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(12) **United States Patent**
Bonutti

(10) **Patent No.: US 6,702,821 B2**
(45) **Date of Patent: Mar. 9, 2004**

(54) **INSTRUMENTATION FOR MINIMALLY INVASIVE JOINT REPLACEMENT AND METHODS FOR USING SAME**

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(73) Assignee: **The Bonutti 2003 Trust A**, Effingham, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 144 days.

(21) Appl. No.: **09/941,185**

(22) Filed: **Aug. 28, 2001**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 09/815,405, filed on Mar. 22, 2001, now abandoned, and a continuation-in-part of application No. 09/789,621, filed on Feb. 21, 2001, now Pat. No. 6,635,073, 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. 09/602,743, filed on Jun. 23, 2000, now Pat. No. 6,361,565, 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. 09/526,949, filed on Mar. 16, 2000, now Pat. No. 6,620,181, and a continuation-in-part of application No. 09/483,676, filed on Jan. 14, 2000, now Pat. No. 6,468,289.

(51) **Int. Cl.**[7] **A61B 17/56**
(52) **U.S. Cl.** **606/88**; 623/20.14
(58) **Field of Search** 606/79, 80, 82, 606/86, 87, 88, 89; 623/20.14, 20.15, 20.21; 128/898

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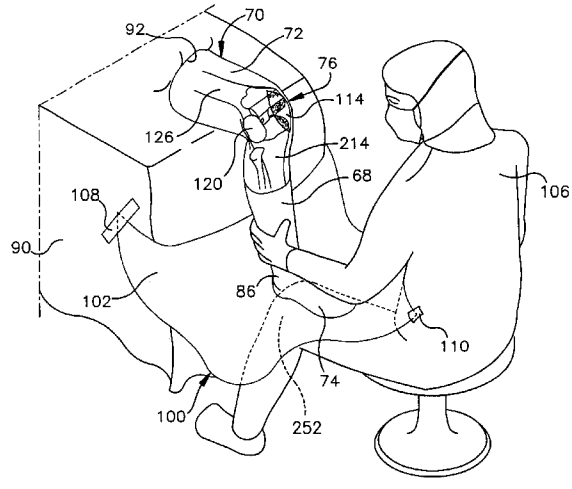
(57) **ABSTRACT**

An improved method of performing surgery on a joint in a patient's body, such as a knee, includes making an incision in a knee portion of one leg while a lower portion of the one leg is extending downward from an upper portion of the one leg and while a foot connected with the lower portion of the one leg is below a support surface on which the patient is disposed. The incision is relatively short, for example, between seven and thirteen centimeters. A patella may be offset from its normal position with an inner side of the patella facing inward during cutting of a bone with a cutting tool. During cutting of the bone, one or more guide members having opposite ends which are spaced apart by a distance less than the width of an implant may be utilized to guide movement of a cutting tool.

39 Claims, 22 Drawing Sheets



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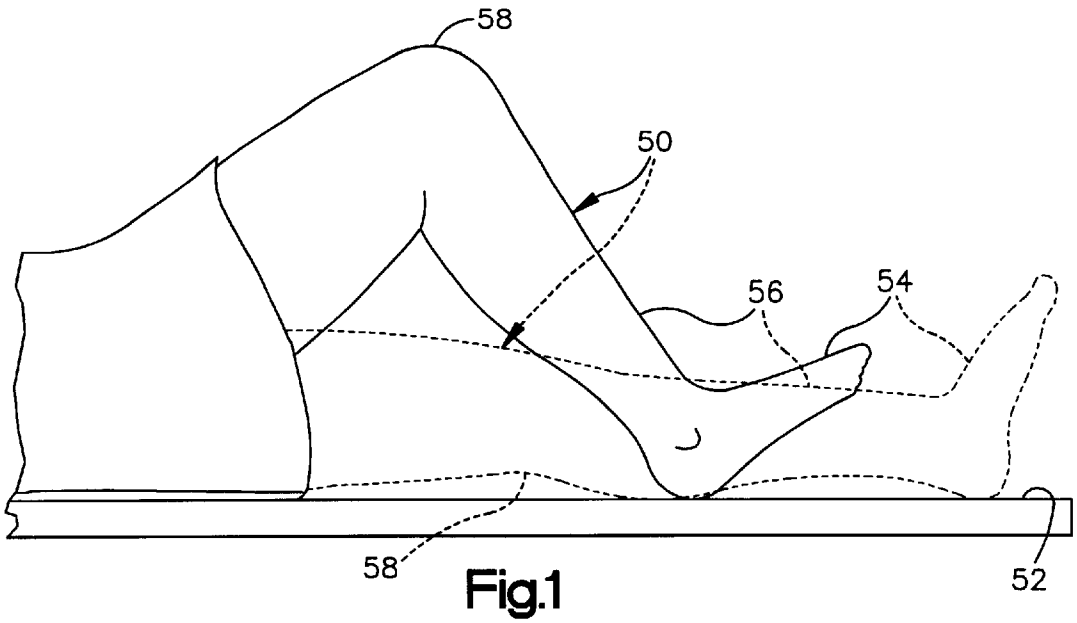

