distal end portion **124** of the femur **126**. Alternatively, a snap type joint **576** could be provided between the portions **572** and **574** of the implant. Although the two portions **572** and **574** of the implant **290** are positioned in engagement with the femur **126** and interconnected while the leg **70** of the patient is in the position illustrated in FIGS. **2**, **3** and **25**, the two portions of the implant could be positioned in engagement with the femur **126** while the leg **70** is straight (extended).

The implant **290** is connected with the femur **126**. However, it is contemplated that a tibial implant could be formed as a plurality of separate portions which are interconnected when they are in the knee portion **76** of the patient's leg **70**. It should be understood that the implant **290** could be formed of more than two portions. For example the implant could be formed with four separate portions which are interconnected in the patient's body. Although the implant **290** is to be used in a knee portion of a patient's body, it is contemplated that implants used at other portions of a patient's body could be interconnected in the patient's body.

In the embodiment of the invention illustrated in FIG. **40**, the separate portions **572** and **574** of the implant **290** are positioned in engagement with the same bone, that is, femur **126** and interconnected. However, it is contemplated that one position of an implant could be positioned in engagement with a first bone and another portion of the implant positioned in engagement with a second bone. However, the two portions of the implant would be interconnected in the patient's body. The two portions of the implant may be interconnected after they have been positioned in engagement with bones in the patient's body. Alternatively, the two portions of the implant could be interconnected in the patient's body, before one or both portions of the implant have been positioned in engagement with a bone.

For example, a first component of an implant may be connected with a femur **126** in a patient's body. A second component may be connected with a tibia **214** in the patient's body. The two components are interconnected, in the patient's body, after they have been connected with the femur and tibia.

Transducer for Ligament Balancing

After the femoral component **290** and tibial components **286** and **294** of the implant had been positioned in the knee portion **76** of the patient's leg **70**, the ligaments are balanced in flexion, extension, and rotation in the manner previously described. It should be understood that even though the implants have not been shown in FIGS. **41** and **42**, ligament balancing may be undertaken before and/or after the implants been positioned in engagement with the femur **126** and tibia **214**. However, it is contemplated that ligament balancing could be undertaken during surgical procedures which do not require cutting of the femur **126** and tibia **214** and/or implants.

In accordance with one of the features of the invention, during ligament balancing, tension forces in fibrous connective tissue such as collateral ligaments **590** and **592** (FIGS. **41** and **42**) are compared. If the forces in one of the ligaments **590** or **592** are excessive, the ligament in which the excessive force is present may be released. Similarly, if one of the ligaments is too loose, the ligament may be tightened.

In accordance with another one of the features of the invention, transducers are positioned between one or more bones in the knee portion **76** of the leg **70** of the patient. The transducers enable tension forces in ligaments **590** and **592** to be compared. The transducers may be used to determine the magnitude of the tension forces in the ligaments **590** and **592**.

Thus, a first or lateral transducer **596** (FIGS. **41** and **42**) is positioned between a lateral side of the distal end portion **124** of the femur **126** and a lateral side of the proximal end portion **212** of the tibia **214**. Similarly, a second or medial transducer **598** is positioned between a medial side of the distal end portion **124** of the femur **126** and a medial side of the proximal end portion of the tibia **214**. The transducers **596** and **598** are connected with a computer **600** (FIG. **41**) or other processor.

The computer **600** (FIG. **41**) has a display area **601** at which the output from the lateral transducer **596** is displayed. Similarly, the computer **600** has a display area **602** at which the output from the medial transducer **598** is displayed. By comparing the outputs at the display areas **601** and **602**, a surgeon can determine the relationship between the tension in the ligament **590** and the tension in the ligament **592**. In addition, the surgeon can determine the magnitude of the tension in the ligaments **590** and **592**.

It is contemplated that the leg **70** of the patient will be moved between the flexed condition of FIGS. **2**, **3**, **25** and **41** and an extended position or straight condition (FIGS. **4** and **42**), while the output from the transducers **596** and **598** is viewed at the display areas **601** and **602** of the computer **600**. This will provide the surgeon with a clear indication of the manner in which tension forces in the ligaments **590** and **592** varies during bending of the knee portion **76** of the leg **70** of a patient. If an image generating device, similar to the C-arm fluoroscope **360** of FIG. **34**, is used in association with the transducers **596** and **598**, the surgeon can see how components of the knee joint are interacting as the tension in the ligaments varies.

In addition to checking the tension in the ligaments **590** and **592** during movement of the leg **70** of the patient between flexed and extended conditions, it is contemplated that the tension in the ligaments **590** and **592** will be compared during the application of rotational forces to the lower portion **68** of the knee of the patient. Thus, forces tending to rotate the lower portion **68** of the leg of the patient in the direction of the arrow **258** in FIG. **25** are applied to the lower portion **68** of the leg **70**. As these rotational forces are applied, the outputs from the transducers **596** and **598** (FIG. **41**) are displayed for review by a surgeon to determine whether or not the ligaments **590** and **592** are rotationally balanced. The transducers **596** and **598** may be utilized to provide outputs corresponding to forces resulting from a combination of flexion/extension movement and rotational movement of the lower portion **68** of the patient's leg **70**. It should be understood that the transducers **596** and **598** may be utilized throughout the entire ligament balancing process previously described herein in order to enable a surgeon to compare tension forces in the ligaments **590** and **592** throughout the ligament balancing process.

Although the transducers **596** and **598** have been illustrated schematically in FIGS. **41** and **42** as being associated with the end portions of the femur **126** and tibia **214**, it should be understood that the transducers **596** and **598** could be associated with other joints if desired. For example, the transducers **596** and **598** could be positioned between vertebrae in a patient's spine. If this was done, the patient's spine could be bent in either anterior or lateral flexion and extension. The output at the display areas **601** and **602** would indicate the manner in which forces transmitted between the vertebrae vary during bending of the spine.

It is contemplated that the transducers **596** and **598** could have many different constructions. However, in the illustrated embodiment of the invention, the transducers **596** and **598** are pneumatic transducers. Thus, the lateral transducer **596** (FIG. **42**) includes a container or bladder having a chamber which is filled with fluid. It is contemplated that the chamber could be filled with either a gas or a liquid. In the embodiment of the invention illustrated in FIGS. **41** and **42**, the transducers **596** and **598** have the same construction and are of pneumatic type. Therefore, the chamber is filled with air. However, the chamber could be filled with a liquid, for example, saline solution, if desired.

The transducers **596** and **598** are disposed between the femur **126** and the tibia **214**. Although it should be understood that the femoral implant **290** and tibial tray **286** and bearing **294** have not been illustrated in FIGS. **41** and **42**, the implants may or may not be present when the transducers are positioned between the femur **126** and tibia **214**. Depending upon the location of the transducers **596** and **598** they may or may not be disposed in engagement with a portion of either the femoral or tibial implant. With a partial knee replacement, one of the transducers **596** or **598**, is disposed between femoral and tibial implants. The other transducer is disposed between surfaces on the femur **126** and the tibia **214**.

A conductor **604** is provided to transmit an output signal from the lateral transducer **596** to the computer display **601** (FIG. **42**). The conductor **604** could be constructed so as to conduct either fluid pressure from the transducer **596** to the computer **600** or to conduct an electrical signal from a fluid pressure transducer exposed to the fluid pressure in the transducer **596**. The medial transducer **598** is connected with the display **602** by a conductor **606**.

It is contemplated that the transducers **596** and **598** could have many different constructions including any one of the constructions disclosed in U.S. Pat. No. 5,667,520 or in U.S. patent application Ser. No. 09/483,676 filed Jan. 14, 2000 by Peter M. Bonutti and having a disclosure corresponding to the disclosure in U.S. Pat. No. 5,269,785. The transducers **596** and **598** may be formed of a material which is biodegradable or a material which is non-biodegradable.

Although the illustrated transducers **596** and **598** (FIGS. **41** and **42**) are of the pneumatic type, it is contemplated that a different type of transducer could be utilized if desired. For example, the transducers **596** and **598** could be solid state devices, such as piezoelectric load cells. Alternatively, the transducers could include deformable members to which strain gauges are attached.

It should be understood that the transducers **596** and **598** could be used to measure and/or compare tension in the ligaments **590** and **592** immediately after making the incision **114**. In addition or alternatively, the transducers **596** and **598** could be used to measure and/or compare tension in the ligaments **590** and **592** during trials with provisional components. Of course, the transducers **596** and **598** can be used to measure and/or compare tension in the ligaments after the implants **286**, **290** and **294** have been mounted in the knee portion **76**.

In the embodiment of this invention illustrated in FIGS. **41** and **42**, the transducers **596** and **598** are disposed between end portions of the femur **216** and tibia **214**. Therefore, the transducers **596** and **598** only indirectly respond to variations in tension in the collateral ligaments **590** and **592**. It is contemplated that the transducers **596** and **598** could be positioned so as to directly respond to variations in the tension in the collateral ligaments **590** and **592**.

For example, the transducer **596** could be positioned between the ligament **590** and lateral sides of the femur **126** and/or tibia **214**. Similarly, the transducer **598** could be positioned between the ligament **592** and medial sides of the femur **126** and/or tibia **214**.

It is contemplated that transducers, similar to the transducers **596** and **598**, could be utilized to determine variations in tension in ligaments and/or tendons other than the ligaments **590** and **592**. For example, transducers could be utilized to determine the tension in the patellar tendon **456** (FIG. **42**) and/or the patellar ligament **458**. If desired, transducers, similar to the transducers **596** and **598**, could be positioned so as to respond to variations in tension in the posterior cruciate ligament **250** and/or the anterior cruciate ligament. It is contemplated that a plurality of transducers, similar to the transducers **596** and **598**, may be positioned so as to respond to variations in tension in various combinations of ligaments and/or tendons.

In addition to providing outputs which are a function of variations in tension in ligaments and/or tendons, the transducers **596** and **598** may be utilized to apply force against the femur **126** and tibia **214**. When this is to be done, fluid under pressure is conducted to either or both of the transducers **596** and/or **598**. An increase in fluid pressure conducted to the transducers **596** and **598** is effective to expand containers or bladders in the transducers.

The fluid pressure force applied against the transducers **596** and/or **598** is transmitted to the femur **126** and tibia **214**. This force may be used to stretch the collateral ligaments **590** and **592** and/or other body tissue. If it is desired to stretch one of the ligaments **590** or **592** to a greater extent the other ligament, the fluid pressure transmitted to one of the transducers **596** or **598** would be greater than the fluid pressure transmitted to the other transducer. The force transmitted to the femur **126** and tibia **214** is indicated at the displays **61** and **601**.

It is contemplated that the transducers **596** and **598** will be removed before the limited incision **114** is closed. However, if it is desired, the transducers **596** and **598** may be left in place and utilized after the incision **114** is closed. When this is to be done, the transducers **596** and **598** may advantageously be formed of biodegradable material. By leaving the transducers **596** and **598** in place after the incision **114** is closed, the tension in the ligaments **590** and **592** may be compared during therapy. If desired, one or both ligaments **596** and/or **598** could be conducting fluid pressure to one or both transducers **596** and/or **598** during therapy.

Inlaid Implant—Femur

In the embodiment of the invention illustrated in FIGS. **8-28**, articular surfaces on the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** are cut away using a saw or other cutting tool. This results in areas on the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**, where articular surfaces were previously disposed, being cut to have a flat planar configuration. Thus, an anterior skim cut, a distal end cut, and chamfer cuts are made on the distal end portion **124** of the femur **126** while a proximal end cut is made on the proximal end portion **212** of the tibia **214**. After the cuts have been made, the femoral implant extends across or encloses the cuts on the distal end portion **124** of the femur **126** and the tibial implant extends across the cut on the tibial end portion **212** of the tibia **214**.

It is contemplated that rather than enclosing the end portions of the femur and tibia with implants, the implants could be inlaid into the end portion of the femur and/or tibia. When an implant is to be inlaid into the distal end portion **124** of the femur **126** (FIG. **43**), a recess **610** is formed in the distal end portion **124** of the femur **126**. To form the recess **610**, a cutting tool, such as a milling cutter **614** (FIG. **44**), is utilized to cut away a defective portion of an articular surface on the distal end portion **124** of the femur **126**. The milling cutter **614** is rotated about its longitudinal central axis and has cutting edges disposed in a cylindrical array about the periphery of the milling cutter. The extent of the defective portion of the articular surface determines the extent to which the milling cutter **614** cuts away the articular surface.

A guide **620** (FIG. **44**) is provided for the milling cutter or other cutting tool. The guide **620** is effective to limit the extent of axial movement of the milling cutter **614** into the distal end portion **124** of the femur **126** to thereby limit the depth of the recess **610**. The guide **620** limits side wise, that is, radial movement of the milling cutter **614** to an area corresponding to the desired configuration of the recess **610**. This results in the recess **610** being formed with a uniform depth throughout the extent of the recess and with a desired configuration. The construction of the guide **620** in the manner in which it cooperates with the milling cutter **614** may be similar to that disclosed in U.S. Pat. Nos. 5,344,423; 5,769,855; and/or 5,860,981.

Once the recess **610** has been formed using the milling cutter **614** in the manner illustrated schematically in FIG. **44**, an implant **626** (FIGS. **43** and **45**) is positioned in the recess. The implant **626** fills the recess **610** and has an outer surface **628** (FIG. **45**) which forms a continuation of the naturally occurring articular surface **616** formed by the distal end portion **124** of the femur **126**. The outer surface **628** of the implant **626** replaces defective articular surface area removed by the milling cutter **614** from the distal end portion **124** of the femur **126**.

The outer surface **628** on the implant **626** cooperates with an articular surface on a tibia **214** in the same general manner as the original articular surface area removed by the milling cutter **614**. Of course, the outer surface **628** of the implant **626** is free of defects that made it necessary to replace the corresponding area on the articular surface **616** of the distal end portion **124** of the femur **126**. The outer surface **628** of the implant **626** may engage an articular surface formed by the boney material of the tibia **214**. Alternatively, the outer surface **628** of the implant **626** may engage the surface of an implant disposed on the tibia **214**.

During recovery of the patient, the naturally occurring surface **616** on the femur **126** and the implant **626** may both be load bearing. By having the implant **626** surrounded by load bearing natural bone, the implant is held in place on the distal end portion **124** of the femur **26**. In addition, the magnitude of the load which must be transmitted through the implant **626** is minimized.

The implant **626** could have any desired construction. Thus, the implant could be formed of a polymeric material or it could be formed of a metallic material. However, in accordance with one of the features of the invention, the implant **626** is formed of a material which promotes biological resurfacing and the growth of bone from the distal end portion **124** of the femur **126** into the implant to fill the recess **610** with new bone growth. The implant **626** may also be at least partially formed of material which promotes the growth of cartilage or other tissue over the implant.

The implant **626** may be formed with a non-living three dimensional scaffold or framework structure on which bone growth promoting materials, such as bone morphogenetic proteins, are disposed. The three dimensional framework or platform on which the bone growth promoting materials are disposed may be formed of either a biodegradable or a non-biodegradable material. When the scaffold or framework structure is formed of a non-biodegradable material, the bone from the distal end portion **124** will grow through the scaffold so that the scaffold becomes embedded in new bone growth. The scaffold may be formed of a porous metal or ceramic material. When the scaffold is formed of a bio-degradable material, the scaffold will eventually degrade and be absorbed by body tissue.

The scaffold may be formed of a mesh or a felt-like material, or a porous material similar to coral. The scaffold forms a growth supporting matrix to support cellular migration from the boney material of the distal end portion **124** of the femur **126** into the implant **626**. If the scaffold or platform is made of a bio-degradable material, then the scaffold or platform degrades and disappears after a period of time. It is contemplated that the scaffold could be formed of a bio-degradable material such as polyglycolic acid or polylactic acid. If desired, the scaffold or framework could be formed of fibrous connective materials such as portions of ligaments, tendons and/or bones obtained from human and/or animal sources. The scaffold could be formed of collagen. The scaffold may be formed of submucosal tissue.

The scaffold holds bone growth inducing materials and may include bone fragments to which tri-calcium phosphate, an antibiotic, hydroxyapatiate, allografts, autografts, and/or any other polymeric has been added. It is believed that it will be particularly advantageous to provide a bone growth morphogenetics protein in the implant **626** to promote the growth of bone into the implant. The scaffold may hold cultured and/or noncultured cells which promote biological resurfacing.

The matrix or scaffold for the implant **626** may contain tissue inductive factors and/or cells. The cells may be mesenchymal cells which are introduced into the scaffold in the operating room. Thus, the matrix or scaffold may be either biodegradable or non-biodegradable and may be constructed at a location remote from an operation. After the scaffold has been transported to the operating room the mesenchymal cells may be introduced into the scaffold.

It is contemplated that the matrix or scaffold for the implant **626** may contain stem cells and/or fetal cells. The stem cells and/or fetal cells may be introduced into either a biodegradable or non-biodegradable matrix or scaffold in the operating room. It is contemplated that tissue inductive factors may be provided in the matrix or scaffold along with any desired type of precursor cells.

The matrix or scaffold for the implant **626** may contain osteoinductive materials. The implant **626** may contain osteoblasts or osteoclast cells or their precursors. The implant **626** may also contain platlet matrix centrifuged from blood in a manner similar to that described in U.S. patent application Ser. No. 09/483,676, filed Jan. 14, 2000 by Peter M. Bonutti.

The matrix or scaffold for the implant **626** may be formed of allograft bone or collagen. Cartilage may be used to form the scaffold or matrix. The scaffold or matrix for the implant **626** may have a layered construction with the layers being formed of different materials. Each of the layers of the scaffold or matrix forming the implant **626** may be impregnated with a different material. For example, precursor cells may be provided in one layer and bone morphogentic protein may be provided in another layer.

It is contemplated that submucosal tissue may be used to form the scaffold for one or more of the layers of the implant **626**. The submucosal tissue may be prepared in a manner similar to the manner disclosed in U.S. Pat. No. 5,755,791. The various layers of the implant **626** may be assembled in the operating room.

The implant **626** may be formed of multiple tissue fragments. Thus, a tissue press, similar to the tissue presses disclosed in U.S. patent application Ser. No. 09/602,743 filed Jun. 23, 2000, by Peter M. Bonutti and having a disclosure which corresponds to the disclosure in U.S. Pat. No. 5,662,710 may be utilized to shape the implant to a desired configuration.

The implant **626** may be formed to have any one of a plurality of different sizes and configurations. The implant may be shaped to the desired configuration at a location remote from an operating room and transported to the operating room. Alternatively, the implant **626** could be cut to the desired shape in the operating room.

By providing a substantial number of implants of different sizes in the operating room and/or by cutting an implant to obtain a desired configuration, it is possible for a surgeon to make a recess **610** to a shape which corresponds to a defective area on a portion of the femur **126**. An implant **626** having the configuration of the particular recess can then be provided. This enables the surgeon to remove a relatively small defective area of the bone forming the articular surface on the femur **126** and to minimize the size of the implant **626**.

It is believed that it will be desired to provide a series of implants of different sizes ranging from a relatively small size to a relatively large size. In addition, it is believed that it will be desired to provide a plurality of guides **620**. The guides **620** will have surfaces to guide movement of the milling cutter **614** or other cutting tool to form a recess **610** of a size corresponding to any one of the sizes of the implants in the series of implants. Thus, the plurality of guides **620** would be provided with each guide having guide surfaces corresponding to the configuration of an implant of a different size.

The scaffold or base of the implant **626** may be formed of a porous bio-degradable material. The porous bio-degradable material provides a matrix for demineralized bone, collagen, bone morphogenetic protein, growth factors, and autogenous bone marrow. In addition, progenitor cells, stem cells and/or fetal cells may be disposed on the scaffold. Some non-tissue-derived components may include coralline-based HA (ProOsteon), antibiotics, calcium sulfate, calcium and phosphorus oxide rich amorphous glass, anti-inflammatories, and bovine fibrillar collagen. The resulting material will have osteoinductive and osteoconductive qualities. Cortical cancellous bone chips which are freeze dried may be provided in the implant **626**. In addition, demineralized bone matrix may be provided in the implant **626**.

The implant **626** may be secured in the recess **610** with a suitable adhesive. There are many different known adhesives which may be used. Fibrin can be used as an adhesive, either in a natural state or after being compressed, to hold material together and to hold the implant **626** in the recess **610**.

It is contemplated that the patient's leg **70** may be in the position illustrated in FIGS. **2**, **3** and **25** during forming of the recess **610** and positioning of the implant **626** in the recess. The upper portion **72** of the patient's leg **70** may be supported above the support surface **64** by the leg support **80**. The limited incision **114** (FIG. **6**) may be formed in the knee portion **76** of the patient's leg. The patella **120** may be in the offset position of FIG. **8** during forming of the recess **610**.

The drapery system **100** of FIGS. **4** and **5** may advantageously be utilized to provide a sterile field. Although it may be desired to use a milling cutter as the cutting tool **614** (FIG. **44**), other known cutting tools could be used if desired. For example, a laser or ultrasonic cutting tool could be used to form the recess **610**.

Although it is believed that it will be preferred to have the patient's leg **70** in the position illustrated in FIGS. **2**, **3** and **25**, to support the patient's leg **70** with the leg support **80**, to offset the patella **120**, and to use the drapery system **100**, the implant **626** may be positioned in a patient's leg **70** without using any one or any combination of these features. Thus, the implant **626** could be positioned in a patient's leg **70** with the leg in the position shown in FIG. **1** with any known drapery system. The patella may be everted (FIG. **7**) rather than offset.

The foregoing description of the implant **626** has assumed that the implant is to be positioned in the femur **126** in a leg of a patient. However, the implant **626** could be positioned in any desired bone in a patient's body. The implant **626** could be positioned at a location remote from an articular surface of a bone. The implant **626** may be positioned on a bone in ways other than positioning the implant in a recess similar to the recess **610**.

Inlaid Implant—Tibia

The implant **626** is illustrated in FIG. **43** in association with a femur **126** in a patient's body. It is contemplated that a similar implant **640** (FIG. **46**) may be provided in the proximal end portion **212** of the tibia **214** in a leg **70** of the patient. The implant **640** is disposed in a recess **642**. The recess **642** may have any desired configuration. It is contemplated that the configuration of the recess **642** would be a function of the configuration of defective portions of the bone in the proximal end portion **212** of the tibia **214**.

The recess **642** is surrounded by an articular surface **644** of naturally occurring bone. Thus, the articular surface **644** is not defective and extends around the recess **642**. It should be understood that the extent of the articular surface **644** around the recess **642** could be substantially greater than is illustrated in FIG. **46** relative to the size of the implant **640**. This is because the implant **640** is sized and has a configuration which is a function of the size and configuration of an area which was previously defective bone on the proximal end portion **212** of the tibia **214**. The articular surface **644** is load bearing and functions to transmit forces between the tibia **214** and the femur **126** in the leg **70** of the patient.

The recess **642** is formed with the milling cutter **614** (FIG. **47**). A guide **620** is provided to control the depth to which the milling cutter **614** removes bone from the proximal end portion **212** of the tibia **214** in the manner previously explained in conjunction with femur **126** (FIGS. **43**-**45**). The guide **620** and milling cutter **614** are utilized to form the recess **642** in a manner which is similar to that disclosed in U.S. Pat. No. 5,908,424. Rather than being formed by the use of a milling cutter **614** and guide **620**, it is contemplated that the recess **642** in the proximal end portion **212** of the tibia **214** and/or the recess **610** in the distal end portion **124** of the femur **126** could be formed by a robot having a construction similar to the construction of the robot **370** of FIG. **33**.

The implant **640** (FIGS. **46** and **48**) may be formed of metal or a hard polymeric material. Alternatively, the implant **626** may be of a layered construction with a layer of metal backed by polymeric material. The surface of the implant forms a portion of the overall articular surface on the proximal end portion **212** of the tibia **214**.

Of course, the articular surface area on the proximal end portion **212** of the tibia **214** cooperates with articular surface areas on the distal end portion **124** of the femur **126** (FIG. **43**). It is contemplated that the implant **626** in the femur **126** and the implant **640** in the tibia **214** (FIG. **46**) could be disposed in engagement with each other. Alternatively, the implant **626** in the distal end portion **124** of the femur **126** (FIG. **43**) could be engaged by a naturally occurring articular surface on the proximal end portion **212** of the tibia **214** (FIG. **46**). Similarly, the implant **640** in the proximal end portion **212** of the tibia **214** may engage a naturally occurring articular surface area on the distal end portion **124** of the femur **126**.

It is contemplated that it may be preferred that the implant **640** contain bone growth promoting materials and/or materials which promote biological resurfacing. These bone growth promoting materials would promote growth of bone from the proximal end portion **212** of the tibia **214** into the recess **642**. This would result in the recess **642** being filled with new bone growth. The biological resurfacing materials would promote the growth of naturally occurring tissues on the implant **640**.

The implant **640** may include a three dimensional scaffold or framework structure formed of either a biodegradable material or a non-biodegradable material. Osteoinductive and/or osteoconductive materials may be disposed on this framework or platform. The scaffold may be formed of cortical bone, cartilage submucosal tissue, or other materials.