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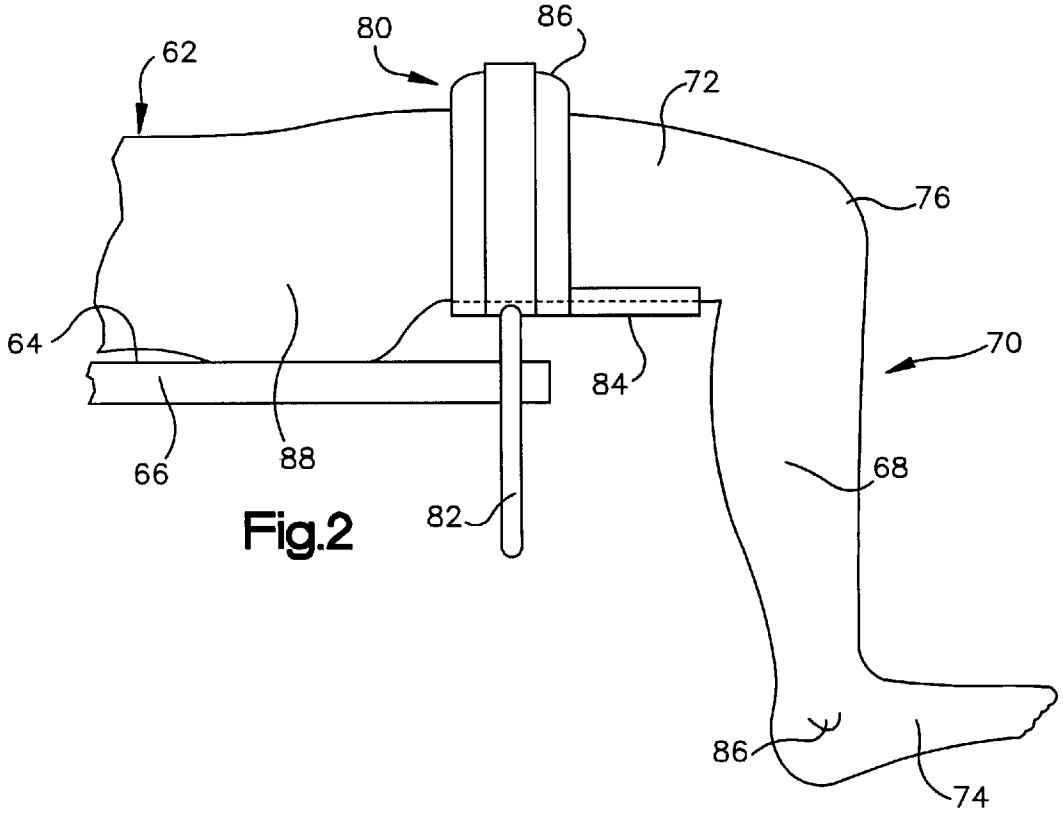

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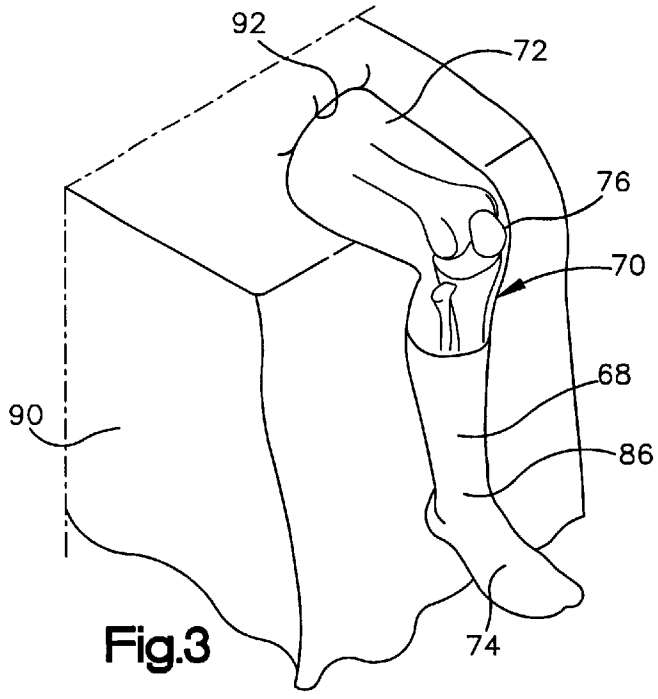
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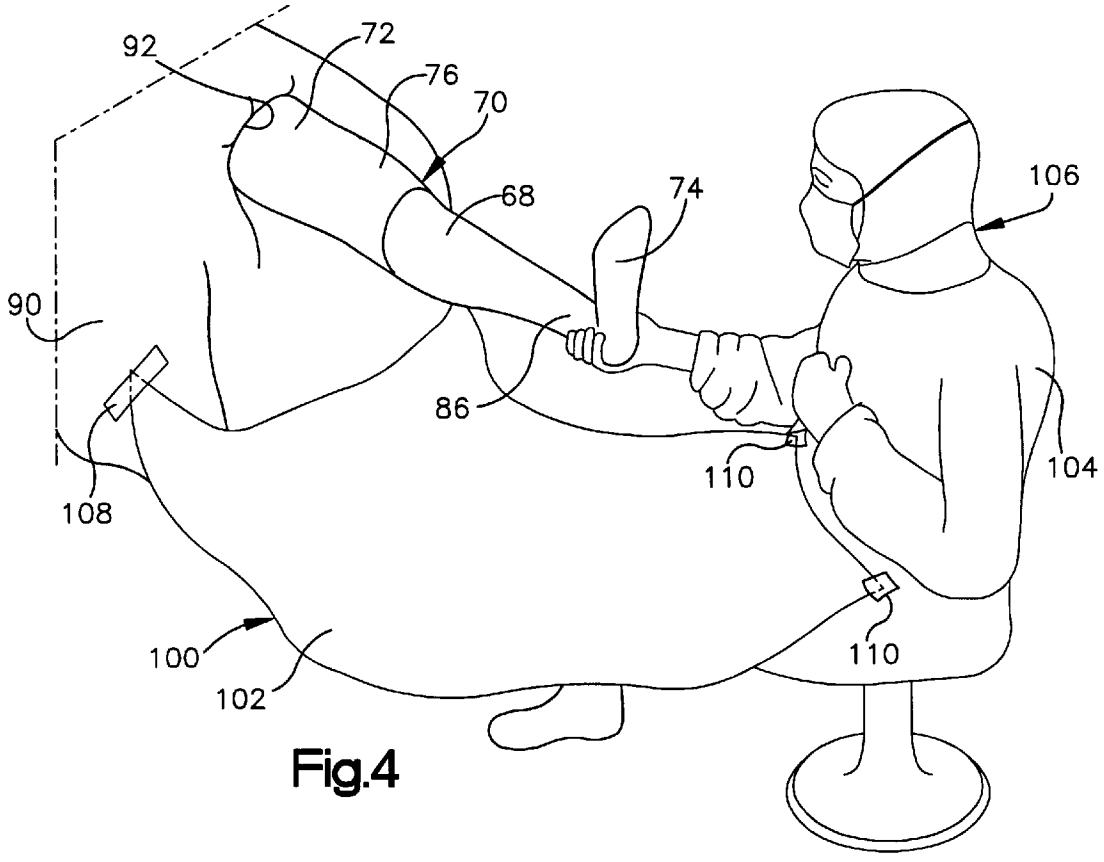
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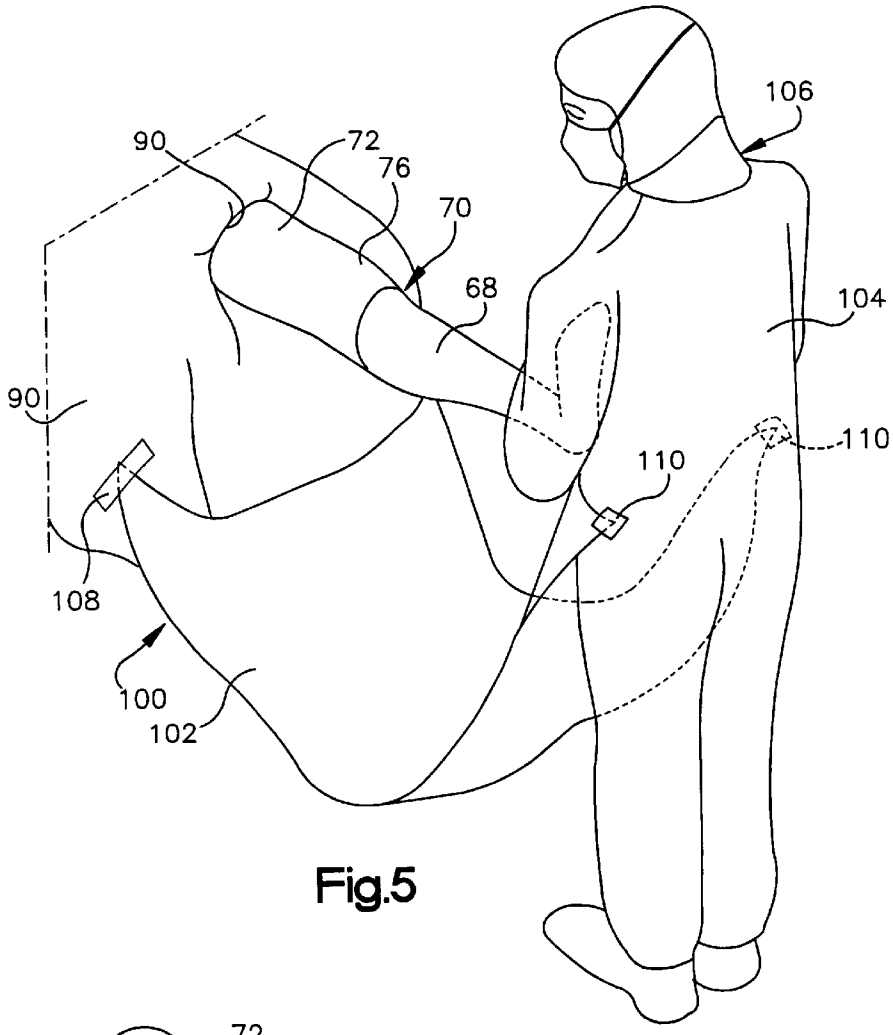

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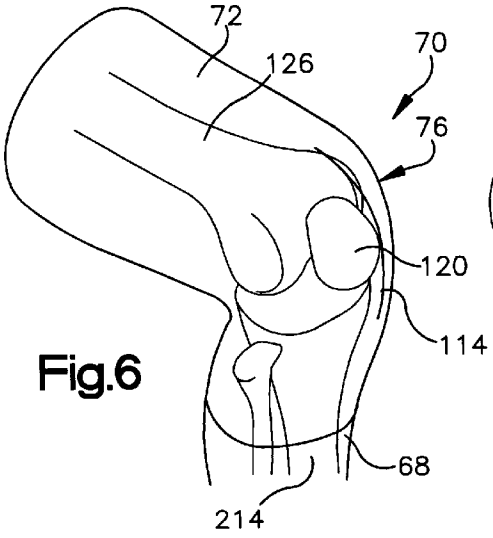

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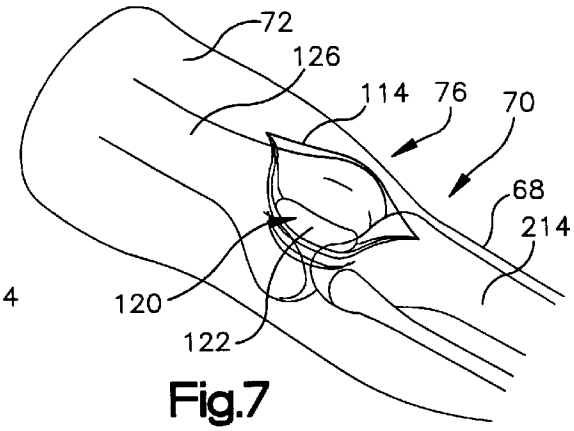