The matrix or scaffold for the implant **640** has interstitial spaces which contain material which promotes the growth of bone from the proximal end portion **212** of the tibia **214** into the matrix or scaffold. The bone growth materials may include bone morphogenic protein, factors that stimulate migration of cells, anti-inflammatories and/or immuno suppressants. Collagen, fibrin, osteoinductive materials, progenitor cells, and/or tissue inductive factors may be disposed on the platform. The implant **640** may contain cortical cancellous bone chips or demineralized bone matrix. It may be preferred to form the outer surface of the implant **640** of materials which promote biological resurfacing.

When the implant **640** is formed with a biodegradable three dimensional scaffold or matrix, it is contemplated that there will be cellular migration and growth of bone from the proximal end portion **212** of the tibia **214** into the scaffold or matrix. The scaffold or matrix will then degrade and disappear as material of the scaffold or platform hydrolyzes. However, if the matrix or scaffold is made of a non-biodegradable material, it is contemplated that the scaffold will become embedded in the bone growth from the proximal end portion **212** of the tibia **214** into the recess **614**. The scaffold, whether biodegradable or non-biodegradable, may be impregnated with mesenchymal cells.

The implant **640** on the tibia has the same construction as the implant **626** on the femur. However, the implant **640** on the tibia could have a construction which is different than the construction of the implant **626** on the femur.

It is contemplated that the patient's leg will be in the position illustrated in FIGS. **2**, **3** and **25** during forming of the recess **642** and positioning of the implant **640** in the recess. The upper portion **72** of the patient's leg **70** will be supported above the support surface **64** by the leg support **80**. The limited incision **114** (FIG. **6**) will be formed in the knee portion **76** of the patient's leg. The patella **120** will be in the offset position of FIG. **8** during forming of the recess **642**. The drapery system of FIGS. **4** and **5** may advantageously be utilized to provide a sterile field. Although it may be desired to use a milling cutter as the cutting tool, other known cutting tools could be used if desired.

Layered Implant

A multi layered inlaid implant **670** for use in biological resurfacing is schematically illustrated in FIG. **49**. The implant **670** is disposed in a recess **672** formed in a bone **674**. The recess **672** is formed in the same manner as is illustrated in FIGS. **44** and **47** for forming the recess **610** and the recess **642**. The recess **672** may be disposed in a defective portion of an articular surface on the distal end portion **124** of a femur **126**, as illustrated in FIG. **43**, or may be located at a defective portion of an articular surface on the proximal end portion **212** of a tibia **214** as illustrated in FIG. **46**. However, it is contemplated that the implant **670** may be disposed in the bone **674** at many different locations. At least some of these locations would be spaced from an articular surface on the bone. The bone may be located in many different portions of a patient's body, for example, a shoulder, spine, arm, hand, hip or foot.

The implant **670** is formed by a plurality of layers. The specific implant **670** illustrated in FIG. **49** has a base layer **678** and an outer layer **680**. It should be understood that more than two layers could be provided if desired. For example, an intermediate layer could be disposed between the base layer **678** and outer layer **680** if desired. Each of the layers **678** and **680** of the implant **670** could be formed with its own separate platform or scaffold made of biodegradable materials. Alternatively, a single biodegradable scaffold or matrix could extend between the two layers **678** and **680**.

The inner or base layer **678** is disposed in engagement with the bone **674**. The inner layer **678** may be formed of bone growth promoting materials which promote migration of bone cells from the bone **674** to the base layer **678**. New bone growth into the base layer **678** will interconnect the base layer and the bone **674**. The base layer **678** may contain cortical cancellous bone power or chips and/or demineralized bone matrix, bone morphogenic protein, anti-inflammatories and/or immuno suppressants may be disposed in the base layer **678**. An antibiotic, hydroxyapatiate, tricalcium phosphate and/or polymers and copolymers may also be included in the base layer **678**.

The outer layer **680** may be formed of cartilage. Embryonal cells, fetal cells, and/or stem cells may be provided in the outer layer **680**. The outer layer **680** may be formed of submucosal tissue. The outer layer **680** promotes biological resurfacing of a portion of the bone **674** where the implant **670** is disposed.

It is contemplated that the recess **672** may be formed in the bone **674** at a location where there is a defect in an articular surface on the bone. However, it is also contemplated that the recess **672** in a position in a portion of the bone **674** where there is no articular surface.

It is contemplated that the patient's leg will be in the position illustrated in FIGS. **2**, **3** and **25** during forming of the recess **672** and positioning of the implant **670** in the recess. The upper portion **72** of the patient's leg **70** will be supported above the support surface **64** by the leg support **80**. The limited incision **114** (FIG. **6**) will be formed in the knee portion **76** of the patient's leg. The patella **120** will be in the offset position of FIG. **8** during forming of the recess **672**. The drapery system of FIGS. **4** and **5** may advantageously be utilized to provide a sterile field. Although it may be desired to use a milling cutter as the cutting tool, other known cutting tools could be used if desired.

Implant

An improved implant **690** is illustrated in FIG. **50**. The implant **690** may be utilized in association with either a full or partial knee replacement. Alternatively, the implant **690** could be utilized in association with a repair of a glenoid joint, an elbow, an ankle, a spine or any desired joint in a patient's body. Implant **690** includes a base **692** and an articular layer **694**. The base **692** has been illustrated in FIG. **50** as being connected with the proximal end portion **212** of a tibia **214**. The implant **690** is intended for use in association with either a partial or full knee replacement. However, it should be understood that an implant having a construction corresponding to the construction of the implant **690** could be utilized in association with any desired joint in a patient's body.

The base **692** (FIG. **50**) is connected with the tibia **214** by projection **700** and a fastener **702**. The projection **700** has a generally cylindrical configuration and extends from a main section **706** of base **692**. The projection **700** extends at an acute angle to the main section **706** in a direction away from the fastener **702**.

When the implant **690** is positioned on the proximal end portion **212** of the tibia **214**, the implant is moved along a path which extends parallel to a longitudinal central axis of the projection **700**. The path of movement of the implant **690** onto the proximal end portion **212** of the tibia **214** is indicated by an arrow **707** in FIG. **50**. The arrow **707** is skewed at an acute angle to a longitudinal central axis of the tibia **214**. This results in the projection **700** being forced into the bone of the proximal end portion **212** of the tibia **214**. Deformation of the bone occurs adjacent to a leading end of the projection **700**. There is no significant deformation of the adjacent to a longitudinally extending outer side surface of the generally cylindrical projection **700**.

As the implant **690** is moved into position on the proximal end portion **212** of the tibia **214**, a downwardly extending flange **708** connected with the main section **706** moves into engagement with an outer side surface area on the tibia **214** as the main section **706** of the implant **690** moves into engagement with flat proximal end surface **710** on the tibia **214**. Once the inner side of the main section **706** has been pressed firmly against the flat end surface **710** on the tibia **214** and the projection **700** is moved to the position illustrated in FIG. **50**, the fastener **702** is inserted through the flange **708**. The fastener **702** is a screw and engages the proximal end portion **212** of the tibia **214** to securely connect the implant **690** with the tibia. A longitudinal central axis of the fastener **702** extends generally parallel to a longitudinal central axis of the projection **700**. Therefore, as the fastener **702** is tightened to press the flange **708** against the outer side of the tibia **214**, the projection **700** is cammed or forced inward to press the main section **706** against the end surface **710** on the tibia.

It is contemplated that the base **692** of the implant **690** may be formed of metal. For example, the base **692** may be formed of porous tantalum. Of course, the base **692** could be formed of a different material if desired. Thus, the base **692** could be formed of a polymer or copolymer if desired. The articular layer **694** is formed of a smooth polymeric material which engages in articular surface on a femur.

It is contemplated that the patient's leg will be in the position illustrated in FIGS. **2**, **3** and **25** during positioning of the implant **690** on the proximal end portion of the tibia **214**. The upper portion of the patient's leg **70** will be supported above the support surface **64** (FIG. **2**) by the leg support **80**. The limited incision **114** (FIG. **6**) will be formed in the knee portion **76** of the patient's leg **70**. The patella **120** will be in the offset position of FIG. **8** during positioning of the implant **690**. The drapery system **100** (FIGS. **4** and **5**) will provide a sterile field. The tibial resection guide **218** (FIG. **21**) may be used during forming of the flat end surface **710** on the tibia **214**.

Expandable Devices

In accordance with another feature of the invention, one or more expandable devices **720** and **722** (FIG. **51**) may be utilized to move, stretch, or separate body tissue. The expandable devices **720** and **722** may be utilized at any time during a full or partial knee replacement. Thus, the expandable devices **720** and **722** may be utilized to separate body tissue from the distal end portion **124** of a femur **214** before a femoral component or implant **290** is connected with the femur and before the tibial tray **286** and tibial bearing insert **294** are connected with the proximal end portion **212** of the tibia **214**.

The expandable devices **720** and **722** may be inserted into the knee portion **76** of the patient's leg **70** one or more days before either a partial or full knee replacement operation is to be undertaken. Before the surgery is initiated, the expandable device **720** may be expanded to stretch skin **342**, the joint capsule, and other tissue in the anterior of the knee portion **76**. The viscoelastic body tissue is resiliently stretched by the expandable device **720** in the general area where the limited incision **114** (FIG. **6**) is to be formed.

The incision **114** is subsequently made in the body tissue which has been resiliently stretched by the expandable device **720**. After the surgery on the patient's leg **70** has been completed, for example, after a full or partial knee replacement in accordance with FIGS. **8-29**, the incision **114** in the stretched tissue is closed. The body tissue which was previously resiliently stretched by the expandable device **720** can, after closing of the incision **114**, return to its normal or unstretched condition. As this occurs, the length of any scar resulting from the incision **114** decreases. By making the incision **114** in body tissue which has previously been resiliently stretched by the expandable device **720**, the overall effective length of the incision **114** is reduced.

The expandable devices **720** and **722** may be resilient balloons which are inflated by a gas, such as air, or resilient bladders which are expanded under the influence of a liquid, such as saline solution. The resilient expandable devices **720** and **722** may be formed of a biodegradable material or a non-biodegradable material. It is contemplated that if the expandable devices **720** and **722** are to be left in the patient's body, they may advantageously be formed of a biodegradable material. However, if it is contemplated that when the expandable devices are to be removed from the patient's body during or after surgery, the expandable devices may be formed of a non-biodegradable material.

Rather than being inserted into the knee portion **76** prior to formation of the incision **114**, the expandable devices **720** and **722** (FIG. **51**) may be inserted into the knee portion immediately after making the incision. The expandable devices **720** and **722** may then be expanded to separate body tissue in the knee portion **76**. The expandable devices **720** and **722** are inserted into the knee portion **76** in a collapsed condition. The expandable devices are expanded after being inserted into the knee portion.

For example, the expandable device **720** may be resiliently expanded to stretch the patellar ligament **458** (FIG. **51**) and move the patella **120** away from the distal end portion **124** of the femur **126**. Alternatively, the expandable device **720** may be positioned between the femur **126** and the patellar tendon **456**. Expansion of the expandable device **720** would then result in movement of the patellar tendon **456** and patella **120** away from the distal end portion **124** of the femur **126**. Of course, if expandable devices were provided between the distal end portion **124** of the femur and both the patellar tendon **456** and patellar ligament **458**, the patella tendon and ligament would both be moved by expansion of the expandable devices. Positioning of the expandable device **720** between the patellar ligament and/or tendon facilitates subsequent movement of the patella **120** to offset position of FIG. **8**. As previously noted, expandable device **720** can be used to access the inner surface of the patella **120**.

The expandable device **722** (FIG. **51**) is disposed in the posterior portion of the knee portion **76** of the leg **70**. Expansion of the expandable device **722** in the posterior portion of the patient's knee is effective to move the joint capsule and fibrous connective tissue away from the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**. The expandable device **722** may be expanded immediately after the incision **114** is formed to effect releases of body tissue from the distal end portion **124** of the femur **126** and/or the proximal end portion **212** of the tibia **214**.

Expansion of the expandable device **722** is effective to move arteries, nerves and veins in the posterior of the knee portion **76** away from the distal end portion **124** of the femur **126** and proximal end portion **212** of the tibia **214** prior to making of the femoral and/or tibial cuts (FIGS. **8-29**). If desired, the expandable device **722** may be maintained in the expanded condition during making of one or more of the femoral and/or tibial cuts. If desired, the expandable device **722** may be provided with a tough surface which would protect arteries, nerves and/or veins during the making of one or more of the femoral and tibial cuts.

It should be understood that the expandable device **722** may have a configuration which is different from the configuration illustrated in FIG. **51**. For example, the expandable device **722** may extend for a greater distance along the posterior of the femur **126** and tibia **214** if desired. Although the implants **286**, **290** and **294** have been illustrated in FIG. **51**, it should be understood that the expandable devices **720** and **722** may be used before and/or after installation of the implants. The expandable devices **720** and **722** may be positioned in the knee portion **76** of the patient's leg **70** with the leg in the flexed condition of FIGS. **2** and **3** or with the leg in the extended condition of FIG. **51**.

After the femoral component **290** and tibial tray **286** and tibial bearing insert **294** have been positioned in the knee portion **726** of the patient's leg **70**, the expandable devices **720** and **722** may be utilized to assist the surgeon during ligament balancing. The expandable devices **720** and **722** will also assist the surgeon in obtaining a full range of motion of the knee portion **76**. Thus, the expandable devices **720** and **722** may be expanded, under the influence of fluid pressure, to effect ligament releases or to move tissue out of an interfering relationship with relative movement between the femur **126** and tibia **214**.

The expandable devices **720** and **722** may be resiliently expanded under the influence of fluid pressure conducted through conduits to the expandable devices. If the expandable devices **720** and **722** are inserted after the incision **114** is formed in the knee portion **76** of the patient's leg **70**, the conduits for conducting fluid to and from the expandable devices **720** and **722** may extend through the incision. However, if the expandable devices **720** and **722** are inserted prior to making of the incision **114**, the conduits for conducting fluid to and from the expandable devices may extend through small portals or stab wounds formed in the knee portion of the patient's leg. It should be understood that the conduits for conducting fluid to and from the expandable devices **720** and **722** may extend through small secondary incisions spaced from the main incision **114** even though the expandable devices **720** and **722** are positioned in the knee portion **76** after making the main incision.

The small portals or stab wounds which form secondary incisions are spaced from the location where the main incision **114** is formed. Thus, the conduit for conducting fluid to and from the expandable device **722** may extend through a portal or stab wound formed in the posterior portion of the knee portion **76** of the patient's leg **70**. Before they are expanded, the contracted expandable devices **720** and **722**, are very small and flexible. The contracted expandable devices **720** and **722** have an appearance similar to a collapsed balloon. The contracted expandable devices are easily moved through the small secondary incisions.

It is contemplated that the expandable devices **720** and **722** may be left in the knee portion **76** of a patient's leg **70** after the incision **114** has been closed. If this is done, the expandable devices **720** and **722** may be utilized to obtain a full range of motion of the patient's knee **76** during therapy and/or recovery of the patient after the incision has been closed. If the expandable devices **720** and **722** are formed of a non-biodegradable material, it may be desirable to remove the expandable devices after the incision **114** has been closed. If the expandable devices **720** and **722** are formed of a biodegradable material, they do not have to be removed after the incision has been closed. It is contemplated that the expandable devices **720** and **722** may be contracted by piercing the skin **342** and puncturing the expandable devices.

It is contemplated that it may be desired to form the expandable devices **720** and **722** (and/or the conduits for inflating expandable devices **720** and **722**) of a biodegradable material which is absorbable by the patient's body. If this is done, the expandable devices **720** and **722** may be formed of polyglycolic acid, polylactic acid, or combinations of these materials. It is contemplated that the expandable devices **720** and **722** could be formed of materials which include hyaluronic acid, catgut material, gelatin, cellulose, nitrocellulose, collagen or other naturally occurring biodegradable materials. Although it is believed that it would be preferred to form the expandable devices **720** and **722** of biodegradable materials so that they can be left in the patient's body and hydrolyzed so as to be absorbed by the patient's body, it is contemplated that the expandable devices **720** and **722** could be made of a non-biodegradable material if desired. The resiliently expandable devices **720** and **722** may have any of the constructions disclosed in U.S. Pat. Nos. 5,163,949; 5,454,365 and 5,514,153. Of course, the resiliently expandable devices **720** and **722** could have a different construction if desired.

Obtaining Range of Motion

After the implants **286**, **290** and **294** have been positioned on the femur **126** and tibia **214** in the manner illustrated schematically in FIG. **52**, it is contemplated that the range of motion of the knee portion **76** will be checked. During the check of the range of motion of the knee portion **76**, it may be found that the range is unduly limited due to interference between body tissue in the posterior of the knee portion **76** and the implants. The range of motion of the knee portion **76** may be limited by tightness of tendons, ligaments and/or other tissue in the knee portion **76**.

Although it is believed that the expandable devices **720** and **722** of FIG. **51** may be utilized to alleviate these conditions, it may be preferred to use an expandable device **730** (FIG. **52**) which is inserted between the tibial bearing insert **294** and the trochlear groove in the femur **126**. Thus, once the implants **286**, **290** and **294** have been positioned in the knee portion **76** of the patient's leg **70**, the expandable device **730** may be moved through the incision **114**. The expandable device **730** is then moved between the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**.

The expandable device **730** may be a balloon or bladder which is made of resilient material. When fluid pressure in the expandable device **730** is increased, the expandable device is expanded from a collapsed condition to an extended condition. The resilient material of the expandable device **730** may or may not be stretched when the expandable device **730** is expanded.

The expandable device **730** may be moved posteriorly of the implants **286**, **290** and **294** so as to engage tissue in the posterior portion of the patient's knee. Alternatively, the expandable device **730** may be positioned between the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**. It is contemplated that the patient's leg **70** will be in the position illustrated in FIGS. **2** and **3** with the patella **120** (FIG. **52**) offset when the expandable device **730** is positioned in the knee portion **76**.

When the expandable device **730** is moved to the posterior of the patient's knee portion **76**, expansion of the expandable device **730** applies pressure against tissue in the posterior portion of the patient's knee. This results in movement of body tissue away from the implants **286**, **290** and **294**. Assuming that body tissue in the posterior of the patient's knee portion **76** is interfering with the range of relative movement between the implants **286**, **290** and **294**, applying pressure against the body tissue in the posterior of knee portion will move the body tissue away from the implants to enable the range of motion to be increased.

Expansion of the expandable device **730** is effective to move and stretch body tissue, such as the joint capsule, ligaments, tendons, skin or other tissue associated with the posterior portion of the patient's knee. Space is established between the distal end portion **120** of the femur **126** and body tissue. Space is also established between the proximal end portion **212** of the tibia **214** and body tissue. Since the body tissue is moved and stretched by expansion of the expandable device **730**, a portion of the space tends to remain even though the viscoelastic body tissue retracts when fluid is conducted from the expandable device **730** and the size of the device decreases.

The expandable device **730** may be left in place in the posterior of the patient's knee portion **76** after the incision **114** is closed. A conduit **734** connected with the expandable device **730** would extend through the closed incision **114** to enable fluid to be conducted to and from the expandable device **730**. Therefore, after the incision **114** has been closed, the expandable device **730** can be expanded to increase the range of movement of the knee portion **76** of the patient's leg **70**. After fluid has been conducted from the expandable device through the conduit **734**, the size of the expandable device is reduced by exhausting fluid through the conduit. The reduced size of the expandable device enables the conduit **734** to be pulled outward, away from the knee portion **76**, to pull the expandable device **730** through a very small opening in the closed incision.

If desired, the expandable device **730** could be formed of a biodegradable material and left in the posterior of the knee portion **76**. The conduit **734** could be formed of a non-biodegradable material and pulled from the opening in the incision after the expandable device **730** has at least started to degrade. Of course, the conduit **734** could also be biodegradable.

Rather than applying force against body tissue at the posterior of the knee portion **76**, the expandable device **734** may be utilized to apply force against the distal end portion **124** of the femur **126** and against the proximal end portion **212** of the tibia **214**. This force would tend to stretch or release ligaments or other fibrous connective tissue connected with the femur **126** and tibia **214**. This force would also stretch the joint capsule, collateral ligaments **590** and **592** (FIG. **41**), and other tissues around the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**.

When this is to be done, the expandable device **730** (FIG. **52**) is moved to a position midway between posterior and anterior portions of the implants **286**, **290** and **294**. The expandable device **730** is then expanded under the influence of fluid pressure conducted through the conduit **734**. As the expandable device expands, it acts as a joint jack to apply force against the femur **126** and tibia **214**. This force will tend to stretch the collateral ligaments and other ligaments and tendons connected with the femur **126** and tibia **214**.

Once the expandable device **730** has been utilized to apply an upwardly directed force (as viewed in FIG. **52**) against the distal end portion **120** of the femur **126** and a downwardly directed force (as viewed in FIG. **52**) against the proximal end portion **212** of the tibia **214**, the expandable device **730** is contracted by conducting a flow of fluid from the expandable device through the conduit **734**. The surgeon can then check ligament balancing and/or the range of motion of the knee portion **76**. If the ligament balancing check and/or range of motion check indicates that it would be beneficial, the expandable device **730** can again be utilized to apply force against the femur **126** and tibia **214**. Fluid pressure would again connected through the conduit **734** to the expandable device **730**. Expansion and contraction of the expandable device **730** can be repeated as many times as necessary to obtain the desired ligament balancing and/or range of motion of the knee portion **76**.

In FIG. **52**, the leg **70** of the patient is in the position indicated in FIGS. **2**, **3** and **25**. However, the leg **70** of the patient could be moved from the flexed position of FIG. **52** to the extended condition of FIG. **51** with the expandable device in position between the distal end portion **120** of the femur **126** and the proximal end portion **212** of the tibia **214**. It should be understood that the expandable devices **720**, **722** and **730** of FIGS. **51** and **52** may be utilized with the leg **70** of the patient in either the extended orientation of FIG. **51** or the flexed orientation of FIG. **52**. The leg **70** of the patient may be maintained stationary after insertion of the expandable devices **720**, **722** and/or **730**. Alternatively, the patient's leg **70** may be moved in any one or a combination of the directions indicated by the arrows **256**, **258**, **259** and **260** in FIG. **25** after insertion of the expandable devices **720**, **722** and/or **730**.

Although a single expandable device **730** is illustrated in FIG. **52**, it should be understood that a plurality of expandable devices **730** could be inserted into the knee portion **76** of the patient's leg. A first one of the expandable devices **730** may be inserted into the posterior of the knee portion **76**. A second expandable devices **730** may be positioned between the lateral portions of the femur **126** and tibia, that is, in a position similar to the position of the transducer **596** in FIG. **41**. A third expandable device **730** may be positioned between medial portions of the femur **126** and tibia **214**, that is, in a position similar to the position of the transducer **598** in FIG. **41**.

It is contemplated that different pressures may be conducted to the expandable devices in different positions in the knee portion **76**. For example, a relatively low fluid pressure may be conducted to the first expandable device **730** in the posterior of the knee portion **76** to move and/or stretch body tissue with a limited force. A relatively high fluid pressure may be conducted to the second and third expandable devices **730** disposed between the femur **126** and tibia **214** to effect relative movement between the femur and tibia.

If desired, a higher fluid pressure could be conducted to one of the expandable devices **730** disposed between the femur **126** and tibia **214** than the other expandable device. For example, a higher fluid pressure may be conducted to the second expandable device **730** disposed between lateral portions of the femur **126** and tibia **214** than to the third expandable device **730** disposed between the medial portions of the femur and tibia. Alternatively, a higher fluid pressure may be conducted to the third expandable device **730** disposed between medial portions of the femur **126** and tibia **214** than to the second expandable device **730** disposed between lateral portions of the femur **126** and tibia **214**.

When a plurality of expandable devices **730** are used, the expandable devices may be made of the same material or different materials. For example, the first expandable device **730** in the posterior of the knee portion may be formed of a biodegradable material. The second and third expandable devices **730**, located between the femur **126** and tibia **214**, may be formed of a non-biodegradable material. Alternatively, the expandable devices **730** may all be formed of the same biodegradable material as the expandable devices **720** and **722**.

It is contemplated that the expandable devices **720**, **722** and/or **730** of FIGS. **51** and **52** may be utilized in association with many different joints in a patient's body. For example, the expandable devices may be utilized in association with surgery on a glenoid joint. Alternatively, the expandable devices may be used in association with surgery on a patient's spine. During spinal surgery, the expandable devices **720**, **722** and/or **730** may be utilized to move one vertebra relative to an adjacent vertebra during replacement of an intravertebral disc between the vertebrae. If desired, the expandable devices **720**, **722** and **730** could be positioned between articular processes on vertebrae. When the expandable devices **720**, **722** and **730** are formed of a biodegradable material, they may be positioned relative to a patient's vertebral column during surgery and left in place after the surgery. This would allow at least partial healing after the surgery with the expandable devices being effective to transmit force between components of the patient's vertebral column.

The manner in which the expandable devices **720**, **722** and **730** may be utilized in association with any one of many joints in the patient's body is similar to that disclosed in U.S. patent application Ser. No. 09/526, 949 filed on Mar. 16, 2000. The manner in which an expandable device similar to the expandable devices **720**, **722** and **730** may be placed within a shoulder joint is similar to the disclosure in the aforementioned application Ser. No. 09/526,949 of which this application is a continuation-in-part. The expandable devices **720**, **722** and **730** may be utilized during carpal tunnel surgery in the manner disclosed in the aforementioned application Ser. No. 09/526,949. It is believed that it will be particularly advantageous to make the expandable devices **720**, **722** and **730** of biodegradable material so that they may be left in a patient's body at the end of the surgery.