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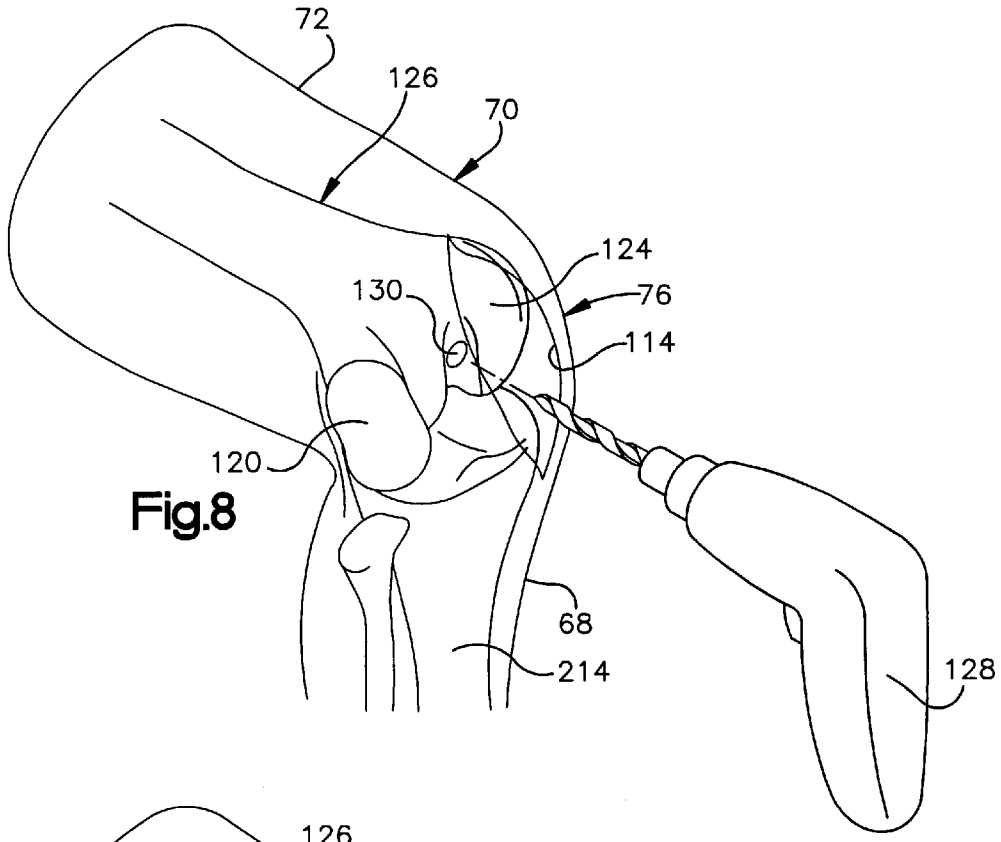
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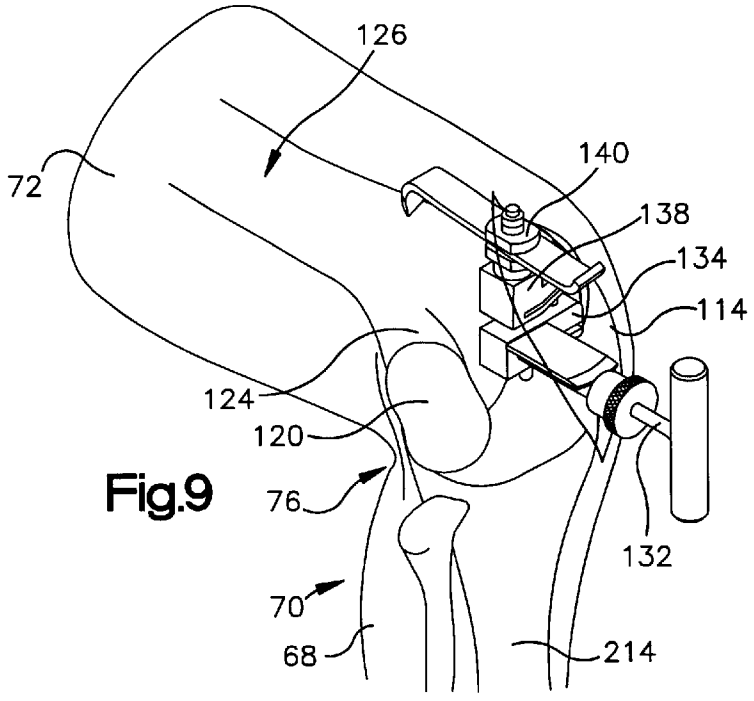
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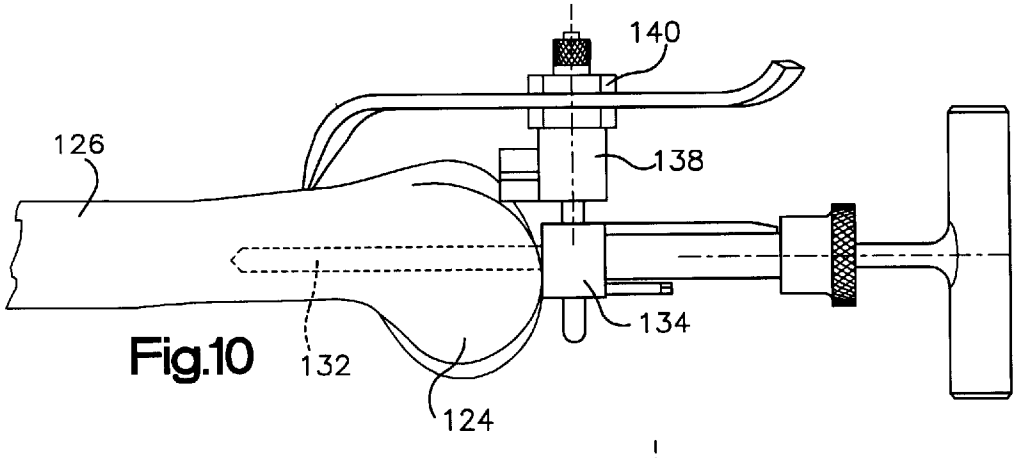

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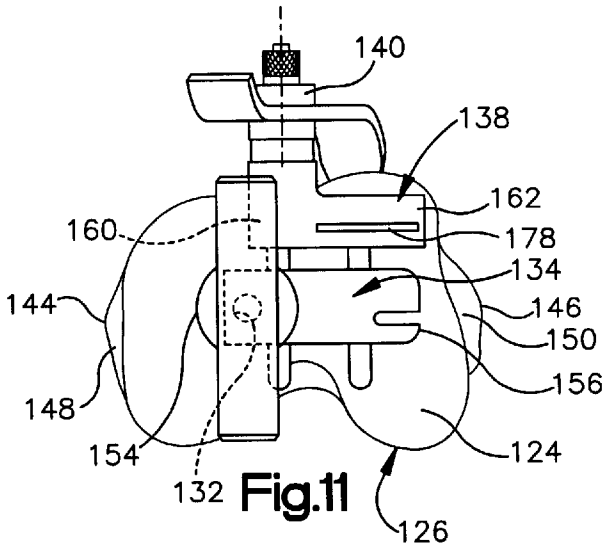

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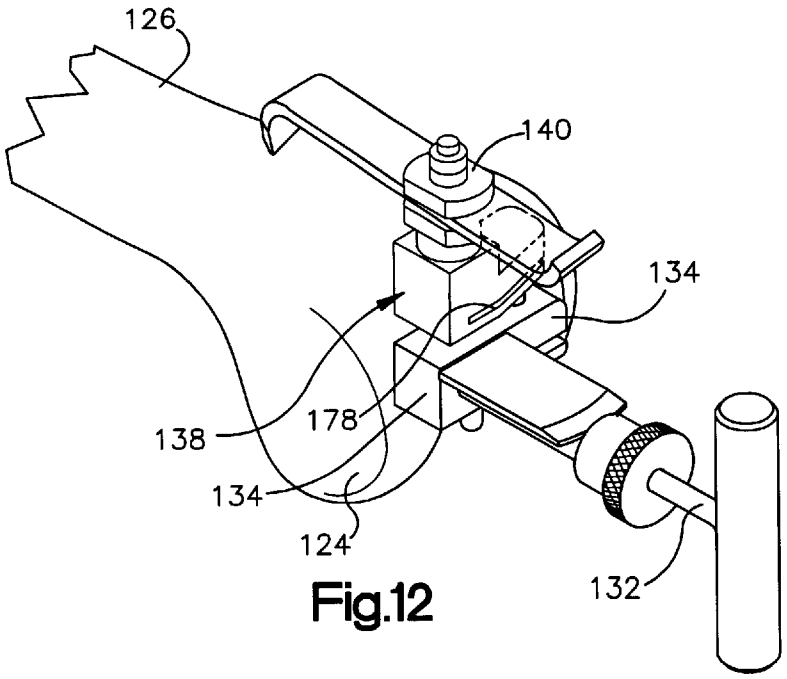

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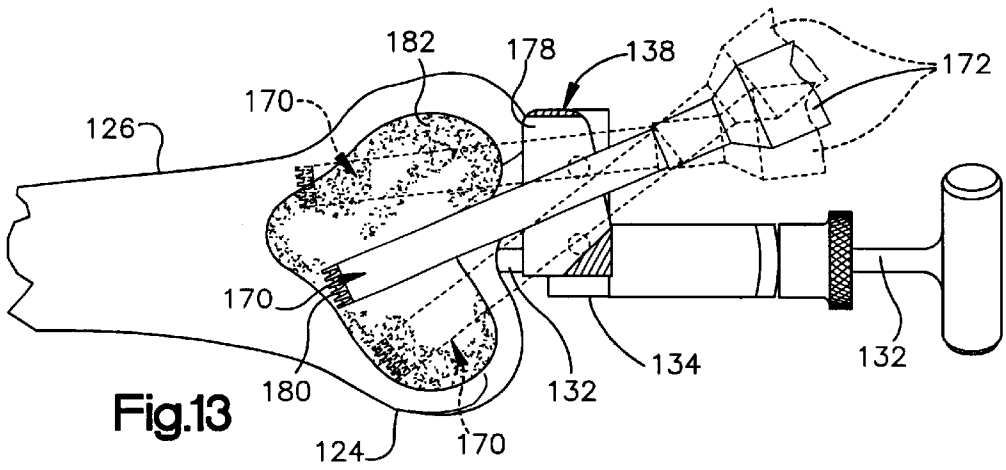

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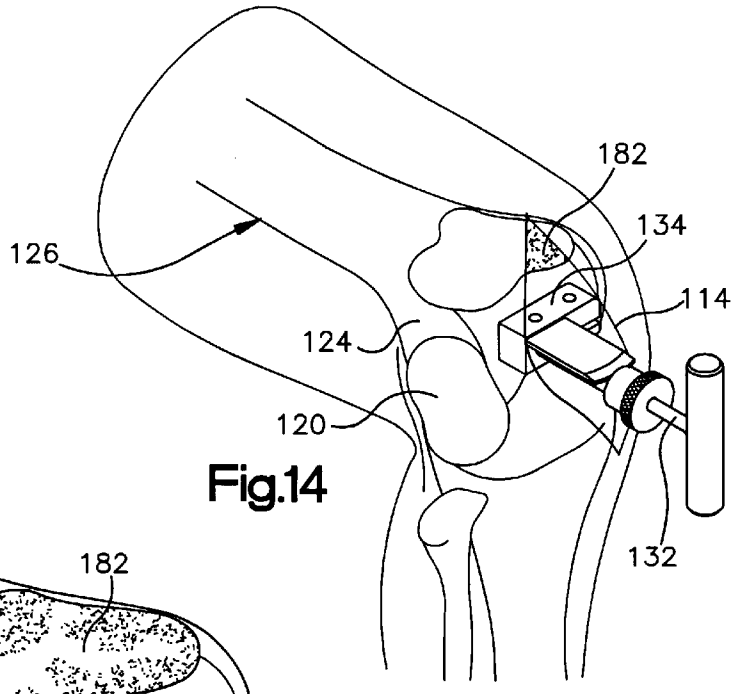

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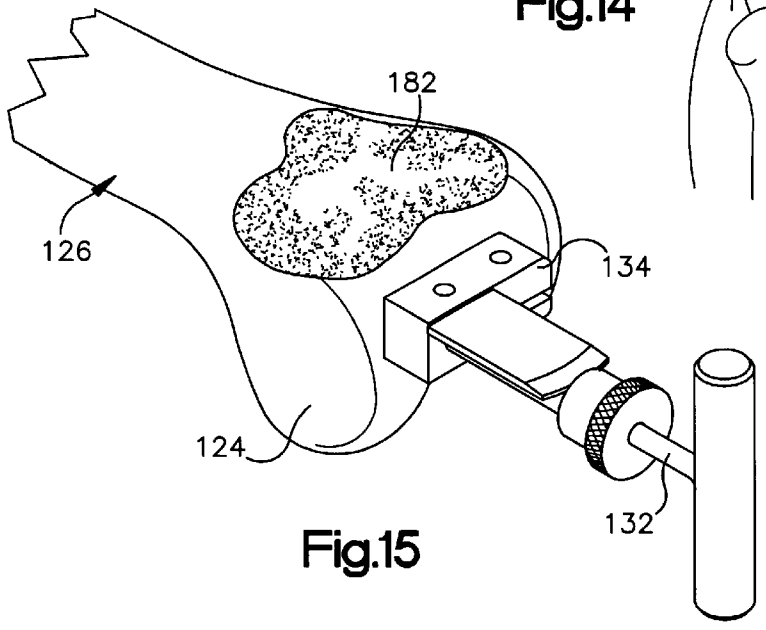