As previously mentioned, the expandable devices **720**, **722** and **730** may be utilized during therapy after surgery to stretch body tissue in the knee portion **76** of the patient's leg **70** and/or to increase the range of motion of the knee portion. It is contemplated that an orthosis may be utilized to stretch tissue that limits joint movement. The orthosis may have a construction similar to the construction disclosed in U.S. Pat. No. 5,611,764. The orthosis may be utilized to affect static progressive stretching of tissue in the knee portion **76** of the patient's leg **70**. In addition, the orthosis may be utilized during progressive stress reduction. The orthosis may be utilized in conjunction with one or more expandable devices corresponding to the expandable devices **720**, **722** and **730** in the patient's knee portion. Alternatively, the orthosis may be utilized without providing expandable devices in the patient's knee portion.

It is contemplated that, during restoration of the range of motion of the knee portion **76**, a constant passive motion device may be connected with the patient's leg. The constant passive motion device may include one or more load or force limiting devices similar to those disclosed in U.S. Pat. No. 5,456,268. The constant passive motion device may have a construction similar to that illustrated in U.S. Pat. No. 5,285, 773. Of course, the constant passive motion device may have a different construction if desired. It is contemplated that a pulsatile stocking may be utilized to reduce the possibility of blood clots while a constant passive motion machine is utilized to increase the range of motion of the knee portion of a patient's leg.

It is contemplated that a laminar spreader may be used in association with the knee portion **76** during ligament balancing and/or gap balancing with the implants **286**, **290** and **294**. Alternatively, a distraction device which is spring loaded may be utilized on a medial, lateral or both sides of the knee portion **56** rather than the expandable elements **720**, **722** and **730** to increase range of motion and/or provide a desired ligament balancing. Insol's technique may be utilized in establishing a desire range of motion of the knee portion **76** of the patient's leg **70**.

Surgical Procedure

In the foregoing description of a specific surgical procedure which may be utilized in association with a knee portion **76** of a patient's leg, the femoral and tibial cuts are made, the patella is repaired and implants are installed in the knee portion **76** of the leg **70**. However, it is contemplated that the various steps in this surgical operation may be performed in a different order if desired.

Immediately after the limited incision **114** (FIG. **6**) is made in the knee portion **76** in the manner previously explained, repair of the patella **120** may be undertaken. During repair of the patella **120**, the patient's leg **70** is in the position illustrated in FIGS. **2** and **3**. The patella **120** is cut in situ with the guide assembly **464** (FIG. **36**). After a flat surface has been cut along the plane **484** (FIG. **35**) to form a flat surface on the inside of the patella, a layer on which the inner side **122** of the patella is disposed is removed. This decreases the thickness of the patella.

After the patellar cut has been made, in the manner previously explained and before installation of the patellar implant, the tibial cut is undertaken. During the tibial cut, the patient's leg **70** is in the position illustrated in FIGS. **2** and **3**. The proximal end portion **212** of the tibia **214** is cut, in the manner illustrated schematically in FIG. **21**.

While the tibial cut is being made, the patella **120** is offset from its normal position with the flat cut surface, previously formed on the inner side of the patella, facing toward the distal end portion **124** of the femur **126**. Since the patellar cut has already been made, the patella **120** is relatively thin and provides minimal stretching of the skin **342** and other tissues in the knee portion **76** when the patella is in the offset position of FIG. **21** during the making of the tibial cut.

After the tibial cut has been made, the femoral cuts are made. Making of the femoral cuts after making of the tibial cut and after making of the patellar cut maximizes the space which is available for the making of the femoral cuts. During the making of the femoral cuts, the patient's leg **70** is in the position illustrated in FIGS. **2** and **3**. After the tibial cut has been made, a layer is removed from the tibia and the cut surface **246** (FIGS. **22** and **23**) on the proximal end portion **212** of the tibia is spaced from the distal end portion **124** of the femur **126**. In addition, the patellar cut has been made so that the patella **120** is relatively thin and provides minimal interference. The femoral cuts are made in the manner previously explained in conjunction with FIGS. **8-20**.

After the femoral cuts have been made, the tibial tray **286** is positioned on the distal end portion **212** of the tibia **214** in the manner illustrated schematically in FIGS. **27** and **28**. After the tibial tray **286** has been positioned on the tibia **214**, the femoral implant **290** (FIG. **29**) is positioned on the distal end portion **124** of the femur **126**. After the femoral implant **290** has been positioned on the distal end portion **124** of the femur **126**, the tibial bearing insert **294** (FIG. **29**) is positioned on the tibial tray **286** in the manner previously explained.

Once the tibial and femoral implants **286**, **290** and **294** have been positioned, the patellar implant is mounted on the cut surface of the patella **120**. The patellar implant is positioned on the cut surface of the patella **120** while the patella is in the medially offset position illustrated in FIG. **29**. By applying force to the patella pulling it outward away from the distal end portion **124** of the femur **126**, a patellar implant can be moved between the patella **120** and the femoral implant **290** (FIG. **29**) and mounted on the patella **120**. When the patella **120** has been moved back to the normal or initial position illustrated in FIG. **6**, the implant on the patella is aligned with the distal end portion **124** of the femur **126**.

By making the patellar cut before making of the tibial cut and the femoral cuts, the available space for the tibial cut and femoral cuts is maximized. Maximization of the space for the tibial cut and femoral cuts and for the insertion of the femoral implant **290** and tibial implants **286** and **294** is maximized by mounting the patellar implant after the femoral and tibial implants have been mounted.

It should be understood that the foregoing procedure is performed with the patient's leg in the position illustrated in

FIGS. **2**, **3** and **25**. Thus, the upper portion **72** of the patient's leg is supported above the support surface **64** by the leg support **80**. The lower portion **68** of the patient's leg is suspended from the upper portion **72** of the patient's leg. The foot **74** is disposed below the support surface **64**.

Femoral Cutting Guide

A femoral cutting guide **750** (FIG. **53**) has cutting guide slots **752** and **754** with open ends **756** and **758**. The guide slot **752** has parallel guide surfaces **762**. Similarly, the guide slot **754** has parallel guide surfaces **764**.

The guide surfaces **762** for the guide slot **752** are skewed at an acute angle of forty-five degrees to a major side surface **766** of the femoral cutting guide **750**. Similarly, the guide surfaces **764** are skewed at an angle of forty-five degrees to the major side surface **756** of the femoral cutting guide **750**. The guide surfaces **762** extend perpendicular to the guide surfaces **764**. The guide surface **762** guide a saw blade during the making of an anterior chamfer resection on the distal end portion **124** of the femur **126**. Similarly, the guide surfaces **764** guide a saw blade during the making of a posterior chamfer cut on the distal end portion **124** of the femur **126**.

The femoral cutting guide **750** has an anterior guide surface **770** which guides movement of a saw blade during the making of an anterior resection on the distal end portion **124** of the femur **126**. Anterior guide surface **770** extends across the femoral cutting guide **750** between the lateral end portion **774** and a medial end portion **776** of the femoral cutting guide **750**. The anterior guide surface **750** extends perpendicular to the major side surface **766** of the femoral cutting guide **750**.

A posterior guide surface **780** guides movement of a saw blade during the making of a posterior resection on the distal end portion **124** of the femur **126**. The posterior guide surface **780** extends between the lateral end portion **774** and the medial end portion **776** of the femoral cutting guide **770**. The posterior guide surface **780** extends perpendicular to the major side surface **766** and extends parallel to the anterior guide surface **770**. The anterior guide surface **770** and the posterior guide surface **780** extend transverse to the guide surfaces **762** and **764** of the guide slots **752** and **754**.

The femoral cutting guide **750** is disposed on the distal end of the femur **126**. The femoral cutting guide **750** is connected with the distal end of the femur **126** by a pair of pins **784** and **786**. The pins **784** and **786** have longitudinal central axes which extend perpendicular to the major side surface **766** of the femoral cutting guide **750** and extend generally parallel to a longitudinal central axis of the femur **126**.

When the femoral cuts are to be made on the distal end portion **124** of the femur **126**, the femoral cutting guide **750** is connected to the distal end of the femur. Initial portions of the various femoral cuts are then made by moving the saw blade along the guide surfaces **762**, **764**, **770** and **780** on the femoral cutting guide **750**. Since the femoral cutting guide **750** extends only part way across the distal end portion **124** of the femur **126**, the femoral cutting guide is disconnected from the femur and the femoral cuts are completed.

After the femoral cutting guide **750** has been disconnected from the femur **126**, cut surfaces during formation of the initial portion of the anterior femoral cut are utilized to guide the saw blade during completion of the anterior femoral cut. Similarly, cut surfaces formed during the initial portion of the posterior femoral cut are utilized to guide the saw blade during completion of the posterior femoral cut. Cut surfaces formed during the making of anterior chamfer cut are utilized to guide the saw blade during completion of the anterior chamfer cut. Similarly, cut surfaces formed during making of the initial portion of the posterior chamfer cut are utilized to guide the saw blade during completion of the posterior chamfer cut.

The cutting tool which is used to form the femoral cuts, tibial cuts, and patellar cut may have any desired construction. Although a saw **172** and blade **170** have been disclosed herein as making the various cuts, many known types of cutting tools may be used if desired. For example, laser cutters, milling cutters, and/or ultrasonic cutters may be utilized. When one or more features of the present invention are utilized to perform knee joint revisions, an ultrasonic cutter may advantageously be utilized to cut cement previously used in association with an implant.

Side Cutting Guide

Using the femoral cutting guide **210** of FIG. **19** or the femoral cutting guide **750** of FIG. **53**, the femoral cuts are made by moving a saw blade from a distal end of the femur **126** toward a proximal end of the femur. However, it is contemplated that the femoral cuts could be made by moving a saw blade between opposite sides of the femur in a direction extending generally perpendicular to a longitudinal central axis of the femur. Thus, the saw blade is moved along a path which extends between lateral and medial surfaces on the distal end portion **124** of the femur **126**.

A femoral cutting guide **800** is illustrated in FIG. **54** as being mounted on a lateral surface **802** of the femur **126**. However, the femoral cutting guide **800** could be mounted on the medial surface of the femur **126** if desired. When the cutting guide **800** is mounted on the lateral surface **802** of the femur **126**, the incision **114** (FIG. **6**) is laterally offset. Similarly, when the cutting guide **800** is mounted on a medial surface of the femur **126**, the incision **114** is medially offset.

The femoral cutting guide **800** has a distal guide surface **806**. The distal guide surface **806** is disposed in a plane which extends perpendicular to a longitudinal central axis of the femur **126** and extends through the lateral and medial condyles. The distal guide surface **806** extends perpendicular to a major side surface **808** of the femoral cutting guide **800**.

An anterior chamfer guide surface **812** extends between opposite major sides of the femoral cutting guide **800**. The anterior chamfer guide surface **812** is disposed in a plane which extends at an acute angle of forty-five degrees to a plane containing the distal guide surface **806**. The anterior chamfer guide surface **812** extends perpendicular to the major side surface **808** of the femoral cutting guide **800**. Similarly, a posterior chamfer guide surface **816** extends between opposite major sides of the femoral cutting guide **800**. The posterior chamfer guide surface **816** is disposed in a plane which extends at an acute angle of forty-five degrees to a plane containing the distal guide surface **806**. The plane containing the posterior chamfer guide surface **816** extends perpendicular to the plane containing the anterior chamfer guide surface **812**.

An anterior guide surface **820** is disposed on the femoral cutting guide **800**. The anterior guide surface **820** extends between opposite major sides of the femoral cutting guide **800**. The anterior guide surface **820** is disposed in a plane which extends perpendicular to a plane containing the distal guide surface **806**. The plane containing the anterior guide surface **820** extends generally parallel to a longitudinal central axis of the femur **126**.

Similarly, the femoral cutting guide **800** includes a posterior guide surface **824**. The posterior guide surface **824** extends between opposite major sides of the femoral cutting guide **800**. The posterior guide surface **824** is disposed in a plane which extends parallel to a plane containing the anterior guide surface **820** and perpendicular to a plane containing the distal guide surface **806**.

The femoral guide **800** is formed of one piece of metal and has parallel opposite major side surfaces **808**. The femoral cutting guide **800** is connected with the lateral side **802** of the distal end portion **124** of the femur **126** by a pair of pins **830** and **832**. The lateral side **802** of the femur may be cut to form a flat surface which is abuttingly engaged by a major side surface of the femoral cutting guide **800**.

When the femoral cuts are to be made, the lateral side of the femur is cut to form a flat side surface on which the femoral cutting guide **800** is mounted by the pins **830** and **832**. A saw blade or other cutting tool is then moved from the lateral side to the medial side of the distal end portion **124** of the femur **126** while the saw blade or other cutting tool is guided by the distal guide surface **806** on the femoral cutting guide **800**. The distal guide surface **806** has an extent which is less than the extent of the distal end cut to be formed on the distal end portion **124** of the femur **126**. Therefore, after an initial portion of the distal end cut has been made utilizing the guide surface **806** to guide movement of a saw blade or other cutting tool, the cut surfaces are utilized to guide movement of the cutting tool during completion of the distal end cut.

Once the distal end cut has been completed, the saw blade or other cutting tool is moved from the lateral side of the femur **126** to the medial side of the femur along the anterior chamfer guide surface **812**. The cutting tool is then moved from the lateral side of the femur **126** to the medial side of the femur along the posterior chamfer guide surface **816**. Since the anterior chamfer guide surface **812** and posterior chamfer guide surface **816** have lengths which are less than the length of the anterior chamfer cut and posterior chamfer cut, only the initial portions of the chamfer cuts are made utilizing the guide surfaces **812** and **816** on the femoral cutting guide **800**. The cuts are completed by guiding movement of the saw blade or other cutting tool with the previously cut surfaces.

The anterior guide surface **820** is then utilized to guide movement of the saw blade during an initial portion of an anterior cut. During making of the anterior cut, the saw blade or other cutting tool is moved from the lateral side to the medial side of the distal end portion **124** of the femur **126**. Since the anterior guide surface **820** is smaller than the anterior cut, surfaces formed during making of an initial portion of the anterior cut are utilized to guide the saw blade or other cutting tool during a final portion of the anterior cut.

Similarly, the posterior guide surface **824** on the femoral cutting guide **800** is utilized to guide the saw blade or other cutting tool during making of a posterior cut. During the making of an initial portion of the posterior cut, the saw blade is moved along the posterior guide surface **824** from the lateral side **802** of the distal end portion **124** of the femur **126** to the medial side. The posterior guide surface **824** is shorter than the posterior cut. Therefore, cut surfaces formed during an initial portion of the posterior cut are utilized to guide the saw blade during completion of the posterior cut.

The femoral cutting guide **800** remains connected with the femur **126** during the initial portion of each of the femoral cuts and during completion of the femoral cuts. The femoral cutting guide **800** is not of the capture type. Therefore, a saw blade is free to move past the guide surfaces **806**, **812**, **816**, **820** and **824** during completion of the femoral cuts. If the guide surfaces **806**, **812**, **816**, **820** and **824** were formed by slots, the femoral cutting guide **800** would have to be disconnected from the femur before the femoral cuts could be completed.

The femoral cutting guide **800** has been illustrated in FIG. **54** as being mounted on the lateral side **802** of the femur **126**. However, it is contemplated that the femoral cutting guide could be mounted on the medial side of the femur if desired. The distal cuts, chamfer cuts, anterior cuts and posterior cuts were set forth as being performed in that order. However, there is no critical order as to the sequence of the cuts. It is contemplated that the cuts may be formed in any desired sequence.

During use of the femoral cutting guide **800**, the patient's leg **70** can be in the orientation illustrated in FIGS. **2**, **3** and **25**. The drapery system **100** can be utilized to maintain a sterile field during the operation on the patient's leg.

Optical Systems

Rather than using the guide members illustrated in FIGS. **9-21**, it is contemplated that an optically created guide could be utilized. The optically created guide may be a three dimensional image created by projecting a hologram onto an end portion of a bone which is to be cut. For example, a hologram may be used in projecting a three dimensional image of any one of the guides **138** (FIG. **11**), **186** (FIG. **17**), **210** (FIG. **20**), and **218** (FIG. **21**) onto a femur **126** or tibia **214** in a patient's body. Alternatively, one or more beams of coherent or non-coherent light may be projected onto the bone which is to be cut to provide a two dimensional cutting guide.

Utilizing pre-operative templating based on images of one or more bones in a patient's body, for example, a distal end portion **124** (FIG. **55**) of a femur **126**, a hologram may be developed. The hologram is utilized with a projector **858** to create a three dimensional image **850**. The illustrated three dimensional image is of a pattern of cuts to be made on the distal end portion of the femur **126**. In FIG. **55**, the three dimensional image **850** is visible to the surgeon **106** and is utilized to replace the femoral cutting guide **800** of FIG. **54**. Rather than replacing the femoral cutting guide **800** with a pattern of cuts as shown in FIG. **55**, the three dimensional image **850** may be an image of the femoral cutting guide **800**.

Although a hologram may be used to produce the three dimensional image **850** which is visible to the surgeon **106**, the image may be created in other ways if desired. When the visible image **850** is to be projected onto a flat surface cut on the distal end portion **124** of the femur **126**, a two dimensional image may be utilized if desired. The two dimensional image **850** may be accurately projected on to the flat surface on the end portion **124** of thee femur **126** utilizing either coherent or non-coherent light and known image projection techniques.

The three dimensional image **850** has visible light beams **852** and **854** which define opposite ends of a sight line for guidance of a saw **172** or other cutting tool. If desired, light may be projected with a plane of colored light which extends between the light beams **852** and **854**. The colored light plane extending between the light beams **852** and **854** is visible and provides a guide for alignment of a blade **170** in a desired spatial orientation relative to the side surface **802** on the femur **126**.

The surgeon **106** moves the saw blade **170** along the colored plane of light extending between the light beams **852** and **854**. The colored plane of light extending between the light beams **852** and **854** indicates to the surgeon the desired spatial orientation of the saw blade **170** during the making of a cut. A sensor connected with the saw **172** enables a computer connected with a source **858** of the image **850** to have the plane of light extend along each of the desired saw cuts during the making of the saw cut. Thus, during the making of the femoral cut which extends between the light beams **852** and **854**, a plane of colored light extends between the light beams. This enables the surgeon to determine when the saw blade is properly aligned with the side surface **802** of the femur **126**. When a different cut is to be made, for example, a cut between the light beam **852** and a light beam **862**, a plane of colored light extends between the light beams **852** and **862**. The plane of light is visible and indicates to the surgeon the desired spatial orientation of the blade **170** of the saw **172** relative to the femur **126**.

In addition, locating laser light beams **866** and **868** are projected from laser light sources **872** and **874** mounted on the saw **172**. The locating laser light beams **866** and **868** are visible to the surgeon **106** and are of a different color than the plane of light extending between the light beams **852** and **854** of the image **850**. Therefore, a surgeon can visually determine when the locating laser light beams **866** and **868** are aligned with the plane of light extending between the light beams **852** and **854** of the image **850**.

When the locating laser light beams **866** and **868** are disposed in the plane of light extending between the light beams **852** and **854**, the saw blade **170** is accurately aligned with the portion of the femoral cut to be made between the light beams **852** and **854** of the image **850**. If the locating laser light beams **866** and **868** are not disposed in the plane of light extending the light beams **852** and **854**, the saw blade **170** is not in alignment with the desired location for the femoral cut.

In addition to the visual indication provided by alignment of the locating laser light beams **866** and **868** with the plane of light between the light beams **852** and **854**, audible and/or visual signals may be provided to the surgeon indicating whether or not the locating laser light beams **866** and **868** are in alignment with the plane of colored light extending between the light beams **852** and **854**. For example, a green light may be illuminated when the locating laser light beams **866** and **868** are in the same plane as the light beams **852** and **854** of the image **850**. A red light may be illuminated when either or both of the locating laser light beams **866** and **868** are not located in the plane of colored light extending between the light beam **852** and the light beam **854**. In addition, a warning sound, that is, an alarm, may be sounded when either one of the locating laser light beams **866** or **868** is offset from the plane of colored light extending between the light beams **852** and **854**.

Once the femoral cut extending between the light beams **852** and **854** has been completed, the saw **172** and saw blade **170** are moved into alignment with a plane of colored light extending between the light beam **852** and **862**. A second femoral cut is then made in the same manner as previously described in conjunction with the light beams **852** and **854**. This process is repeated until the desired number of femoral cuts have been made.

In the embodiment illustrated in FIG. **55**, the image **850** is projected onto a side surface **802** of the femur **26**. If desired, a three dimensional image may be projected onto all sides of the distal end portion **124** of the femur **126**. If this is done, the image may advantageously be a three dimensional image formed by lines which define the cuts to be made. As the saw blade **170** moves along lines of the three dimensional image, the saw blade **170** is moved to orientations corresponding to the orientations of the saw blade when making the femoral cuts illustrated in FIGS. **12-23**. However, rather than using the cutting guides illustrated in FIGS. **12-23**, the three dimensional image, corresponding to the image **850** of FIG. **55**, is projected onto the entire distal end portion **124** of the femur **126**. Locating laser light beams would be projected from the saw **172** to indicate to a surgeon when a saw was in the desired orientation relative to light planes forming portions of the image projected onto the distal end **874**. This enables the saw blade **170** to be located relative to the distal end **874** of the femur **126** in the same manner as previously explained in conjunction with the side surface **802** of the femur.

As was previously mentioned, the three dimensional image **850** may be an image of anyone of the guides **138**, **186**, **210**, **500**, **750** or **800**. The saw blade **170** would be moved along the image of a guide surface on the three dimensional image of the guide. The locating laser light beams **866** and **868** would indicate to the surgeon the orientation of the saw blade **170** relative to the three dimensional image of a guide surface on the three dimensional image of any one of the guides **138**, **186**, **210**, **218**, **500**, **750** or **800**. This would eliminate the heavy metal guides which have previously been used. When the size of any one of the three dimensional images of one of the guides **138**, **186**, **210**, **218**, **500**, **750** or **800** is to be changed, it is merely necessary to have a computer controlling the projection of the three dimensional image to change a hologram being used to project the image or to effect a change in optics through which the image is projected.

Once the femoral cuts have been completed, an optical measuring device, such as an interferometer, may scan the cuts to determine if they have the desired configuration. Scanning the cuts with an optical measuring device may be used to eliminate the necessity of performing trials with provisional components. Eliminating the necessity of utilizing provisional components substantially reduces the amount of equipment required during a partial or total knee replacement.

The cut surfaces on the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** are illustrated in FIGS. **22** and **23**. Rather than performing trials with provisional implants, the cut surfaces on the femur **126** and tibia **214** are measured using known optical measuring devices. A computer, connected with the optical measuring device, is utilized to compare the measurement of the cut surfaces on the femur **216** and the tibia **214** with desired measurements for the specific implants **286**, **290** and **294** to be mounted on the femur and tibia. The computer also compares optically determined orientations of the cut surfaces on the femur **126** and tibia **214** relative to desired orientations of the cut surfaces.

The optical measuring device may have any one of many known constructions. For example, the optical measuring device may have the construction illustrated in U.S. Pat. Nos. 6,185,315 or 6,195,168 if desired. If an optical measuring device or other measuring device indicates that the cut surfaces are incorrect, a computer connected with the source **858** (FIG. **55**) of the image **850** will change the hologram to correspond to a next smaller size of implant. When a surgeon determines that the femur **126** should be cut for the next smaller size implant, the surgeon manually enters data into the computer. In response to this data, the computer causes the projector **858** of the image **850** to project an image corresponding to a next smaller size image. The saw **172** is then utilized to cut the femur along the lines indicated by the next smaller size image. This will allow the next smaller size implant to be mounted on the femur.

It is contemplated that the projector **858** could have any desired construction. For example, the projector **858** could have a construction which is generally similar to the construction of apparatus disclosed in U.S. Pat. No. 6,211,976. It is contemplated that the laser light sources **872** and **874** could have a construction similar to the construction of devices disclosed in U.S. Pat. No. 5,425,355. The laser light sources **872** and **874** may have a construction which is similar to the construction of devices which are commercially available from Laserscope, Inc. of San Jose, Calif.

It is contemplated that the patient's leg **70** will be in the position illustrated in FIGS. **2** and **3** when either the two dimensional or the three dimensional image is projected onto the end portion **124** of the femur **126**. The relatively small incision **114** may be resiliently expanded and/or moved relative to the distal end portion **124** of the femur **126** to allow the image **850** to be sequentially projected onto various areas on the distal end portion **124** of the femur **126**. A three dimensional image may be generated by any one of several known methods, including the method disclosed in U.S. Pat. No. 5,379,133.

It is contemplated that the three dimensional image **850** may be used with procedures other than cutting of one or more bones in a patient's leg **70**. For example, a three dimensional image of cuts to be made on a vertebra in a patient's back may be projected onto the vertebra. The three dimensional image may be used in surgery involving soft tissue in a patient's body. For example, the three dimensional image may be projected to a location in a patient's body where a vascular anastomosis or an intestinal anastomosis is to be undertaken. The three dimensional image may correspond to a pattern of stitches to be made between portions of soft body tissue. By projecting the three dimensional image into a patient's body at any desired location where surgery of any type is to be undertaken, a guide is provided in the patient's body to assist the surgeon.