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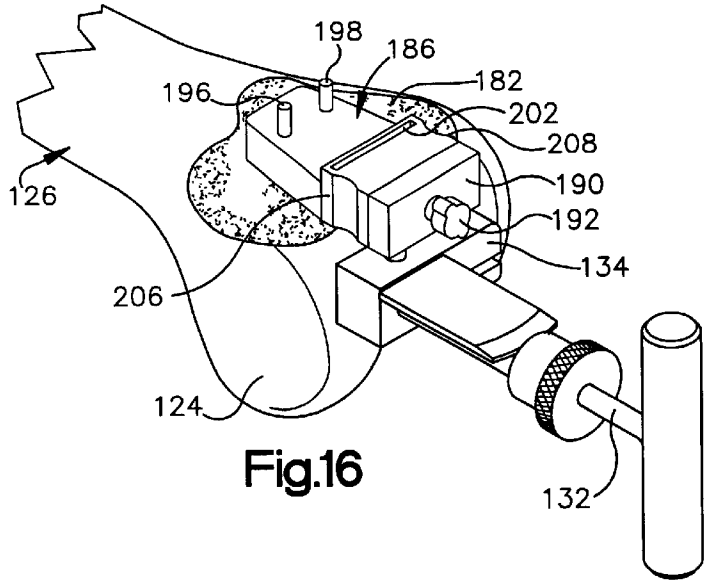

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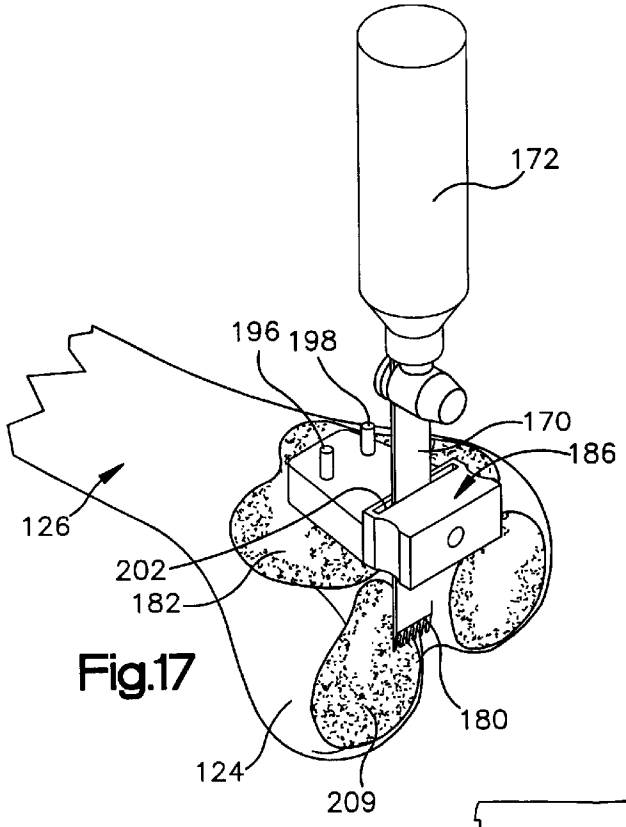

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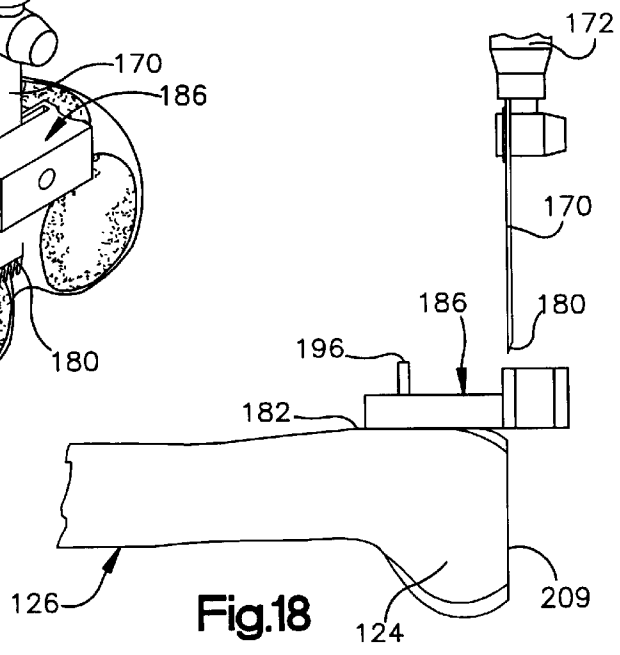

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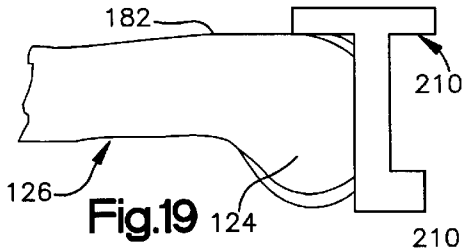

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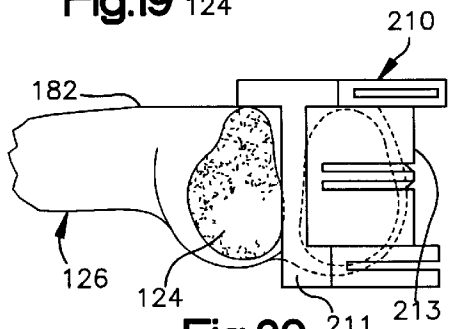

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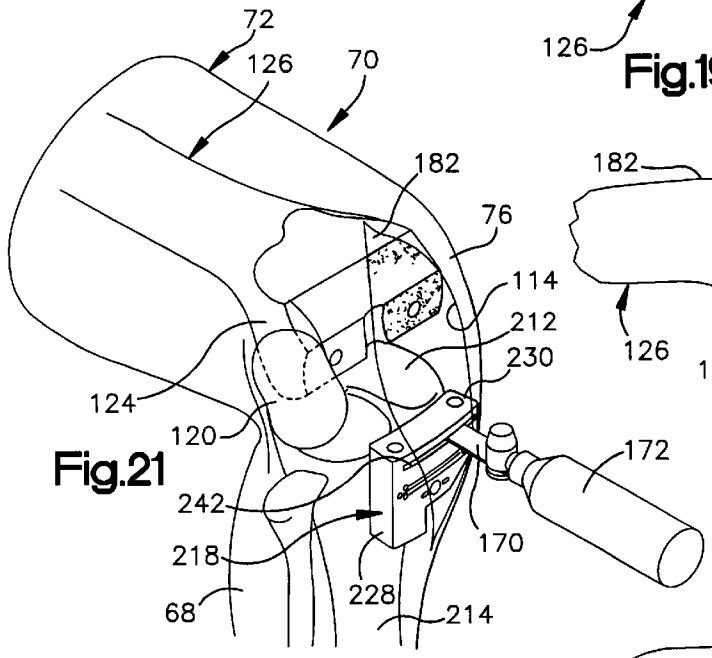

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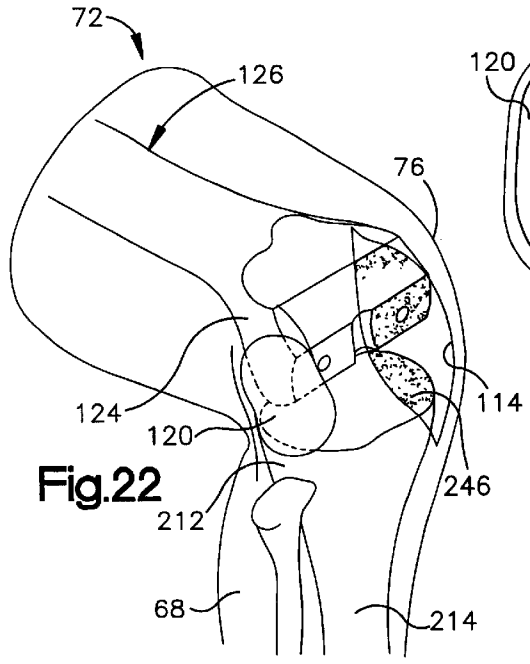

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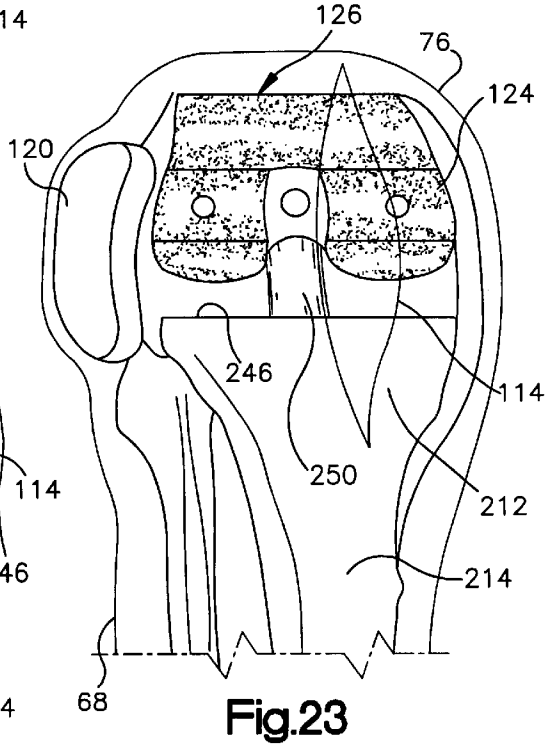