The locating laser light beams **852** and **854** may be used with surgical instruments other than the saw **172**. For example, the locating laser light beams **852** and/or **854** could be utilized to indicate the position of a bovie, or a needle, or forceps relative to body tissue. The locating laser light beams may have an intensity which is sufficient to shine through body tissue and enable a surgeon on one side of body tissue to visually determine the position of a surgical instrument on the opposite side of the body tissue.

Unicompartmental Knee Replacement

The drawings associated with the foregoing description have illustrated a full knee replacement rather than a partial knee replacement. However, it is contemplated that the previously described features of the present invention may be utilized with either a partial knee replacement or a full knee replacement. A femur **126** is illustrated schematically in FIG. **56** and has a distal end portion **124** with a pair of condyles **890** and **892**. When a partial knee replacement is to be made, only one of the two condyles, that is the condyle **892**, is cut. A saw **172** having a blade **170** is used to cut the condyle **892** along a line indicated at **896** in FIG. **56**.

The saw **172** is provided with laser light sources **902** and **904**. The laser light sources **902** and **904** project visible locating laser light beams **906** and **908** which extend along opposite longitudinal edges of the saw blade **170**. The locating laser light beams **906** and **908** impinge against the condyle **892**. The locating light beams are of colored coherent light which is visible to a surgeon to indicate the orientation of the saw blade **170** relative to the condyle **892**.

It is contemplated that the saw **172** and blade **170** may be utilized in association with a guide member which is connected with the femur **126**. Alternatively, a two or three dimensional image, corresponding to the image **850** of FIG. **55**, may be projected onto the distal end portion of the femur **126**. Another alternative would be to make a line **896** on the condyle **892** with a marking instrument.

Rather than using a saw blade **170** to make the cut in the condyle **892**, it should be understood that a different type of cutting tool could be utilized if desired. For example, a milling cutter could be used to cut along a line **896** in FIG. **56**. If a full knee replacement, rather than a partial knee replacement, is desired, both condyles **890** and **892** may be cut with the saw **172** and blade **170** using the laser light sources **902** and **904** to indicate the position of the saw blade relative to the distal end portion **124** of the femur **126**. Once the femoral cuts have been made, an optical measuring device may be utilized to determine whether or not the cuts are of the proper size.

Multiple Incisions

A single incision **114** is illustrated in FIGS. **6-8** to provide access to the knee portion **76** of the patient's leg **70**. As has been previously explained herein, the length of the incision **114** is minimized. However, it is contemplated that the length of the incision **114** could be further reduced by providing one or more very small incisions **920** (FIG. **57**) in the knee portion **76** of a patient's leg **70** in association with the incision **114**. The incision **920** is a small stab wound which forms a portal through the skin **342**. The blade **170** of the saw **172** or other cutting tool may be moved through the small incision **920** to make one or more femoral cuts.

After the femoral cuts have been made through the small incision **920** and the larger or main incision **114**, femoral and/or tibial implants are moved through the main incision. By providing the small incision **920** in association with the larger main incision **114**, the overall length of the main incision may be minimized.

During making of the incisions **114** and **970**, the patient's leg **70** is in the position illustrated in FIGS. **2** and **3**. During making of the tibial and femoral cuts and insertion of the implants, the patient's leg **70** is also in the position illustrated in FIGS. **2** and **3**. If desired, one or more expandable devices, corresponding to the expandable devices of FIGS. **51** and **52**, may be inserted through one or more small incisions **920** and/or the main incision **114**.

In the embodiment of the invention illustrated in FIG. **57**, laser light sources **902** and **904** are connected with the saw **172** in the manner illustrated schematically in FIG. **56**. The laser light sources provide visible locating laser light beams, corresponding to the locating laser light beams **906** and **908** of FIG. **56**.

By using more than one incision, that is, the main incision **114** and one or more small incisions **920**, cutting tools can approach and move along the distal end portion **124** of the femur **126** from different directions. Thus, the saw blade **170** moves from the right to the left as viewed in FIG. **57**, that is, in a lateral direction, during making of a femoral cut. A cutting tool which moves through the incision **114** may move in a superior direction along the femur **126**, that is, from the distal end portion **124** of the femur **126** toward a proximal end portion of the femur. The cutting tools may be used to make cuts required for either a partial or full knee replacement.

Although it is preferred to make the incisions **114** and **920** and to cut the femur **126** with the leg **70** of the patient in the position illustrated in FIGS. **2** and **3**, it should be understood that the use of a plurality of incisions during the surgery with the leg in other positions may be desired. Although the foregoing description has been in conjunction with surgery on a knee portion of a leg **70** of a patient, it is contemplated that the surgery could be performed on a different portion of the patient if desired.

Patellar Tracking

A pair of transducers **596** and **598** are illustrated in FIGS. **41** and **42** to compare tension and collateral ligaments **590** and **592**. The manner in which the transducers **596** and **598** are positioned between the femur **126** and tibia **214** is illustrated schematically in FIG. **58**.

In accordance with another feature of the invention, a pair of patellar transducers **930** and **932** are disposed on an inner side of the patella **120**. The patellar transducers **930** and **932** are connected with a display, corresponding to the computer display areas **601** and **602** of FIG. **41**. The patellar transducers **930** and **932** are disposed between the distal end portion **124** of the femur **126** and the patella **120**.

The patellar transducers **930** and **932** have outputs which correspond to force transmitted between the patella **120** and the femur **126**. Thus, the output from the transducer **930** corresponds to the force transmitted between the lateral side of the patella **120** and a lateral side of a trochlear groove in the femur **126**. Similarly, the output from the transducer **932** corresponds to the force transmitted between a medial side of the patella **120** and a medial side of the trochlear groove in the femur **126**. By comparing the output from the patellar transducers **930** and **932** during relative movement between the femur **126** and tibia **214**, variations in the force transmitted between the lateral and medial portions of the patella **120** can be compared. This enables a surgeon to determine when the patella is tracking properly relative to the femur **126**.

The patellar transducers **930** and **932** are resiliently expandable containers which hold fluid. As the force transmitted between the patella **120** and the femur **126** increases, the pressure of the fluid in the patellar transducers **930** and **932** increases. It is contemplated that the containers **930** and **932** may hold either a gas or a liquid. Pressure signals corresponding to the pressure in the patellar transducers **930** and **932** are conducted through conductors **934** and **936** to a display, corresponding to the computer displays **601** and **602** of FIG. **41**. The patellar transducers **930** and **932** may have any desired construction which enables them to measure the force transmitted between the patella **120** and the femur **126**. Thus, the transducers **930** and **932** could be of the piezoelectric type or of a strain-gauge type.

During checking of patellar tracking with the transducers **930** and **932**, the upper portion **72** of the leg **70** of the patient is supported above the support surface **64** by the leg holder **80** (FIG. **2**). The leg **70** is moved between the flexed condition of FIGS. **2** and **3** and the extended condition of FIG. **4**. During movement of the leg **70** between the flexed and extended conditions, there is relative movement between the end portion **124** of the femur **126** and the patella **120** (FIG. **58**). During relative movement between the femur **126** and patella **120**, the output from the patellar transducers **930** and **932** indicates the manner in which force transmitted between the patella and femur varies. This enables a surgeon to detect any defects in tracking of the patella **120** relative to the femur **126**.

The patellar transducers **930** and **932** are mounted on the patella **120** after the patellar implant has been mounted on the patella. This enables the patellar transducers **930** and **932** to be utilized to detect any irregularities in the manner in which the patellar implant cooperates with the femoral implant **290** (FIG. **29**). However, it is contemplated that the patellar transducers may be mounted on the patella **120** before the patellar implant is mounted on the patella. When this is to be done, the transducers **930** and **932** may be mounted in a body having a size and configuration corresponding to the intended size and configuration of the patellar implant.

In the embodiment of FIG. **58**, the patellar transducers **930** and **932** extend across the patella **120** between lateral and medial edges of the patella. However, it is contemplated that the transducers **930** and **932** may extend only part way across the patella. If desired, more than the two illustrated patellar transducers **930** and **932** may be provided on the patella **120**.

The transducers **596** and **598** can be utilized in combination with the patellar transducers **930** and **932** (FIG. **58**). This enables the surgeon to determine the manner in which tension varies in the collateral ligaments **590** and **592** (FIGS. **41** and **42**) with variations in force transmitted between the patella **120** (FIG. **58**) and the femur **126**. However, the patellar transducers **930** and **932** may be utilized without the transducers **596** and **598**.

When it is determined that the patella **120** is not tracking properly, corrective action may be taken by increasing the fluid pressure in either or both of the patellar transducers **930** and **932**. If the transducers **596** and **598** are utilized, the corrective action may include increasing the fluid pressure in either or both of the transducers **596** and **598**. The transducers **596** and **598** and the patella transducers **930** and **932** are formed of resilient material which can be expanded under the influence of fluid pressure.

Although the patellar transducers **930** and **932** are utilized to measure force transmitted between lateral and medial portions of the patella **120** and the femur **126**, the patellar transducers can be utilized to stretch or move body tissue in the same manner as the expandable devices **720**, **722** and **730** (FIGS. **51** and **52**). By increasing the fluid pressure conducted to the patellar transducer **930** (FIG. **58**), the patellar transducer expands to stretch fibrous connective body tissue connected with the lateral side of the patella **120**. Similarly, increasing the fluid pressure conducted to the patellar transducer **932** expands the patellar transducer **932** to stretch fibrous connective body tissue connected with the medial side of the patella **120**. Increasing the fluid pressure conducted to both patellar transducers **930** and **932** is effective to expand both transducers and stretch fibrous connective body tissue with both sides of the patella **120**.

The patellar transducers **930** and **932** may be formed of either a biodegradable material or a non-biodegradable material. When the patellar transducers **930** and **932** are to be left in the knee portion **76**, the patellar transducers may be formed of a biodegradable material which is eventually absorbed by the patient's body. When the patellar transducers **930** and **932** are to be removed from the knee portion **76**, the patella transducers may be formed of a non-biodegradable material. If the patellar transducers **930** and **932** are formed of a biodegradable material and are left in the knee portion **76** after closing of the incision **114**, the patellar transducers may be expanded during therapy to stretch body tissue connected with the patella **120**.

Movable Implant

The implant **690** of FIG. **50** is fixedly secured to the proximal end portion **212** of a tibia **214** by the projection **700** and fastener **702**. In the embodiment of the invention illustrated in FIG. **59**, a moveable implant **950** is provided between the distal end portion **124** of a femur **126** and a proximal end portion **212** of a tibia **214**. In accordance with a feature of this embodiment of the invention, the implant **950** is freely moveable relative to both the femur **126** and the tibia **214**.

The moveable implant **950** has a smooth upper (as viewed in FIG. **59**) surface **952** which is engaged by a medial portion of the distal end portion **124** of the femur. Similarly, the moveable implant **950** has a smooth lower (as viewed in FIG. **59**) surface **954** which is engaged by a medial portion of the proximal end portion **212** of the tibia **214**. This smooth upper and lower end surfaces **952** and **954** compensate for defects in the existing surfaces on the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**. By providing the moveable implant **950** between the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**, pain which results from engagement of a surface **958** on the distal end portion **124** of the femur **126** with a surface **960** on the proximal end portion **212** of the tibia **214** is eliminated or at least substantially reduced.

During bending of the knee portion **76** of the patient's leg **70**, the implant **950** may move relative to both the femur **126** and the tibia **214**. The implant **950** can move in either a lateral or medial direction relative to the femur **126** and tibia **214**. In addition, the implant **950** can move in either a posterior or anterior direction relative to the femur **126** and tibia **214**.

By having a three hundred and sixty degree (360°) range of movement relative to both the femur **126** and tibia **214**, the moveable implant **950** accommodates relative movement between the femur and tibia with minimal pain. This is because relative movement will occur between the implant **950**, femur **126** and tibia **214** at locations where frictional forces due to irregularities on the surfaces of the femur **126** and tibia **214** are minimal. In addition, the implant **950** can shift relative to the femur **126** and tibia **214** during bending of the knee portion **76** to accommodate irregularities in the existing surfaces **958** and **960** on the distal end portion **124** of the femur and the proximal end portion **212** of the tibia.

The range of movement of the implant **950** relative to the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214** is limited by engagement of the moveable implant **950** with soft tissue in the knee portion **76** of the patient's leg **70**. Therefore, even though the implant **950** can move relative to the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**, the implant is held against excessive movement relative to the femur and tibia by soft tissues associated with the femur and tibia.

For example, engagement of the implant **950** with cartilage or other soft tissue which is located at the peripheral aspect of the knee joint between the femur **126** and tibia **214** retains the implant **950** within a desired range of movement. The cartilage may be articular cartilage and/or fibrocartilage. The cartilage is engaged by peripheral surfaces on the moveable implant **952** and retains the implant in a desired position relative to the femur **126** and tibia **214**. In addition, fibrous connective tissue extending between the femur **126** and tibia **214** limits movement of the implant **950** relative to the femur and tibia.

The joint capsule in the knee portion **76** of the patient's leg may be engaged by the periphery of the implant **950** to retain the implant in a desired position. By using cartilaginous, ligamentous, or other tissues to limit the range of movement of the moveable implant **950**, the implant can freely shift relative to the femur **126** and tibia **214** through a limited range of movement during bending of the knee portion **76** of the patient's leg **70**. If desired, growth of the tissues used to limit the range of movement of the implant may be promoted.

The moveable implant **950** is sized so as to fit the surfaces **958** and **960** on the distal end portion **124** and proximal end portion **212** of the femur **126** and tibia **214** (FIG. **59**). The sizing is accomplished by imaging the knee portion **76** of the patient's leg. The moveable implant **950** may be one of a series of implants of different sizes. After the patient's knee portion **76** has been imaged, a moveable implant is selected from the series of moveable implants of different sizes. The size of the selected moveable implant closely approximates the size of the space between the surfaces **958** and **960** on the distal end portion **124** and proximal end portion **212** of the femur **126** and tibia **214**.

Thus, for a relatively large individual, a moveable implant **950** having a relatively large size is selected from the series of moveable implants. Similarly, for an individual having a relatively small size, a moveable implant **950** having a relatively small size is selected from the series of moveable implants. The selected implant has a size which corresponds to the general size of the space between the surfaces **958** and **960**.

As a result of imaging of the knee portion **76** of the patient's leg **70**, the actual configurations of the existing surfaces **958** and **960** on the femur **126** and tibia **214** can be accommodated by shaping the upper surface **952** of the moveable implant **958** to have a configuration corresponding to the surface **958** on the femur **126**. Similarly, the lower surface **954** on the moveable implant **950** can be shaped to have a configuration corresponding to the configuration of the surface **960** on the tibia **214**. Of course, the configuration of the periphery of the moveable implant can be changed to correspond to the configuration of the periphery of the space between the surfaces **958** and **960** into which the moveable implant **950** is to be placed.

It is contemplated that the imaging of the knee portion **76** of the patient's leg **70** may be done preoperatively, on an outpatient basis. The moveable implant **950** may then be selected from the series of available moveable implants and shaped to have a configuration which corresponds to the configuration of the space between the surfaces **958** and **960**. The implant **950**, which has been shaped to conform to the space between the surfaces **958** and **960**, may then be moved to an operating room for insertion into a patient during the surgical procedure. Alternatively, the imaging of the knee portion **76** and shaping of the moveable implant **950** to the desired configuration may be performed in the operating room as part of the surgical procedure.

When the moveable implant **950** is to be positioned in the knee portion **76** of the patient's leg **70**, in the manner indicated schematically in FIG. **59**, a limited incision is made in the knee portion of the patient's leg. The limited incision is made while the patient's leg **70** is supported in the position shown in FIGS. **2**, **3** and **25**. The upper portion of the patient's leg is supported by the leg support **80**.

The incision may have a limited length, corresponding to the limited length of the incision **114** of FIG. **7** and be located adjacent to an edge of the patella **120**. When the implant **950** is to be positioned adjacent to a medial portion of the femur **126** and a medial portion of the tibia **214**, in the manner illustrated schematically in FIG. **59**, the incision **114** would be located adjacent to a medial edge of the patella **120**, in the manner illustrated in FIG. **6**. However, it should be understood that if the implant **950** is to be located adjacent to a lateral portion of the femur **126** and a lateral portion of the tibia **214**, the incision **114** could be formed adjacent to a lateral edge of the patella **120**.

Once the limited incision **114** has been formed in the manner previously described in conjunction with FIGS. **6** and **7** herein, the patella **120** may be moved to the offset position of FIG. **8** with the inner side **122** of the patella facing inward to facilitate utilization of an incision **114** having a limited length. Once the limited incision **114** has been formed, locations in the knee portion **76** of the patient's leg **70** may be inspected utilizing an optical device similar to the endoscope **352** of FIGS. **32** and **33**. It is believed that the surgeon will bend the leg **70** of the patient between the flexed condition of FIG. **32** and the extended condition of FIG. **33** and will rotate the lower portion of the leg about it longitudinal central axis, in the manner indicated by the arrow **258** in FIG. **25** prior to positioning of the implant **950** in the knee portion **76** of the leg **70**. This will enable the surgeon to detect any present or potential interference between the implant **950** and tissue in the knee portion **76** of the patient's leg **70**.

Once this has been done, the surgeon may or may not decide to cut tissue in the knee portion **76** of the patient's leg **70** before inserting the moveable implant **950**. If the surgeon elects to cut tissue in the knee portion **76** before insertion of the implant, this cutting will be relatively minor and will not involve the femoral and tibial cuts depicted in FIGS. **13-23** herein. This is because the moveable implant **950** is to be positioned between surfaces **958** and **960** which are in their existing condition. Of course, eliminating the major femoral and tibial cuts illustrated in FIGS. **13-23** herein will reduce the patient's post-operative recovery time. In addition, elimination of the major femoral and tibial cuts illustrated in FIGS. **13-23** enables the size of the incision **114** to be reduced.

Once the moveable implant **950** has been positioned between the existing surfaces **958** and **960** on the femur **126** and tibia **214**, the patella **120** is moved from the offset position of FIG. **8** back to its normal position relative to the distal end portion **124** of the femur **126** and the proximal end portion **212** of the tibia **214**. While the lower portion of the leg **70** is suspended from the upper portion of the leg and while the upper portion of the leg is held above the support surface **64** by the leg support **80** (FIG. **2**), the incision **114** is closed in a normal manner. Prior to closing of the incision, an imaging apparatus can be utilized to generate images of the knee portion **76** during bending of the leg **70** between the flexed and extended conditions of FIGS. **32** and **33**.

Any known imaging apparatus may utilized to image the knee portion **76** of the patient's leg **70**. For example, the known C-arm fluoroscope **360** of FIG. **34** may be utilized to generate images of the knee portion **76** of the patient's leg **70**. These images will enable the surgeon to determine the manner in which the implant **950** will move relative to the femur **126** and tibia **214** during bending of the patient's leg. Prior to closing of the incision **114**, any corrective action which the surgeon may believe is necessary can be taken to make certain that the moveable implant **950** is in the desired relationship with the femur **126** and tibia **214**.

Rather than forming the incision **114** in the manner illustrated schematically in FIG. **6**, the incision may be formed with an even shorter length and a cannula, corresponding to the cannula **364** of FIG. **39**, inserted into the incision. The implant **950** may be moved through the resiliently expandable cannula into the space between the existing surfaces **958** and **960** (FIG. **59**) on the femur **126** and tibia **214**. The cannula would stretch the viscoelastic material of tissues in which the very limited incision is formed to resiliently expand the extent of the incision **114** to enable the implant **950** to be moved through the incision even though the moveable implant **950** is larger than the incision.

The cannula **564** (FIG. **39**) through which the implant **950** (FIG. **59**) is moved into the space between the surfaces **958** and **960** is advantageously expandable to accommodate the implant **950**. The cannula may have any one of the constructions previously described in conjunction with FIG. **39** herein. If desired, multiple incisions, corresponding to the incisions **114** and **920** of FIG. **57** may be utilized during positioning of the implant **950**. An expandable cannula may be associated with either or both of the incisions. Fiberoptic devices, such as an endoscope or arthroscope, may be inserted through a very small incision, corresponding to the incision **920** of FIG. **57**, to facilitate positioning of the implant **950**. By utilizing an expandable cannula and/or arthroscopic and endoscopic surgical procedures, the size of the incision **114** through which the implant **950** is moved can be minimized.

The moveable implant **950** is flexible so that force transmitted between the femur **126** and tibia **214** deflects the moveable implant **950**. This results in the moveable implant **950** being shaped by the surfaces **958** and **960** on the femur **126** and tibia **214**. By shaping the upper surface **952** on the moveable implant **950** with the surface **958** on the femur **126**, smooth sliding engagement is provided between the surface **958** on the femur **126** and the upper surface **952** on the moveable implant **950**. Similarly, the lower surface **954** on the implant **950** is shaped by the surface **960** on the tibia **214**. By shaping the lower surface **954** on the implant **950** with the surface **960** on the tibia **214**, smooth sliding engagement is provided between the surface **960** on the tibia **214** and the lower surface **954** on the moveable implant **950** during bending of the knee portion **76**.

Shaping of the surfaces **952** and **954** on the moveable implant **950** may be accomplished in any one of many different ways. For example, the implant **950** may be formed of a material which is resiliently deflected by the surfaces **958** and **960** on the femur **126** and tibia **214**. This results in the upper surface **952** and lower surface **954** and the moveable implant **950** being resiliently deflected to have a configuration corresponding to the configuration of the portions of the surfaces **958** and **960** which are engaged by the moveable implant during bending of the knee portion **76**. During bending of the knee portion **76**, the moveable implant **950** shifts or moves relative to the surfaces **958** and **960** on the femur **126** and tibia **214**. During this shifting movement, the configuration of the upper surface **952** and the lower surface **954** of the moveable implant **950** is resiliently changed by forces transmitted between the femur **126** and tibia **214** through the moveable implant **950**.

Rather than having the moveable implant **950** resiliently deflected by force transmitted between the femur **126** and tibia **214**, the moveable implant **950** may be plastically deformed by the force transmitted between the femur and the tibia. Thus, the surface **958** on the femur **126** may plastically deform the upper surface **952** on the moveable implant **950** so that it retains a configuration corresponding to the configuration of the surface **958** on the femur **126**. Similarly, the surface **960** on the tibia **214** may be plastically deform the lower surface **954** on the moveable implant **950** so that it maintains a configuration corresponding to the configuration of the surface **960** on the tibia **214**. By plastically deforming the material of the moveable implant **950** with the surfaces **958** and **960** on the femur **126** and tibia **214**, smooth sliding engagement is obtained between the upper and lower surfaces **952** and **954** on the moveable implant **950** during bending of the knee portion **76**.

Even though the upper and lower surfaces **952** and **954** on the moveable implant **950** are either elastically or plastically shaped by the force transmitted between the femur **126** or tibia **214**, the moveable implant will, initially, be configured to have a shape corresponding to the existing space between the surfaces **958** and **960**. It is contemplated that this will result in the surfaces **952** and **954** being spaced apart by different distances between different portions of the moveable implant **950**.

For example, the distance between the upper surface **952** and lower surface **954** on the moveable implant **950** may be relatively large adjacent to a medial edge portion of the moveable implant **950**. The distance between the upper and lower surfaces **952** and **954** on the moveable implant **950** may be relatively small adjacent to a lateral edge portion of the moveable implant. As was previously mentioned, it is contemplated that images be generated of the knee portion **76** to enable the shape of the existing space between the surfaces **958** and **960** to be determined and to enable the moveable implant **950** to be configured, outside of the patient's body, to a configuration which generally conforms to the configuration of the space between the surfaces **958** and **960**. Once the moveable implant **950** has been initially shaped to a configuration corresponding to the configuration of the space between the surfaces **958** and **960**, the implant is positioned between the surfaces.

It is contemplated that the moveable implant **950** may be relatively thin compared to the thickness of the moveable implant illustrated schematically in FIG. **59**. This would result in the upper surface **952** of the moveable implant **950** being spaced apart from the lower surface **954** of the moveable implant by a relatively small distance. By forming the moveable implant **950** with a relatively small thickness, that is, the distance between the upper surface **952** and the lower surface **954**, the implant will be relatively flexible. This enables the implant to be deflected by force transmitted between the surfaces **958** and **960** on the femur **126** and the tibia **214**.

It is contemplated that a relatively flexible moveable implant **950** may be configured so as to readily fit into an existing space in the knee portion **76**. This would result in a tendency for the moveable implant **950** to become seated on the proximal end portion **212** of the tibia **214**. The moveable implant **950** would be seated on the proximal end portion **212** of the tibia **214** by force applied against the moveable implant by the surface **958** on the femur **126**. The lower surface of the moveable implant would be permanently deflected to have a configuration corresponding to the configuration of the upper surface **960** in the tibia **214**. The upper surface **952** of the moveable implant would have an overall configuration which may differ from the configuration of the surface **958** on the femur **126**. However, even though the configuration of the upper surface **952** on the moveable implant **950** is different than the configuration on the surface **958** on the femur **126**, there would be smooth sliding engagement between the surface **958** on the femur **126** and the upper surface **952** of the moveable implant **950**. The result would be that there would be relatively little movement between the lower surface **954** of the moveable implant **950** and the surface **960** on the tibia **214** during bending of the knee portion **76**. However, there would be a relatively large amount of movement between the upper surface **952** of the implant **950** and the surface **958** on the femur **126**. Since the moveable implant **950** would be permanently deflected to have a configuration corresponding to the space between the existing surfaces **958** and **960** on the femur **126** and tibia **214**, the existing surfaces **958** and **960** on the femur **126** and tibia **214** would cooperate with the moveable implant **950** without inducing pain in the knee portion **76** of the leg **70** of the patient.

It is contemplated that the moveable implant **950** may be formed of many different materials. For example, the moveable implant **950** may be formed of a biological material. For example, the moveable implant **950** may be formed of allograft or autograft or xenograft. Combinations of these graft materials may be utilized. These graft materials may be shaped in the manner disclosed in U.S. Pat. No. 5,888,219. The moveable implant **950** may be formed of the same materials as the implant **626** of FIGS. **43** and **45** if desired.

It is believed that it may be desired to form the moveable implant **950** of metal. For example, the moveable implant **950** could be formed of chromium, titanium, tantalum, zirconium or aluminum. The metal forming a moveable implant may or may not have a porous construction. The metal forming the moveable implant **950** would have a wettable surface which can be wetted by body fluids to provide lubricity. If the moveable implant **950** is formed of a porous metal, the metal may be impregnated with one or more polymeric materials which function as lubricants.

The moveable implant **950** may be formed of a ceramic material. The ceramic material of the moveable implant may have either a porous or non-porous construction. When the ceramic material of the moveable implant **950** has a porous construction, it is contemplated that the openings in the ceramic material will be filled with a lubricant to facilitate relative movement between the surfaces **958** and **960** on the femur **126** and tibia **214** and the surfaces **952** and **954** on the moveable implant **950**.

When the moveable implant **950** is formed of a porous material, for example a porous metal or a porous ceramic, it is contemplated that the moveable implant could be impregnated with both a bone growth promoting material and a lubricant. For example, the portion of the porous moveable implant **950** adjacent to the upper surface **952** of the implant may be impregnated with a lubricant. The portion of the moveable implant **950** adjacent to the lower surface **954** may be impregnated with bone growth inductive materials.

With such a construction, the lower surface **954** of the moveable implant is configured to correspond to the configuration of the surface **960** on the tibia **214**. Therefore, the moveable implant will tend to become seated on the proximal end portion **212** of the tibia **214**. Once this has occurred, the bone growth promoting materials in the porous implant **950**, adjacent to the lower surface **954** of the implant, will promote growth of bone into the moveable implant **950** to connect the moveable implant with the tibia **214**. The lubricant in the porous material adjacent to the upper surface **952** of the moveable implant **950** will minimize friction with the surface **958** on the femur **126** so that there will be minimal tendencies for the moveable implant **950** to move relative to the tibia **214** once the moveable implant has become seated on the proximal end portion **212** of the tibia. Of course, this will facilitate the growth of bone between the surface **960** on the proximal end portion **212** of the tibia **214** and the moveable implant **950**.

The moveable implant **950** may be formed of graft materials which have been shaped in the manner disclosed in U.S. Pat. No. 5,888,219. If desired, the moveable implant **950** may have a three dimensional scaffold or framework structure on which graft materials are disposed. The framework on which the graft materials are disposed may have sufficient flexibility to enable the moveable implant **950** to be flexed to correspond to the configuration of the surface **960** on the tibia **214** by force applied against the upper surface **952** of the moveable implant by the femur **126**. The graft materials on the scaffold will be shaped by the surface **958** on the femur **126** to form the upper surface **952** of the implant with the configuration which corresponds to the configuration of the surface **958** on the femur.

It is contemplated that the moveable implant **950** may be formed of materials which degrade with the passage of time. Thus, after the implant **950** has been disposed in the knee portion **76** of a patient's leg **70** for a predetermined period of time, for example two years, it may be necessary to replace the moveable implant **950**. Due to the limited incision required to enable the implant **950** to be positioned in the knee portion **76**, it is a relatively simple operation to replace the moveable implant **950**. The size of the incision and the trauma induced in the patient by replacing the moveable implant **950** may be minimized by the use of a cannula corresponding to the cannula **564** of FIG. **39**. The cannula through which the implant **950** is moved into the knee portion **76** of the patient's leg may have a construction similar to the construction illustrated in U.S. Pat. Nos. 3,811,449; 5,183,464; and/or 5,961,499.

Seating of the moveable implant on the tibia **214** may be promoted by forming the moveable implant of a hydrophilic material which absorbs body fluids and expands. When the implant **950** of hydrophilic material is positioned in the space between the surfaces **958** and **960** on the femur **126** and tibia **214**, the hydrophilic material of the implant will absorb body fluids and expand to fully occupy the space. This will result in the lower surface **954** of the moveable implant **950** being pressed firmly against the surface **960** on the tibia **214**. Similarly, the upper surface **952** on the moveable implant **950** will be pressed against the surface **958** on the femur **126** as the moveable implant absorbs body fluids and expands. This results in the moveable implant **950** expanding in such a manner as to change the configuration of the moveable implant to the configuration of the space between the surfaces **958** and **960** on the femur **126** and tibia **214**.

The hydrophilic material of the moveable implant **950** may be a polymeric material which is either a copolymer or a dipolymer. The hydrophilic material may contain petroylglupamic acid, carboxymethylcellulose, a collagen or polylactide. The hydrophilic material may be a ceramic that is found in hydroxyapatite composites with polyethylene, polylactide or polyhydroxybutyrate. Of course, the moveable implant **950** could be formed of other known hydrophilic materials which attract body liquid under the influence of molecular attraction and establishes molecular linkages with the body liquid. The hydrophilic material may be disposed on a frame work or base which is formed of a non-hydrophilic material such as a porous metal.

It should be understood that the patient's leg **70** is supported in a manner previously explained herein in conjunction with FIGS. **2** and **3**. The improved drape system **100** of FIGS. **4** and **5** may be utilized during surgery in which the moveable implant **950** is positioned in the knee portion **76** of the patient's leg **70**. The patient's leg **70** may be moved in the manner schematically by arrows in FIG. **25** to enable a surgeon to make certain that the moveable implant **950** cooperates with the femur **126** and tibia **214** in a desired manner. The articular surface **122** on the patella **120** may be repaired in the manner indicated schematically in FIGS. **35** and **36**, contemporaneously with positioning of the moveable implant **950** in the knee portion **76**. One or more expandable devices, similar to the expandable devices **720**, **722** and **730** of FIGS. **51** and **52** may be utilized to facilitate positioning of the moveable implant **950** in the knee portion **76** of a patient's leg **70**. It should be understood that any of the features previously described in conjunction with FIGS. **1-58** herein could be utilized, if desired, in association with the moveable implant **950**.

Moveable Inlay

In the embodiment of FIG. **59**, the moveable implant **950** is positioned in engagement with existing surfaces **958** and **960** on the femur **126** and tibia **214**. In the embodiment illustrated in FIG. **60**, a moveable implant **970** is positioned in a recess **972** formed in a medial portion of the proximal end portion **212** of the tibia **214**. The recess **972** may be relatively shallow and formed with a minimum or no cutting away of bone from the proximal end portion **212** of the tibia **214**. The recess may be formed by cutting away cartilage and/or other material disclosed on the proximal end portion **212** of the tibia **214**. Depending upon the condition of the proximal end portion **212** of the tibia **214**, the bone may or may not be cut away to form the recess **972**. Thus, the recess may be formed in tissues, such as fibrous tissues, associated with the end portion of the bone at the proximal end portion of the tibia **214**.

The moveable implant **970** may be held in position relative to the proximal end portion **212** of the tibia **214** by engagement with the recess **972**. If this is done, tissue growth promoting materials and/or materials which promote biological resurfacing may be provided in the moveable implant **970**. These materials would promote the growth of tissue adjacent to the proximal end portion **212** of the tibia **214** into the moveable implant **970**. The biological resurfacing materials would promote the growth of naturally occurring tissues, which were not removed to form the recess **972**, into the moveable implant **970**. Thus, cartilage tissues located adjacent to the peripheral aspect of the proximal end portion **212** of the tibia **214** would grow into the moveable implant **970**.

It should be understood that the recess **972** may have a lower surface formed by the existing surface **960** of the tibia and side surfaces formed by fibrocartilage which extends around the periphery of the moveable implant **970**. It is believed that it will be desired to position the moveable implant **970** in the recess **972** without anchoring the moveable implant to the tibia **214**. However, if desired, an adhesive such as fibrin could be utilized to connect the moveable implant with the existing surface **960** on the proximal end portion **212** of the tibia. The moveable implant **970** may have any one of the constructions previously described in conjunction with the implant **640** of FIGS. **46** and **48** or the multi layered implant **670** of FIG. **49**.

Multi Component Moveable Implant

The moveable implant **950** of FIG. **59** is formed as one piece. In the embodiment of the invention illustrated in FIG. **61**, the moveable implant **980** is formed with a plurality of pieces. The moveable implant **980** is disposed between a medial portion of the distal end portion **124** of a femur **126** and a medial portion of the proximal end portion **212** of a tibia **214**. The moveable implant **960** is positioned between an existing surface **958** on the femur **126** and an existing surface **960** on the tibia **214**. The moveable implant **980** includes an upper section **982** and a lower section **984**. The upper section **982** has an upper surface **988** which engages the existing surface **958** on the distal end portion **124** of the femur **126**. The upper section **982** of the moveable implant **980** has a lower surface **990** which engages the lower section **984** of the moveable implant **980**.

The lower section **984** of the moveable implant **980** has a lower surface **994** which engages the existing surface **960** on the proximal end portion **212** of the tibia **214**. In addition, the lower section **984** of the implant **980** has an upper surface **986** which engages a lower surface **990** on the upper section **982** of the moveable implant **980**.

The surfaces on the moveable implant **980** which engage existing surfaces on the femur **126** or tibia **214** are shaped to conform to the configuration of the existing surfaces on the femur and the tibia. To enable the surfaces on the moveable implant to be shaped to conform to the configuration of existing surfaces on the femur **126** and tibia **214**, images of the femur and tibia are generated utilizing known imaging apparatus, such as an MRI, X-ray, or fluoroscope. These images are utilized to determine the configuration of the existing surface **958** on the femur **126** and the existing surface **960** on the tibia **214**. The upper surface **988** on the upper section **982** of the moveable implant **980** is then shaped to a configuration corresponding to the configuration of the existing surface **958** on the femur **156**. The lower surface **994** on the lower section **984** of the moveable implant **980** is shaped to a configuration corresponding to the configuration of the existing surface **960** on the tibia **214**. By shaping the upper and lower surfaces **988** and **994** on the implant **990** to conform to the shape of the existing surfaces **958** and **960** on the femur **126** and tibia **214**, the upper and lower sections **982** and **984** tend to seat themselves on the femur **126** and tibia **214**. Thus, the upper surface **988** on the upper section **982** of the moveable implant **980** becomes seated against the existing surface **958** on the femur **126** under the influence of force transmitted between the existing surface **958** on the femur and the upper surface **988** on the upper section **982** of the moveable implant **980**. Similarly, the lower surface **994** on the lower section **984** of the implant **980** becomes seated against the existing surface **960** on the tibia **214** under the influence of force applied to the upper surface **996** on the lower section **984** of the moveable implant **980** by the upper section **982** of the moveable implant.

The lower surface **990** on the upper section **982** of the moveable implant **980** and the upper surface **996** on the lower section **984** of the moveable implant **980** are shaped to promote the desired articulation in the knee portion **76** of the leg **70**. Once the two sections **982** and **984** of the moveable implant **980** have been positioned between the existing surfaces **958** and **960** on the femur **126** and tibia **214**, relative movement occurs where the lower surface **990** on the upper section **982** of the moveable implant **980** engages the upper surface **996** on the lower section **984** of the moveable implant. This tends to minimize any pain or discomfort resulting from defects in the existing surfaces **958** and **960** on the femur **126** and tibia **214** during bending of the knee portion **76**.

The upper section **982** and lower section **984** may be formed of the same materials or any combination of the same materials as previously described in conjunction with the moveable implant **950** of FIG. **59**. Although the upper section **982** and lower section **984** of the moveable implant **980** are formed of the same material, it is contemplated that the upper section **982** could be formed of a material which is different than the material forming the lower section **984** of the moveable implant **980**.

The moveable implant **980** will be positioned in the space between the existing surfaces **958** and **960** on the femur **126** and tibia **214** in the manner previously discussed in conjunction with the embodiment of the invention illustrated in FIG. **59**. Thus, the patient's leg will be supported in the orientation illustrated in FIGS. **2** and **3** during the making of a limited incision along one side of the patella **120** in the manner illustrated in FIG. **6**. The patella **120** may then be offset to one side. Alternatively, the patella may remain in its initial position or be offset just slightly to provide sufficient space to insert the moveable implant **980**. It is contemplated that the knee portion **76** will be inspected utilizing fiberoptic devices similar to the endoscope **352** of FIGS. **32** and **33**. An expandable cannula corresponding to the cannula **364** of FIG. **39**, may be inserted into the incision and the endoscope and/or the moveable implant **980** inserted into the knee portion **76** through the expandable cannula.

Moveable Implant with Anchored Section

In the embodiment of the invention illustrated in FIG. **61**, the moveable implant **980** has upper and lower sections **982** and **984** which are moveable relative to each other and relative to the femur **126** and tibia **214**. In the embodiment of the invention illustrated in FIG. **62**, a moveable implant **1002** has a section which is fixedly connected with a bone in the knee portion **76** of the patient. In the embodiment of the invention illustrated in FIG. **62**, the moveable implant **1002** includes an upper section **1006** and a lower section **1008**. The upper section **1006** of the implant **1002** is freely moveable relative to the femur **126**. The lower section **1008** of the moveable implant **1002** is anchored to the tibia **214**. Thus, the upper section **1006** of the moveable implant **1002** is freely moveable relative to the existing surface **958** on a medial portion of the distal end portion **124** of the femur **126**. The upper section **1006** is also freely moveable relative to the tibia **214**. However, the lower section **1008** of the moveable implant **1002** is anchored to the tibia **214** by a keel or projecting section **1012**. The projecting section **1012** extends through the existing surface **960** on a medial portion of the proximal end portion **212** of the tibia **214**.

The upper section **1006** and lower section **1008** of the moveable implant **1002** are formed of the same material as previously discussed in conjunction with the moveable implant **950**. The upper and lower sections **1006** and **1008** of the moveable implant **1002** are positioned in the space between the existing surfaces **958** and **960** through a cannula which corresponds to the cannula **564** of FIG. **39**. The cannula extends into a limited incision and is resiliently expandable to stretch the viscoelastic body tissue in which the limited incision is formed to enable the moveable implant **1002** to be moved through the cannula into the space between the existing surfaces **958** and **960** on the femur **126** and tibia **214**.

Although the lower section **1008** of the moveable implant **1002** has been illustrated in FIG. **62** as being anchored to the tibia **214** and the upper section **1006** freely moveable relative to the femur **126**, this could be reversed if desired. Thus, the upper section **1006** of the moveable implant **1002** could be anchored to the femur **126**. If this was done, the lower section **1008** of the moveable implant **1002** would be freely moveable relative to the tibia **214**.

Securing Moveable Anchor

In the embodiment of the invention illustrated in FIG. **59**, the moveable implant **950** is freely moveable relative to the existing surfaces **958** and **960** on the femur **126** and tibia **214**. In the embodiment of the invention illustrated in FIG. **63**, a moveable implant **1020** is connected with the medial collateral ligament **1022**. Although the moveable implant **1020** is disposed between and is freely moveable relative to existing surfaces **958** and **960** on the femur **126** an the tibia **214**, the connection between the moveable implant **1020** and the medial collateral ligament **1022** limits the range of movement of the moveable implant **1020** relative to the existing surface **958** on a medial portion of the distal end portion **124** of the femur **126**. Similarly, the connection between the moveable implant **1020** and the medial collateral ligament **1022** limits the range of movement of the implant **1020** relative to the existing surface **960** on a medial portion of the proximal end portion **212** of the tibia **214**.

The moveable implant **1020** has the same construction as the moveable implant **950** of FIG. **59**. However, the moveable implant **1020** is provided with a small passage or opening which enables a suture **1026** to be used to interconnect the moveable implant **1020** and the ligament **1022**. The suture **1026** extends through the opening in the moveable implant **1020** and extends around the ligament **1022**. The suture **1026** holds the moveable implant **1020** in engagement with the ligament **1022**. This results in a side surface **1030** on the moveable implant **1020** being held in intimate apposition with the ligament **1022**. Due to engagement of the side surface **1030** on the moveable implant **1020** with the ligament **1022**, tissue can grow from the ligament into the moveable implant **1020** to further interconnect the ligament and the movable implant.

It is contemplated that the moveable implant **1020** will have a construction which promotes the in growth of tissue from the ligament **1022** into the implant. Thus, the moveable implant **1020** may have a porous scaffold on which tissue growth inductive factors are disposed. For example, the moveable implant **1020** could be formed of porous tantalum. The porous tantalum scaffold could contain collagen, fibrin, progenitor cells and/or tissue inductive factors. Of course, other known materials which promote biological resurfacing could be provided on the porous metal scaffold of the moveable implant **1020** if desired.

Although one specific construction of the moveable implant **1020** has been described, it is contemplated that the moveable implant **1020** could have many different constructions. For example, the moveable implant **1020** could have any one of the constructions and be formed of any one or more of the materials previously described in conjunction with the moveable implant **950**.

It is contemplated that the patient's leg **70** may be in the position illustrated in FIGS. **2** and **3** during positioning of the moveable implant **1020** in the space between the existing surfaces **958** and **960** on the femur **126** and tibia **214**. The upper portion of the patient's leg **70** may be supported above the support surface **64** (FIG. **2**) by the leg support **80**. The drapery system **100** of FIGS. **4** and **5** may advantageously be utilized during positioning of the moveable implant **1020** to provide a sterile field.

Connection of Moveable Implant with Soft Tissue

In the embodiment of the invention illustrated in FIG. **59**, the moveable implant **950** is freely moveable relative to the existing surfaces **958** and **960** on the femur **126** and tibia **214**. In the embodiment of the invention illustrated in FIG. **63**, the moveable implant **1020** is connected with the ligament **1022** to limit the range of movement of the moveable implant **1020**. In the embodiment of the invention illustrated in FIG. **64**, a moveable implant **1040** is connected with soft tissue other than the ligament **1022** of FIG. **63**. Rather than being connected with the soft tissue by single suture **1026** in the manner illustrated in FIG. **63**, the moveable implant **1040** is connected with soft tissue in a plurality of locations by a plurality of sutures.

The moveable implant **1040** (FIG. **64**) has the same construction as the moveable implant **950** of FIG. **59**. The moveable implant **1040** is positioned between existing surfaces **958** and **960** (FIG. **59**) on a femur **126** and tibia **214** in the same manner as is illustrated schematically in FIG. **59** for the moveable implant **950**. The moveable implant **1040** is moved into position between the existing surfaces on a femur and a tibia in the same manner as previously explained in conjunction with the moveable implant **950** of FIG. **59**. Thus, the moveable implant **1040** of FIG. **64** is moved into a position between existing surfaces **958** and **960** on a femur and tibia through a limited incision and a resiliently expandable cannula corresponding to the cannula **564** of FIG. **39**.

In accordance with one of the features of this embodiment of the invention, a plurality of connections **1044** are provided between the periphery of the moveable implant **1040** and soft tissue **1046**. Although many different soft tissues in the knee portion **76** of a patient's leg may be connected with the moveable implant **1040** by connections **1044**, in the embodiment of the invention illustrated in FIG. **64**, the moveable implant **1040** is connected with the joint capsule in the knee portion **76** of the patient's leg **70**. The joint capsule extends around and encloses the knee joint. Therefore, the connections **1044** can be formed between the moveable implant **1040** and the soft tissue of the joint capsule **1046** at a plurality of locations in the manner illustrated in FIG. **64**.

By providing anterior and posterior connections **1044** with the soft tissue of the joint capsule **1046**, the moveable implant **1040** is held against excessive movement in either a posterior or anterior direction. Similarly, the connections **1044** between the moveable implant **1040** and the medial portion of the soft tissue or joint capsule **1046** holds the moveable implant **1040** against excessive movement in either the medial or lateral direction. The connections **1040** may initially be formed by sutures.

Although the range of movement of the moveable implant **1040** relative to the femur **126** and tibia **214** (FIG. **59**) is limited by the connections **1044** (FIG. **64**), the moveable implant **1040** is freely moveable relative to the existing surfaces **958** and **960** (FIG. **59**) on the femur **126** and tibia **214** within the range of movement established by the connections **1044** with the soft tissue or joint capsule **1046**.

Tissue inductive growth factors are provided on the moveable implant **1040**. The tissue inductive growth factors promote a growth of the soft tissue onto the moveable implant **1040**. It is contemplated that the moveable implant **1040** will have a porous platform in which the tissue growth inductive factors are disposed. This will promote a growth of the soft tissue or joint capsule **1046** into the moveable implant **1040** to assist the sutures at the connections **1044** in interconnecting the moveable implant **1040** and the soft tissue or joint capsule **1046**.

Thus, the connections **1044** between the moveable implant **1040** and the soft tissue **1046** is initially established by sutures which extend between the moveable implant **1040** and the soft tissue or joint capsule **1046**. With the passage of time, tissue grows from the soft tissue or joint capsule **1046** into the periphery of the moveable implant **1040** to further interconnect the moveable implant **1040** and the soft tissue. The sutures which initially form the connections **1044**, hold the periphery of the moveable implant **1040** in engagement with the soft tissue **1046**. Due to the intimate apposition of the moveable implant **1040** with the soft tissue or joint capsule **1046** and the tissue growth promoting factors in the moveable implant **1040**, growth of the soft tissue or joint capsule **1046** into the periphery of the moveable implant **1040** is promoted.

Molded Implant

In the embodiment of the invention illustrated in FIGS. **65** and **66**, an implant **1060** is molded onto an existing surface **960** on the proximal end portion **212** of the tibia **214**. The implant **1060** is formed of bone cement which is held in place by a retainer or dam **1064** which extends around a medial portion of the proximal end portion **212** of the tibia **214**. The dam forms a compartment which is filled with the bone cement. As the bone cement hardens, the femur **126** (FIG. **59**) is moved relative to the tibia **214** to impart a desired configuration to the bone cement.

Once the bone cement has hardened, the retainer or dam **1064** may be removed. The bone cement then forms an implant which is disposed on the existing surface **960** of the tibia **214**. The bone cement is connected with existing surface **960** of the tibia **214** by adhesion between the implant **1060** and the existing surface **960** of the tibia **214**. It is contemplated that a releasing agent could be mixed with the bone cement which is used to form the implant **1060** so that the implant would not adhere to the existing surface **960** of the tibia **214**. This would result in the implant **1060** being freely moveable relative to both the tibia **214** and the femur **126** in the same manner as in which the moveable implant **950** is freely moveable relative to the femur **126** and tibia **214**.

Deformity Correction

The moveable implants of FIGS. **59-66** are utilized to affect a resurfacing of joint surfaces to minimize pain resulting from defective joint surfaces. The moveable implants of FIGS. **59-66** are not particularly effective in correcting deformities in the femur **126** and/or tibia **214**. Thus, the moveable implant **950** (FIG. **67**) is positioned between the femur **126** and tibia **214** to compensate for defects in the existing surfaces **958** and **960** on the femur **126** and tibia **214**. It is contemplated that other devices will have to be utilized to compensate for bone deformities. The devices which are utilized to compensate for bone deformities may be positioned in the femur **126** and/or tibia **214**.

The devices which compensate for bone deformities may have a construction similar to the construction of any one of the devices disclosed in U.S. Pat. No. 6,086,593. Of course, other known devices could be utilized to correct bone deformities if desired.

One specific device which may be utilized to correct bone deformities is a wedge member **1080** (FIG. **67**). The wedge member **1080** is formed of a relatively hard rigid material. The wedge member **1080** is capable of transmitting force between upper and lower portions of a bone, such as the tibia **214**. The wedge member **1080** may be hollow and have a compartment which is filled with bone growth inductive material. The wedge member may be formed of a suitable rigid material, such as tantalum or stainless steel. Alternatively, the wedge member **1080** could be formed of a biodegradable material. It is contemplated that the wedge member **1080** may be formed of human bone.

When the wedge member **1080** is to be positioned in the tibia **214**, a saw cut is made to form a slot at the location where the wedge member **1080** is to be installed. The saw cut and resulting slot extend only part way through the tibia **214**. The wedge member **1080** is then moved into the slot. As the wedge member is forced into the slot, the wedge member pivots an upper portion of the tibia **214** in a counter-clockwise direction (as viewed in FIG. **67**) relative to a lower portion of the tibia to correct a deformity in the tibia or to compensate for a deformity in the femur **126**.

Although the wedge member **1080** has been illustrated in FIG. **67** as being installed in the tibia **214**, it is contemplated that the wedge member could be installed in the femur **126** if desired. Although the wedge member **1080** has been illustrated in FIG. **67** as being installed in a medial portion of the tibia **214**, the wedge member **1080** could be installed in a posterior, anterior or lateral portion of the tibia if desired. The wedge member **1080** has the same construction and cooperates with the femur in the same manner as is disclosed in the aforementioned U.S. Pat. No. 6,086,593.

It is contemplated that the patient's leg **70** will be in the position illustrated in FIGS. **2** and **3** during installation of any one of the implants illustrated in FIGS. **59-66**. However, the implants could be positioned in the patient's leg with the patient's leg in a different orientation if desired. Thus, any one of the implants of FIGS. **59-66** could be placed in the patient's leg with the patient's leg in either the flexed or extended orientation illustrated in FIG. **1**.

The foregoing description of the moveable implants of FIGS. **59-66** has been in conjunction with the knee portion **76** of a patient's leg **70**. However, it is contemplated that the implants will be used in association with other joints in a patient's body. For example, any one of the implants of FIGS. **59-66** could be utilized in association with a glenoid joint. Alternatively, any one of the implants could be used in association with an ankle, wrist or elbow joint. It is contemplated that any one of the many different features of the present invention may be utilized separately or in association with the implants illustrated in FIGS. **59-66** and that the implants may be used in association with any desired joint in a patient's body.

In-Situ Bone Removal

As previously detailed, one aspect of the present invention is the performance of all or a portion of a surgical procedure through a cannula. FIGS. **68-74** show one embodiment of this aspect as applied to the hip joint. Access to acetabulum **1100** and proximal portion of femur **1102** may be obtained through a cannula **1104**. Cannula **1104** is inserted into incision **1106**, which is formed with a relatively short length (generally less than 10 cm in length) in the manner previously described herein. Cannula **1104** has an initial size, illustrated in FIG. **68**, which stretches the viscoelastic tissue around the hip joint. Therefore, initial insertion of cannula **1104** into incision **1106** is effective to expand the incision.

FIG. **68** shows one manner in which guidance of the cannula (and any subsequent surgical implement going therethrough) to the desired location can be facilitated. A guide wire **1108** having a sharp tip is driven through femur **1102** and pinned to bone. Although guide wire **1108** is shown pinned to acetabulum **1100**, guide wire **1108** can be pinned to femur **1102**, as discussed below. Pinning guide wire **1108** to bone helps to ensure that the location of cannula **1104** remains relatively constant during the surgical procedure.

A pilot hole can be created through femur **1102** to help insert guide wire **1108**. Additionally, the creation of this pilot hole and/or the insertion of guide wire **1108** can be done under imaging guidance, such as fluoroscopy. Additionally, the proximal end of guide wire **1108** or cannula **1104** (FIG. **69**) can include an IR reflector **1109** for use with a computer surgical navigation system to monitor the location of guide wire **1108**. As is well known, IR reflector **1109** can alternatively be an electromagnetic radiation transmitter or receiver depending on the specific computer surgical navigation system.

Cannula **1104** is advantageously expandable to further stretch the viscoelastic tissue. Of course, expanding cannula **1104** increases the size of a passage **1110** formed by an inner side **1112** of cannula **1104**, thereby enabling a relatively large object to pass through the passage. Thus, cannula **1104** may be expanded to facilitate movement of surgical implements, such as implants and instruments through the cannula.

It is contemplated that expandable cannula **1104** may have many different known constructions. The illustrated cannula **1104** is formed of elastomeric material and has the same construction as disclosed in U.S. Pat. No. 6,338,730. It should be understood that cannula **1104** could have a different construction, for example, a construction similar to the constructions disclosed in U.S. Pat. Nos. 3,811,449 or 5,183,464.

Cannula **1104** can be expanded in many different ways other than under the influence of force transmitted directly to the cannula from an object moving through the cannula. Cannula **1104** may be expanded by inserting tubular members into the cannula. Alternatively, fluid pressure could be used to expand cannula **1104** in the manner disclosed in the aforementioned U.S. Pat. No. 6,338,730.

By utilizing expandable cannula **1104** or the expandable pneumatic retractors previously disclosed, force can be applied against opposite sides of incision **1106** to stretch the viscoelastic material disposed adjacent to opposite sides of the incision. This will result in the relatively small incision **1106** being expanded to accommodate relatively large surgical instruments and/or implants.

Once cannula **1104** is inserted, guide wire **1108** can be removed if desired. Alternatively, guide wire **1108** can be used to direct insertion of other surgical implements. Regardless of whether guide wire **1108** is removed, cannula **1104** can be moved or pivoted about incision **1106** so that its location can be varied. This is particularly useful, for example, if the area surrounding the surgical site needs to be accessed.

Although a single incision **1106** is illustrated in FIG. **68**, it is contemplated that a plurality of incisions could be provided. Thus, a small incision may be spaced from the incision **1106** to enable a suctioning tool to be moved into the hip joint along a path which is spaced from and may be transverse to a path along which a cutting tool is moved through the incision **1106**. A second cannula, which is smaller than the cannula **1106**, may be utilized with the second incision.

If desired, tissue retractors and/or dissectors can be used to create space between the soft tissue and the bones of the hip joint. Prior art mechanical dissectors and retractors can be used. It is also contemplated that fluid operated retractors, expanders, and/or dissectors may be used to retract, expand or dissect body tissue. For example, retractors having a construction similar to any one of the constructions disclosed in U.S. Pat. No. 5,197,971 may be utilized to release tissue at locations spaced from incision **1106**. When tissue is to be released at locations where there is limited accessibility from incision **1106**, a device similar to any one of the devices disclosed in U.S. Pat. No. 5,295,994 may be utilized. It is believed that devices similar to those disclosed in U.S. patent application Ser. No. 09/526,949 filed Mar. 16, 2000 may be used in ways similar to those disclosed therein to move and/or release body tissue.

As shown in FIG. **69**, a fluid operated device **1114** is inserted through cannula **1104** so that a bladder **1116** is placed between soft tissue **1117** and acetabulum **1100** and femur **1102**. Bladder **1116** is inflated by fluid introduced via tubing **1118** to move soft tissue **1117** relative to acetabulum **1100** and femur **1102**. Fluid operated device **1114** may be formed of biodegradable or non-biodegradable material. If bladder **1116** and tubing **1118** are formed of a biodegradable material, they need not be removed prior to closing of incision **1106**.

In the case of a hip replacement surgery (total or partial), a reamer is typically used to create a uniform cavity for the acetabular component and/or an oscillating blade is typically used to remove a portion of the femoral head so that the femoral component can be received in the medullary canal of the femur. In this regard, compact cutting tools, similar to those utilized for arthroscopic, endoscopic, or fiber optic assisted surgery may be at least partially moved through passage **1110** to affect in situ removal of bone. The cutting tools may have a construction similar to the construction illustrated in U.S. Pat. Nos. 5,540,695 or 5,609,603. Alternatively, the cutting tools may have a construction similar to the construction disclosed in published U.S. Patent Application No. 2002/0055755 A1.

U.S. Pat. No. 5,269,785 also discloses a tissue removal system and method that can be used with the limited incision system according to the present invention. This patent discloses a device with a flexible shaft and a controllable tip. Furthermore, the device can be single lumen or multi-lumen, with a cannula if desired. The cutting tip can be controlled via valves, pneumatics, radio control, fiberoptic control, electric wire control, cable control, or pneumatic control. Multiple movable segments or a single movable segment can provide the flexibility. Joints can be provided between rigid sections. The flexibility and controllability are particularly useful in limited incision procedures. For example, the device can be bent over a 60-90° angle, and then selectively remove osteophytes at the edge of the tissue without damaging the associated tissue. Furthermore, the option of suction provides for tissue removal and the option of irrigation minimizes heat necrosis in the limited operative space.

The reaming of the acetabulum can be done in a single pass with a single reamer, or a plurality of progressively larger reamers can be used. Guide wire **1108** is particularly helpful with multiple reamers since the locking of guide wire **1108** with respect to acetabulum **1100** helps ensure that each reamer is reaming about the same central axis.

FIGS. **70A-70B** show another embodiment of a tissue removing surgical instrument particularly useful for minimally invasive hip replacement surgeries. FIG. **70A** shows tissue removing surgical instrument **1120** in a retracted position so that instrument **1120** can move freely within lumen **1110** of cannula **1104**. Instrument **1120** is provided with a cannulation **1122** along a shaft **1123** so that instrument **1120** can be moved along guide wire **1108**. Upon activation, distal end **1124** of instrument **1120** assumes the shape shown in FIG. **70B**. Concave underside **1126** of the cup-shaped distal end **1124** has at least one cutting surface **1128** so that rotation of instrument **1120** in conjunction with retrograde movement of instrument **1120**, i.e. movement in the direction of arrow **1130** (FIG. **71**), causes removal of the bone forming the head of femur **1102**.

Convex top side **1132** of the cup-shaped distal end **1124** has at least one cutting surface **1134** (shown in the form of gratings typical of prior art acetabular reamers) so that rotation of instrument **1120** in conjunction with antegrade movement of instrument **1120**, i.e. movement in the direction of arrow **1136** (FIG. **72**), causes reaming of acetabulum **1100**. Instrument **1120** can be provided with irrigation and suctioning capacities, as taught in published U.S. Patent Application No. 2002/0055755 A1 to minimize heat necrosis and aid in the evacuation of the removed bone. Alternatively, a separate suctioning, and if desired, irrigation device, can be used. The separate device(s) can extend through cannula **1104** or an additional cannula.

Activation of instrument **1120** can occur in a number of different ways. For example, rotational movement of instrument **1120** alone can cause instrument **1120** to go from the retracted (FIG. **70A**) to the extended position (FIG. **70B**). U.S. Pat. No. 5,445,639 teaches one such rotational mechanism. Alternatively, fluid pressure, cable means, or other similar mechanisms can be used for activation.

After removal of the head of femur **1102** and reaming of acetabulum **1100**, the cutting tool or tools can be withdrawn from the hip joint. In the case of instrument **1120**, instrument **1120** can be pulled back through passage **1110**, with distal end **1124** in the retracted position, or in the expanded position if the diameter of passage **1110** permits and the surgeon so desires. Alternatively, distal end **1124** can be separated from the rest of instrument **1120**, for example by cutting off and removal through a separate incision.

It should be noted that the reaming of acetabulum **1100** and removal of the head of femur **1102** can be done with minimal, i.e. subluxation, or no dislocation of the hip joint. As previously noted, access to the joint space can be increased by movement of cannula **1104**. Additionally, the joint space can be manipulated remotely. For example and as shown in FIG. **68**, an elongate member **1138**, such as a Schanz screw, can be inserted through a stab wound and attached to femur **1102**. Elongate member **1138** can be used as a lever arm to increase the access to the hip joint. As a result of the reduction or elimination of dislocation, the interoperative strain on the soft tissue surrounding the hip joint is minimized. Any damage or cutting of soft tissue is also minimized. These features limit post-operative pain and lead to quicker surgical recovery.

The present invention also envisions insertion of some or all of the implant components through cannula **1104**. This concept will be illustrated with a description of the procedure for an acetabular component. An analogous procedure for the femoral component can be used and a procedure for use with the knee has been described above. FIG. **73** shows the backing **1140** (typically made of a metal) of an acetabular component being inserted. Cannula **1104** is in an expanded state to accommodate the backing **1140**. Alternatively, a larger non-expandable cannula could be used. Preferably, guide wire **1108** is the same guide wire that was used for cannula **1104** and tissue removing instrument **1120**. This helps to ensure that backing **1140** is implanted at the same location that the reaming occurred.

Guide wire **1108** can be removed so that a standard liner or insert (typically made of polyethylene) can be used in conjunction with backing **1140**. Alternatively and as shown in FIG. **74**A, an insert **1142** having a bore **1144** can be used so that insert **1142** can slide over guide wire **1108** in a manner similar to backing **1140**. FIG. **74**B shows another design for an insert **1146** that has a bore **1148** so that insert **1146** can slide over guide wire **1108**. One different between insert **1142** and insert **1146** is the location of bore **1144** compared to bore **1148**. Bore **1148** is placed in an area where no articulation with the ball of the femoral component occurs. As a result, the tolerances for the edges surrounding bore **1148** are not a significant concern for the generation of wear debris. Regardless of the location, the bore can be sealed, for example with an adhesive, to help contain any wear debris and minimize migration.

Other acetabular designs can be used. For example, the backing and liner acetabular components can be bonded together, either inside or outside of the patient. The portions may be bonded together by the application of energy in any one of many different forms, such as ultrasonic energy and heat. The present invention also envisions the application of the principles described and shown in FIGS. **68-74** to other locations in the body. Examples include the knee, the shoulder (both the glenoid and humeral components), the joints of the hand and wrist, the joints of the foot and ankle, and the spine. With respect to the spine, suitable procedures include any procedure involving the disc space and/or the vertebra, such as fusions, pedicle screw insertions, cages, or other implants.

In knee replacement procedures, in situ reaming of the patella as well as the condyles of the femur and tibia can be performed. Specifically, a guide wire is placed over the condyles and reaming occurs over this guide wire using a mill or a cutting saw. The patella could be removed in a similar fashion with a retrograde reamer directed by a guide wire. As previously described, the milling/cutting tools could be used in conjunction with jigs that allow a plurality of intersecting straight cuts or a smooth arc cut. The jig can be mounted on the medial or lateral side. If desired, the cutting of the femur and tibia can be done using a limited incision approach and the implantation of the femur, tibia, and/or patella components can be done through a larger incision.

Lateral/Medial Approach to Knee Replacement

As previously discussed (see, e.g. FIG. **54** and associated text), one aspect of the present invention includes a medial or lateral approach to joint replacement and other surgeries near a joint. FIGS. **75-77** show one embodiment of this aspect. FIG. **75** shows that femoral medial epicondyle **1150** is osteotomized or cut from distal end **1152** of femur **1102**. This osteotomy removes the superior attachment point of medial collateral ligament **1154** so that the joint space between femur **1102** and tibia **1156** can be pivoted open and accessed from the medial side. As an alternative, the tibial medial epicondyle **1158** could be osteotomized to separate the inferior attachment point of medial collateral ligament **1154** so that the joint space could be accessed from the medial side. Additionally, either the femoral or tibial lateral epicondyle **1160**, **1162** could be osteotomized to separate one of the attachment points of lateral collateral ligament **1164**. Furthermore, medial collateral ligament **1154** or lateral collateral ligament **1164** can be cut without the need for removal of bone, if desired. However, as healing a bone/bone interface can be easier than healing a ligament/ligament interface, separate of the ligament through an osteotomy may be preferable.

In this regard, FIG. **77** shows that femoral medial epicondyle **1150** can be reattached to distal end **1152** of femur **1102** with a screw **1166** or staple. As an alternative to screw **1166**, any method suitable for reattaching one piece of bone to another piece of bone can be used.

By accessing the joint space from a side medial or lateral to the centerline of the joint, the incision can be made shorter, as previously discussed. Additionally, and as previously discussed, a medial or lateral incision stretches less than a direct anterior incision. With respect to the knee joint in particular, when an incision is directly over the patella, the incision length increases 30% from 0° extension to 120° flexion. If the incision is shifted more laterally or medially, such as over the medial collateral ligament, the incision only lengthens approximately 12% from 0° extension to 120° flexion. There is less stress on the soft tissue and therefore less scarring and less postoperative pain. Also by going more medial or lateral with the incision there is less damage and less disruption of the quadriceps mechanism. Furthermore, patella **1168** tends to naturally move toward the pivot location when the joint space is hinged open from either a medial or lateral approach. The natural movement of patella **1168** allows anterior access to the joint space without the need to evert patella **1168**. However, patella **1168** can be minimally subluxed and/or everted to increase the exposure of the joint space, if desired.

Returning to the embodiment in FIGS. **75-77**, any desired procedure can be performed within any joint space. Thus, the medial or lateral approach can be applied, for example, to the hip, shoulder, the joints of the hand and wrist, the joints of the foot and ankle, and the spine. However, this embodiment is particularly useful for knee joint replacement surgeries. FIGS. **78** and **79** show one implant that can be used in this regard. In general, prior art knee prostheses for partially or totally replacing a knee joint include a femoral component for attachment to the distal end of the femur and a tibial component for attachment to the proximal end of the tibia. The tibial component typically includes a base or tray that is implanted in the tibia and an insert or meniscal plate placed on the face of the tray for articulating with the condyles of the femoral component. The tray often includes a keel or stem that inserts in the tibia to provide stability.

In contrast, tibial tray **1170** is a modular unit comprising a base **1172** and a keel **1174**. An inferior surface **1176** of tibial tray **1170** is substantially flat so that tibial tray **1170** can be slid into position from the lateral or medial side onto previously cut or milled tibia **1156**. A side cutting jig analogous to that shown in FIG. **54** or other side cutting or milling techniques can advantageously be used to prepare tibia **1156** for receiving tibial tray **1170**. Tibial tray **1170** is provided with openings **1178** that extend from a superior surface **1180** through inferior surface **1176**. Openings **1178** are sized to receive keel **1174**. As shown, keel **1174** is implanted prior to implantation of tibial tray **1170**. In another embodiment, tibial tray **1170** is implanted prior to implantation of keel **1174**. In this embodiment, openings **1178** are sized so that once tibial tray **1170** is sitting on the tibial surface, keel **1174** can be pushed or pounded through opening **1178** to secure tibial tray **1170** to tibia **1156**.

Base **1172** and keel **1174** can be provided with a locking mechanism to secure keel **1174** to base **1172**. One example of such a mechanism is a locking screw **1181** that inserts through base **1172** and keel **1174**. If keel **1174** is implanted after tibial tray **1170**, keel **1174** can also be provided with a head **1182** or other stop mechanism that prevents further insertion of keel **1174** through openings **1178** once keel **1174** has been inserted through openings **1178** a given distance. In one embodiment, head **1182** can be made to be flush with superior surface **1180** of base **1172**. In this regard, openings **1178** have a countersink **1184** for accommodating keel head **1182**. In another embodiment, head **1182** extends above superior surface **1180** even after full insertion through openings **1178** (i.e. stands proud with respect to superior surface **1180**). In this embodiment, keel head **1182** can cooperate with a bore or slit provided on the inferior surface of a tibial insert to serve as a centering mechanism for insertion (locking the tibial insert to base **1172** in a fixed bearing design) and/or articulation of the femoral and tibial components (in a mobile bearing design).

If tibial tray **1170** were an integral single-piece unit, it would be difficult to insert tibial tray **1170** through a minimal incision, regardless of the location of the incision. However, since tibial tray **1170** is modular, base **1172** can be readily slid in through either a lateral or medial side incision (which can be smaller than typical mid-line incisions) and, keel **1174** can be interoperatively coupled to base **1172** after base **1172** is in the desired position. Keel **1174** can be inserted through the same incision as base **1172** or through a separate incision. This separate incision can be a substantially anterior incision or an incision located on the same or opposite side as the incision for base **1172**. As is well known, tibial tray **1170** can be inserted either with or without bone cement. If bone cement is used, the cement can be placed under base **1172** after it is positioned on tibia **1156** and then keel **1174** is inserted into openings **1178**.

FIG. **80** shows another embodiment of a tibial tray **1186** that can be used with or without a keel. An inferior surface **1188** of tibial tray **1186** includes a slot **1190** extending substantially across the entire width of inferior surface **1188**. Slot **1190** provides stability for tray **1186**. Like tray **1170**, tray **1186** can be inserted from either the medial or lateral side. Slot **1190** and/or tibial tray **1186** can be provided with a bore **1192** (or a plurality of bores) for receiving a screw **1194** or other fastener to further secure tray **1186** to the tibia.

Tibial tray **1186** also includes another feature to assist implantation. Specifically, like prior art tibial trays, tibial tray **1186** includes a rim **1191** for retaining the tibial insert or bearing surface. However, as shown, rim **1191** does not extend around the entire perimeter of tibial tray **1186**. Specifically, lateral and medial posterior regions **1193** have no rim. A centrally located section **1195** can be provided with a rim for retention of the tibial insert. The elimination of rim **1191** from posterior regions **1193**, facilitates implantation of the femoral component as there is no posterior rim in lateral an medial regions **1193** to impede impaction of the femoral component. Section **1195** will not interfere with impaction of the femoral component as the femoral component has a geometry matching the natural condyles of the femur. The novel feature of eliminating the posterior rim can be applied to different tibial tray designs and is not limited to tibial tray **1186**.

In order to facilitate implantation of tray **1186**, a side cutting or milling jig **1196** (FIG. **81**) can be provided with a groove **1198** having a shape that mates with slot **1190**. Thus, when tibia **1156** is cut or milled, the tibia has a recess corresponding to the shape of slot **1190**, thereby allowing tray **1186** to be readily moved into position. It should be noted that use of a jig having a groove is not necessary for implantation of tray **1186**. For example, tray **1186** can be press fit into position, either by tapping in tray **1186** in a direction along the longitudinal axis of slot **1190** or by tapping tray **1186** from the superior direction. It should also be noted that although slot **1190** is shown having a substantially dove-tail shape, slot **1190** can be made to have any suitable shape that provides stability for tray **1186**.

FIG. **82** shows another embodiment of a tibial tray **1200** that has a novel keel design. A keel **1202** extends from an inferior surface **1204** of tibial base **1206**. A superior surface **1208** is generically shown, and, as is well known, is configured and dimensioned for receiving an insert (not shown) that articulates against a femoral component (also not shown). Tibial base **1206** has lateral and medial regions **1210**, **1212**.

When viewed from the anterior (FIG. **82**) or posterior direction, keel **1202** extends downward from inferior surface **1204** at an acute angle α. Thus, keel **1202** extends downward toward lateral region **1210** and away from medial region **1212**. This is in contrast to prior art keels, which generally extend substantially perpendicularly and symmetrically from the tibial base. Like prior art keels, keel **1202** can be tapered and can be inclined either posteriorly or anteriorly when viewed from the medial/lateral direction. Although keel **1202** is shown as connected to inferior surface **1204** centrally located with respect to both lateral and medial regions **1210**, **1212**, keel **1202** can be offset with respect to either lateral or medial regions **1210**, **1212**.

FIGS. **83** and **84** show examples of surgical approaches for which tibial tray **1200** is particularly useful. Specifically, knee joint space **1214** is accessed using a lateral approach such as the procedure previously described in connection with FIGS. **75-77**. Since joint space **1214** is hinged or pivoted open from a lateral aspect **1216** about a medial aspect **1218**, the area of joint space **1214** that is accessible decreases from lateral aspect **1216** to medial aspect **1218**. As a result, it would be difficult to insert a typical tibial tray since the length of the keel (compared to the working space of medial aspect **1216**) would not permit proper implantation.

FIG. **83** shows one method of implanting tibial tray **1200**. Because of the size and geometry of keel **1202**, tibial tray **1200** can be inserted into joint space **1214** at an angle β (defined by the cut surface of tibia **1156** and superior surface **1208** of tibial tray **1200**). At angle β, lateral region **1210** is at the same height as medial region **1212** so that when tibial tray **1200** is initially inserted, inferior surface **1204** of medial region **1212** is in contact (or close to contact) with tibia **1156**. Thus, in order to implant tibial tray **1200** in tibia **1156**, lateral region **1210** is driven in tibia **1156**, with essentially rotation about medial region **1212** occurring.

FIG. **84** shows another method of implanting tibial tray **1200**. Here, superior surface **1208** of tibial tray **1200** is substantially parallel to the cut surface of tibia **1156**. As a result, the distal end of keel **1202** is substantially perpendicular to the cut surface of tibia **1156**. This initial substantially perpendicular relationship facilitates insertion of keel **1202** into tibia **1156**. Regardless of the method of implantation, keel **1202** can have a length so that keel **1202** does not penetrate the lateral cortex of tibia **1156** when fully inserted into tibia **1156**.

Although tibial trays **1170**, **1186**, and **1200** are, as the name implies, intended for use in the tibia, the concepts can be applied to the other components in partial or total knee replacement surgeries. For example, FIG. **85** shows a patellar implant **1220** having a slot **1222** that engages bone. Thus, patellar implant **1220** is analogous to tibial tray **1186**. Typically, patellar implants have one or more pegs that must be driven into bone. This requires substantial working space, so that the patella needs to be everted or dislocated. In contrast, patellar implant **1220** can be slid into position without evertion and with little or no dislocation. If desired, patellar implant **1220** can be fixed into position with bone cement.

FIG. **86** shows a femoral component **1224** that is also analogous to tibial tray **1186**. In particular, femoral component **1224** has a pair of spaced condyle sections **1226** defining curved condyle surfaces **1228**. Joining region **1230** is anterior located and connects the two condyle sections **1226**. Instead of having pins for insertion into the femur, femoral component **1224** is provided with a slot **1232** for securing femoral component **1224** to the femur. Since the pins are absent, femoral component **1224** can be slid into position from the lateral or medial side. As an alternative to slot **1232** (or in addition to slot **1232**), each of condyle sections **1226** can be provided with an aperture for receiving a fastener to secure femoral component **1224** to the femur. This design could be analogous to tibial tray **11170**.

In order to facilitate insertion of femoral component **1224** through a minimally invasive lateral or medial incision, femoral component **1224** can be made modular. This allows femoral component **1224** to be implanted in sections through an incision that would otherwise be much longer which are then coupled in vivo. As shown, femoral component **1224** comprises an anterior femoral section **1234**, and a posterior femoral section **1236**. However, any desired number of sections could be used. Anterior femoral section **1234** is coupled to posterior femoral section **1236**.

FIG. **87** shows one manner of coupling the sections. A tongue **1238** located on one section (shown as anterior femoral section **1234**) mates with a groove **1240** on an adjacent section (shown as posterior femoral section **1236**). The mating results in substantially smooth condyle surfaces **1228** so as to minimize the potential for generation of wear debris.

Self-Centering Mobile Bearing Implant

FIGS. **88** and **89** show one embodiment of a self-centering mobile bearing implant according to the present invention. An implant **1250**, in the form of a prosthetic knee, comprises a femoral component **1252** secured to femur **1102** and a tibial component **1254** secured to tibia **1156**. Femoral component **1252** includes a pair of spaced apart condyle sections **1256** defining curved condyle surfaces **1258**. A joining region **1260** is anterior located and connects the two condyle sections **1256** so that a recess **1262** is defined by condyle sections **1256** and joining region **1260**. The side of femoral component **1252** facing femur **1102** can include fixation pins **1264**. As femoral component **1252** has a structure and function analogous to prior art femoral components, further description is not believed necessary.

Tibial component **1254** includes a tray **1266** and a bearing insert **1268**. Tray **1266** is defined by a tapered keel or spike **1270** and a plate member **1272**. As previously discussed with respect to other embodiments, other mechanisms for fixing tibial component **1254** can be used as an alternative to spike **1270**. Plate member **1272** has a superior surface **1274** defined by a concave, spherically shaped plateau surface.

As is more fully described below, bearing insert **1268** also has a spherically shaped surface so that the interface between tibial tray **1266** and bearing insert **1268** is defined by cooperating spherically shaped, concave and convex surfaces that enable sliding motions along these surfaces. In this regard, superior surface **1274** has a mirror polish to minimize friction during relative slidable movements of bearing insert **1268**. Additionally, superior surface **1274** is provided with a track **1276** that cooperates with a groove located on bearing insert **1268** so that the sliding motion occurs substantially in the anterior-posterior direction. Although a single track **1276** is shown centrally located, track **1276** can be located elsewhere along superior surface **1274** and/or more than one track can be used (e.g. two lateral symmetrically placed tracks). Also, the arrangement of the track and groove can be switched so that bearing insert **1268** is provided with the track and superior surface **1274** is provided with the groove.

Bearing insert **1268** has a superior surface **1278** that includes a pair of spaced apart curved depressions **1280** that form bearing surfaces for condyle surfaces **1258** of femoral component **1252**. Condyle surfaces **1258** and depressions **1280** are shaped so that pivoting motion between femoral component **1252** and bearing insert **1268** can occur over a wide range of motion. A protrusion **1282** can be located between depressions **1280** so that extension of protrusion **1282** into recess **1262** of femoral component **1252** substantially prevents hyperextension (counterclockwise rotation beyond a certain point) of femoral component **1252**. Interference between protrusion **1282** and recess **1262** also prevents relative motion in the lateral-medial direction.

Bearing insert **1268** has an inferior surface **1284** that is convex and spherically shaped and mates with concave superior surface **1274** of tibial tray **1266**. A groove **1286** is located on inferior surface **1284** and is configured and dimensioned to receive track **1276**.

As is evident from the foregoing, implant **1250** operates like prior art mobile bearing knee implants in the occurrence of sliding motion between bearing insert **1268** and both femoral and tibial tray **1266** components **1252**. However, unlike prior art mobile bearing knee implants that rely on tracks and grooves to substantially limit the movement to the anterior-posterior direction, the articulating surfaces are not flat. Rather, superior surface **1274** of tibial tray **1266** and inferior surface **1284** of bearing insert **1268** are mating curved surfaces.

With the prior art flat surfaces, there is increased risk for dislocation and variable degrees of laxity. Additionally, ligament balancing and self-centering of the joint may be more difficult, allowing for some feelings of instability and/or ligamentous laxity. Because superior surface **1274** of tibial tray **1266** and inferior surface **1284** of bearing insert **1268** are mating curved surfaces, the curvature toward the center of the tibia encourages bearing insert **1268** to want to fall back into the center of the curvature of superior surface **1274**.

In order to enhance ligament stability, tray **1266** and/or bearing insert **1268** can be made to have a thickness that increases from the center toward the edge. As shown in FIGS. **88** and **89**, this increase in thickness can occur in both the anterior-posterior direction and the medial-lateral direction. Thus, as bearing insert **1268** slides, both the curvature and decrease in thickness cooperate as a self-centering mechanism that draws bearing insert **1268** back to the center of the tibia (also resisting posterior rollback), the lowest point in tibial tray **1266** when they are at rest. This enhances stability, yet allows free motion and a mobile bearing construct.

The curvature of inferior surface **1284** of bearing insert **1268** can be made to match the curvature of superior surface **1274** of tibial tray **1266**. Alternatively, the curvatures can be different. For example, the curvature of inferior surface **1284** can be smaller than the curvature of superior surface **1274**. Regardless of whether of curvatures match, the curvature of inferior surface **1284** and/or superior surface **1274** can be constant or have a radius which progressively varies.

Each of femoral component **1252**, tibial tray **1266**, and bearing insert **1268** can be made of any suitable biocompatible material. For example, femoral component **1252** and tibial tray **1266** can both be made of a metallic material such as a cobalt-chromium alloy or titanium alloy, and bearing insert **1268** can be made of a polymer such as UHMW polyethylene. This provides metal articulating against a polymer. Additionally and as previously discussed with respect to other embodiments, this can be reversed so that femoral component **1252** and tibial tray **1266** are made of a polymer and bearing insert **1268** is made of a metallic material.

FIG. **90** shows another embodiment of the self-centering mechanism according to the present invention. An implant **1290** in the form of a rotating platform knee implant includes a tibial component **1292** secured to the tibia and a femoral component secured to the femur. As the femoral component used with implant **1290** is analogous to femoral component **1252**, reference is made to FIGS. **88** and **89** and accompanying text and further description is not believed necessary.

Tibial component **1292** includes a tray **1294** and a bearing insert **1296**. Tray **1294** includes a tapered spike **1298** and a plate member **1300**. As was the case for tibial component **1254**, other mechanisms for fixing tibial component **1292** can be used as an alternative to spike **1298**. Plate member **1300** has a superior surface **1302** defined by a concave, spherically shaped plateau surface.

Analogous to bearing insert **1268**, bearing insert **1296** also has a spherically shaped inferior surface **1304** so that the interface between tibial tray **1294** and bearing insert **1296** is defined by cooperating spherically shaped, concave and convex surfaces that enable sliding motions along these surfaces. In this regard, superior surface **1302** has a mirror polish to minimize friction during relative slidable movements of bearing insert **1296**. Additionally, superior surface **1302** is provided with a post **1306** that cooperates with a recess **1308** located on bearing insert **1296** to permit rotation of bearing insert **1296** with respect to tibial tray **1294**. The arrangement of the post and recess can be switched so that bearing insert **1296** is provided with the post and superior surface **1302** is provided with the recess.

As is evident from the foregoing, implant **1290** operates like prior art mobile bearing knee implants in the occurrence of rotation motion between bearing insert **1296** and both femoral and tibial tray components **1292**. However, unlike prior art mobile bearing knee implants that rely on a post mechanism to control the rotational movement, the articulating surfaces are not flat. Rather, superior surface **1302** of tibial tray **1294** and inferior surface **1304** of bearing insert **1296** are mating curved surfaces.

Compared to the prior art, implant **1290**, like implant **1250**, provides improved dislocation risk, ligament balancing, and ligament stability. In order to enhance ligament stability, tray **1294** and/or bearing insert **1296** can be made to have a thickness that increases from the center toward the edge. Thus, as bearing insert **1296** slides, both the curvature and decrease in thickness cooperate as a self-centering mechanism that draws bearing insert **1296** back to the center of post **1306** (also resisting posterior rollback), the lowest point in tibial tray **1294** when they are at rest. This enhances stability, yet allows free motion and a mobile bearing construct.

As is evident from FIG. **90**, post **1306** is not located directly over spike **1298**, i.e. the center of the tibia. Rather, post **1306** is offset medially toward the medial compartment of the knee. In prior art rotating platform designs, the post is substantially in line with the central keel. This design does not account for the anatomical motion of the knee, which has more motion and a greater range of motion laterally with greater anteroposterior translation laterally and less anteroposterior translation medially. Offsetting post **1306** more toward the medial compartment of the knee recreates the natural pivoting motion on the knee, with less translation medially, a more stable joint medially, and more rotational arc or more movement laterally.

Any of the above-described embodiments of self-centering mechanism can be applied to total or partial knee replacement. These embodiments could be used in any joint, such as the shoulder, ankle, wrist, as well as others.

Bicompartment Implants

As previously discussed (see, e.g. FIG. **40** and associated text), the present invention includes implants that have interconnectable portions. Another embodiment of this concept is the combination of limited incision unicompartmental knee replacement with limited incision patellofemoral replacement. This combination can be done percutaneously with limited incisions, possibly one or two smaller incisions to approach the medial aspect of the knee in the patellofemoral joint.

Arthritis typically does not involve the entire joint space. Most arthritis of the knee is medial joint, lateral joint, patellofemoral joint, or some combination of two of these three joint compartments. Usually advanced arthritis involves both the medial or lateral compartment and the patellofemoral joint. Replacement of the medial or lateral compartment through limited incision surgery and then patellofemoral replacement through the same incision or another incision will lead to faster patient rehabilitation. Additionally, limited incision replacement of these compartments that avoided everting the patellofemoral joint and reduced damage of the quadriceps mechanism would further accelerate rehabilitation.

FIG. **91** shows a bicompartment arrangement that includes trochlear implant **1310** and medial implant **1312**. Implants **1310** and **1312** are dimensioned and configured so that bone **1314** is located between the implants. FIG. **92** shows an embodiment of a bicompartment implant **1316** that includes trochlear section **1320** and medial section **1322**. In implant **1316**, there is no bone between the sections. Implant **1316** can be made so that sections **1320** and **1322** are integral. Alternatively, implant **1316** could be modular, being assembled inside the body or outside of the body prior to implantation.

In the interest of brevity, the reader is referred to FIG. **40** and associated text for different methods for coupling sections **1320** and **1322**. As previously discussed, the patella and the other portions of the joint can be resurfaced to receive the implant. In this regard, the resurfacing can be with a mill, saw or robotic arm and computer navigation system. The computer navigation system could also be used to assist in aligning the unicompartmental replacement with the patellofemoral joint replacement. The patellofemoral replacement could be performed from a mid-vastus or sub-vastus approach without disrupting the quadriceps mechanism. As also previously discussed, the patella could be elevated using fluid retractors or simple mechanical retractors to minimize soft tissue damage associated with dislocating or everting the patella.

FIG. **92** shows the tibial component **1324**, which articulates against medial section **1322**. Each of the components can be made of any suitable biocompatible material. For example, all of the components can be made of a metallic material such as a cobalt-chromium alloy or titanium alloy. This provides metal articulating against metal. Alternative articulating surface pairs include metal/polymer, metal/ceramic, metal/composite, polymer/ceramic, polymer/polymer, polymer/composite, ceramic/ceramic, and ceramic/composite.

In order to reduce the generation of wear debris, the articulating surfaces can be magnetically charged to have the same polarity so that the surfaces are repelled from each other. Thus, the surfaces glide smoothly over each other, essentially floating with respect to one another. This would also potentially allow a replacement surface that is a strip or point contact, rather than being a full surface that matches the surface of the joint. This embodiment, which is described in more detail below, would include strips that glide along each other, as opposed to a full resurfacing of the joint so one would have strips in contact with each other rather than a full surface. The surface magnetic charges can diminish with time. Additionally, certain environments could also diminish the magnetic charges. For example, exposure to an MRI apparatus could severely alter the magnetic fields. In order to account for these possibilities, the magnetic charges of the articulating surfaces can be re-magnetized.

The present invention also envisions the application of magnetically charged articulating surfaces to other implant designs and to other locations in the body. Examples include the knee, the shoulder (both the glenoid and humeral components), the joints of the hand and wrist, the joints of the foot and ankle, and the spine. With respect to the spine, suitable procedures include any procedure involving the disc space and/or the vertebra.

Adjustable Cutting Jig

As previously discussed, various embodiments of the present invention involve a lateral or medial approach to accessing a joint space. FIG. **93** shows an adjustable cutting jig **1330** that is particularly useful in such an approach. With the cutting jig **1330**, the femoral cuts can be made by moving a saw blade or other cutting device, such as a miller, between opposite sides of the femur in a direction extending generally perpendicular to a longitudinal central axis of the femur. Thus, the cutting device is moved along a path which extends between lateral and medial surfaces on the distal end portion **1332** of the femur **1334**.

The cutting jig **1330** is illustrated in FIG. **93** as being used on a lateral surface **1336** of the femur **1334**. However, the cutting jig **1330** could be used on the medial surface of the femur **1334** if desired. When the cutting jig **1330** is mounted on the lateral surface **1336** of the femur **1334**, the incision **114** (FIG. **6**) is laterally offset. Similarly, when the cutting jig **1330** is mounted on a medial surface of the femur **1334**, the incision **114** is medially offset.

Although either intramedullary or extramedullary instrumentation can be used to attach the cutting jig **1330** to the femur **1334**, FIG. **93** shows intramedullary instrumentation. Accordingly, the cutting jig **1330** includes a shaft **1338** that can be inserted into the medullary canal of femur **1334** in any known manner, for example using a technique analogous to that previously described in connection with FIGS. **8-10**. In this regard, a separate stab wound incision can be made for shaft **1338**, rather than attempting to stretch the incision **114**.

A length adjustment member **1340** slides along shaft **1338** so that the location of length adjustment member **1340** on shaft **1338** can be changed to accommodate different anatomies. Tightening knob **1342** can be used to lock length adjustment member **1340** at the desired location. Length adjustment member **1340** can also freely rotate about shaft axis **1344**. This is useful, for example, if a medial approach is to be used.

An arm **1346** extends from length adjustment member **1340**. Arm **1346** includes a head **1348** that is received in ring **1350** on length adjustment member **1340**. The arm **1346** can be made as two telescoping rods or a similar configuration so that the length of the arm **1346** can be adjusted. The head **1348** can rotate within the ring **1350** to allow rotation of the arm **1346**. A tightening knob **1352** locks the arm **1346** at the desired position.

An extension **1354** extends from the lateral end of arm **1346**. Like the arm **1346**, extension **1354** can be made as two telescoping rods or a similar configuration so that the length of the extension **1354** can be adjusted. A link **1356** is generically shown to indicate that different types of joints can be used to couple the arm **1346** and the extension **1354**. For example, it may be desirable to have the extension **1354** rotate and/or pivot with respect to the arm **1346**. Regardless of the specific design of the link **1356**, a tightening knob **1358** is provided to lock the extension **1354** at the desired position.

A cutting guide **1360** is located on an end of the extension **1354**. As was the case for link **1356**, different types of joints can be used to couple the cutting guide **1360** to the extension **1354**. The cutting guide **1360** includes a distal guide surface **1362**, an anterior chamfer guide surface **1364**, a posterior chamfer guide surface **1366**, an anterior guide surface **1368**, and a posterior guide surface **1370**. As is readily apparent, the cutting guide **1360** has a structure substantially similar to the cutting guide **800**. Furthermore, the operation and use of the cutting guide **1360** is substantially similar to that of the cutting guide **800**. Accordingly, reference is made thereto.

Each of the guide surfaces **1362**, **1364**, **1366**, **1368**, and **1370** can be made to have a length less than the extent of the cut to be formed on the distal end portion **1332** of the femur **1334**. Therefore, after an initial portion of the cut has been made utilizing the appropriate guide surface to guide movement of the cutting tool, the cut surfaces are utilized to guide movement of the cutting tool during completion of the cut. The cutting guide **1360** is not of the capture type. Therefore, the cutting tool is free to move past the guide surfaces **1362**, **1364**, **1366**, **1368**, and **1370** during completion of the femoral cuts. If the guide surfaces **1362**, **1364**, **1366**, **1368**, and **1370** were formed by slots, the cutting guide **1360** could be disconnected from the femur **1334** to complete the femoral cuts.

The cutting guide **1360** can be made so that one or more of the guide surfaces **1362**, **1364**, **1366**, **1368**, and **1370** have an adjustable length so that the size of the guided portion of the cuts can be adjusted depending upon the size of the bone and the implant that is to be used. Furthermore, the cutting guide **1360** is shown having a plurality of guide surfaces **1362**, **1364**, **1366**, **1368**, and **1370**, with each guide surface being used to make a different cut. Other embodiments of cutting guides **1360** can be used with the cutting jig **1330**.

For example, FIG. **94** shows a cutting guide **1372** that has a single guide surface **1374**. As will be discussed, the guide surface **1374** is movable to make multiple guided cuts of different orientations. As the cutting guide **1372** only has one guide surface **1374**, the cutting guide **1372** can be used through a smaller incision than prior art cutting blocks. The cutting guide **1372** includes a base **1376** that can be positioned on the femur using the adjustable cutting jig **1330**. In other words, the cutting guide **1372** would be a substitute for the cutting guide **1360**. Other intramedullary instrument could be used with the cutting guide **1372**. Additionally, extramedullary instrument could be employed. If desired, the base **1376** could be pinned directly to the femur in a manner analogous to the cutting guide **800** (FIG. **54**). Alternatively, the base **1376** could be positioned on the femur using a computer navigation system.

The base **1376** has a plurality of tracks **1378**, **1380**, **1382**, **1384**, and **1386**. The guide surface **1374** is attached to a pin member **1388**. The pin member **1388** is sized to be received in the tracks **1378**, **1380**, **1382**, **1384**, and **1386**. When pin member **1388** is located in the track **1378**, the guide surface **1374** is positioned on the femur for making an anterior cut, as shown in FIG. **94**. When pin member **1388** is located in the track **1380**, the guide surface **1374** is positioned on the femur for making an anterior chamfer cut, as shown in FIG. **95**. When pin member **1388** is located in the track **1382**, the guide surface **1374** is positioned on the femur for making a distal cut. When pin member **1388** is located in the track **1384**, the guide surface **1374** is positioned on the femur for making a posterior chamfer cut. When pin member **1388** is located in the track **1386**, the guide surface **1374** is positioned on the femur for making a posterior cut.

The pin member **1388** can be locked in the tracks **1378**, **1380**, **1382**, **1384**, and **1386** to stabilize the guide surface **1374** during making of the cuts. This can be done in any number of ways. For example, the pin member **1388** can have a threaded portion that receives a nut to secure the pin member **1388** within the track. The specific configuration of the tracks **1378**, **1380**, **1382**, **1384**, and **1386** shown in FIGS. **94** and **95** are exemplary only, as any configuration that allows movement of the guide surface **1374** with respect to the base **1376** could be used.

As was the case with the cutting guide **1360**, the guide surface **1374** can be made so that the size of the guided portion of the cuts can be adjusted depending upon the size of the bone and the implant that is to be used. Furthermore, the guide surface **1374** can be made to have a length less than the extent of the cut to be formed on the distal end portion of the femur. Therefore, after initial portions of the cuts have been made utilizing the guide surface **1374** to guide movement of the cutting tool, the cut surfaces are utilized to guide movement of the cutting tool during completion of the cut. The cutting guide **1372** is not of the capture type. Therefore, the cutting tool is free to move past the guide surface **1374** during completion of the femoral cuts. If the guide surface **1374** were of the capture type (having a slot), the cutting guide **1372** could be disconnected from the femur to complete the femoral cuts.

The cutting guide **1372** is illustrated in FIGS. **94** and **95** for use on a lateral surface of the femur. However, the cutting guide **1372** could be used on the medial surface of the femur by either flipping or rotating the base **1376**. In this regard, FIG. **96** shows a cutting guide **1390** that could be used on either the lateral or medial side of the femur. In addition to containing the tracks **1378**, **1380**, **1382**, **1384**, and **1386**, a base **1392** includes tracks **1394**, **1396**, and **1398**. As shown, the track **1396** would be used to make a distal femoral cut on the medial side of the femur.

Implants with Reduced Articulating Surfaces

As previously detailed, the present invention relates to methods, implants, and instrumentation for performing surgery through minimally invasive procedures. One aspect is the insertion of a partial or total joint replacement implant through a minimally invasive incision. For example, modular implants that are assembled after insertion in the body can typically be more easily inserted through a smaller incision than a unitary implant of the same size or a modular implant that is assembled prior to implantation. Thus, it is advantageous to have smaller implants, modular or not, in order to reduce the size of the incision that is needed for implantation.

Smaller implants will generally have a smaller articulating surface area. While prior art prosthetic components provide a low-friction articulating surface for the surface of accompanying member, interaction between the articulating component and the member can produce wear debris. Such debris may cause adverse local and systemic reactions in the body. Thus, it is advantageous to minimize the articulating surface area of one or both of a joint component.

FIG. **97** shows one embodiment of a joint component implant **1400** that is both small in size to facilitate implantation through a minimal incision and has a reduced articulating surface area. Specifically, implant **1400** comprises a head **1402** connected to a body **1404**. In use, head **1402** articulates against the other joint component. In this regard, the other component could be an artificial component or a natural component. For example, if implant **1400** were implanted in the acetabulum **1102** as shown in FIG. **98**, the other joint component **1403** could be the natural femoral head or the head of a prosthetic femoral component. Although head **1402** is shown as substantially spherical, any shape that provides a smooth bearing surface could be used.

Body **1404** includes a threaded region **1406** for fixing implant **1400** to tissue. A joining region **1408** is located between head **1402** and threaded region **1406**. Joining region **1408** is provided with multiple surfaces so that an inserter or other tool can be used to thread implant **1400** into tissue. By providing an area separate from head **1402** that is used for insertion, the risk of scratching or otherwise damaging the bearing surface is reduced.

Threaded region **1406** can be eliminated and other mechanisms for attaching implant **1400** can be used. For example, implant **1400** could simply be driven into the tissue. Bone cement or an adhesive could be used to attach implant **1400**. Alternatively, body **1404** could have a rivet type means, an expandable portion, or some other known fixation means.

Implant **1400** can be made from any biocompatible material that will undergo articulating movement with a corresponding natural or prosthetic member. For example, the bearing component could be formed from a variety of metals, polymers, ceramics, or composite materials. In the event that polymers are chosen, a high density polyethylene may be used, although numerous types of polymers may be suitable so long as the material provides both strength and a low-friction articulation surface for the corresponding joint face. If desired, head **1402** and body **1404** can be made of different materials. It may also be advantageous to include some type of known tissue in-growth promoting features on at least a portion of body **1404**. Such features include a porous or textured surface, a porous body (for example so-called "foam metals"), and osteoinductive or osteoconductive materials or factors.

FIG. **98** shows a number of implants **1400** located in the acetabulum **1102** for articulation against femoral head **1403**. As shown, implants **1400** can be implanted through cannula **1104** and can be cannulated so that they can be inserted over guide wire **1108**, without the need to dislocate the joint or with only slight dislocation. Implants **1400** also present a small surface area against which femoral component **1403** articulates. The bearing surface minimizes available surface area of articulation for the component and the production of wear debris. If desired, implants **1400** can be used without the need to ream acetabulum **1102**, thereby saving bone stock. Alternatively, acetabulum could be partially reamed to ensure a surface free of asperities. Because of the overall reduction in size and bearing surface of implants **1400**, a larger femoral component **1403** can be used without the risk of significant increase of wear debris. The larger femoral component **1403** may enhance joint stability.

Although any number of implants **1400** can be used for a given application, the use of three implants **1400** for acetabulum **1102** may be preferable as three implants serve as a centering mechanism for femoral component **1403**. In this regard, the number and location of implants **1400** can be selected to suit a particular application. The size of implants **1400**, and in particular head **1402**, can also be varied. In acetabulum **1102**, smaller heads 3-6 mm in diameter or larger heads 10-15 mm in diameter may be desirable.

Although FIG. **98** shows implants **1400** used in acetabulum **1102**, implants **1400** could be used in any joint component including, a glenoid, patellar, femoral, humoral, tibial, ulnar, radial, wrist, and/or ankle component for a prosthetic joint assembly.

FIG. **99** shows another embodiment of a reduced articulating surface area implant **1410**. Implant **1410** has a substantially annular shape with a curved surface **1412**. When implanted, surface **1412** serves as the bearing surface against which the other joint component articulates. Surface **1412** can be provided with a beveled bearing surface, if desired. The annular shape of implant **1410** defines an interior region **1414**. If implant **1410** were to be used on the femur, implant **1410** would be placed around the femoral head with interior region **1414** in contact with bone. If implant **1410** were to be used on the acetabulum, implant **1410** could be fixed to the bone or freely float within the acetabulum with no fixation. As was the case for implant **1400**, implant **1410** can be used in other joints.

FIG. **100** shows another embodiment of a reduced articulating surface area implant **1416**. Like implant **1410**, implant **1416** is a unitary implant that can be implanted through a minimal incision, has a reduced articulating surface area, and does not require extensive removal of bone. Rather than having a ring shape, implant **1410** has a U-shaped body with curved surface **1418** that serves as the bearing surface.

Disposable Trial Implants, Instruments, and Other Surgical Implements

As previously discussed throughout this specification, the present invention includes disposable surgical implants and instruments. Currently for hip, knee, shoulder, and other joint replacement surgeries (partial or total), there can be six or more trays of instruments and trial implants. Each tray has to be re-sterilized for each procedure. In the case of knee replacement surgeries, one tray may contain femoral trials, one may contain tibial trials, one may contain polyethylene spacer blocks, one may contain tibial cutting instruments, and one tray may contain femoral cutting instruments.

This is cumbersome and unnecessary as only a few of these instruments and trial implants need to be made of surgical grade metal and alloys that are rigid and reusable. There is a significant expense in the multiple tray setups. One company, for example, spends over $150 million just to have instruments in the field. Additionally, shipping charges and re-sterilization costs can be significant. The delay due to the shipping and re-sterilization also adds hidden costs and time. Obviously, money and time can be saved if the number of trays for each procedure were reduced.

Also, as a company modifies implant systems or instruments, representatives of the company need to update their inventories accordingly. Frequently, companies are unable to charge for the new instruments as an incentive to promote a new system. Although these costs cannot be recovered, they ultimately add to the cost of joint replacement surgeries.

These issues can be addressed by a disposable trialing system. For example, the tibial trial base plate **270** (FIG. **26**) and other trial components can be made of a light-weight low cost material such as aluminum, injection molded plastic, composite material, and the like. There would be a series of these disposable trial implants in various sizes for the implant system the surgeon intended to use. Each would come prepackaged in a sterile state. Alternatively, each sterile package could include different components of the same size. In the case of a knee replacement procedure, each sterile package could include a femoral trial, a tibial trial, a patellar trial, and a spacer trial. Preoperatively, the surgeon could obtain an estimate of the needed size from x-rays and other clinical information. Based upon this estimate, one or more sizes of the trial implants would be brought to the operating room or surgical suite.

The use of disposable trial implants would reduce the number of trays needed for a given procedure. The use of disposable cutting blocks would further reduce the number of trays. In this regard, the disposable cutting blocks could be made of a material that has color or some other chemical or physical property that would allow the detection of trace amounts of the cutting blocks. This is particularly useful if the cutting blocks are inadvertently scratched so that any debris could be detected and removed. The instruments and trials could have changeable lugs, changeable stems, or similar modularity to allow modification of the position and the rotation.

If desired, some or all of the instruments and other disposables could be packaged in a single sterile unit. Some items that could be included in the unit include the instruments, draping, cement, cement mixer, pulsatile lavage, retractors, drill bits, pins, and guide wires. This would save significant time for the operating personnel as they open this unit and it has all the cutting blocks.

One advantage of the disposable system is that the disposable cutting blocks could easily be modified for new or updated instrumentation or for customized instrumentation. The disposable system saves the cost and time of cleaning and re-sterilization. Also, the disposable system would improve the sterile technique in the operating room and since these are single use and sterilized there is no risk of cross-contamination going from one patient to another patient.

If desired, only a portion of the trial implants or instrumentation could be disposable. For example, the intramedullary rod for distal femoral cutting blocks could be reusable, however, the actual cutting surface, such as the captured guide **4** in 1 block, the mill cut, etc., could be disposable.

Program for Learning Minimally Invasive Surgical Techniques

As the minimally invasive surgical instruments, implants, systems, and methods disclosed herein represent a significant deviation from those used in open surgical procedures, the present invention includes a program for training surgeons and other health care professionals. The program is a sequential approach in which the trainee starts the training process using an incision of standard length and progressively decreases the incision size as milestones are achieved.

The program is sequential learning, analogous to returning to residency or a mini-fellowship. The program can involve a series of visits to a dedicated training sites and/or remote linking, for example via videoconferences or the Internet, to certain training programs. The goal of the program is to allow the trainee to progress from: working with a standard incision, traditionally to learn anatomy; working through a smaller incision, with a combination of prior art instruments and implants and the downsized instruments and implants according to the present invention; and working through a minimally invasive incision to use the instruments, implants, systems, and techniques according to the present invention. As previously discussed, these techniques include minimizing or avoiding joint dislocation, video and fluoroscopic or other radiographic guidance, computer assisted surgical procedures, cannulated instruments and implants, and downsized instruments and implants.

The program can include the following training tools, in any combination: lectures and video demonstrations to understand the instruments, both intra and extramedullary, implants, systems, and methods; observation and discussion of live broadcast surgeries; practice using saw bones; practice with cadavers, animal models, or plastic models that have artificial skin, muscle, tissue, ligaments, and bones; virtual reality evaluations; and practice with minimal incisions.

Once proficiency with some or all of the training tools have be achieved, which can be determined by grading based on examination, the trainee can be assigned a mentor, a previously certified health care professional. The trainee can be required to visit and observe the mentor during surgery. Additionally, the mentor could visit the trainee at the trainee's practice and supervise or otherwise monitor the trainee's techniques.

Even after the initial visits between the mentor and trainee, the mentor could be available for consultation by the trainee. The trainee could start probationary work at his practice by initially using an incision that is only slightly smaller than standard incisions. The x-rays, inter-operative pictures or videos, and other case data could be reviewed and graded by the mentor or other certified instructor. Advancement to the next level would only be allowed if the review were satisfactory. The next level could involve a return to some or all of the training tools to practice working through a smaller incision, with a combination of prior art instruments and implants and the downsized instruments and implants according to the present invention. After the training tools are mastered, probationary work by the trainee at this level would be followed by review and grading by the mentor or other certified instructor. Once again, advancement to the next level would only be allowed if the review were satisfactory. The process is repeated for the final level.

The program could be implemented so that the trainee must meet given standards in order to receive instrumentation and implants to allow the trainee to perform the procedures independently without supervision. Furthermore, achieving these standards could be required prior to being allowed to promote or advertise proficiency in the techniques. The standards could be coordinated with hospital Institutional Review Boards.

The program could be offered through a professional society, such as the American Academy of Orthopaedic Surgeons and the Hip and Knee Society, a commercial entity, or some combination thereof. Continuing Medical Education (CME) credits and grades could be provided. The instructors and preceptors could be certified, with the certification process through a professional society.

The trainees could pay a portion of the costs of the program. Trainees would offset the costs of the program from the added revenue from the procedures and possible lower insurance premiums. The costs of the program may be subsidized by governmental agencies and commercial entities, which would benefit from sales and leasing of instruments and implants. Costs could be subsidized by insurers, which would benefit from the lower costs of the procedures compared to traditional open procedures. Finally, costs could also be subsidized by surgical centers, which would benefit from having trained personnel and added revenue from the procedures.

In additional to the educational benefits of the program, the program also provides some legal protection to the trainees. Perhaps more importantly, the program affords protection to the patient by ensuring adequately trained medical personnel.

CONCLUSION

In view of the foregoing description, it is apparent that the present invention relates to a new and improved method and apparatus for use in performing any desired type of surgery on a joint in a patient's body. The joint may advantageously be a joint in a knee portion **76** of a patient's leg **70**. However, the method and apparatus may be used in association with surgery on other joints in a patient's body. There are many different features of the present invention which may used either together or separately in association with many different types of surgery. Although features of the present invention may be used with many different surgical procedures, the invention is described herein in conjunction with surgery on a joint in a patient's body.

One of the features of the present invention relates to the making of a limited incision **114**. The limited incision **114** may be in any desired portion of a patient's body. For example, the limited incision **114** may be in a knee portion **76** of a leg **70** of a patient. The limited incision **114** may be made while a lower portion **68** of the leg **70** of the patient is extending downward from the upper portion **72** of the leg of the patient. At this time, a foot **74** connected with the lower portion **68** of the leg of the patient may be below a surface **64** on which the patient is supported. The limited incision **114** may be made while the lower portion **68** of the leg **70** of the patient is suspended from the upper portion of the leg or while the lower portion of the leg and/or the foot **74** of the patient are held by a support device. After the incision **114** has been made, any one of many surgical procedures may be undertaken.

It is believed that in certain circumstances, it may be desired to have a main incision **114** of limited length and a secondary incision **920** of even smaller length. The secondary incision **920** may be a portal or stab wound. A cutting tool **170** may be moved through the secondary incision **920**. An implant **286**, **290** and/or **294** may be moved through the main incision **114**.

Once the incision **114** has been made, a patella **120** in the knee portion **76** of the patient may be offset to one side of its normal position. When the patella **120** is offset, an inner side **122** of the patella faces inward toward the end portions **124** and **212** of a femur **126** and tibia **214**.

Although any one of many known surgical procedures may be undertaken through the limited incision **114**, down sized instrumentation **134**, **138**, **186**, **210** and/or **218** for use in the making of cuts in a femur **126** and/or tibia **214** may be moved through or part way through the incision. The down sized instrumentation may be smaller than implants **286**, **290** and/or **294** to be positioned in the knee portion **76** of the patient. The down sized instrumentation **286**, **290** and/or **294** may have opposite ends which are spaced apart by a distance which is less than the distance between lateral and medial epicondyles on a femur or tibia in the leg of the patient.

It is contemplated that the down sized instrumentation **134**, **138**, **186**, **210** and/or **218** may have cutting tool guide surfaces of reduced length. The length of the cutting tool guide surfaces may be less than the length of a cut to be made on a bone. A cut on a bone in the patient may be completed using previously cut surfaces as a guide for the cutting tool.

It is contemplated that at least some, if not all, cuts on a bone may be made using light directed onto the bone as a guide. The light directed onto the bone may be in the form of a three dimensional image **850**. The light directed onto the bone may be a beam **866** or **868** along which a cutting tool **170** is moved into engagement with the bone.

There are several different orders in which cuts may be made on bones in the knee portion of the leg of the patient. It is believed that it may be advantageous to make the patellar and tibial cuts before making the femoral cuts.

There are many different reasons to check ligament balancing in a knee portion **76** of the leg of a patient. Ligament balancing may be checked while the knee portion **76** of the leg **70** of the patient is flexed and the foot **74** of the patient is below the support surface **64** on which the patient is disposed. Flexion and extension balancing of ligaments may be checked by varying the extent of flexion of the knee portion **76** of the leg **70** of the patient. In addition, rotational stability of the ligaments may be checked by rotating the lower portion of the leg of the patient about its central axis. Balancing of ligaments may also be checked by moving the foot **74** of the patient sideways, rotating the lower portion **68** of the leg **70** of the patient, and/or moving the foot anteriorly or posteriorly.

It is believed that it may be advantageous to utilize an endoscope **352** or a similar apparatus to examine portions of the patient's body which are spaced from the incision **114**. It is also contemplated that images of the knee portion of the patient's leg may be obtained by using any one of many known image generating devices other than an endoscope **352**. The images may be obtained while the patient's leg **70** is stationary or in motion. The images may be obtained to assist a surgeon in conducting any desired type of surgery.

Balancing of the ligaments in the knee portion **76** of a patient's leg **70** may be facilitated by the positioning of one or more transducers **596** and/or **598** between tendons, ligaments, and/or bones in the knee portion. One transducer **598** may be positioned relative to a medial side of a knee joint. Another transducer **596** may be positioned relative to a lateral side of the knee joint. During bending of the knee joint, the output from the transducers **596** and **598** will vary as a function of variations in tension forces in the ligaments. This enables the tension forces in ligaments in opposite sides of the knee portion to be compared to facilitate balancing of the ligaments.

Patellar tracking may be checked by the positioning of one or more transducers **930** and/or **932** between the patella **120** and the distal end portion **124** of the femur **126**. If desired, one transducer **932** may be placed between a medial portion of the patella **120** and the distal end portion **124** of the femur **126**. A second transducer **930** may be placed between a lateral portion of the patella **120** and the distal end portion **124** of the femur **126**. Output signals from a transducer **930** will vary as a function of variations in force transmitted between the patella **120** and femur **126** during bending of the leg.

The articular surface **122** on the patella **120** may be repaired. The defective original articular surface **122** on the patella **120** may be removed by cutting the patella while an inner side of the patella faces toward a distal end portion **124** of a femur **126**. The step of cutting the patella may be performed while the patella is disposed in situ and is urged toward the distal end portion of the femur by connective tissue. An implant may then be positioned on the patella **120**.

It is contemplated that the size of the incision **114** in the knee or other portion of the patient may be minimized by conducting surgery through a cannula **564**. The cannula **564** may be expandable. To facilitate moving of an implant **286**, **290** and/or **294** through the cannula **564**, the implant may be formed in two or more portions **572** and **574**. The portions of the implant **286**, **290** and/or **294** may be interconnected when the portions of the implant have been positioned in the patient's body. Although the implants disclosed herein are associated with a patient's knee, it should be understood that the implants may be positioned at any desired location in a patient's body.

An implant **626**, **640** or **670** may be positioned in a recess **610**, **642** or **672** formed in a bone **126** or **214** in a patient. The implant **626**, **640** or **670** may contain biological resurfacing and/or bone growth promoting materials. The implant **626**, **640** and/or **670** may contain mesenchymal cells and/or tissue inductive factors. Alternatively, the implant **626** or **640** may be formed of one or more materials which do not enable bone to grow into the implant.

In accordance with one of the features of the present invention, body tissue may be moved or stretched by a device **720**, **722** and/or **730** which is expandable. The expandable device **720**, **722** and/or **730** may be biodegradable so that it can be left in a patient's body. The expandable device **720**, **722** and/or **730** may be expanded to move and/or stretch body tissue and increase a range of motion of a joint. The expandable device may be used to stretch body tissue in which an incision is to be made.

An improved drape system **100** is provided to maintain a sterile field between a surgeon **106** and a patient during movement of the surgeon relative to the patient. The improved drape system **100** includes a drape **102** which extends between the surgeon and a drape **90** for the patient. During surgery on a knee portion **76** of a leg **70** of a patient, the drape system **100** extends beneath the foot portion **74** of the leg **70** of a patient. It is contemplated that the drape system **100** will be utilized during many different types of operations other than surgery on a leg of a patient.

An implant **950**, **970**, **980**, **1002**, **1020**, **1040** or **1060** may be movable relative to both a femur **126** and a tibia **214** in a leg of a patient during bending of the leg. The implant may include a single member (FIGS. **59**, **60**, **63**, **64** and **65**) which is disposed between and engage by end portions of the femur and tibia. Alternatively, the implant may include a plurality of members (FIGS. **61** and **62**) which are disposed in engagement with each other. If desired one of the members of the plurality of members may be secured to a bone and engaged by a member which is not secured to a bone. The implant may be secured to soft tissue in the knee portion of the patient's leg (FIGS. **63** and **64**).

There are many different features to the present invention. It is contemplated that these features may be used together or separately. It is also contemplated that the features may be utilized in association with joints in a patient's body other than a knee joint. For example, features of the present invention may be used in association with surgery on vertebral joints or glenoid joints. However, it is believed that many of the features may be advantageously utilized together during the performance of surgery on a patient's knee. However, the invention should not be limited to any particular combination of features or to surgery on any particular joint in a patient's body. It is contemplated that features of the present invention will be used in association with surgery which is not performed on a joint in a patient's body.

Thus, while various descriptions of the present invention are described above, it should be understood that the various features can be used singly or in any combination thereof. Therefore, this invention is not to be limited to only the specifically preferred embodiments depicted herein. Further, it should be understood that variations and modifications within the spirit and scope of the invention may occur to those skilled in the art to which the invention pertains. Accordingly, all expedient modifications readily attainable by one versed in the art from the disclosure set forth herein that are within the scope and spirit of the present invention are to be included as further embodiments of the present invention. The scope of the present invention is accordingly defined as set forth in the appended claims.

What is claimed is:

1. A device to replace an articulating surface of a joint in a body, the joint having first and second sides, comprising:

a base component, including a bone contacting side connectable with bone on the first side of the joint, and a base sliding side on an opposite side of said base component relative to said bone contacting side, having a surface defining a first curved shape;

a movable component, including a movable sliding side operable to be positioned in contact with said base sliding side upon a surface defining a second curved shape, said second curved shape being complementary to said first curved shape, said movable sliding side thereby being matably positionable in sliding engagement with said base sliding side, and an articulating side on an opposite side of said movable component relative to said movable sliding side, shaped to matingly engage an articulating surface of the second side of the joint;

wherein when said base component is connected to the first side of a joint, and said base sliding side is pressed against said movable sliding side, said first and second curved shapes tend to releasable slide to a resting position with respect to each other during use of the device in the body, aligning both sides of the joint to a desired orientation.

2. The device of claim **1**, wherein said base sliding side has a concave shape.

3. The device of claim **2**, wherein the joint is a knee joint.

4. The device of claim **1**, wherein one of said first and second curved shapes is substantially convex, and the other of said first and second curved shapes is substantially concave.

5. The device of claim **1**, wherein one of said surface of said base sliding side and said surface of said movable sliding side is metallic, and the other of said surface of said base sliding side and said surface of said movable sliding side is polymeric.

6. The device of claim **1**, wherein said bone contacting side, base sliding side, movable sliding side and articulating side include a material selected from the group consisting of: metal, cobalt-chromium alloy, titanium alloy, polymer, ceramic, ultra high molecular weight polymer, porous cement, copolymer, dipolymer, hydrophilic material, petroylglupamic acid, carboxymethylcellulose, collagen, polylactide, hydroxyapatite, polyethylene, polylactide, and polyhydroxybutyrate.

7. The device of claim **1**, wherein the curved shape of said base sliding side and said movable sliding side are different, one curved shape being smaller than the other.

8. The device of claim **1**, wherein the curved shape of said base sliding side or said movable sliding side has a curvature selected from the group consisting of: constant radius, variable radius, progressively varying radius.

9. The device of claim **1**, wherein not all articulating compartments of the joint are replaced by said device.

10. The device of claim **1**, wherein the joint is located in a finger, wrist, elbow, shoulder, spine, hip, knee, ankle, or toe.

11. The device of claim **1**, wherein the curved shape of said base sliding side or the curved shape of said movable sliding side changes progressively from a center of said curved shape to a periphery of said curved shape.

12. The device of claim **1**, wherein the curved shape is selected to promote a desired ligament tension throughout a range of motion of the joint.

13. The device of claim **1**, wherein said first curved shape or said second curved shape is non-uniform with respect to an axis passing through the anterior-posterior or the medial-lateral center of said base component or movable component.

14. The device of claim **1**, further including:

a protrusion extending from one of said base sliding side or movable sliding side; and

a recess sized to receive said protrusion, disposed in the other of said base sliding side or movable sliding side, said protrusion and recess matable to constrain movement of said first and second components relative to each other, thereby promoting movement of the joint within desired anatomical limits.

15. A device to replace an articulating surface of a first side of a joint in a body, the joint having first and second sides, comprising:

a base component, including a bone contacting side connectable with bone on the first side of the joint, and a base sliding side on an opposite side of said base component relative to said bone contacting side;

a movable component, including a movable sliding side, said movable sliding side being matably positionable in sliding engagement with said base sliding side, and an articulating side on an opposite side of said movable component relative to said movable sliding side, shaped to matingly engage an articulating surface of the second side of the joint;

a protrusion extending from one of said base sliding side or movable sliding side, said protrusion substantially offset with respect to a midline of the first side of a joint;

a recess sized to receive said protrusion, disposed in the other of said base sliding side or movable sliding side, said protrusion and recess matable to constrain movement of said first and second components relative to each other, thereby promoting movement of the joint within desired anatomical limits.

16. The device of claim **15**, wherein said protrusion and said recess are located substantially offset from a center of said device.

17. The device of claim **15**, wherein the joint is a knee, and said protrusion and said recess are medially offset from a center of said device, whereby said base sliding side and said movable sliding side are less constrained to slideably engage on a lateral side of engagement than on a medial side of engagement, thereby correlating to the movement of a natural knee joint.

18. The device of claim **15**, wherein the joint is a knee.

19. The device of claim **15**, further including a second base component connectable to the second side of the joint, including an articulating surface matable with said articulating side of said movable component.

20. The device of claim **19**, wherein the joint is a knee, and the first base component is connectable to the tibia, and the second base component is connectable to the femur, or the first base component is connectable to the femur, and the second base component is connectable to the tibia.

21. The device of claim **15**, wherein said protrusion and recess engage to permit relative rotation of said base sliding side and said movable sliding side about an axis of said protrusion.

22. The device of claim **15**, wherein said protrusion is a pin, and said recess is a hole sized to receive said pin.

23. The device of claim **15**, wherein said protrusion is a dovetail pin and said recess is a dovetail tail, together forming a dovetail joint.

24. The device of claim **23**, wherein said dovetail joint is elongated, extends in a substantially anterior-posterior orientation, and enables anterior-posterior displacement of the base sliding side relative to the movable sliding side.

25. The device of claim **15**, further including means associated with said protrusion to prevent a separation of said base sliding side and said movable sliding side.

26. The device of claim **15**, wherein not all articulating compartments of the joint are replaced by said device.

27. The device of claim **15**, wherein the joint is located in a finger, wrist, elbow, shoulder, spine, hip, knee, ankle, or toe.

28. The device of claim **15**, wherein said protrusion is offset with respect to an axis passing through the anterior-posterior or the medial-lateral center of said base component or movable component.

29. A device to replace an articulating surface of a first side of a joint in a body, the joint having first and second sides, comprising:

a base component, including a bone contacting side connectable with bone on the first side of the joint, and a base sliding side on an opposite side of said base component relative to said bone contacting side, having a surface defining a first curved shape;

a movable component, including a movable sliding side operable to be positioned in contact with said base sliding side upon a surface defining a second curved shape, said second curved shape being complementary to said first curved shape, said movable sliding side thereby being matably positionable in sliding engagement with said base sliding side, and an articulating side on an opposite side of said movable component relative to said movable sliding side, shaped to matingly engage an articulating surface of the second side of the joint;

wherein the bone contacting side and the base sliding side, or the movable sliding side and the articulating side, define therebetween a base component or movable component peripheral profile height that is non-uniform in thickness with respect to an axis passing through the anterior-posterior or the medial-lateral center of said base component or movable component.

30. The device of claim **29**, wherein said base component or movable component peripheral profile height is greater on a lateral side of the base component or movable component, with respect to an axis passing through the medial-lateral center of said base component or movable component.

31. A knee arthroplasty device, comprising:

a tibial tray including a lower distal surface and an upper proximal surface, said proximal surface having either a post or a cavity, said post or cavity offset from at least one of a medial-lateral centerline and an anterior-posterior centerline of said tibial tray;

a tibial tray insert engageable with said proximal surface and having a mating second cavity if said tibial tray has a post, or a mating post if said tibial tray has a cavity, said mating post or mating cavity offset from at least one of the medial-lateral centerline and the anterior-posterior centerline of said tibial tray, wherein said mating cavity is adapted to receive at least a portion of said post, or said mating post is adapted to be received in at least a portion of said cavity;

wherein said tibial tray insert rotationally moves with respect to said tibial tray, about said post, when the device is used within the body such that the rotation of the tibial tray insert is asymmetric with respect to at least one of the medial-lateral centerline and the anterior-posterior centerline of said tibial tray.

32. The knee arthroplasty device of claim **31**, wherein said post or mating post is offset medially from a medial-lateral centerline of said tibial tray.

33. The knee arthroplasty device of claim **31**, wherein said mating cavity or mating post of said tibial tray insert is offset medially from a medial-lateral centerline of said tibial tray insert.

34. The knee arthroplasty device of claim **31**, wherein the tibial tray has a keel with a central axis, and wherein said post or cavity of said tibial tray is offset from the central axis of said keel.

35. The knee arthroplasty device of claim **31**, wherein the tibial tray has a keel with a central axis, and wherein said mating post or mating cavity of said tibial tray insert is offset from the central axis of said keel.

36. The knee arthroplasty device of claim **31**, wherein a proximal surface of said tibial tray insert includes a mound interposing a medial condyle receiver and a lateral condyle receiver.

37. The knee arthroplasty device of claim **31**, wherein said tibial tray slides with respect to said tibial tray.

38. A method of assembling a tibial component of a knee joint prosthesis comprising:

mounting a tibial tray to a patient's natural tibia so that a distal surface of the tibial tray is adjacent the patient's tibia, the tibial tray including either a longitudinal projection, or a longitudinal cavity, extending in an anterior-posterior direction on a proximal surface of the tibial tray, the longitudinal projection or cavity interposing a lateral bearing surface from a medial bearing surface, both of which are on the proximal surface;

mounting a tibial tray insert to the tibial tray, the tibial tray insert including a medial condyle receiver and a lateral condyle receiver, the tibial tray insert further including a mating projection if said tibial tray includes a longitudinal cavity, or a mating cavity if said tibial tray includes a longitudinal cavity, extending in an anterior-posterior direction on a distal surface, at least a portion of the mating projection or mating cavity matable with the projection or cavity of the tibial tray, where the mating projection or mating cavity interposes a medial camming surface from a lateral camming surface on the distal surface of the tibial tray insert;

wherein the projection or mating projection slides within the cavity or mating cavity to allow the tibial tray to slide in at least one of the anterior direction and the posterior direction so that the medial camming surface slides against the medial bearing surface and the lateral camming surface slides against the lateral bearing surface; and

wherein the tibial tray insert is unencumbered by the tibial tray so that the tibial tray insert is free to slide in both the anterior direction and the posterior direction, when the device is used within the body.

39. The method of claim **38**, wherein the projection or mating projection has a vertical dovetail cross-section.

40. The method of claim **38**, wherein the cavity or mating cavity has a vertical dovetail cross-section.

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