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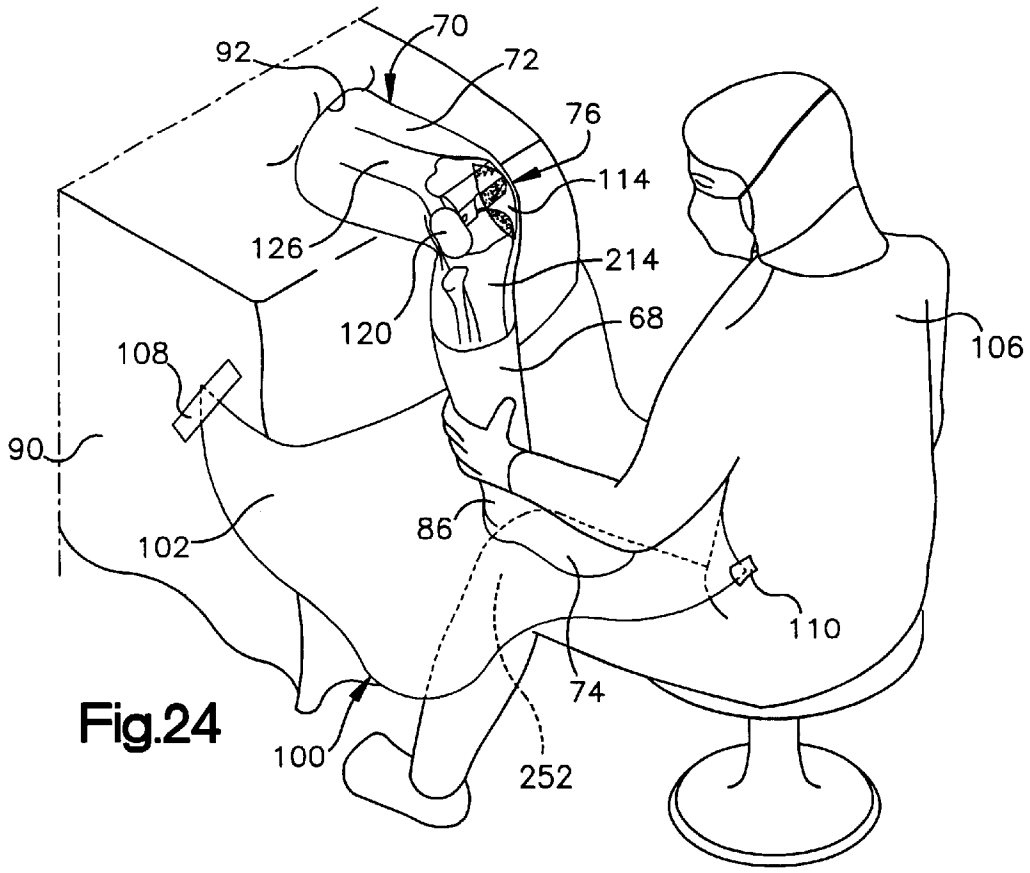
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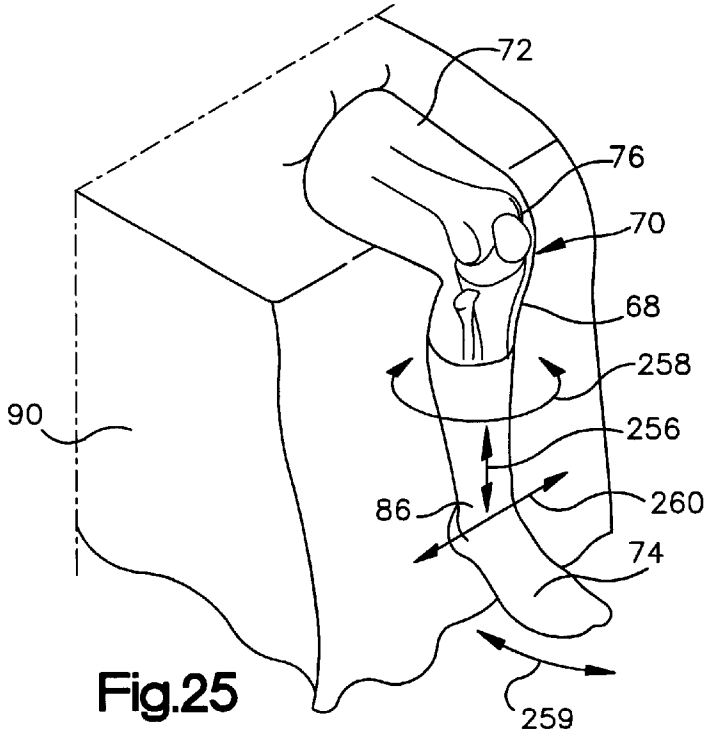
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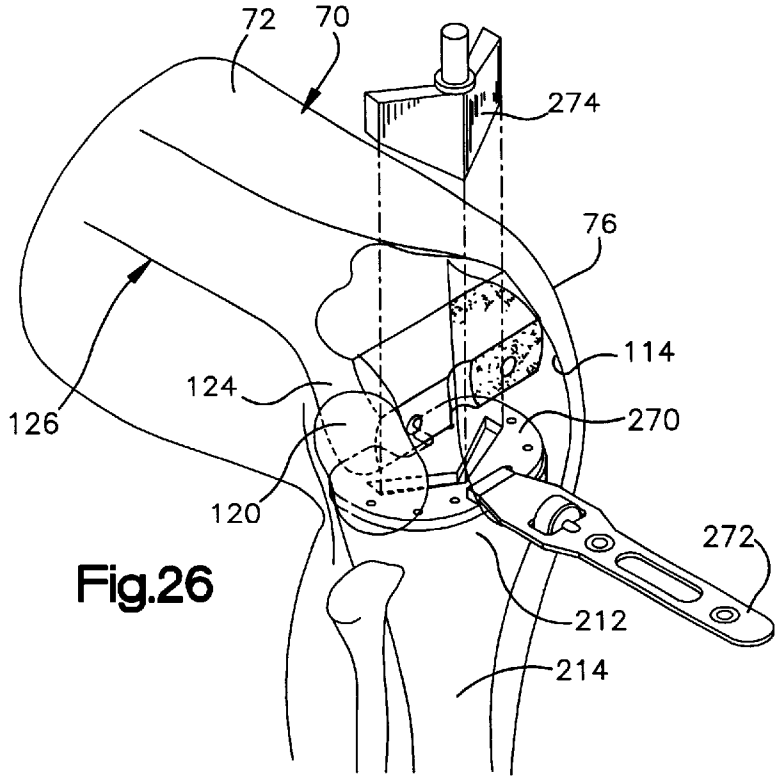
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Fig.26

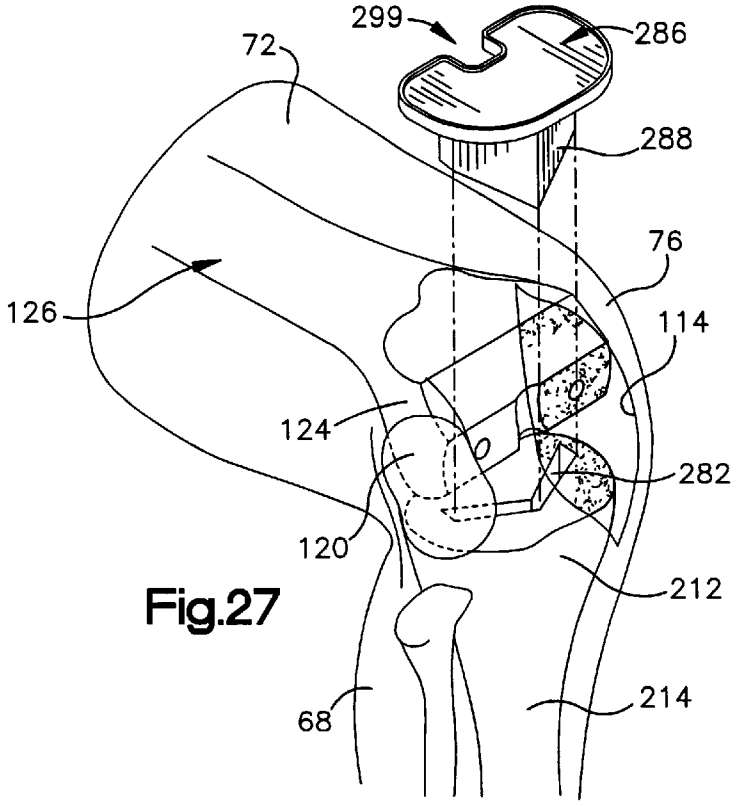
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Fig.27

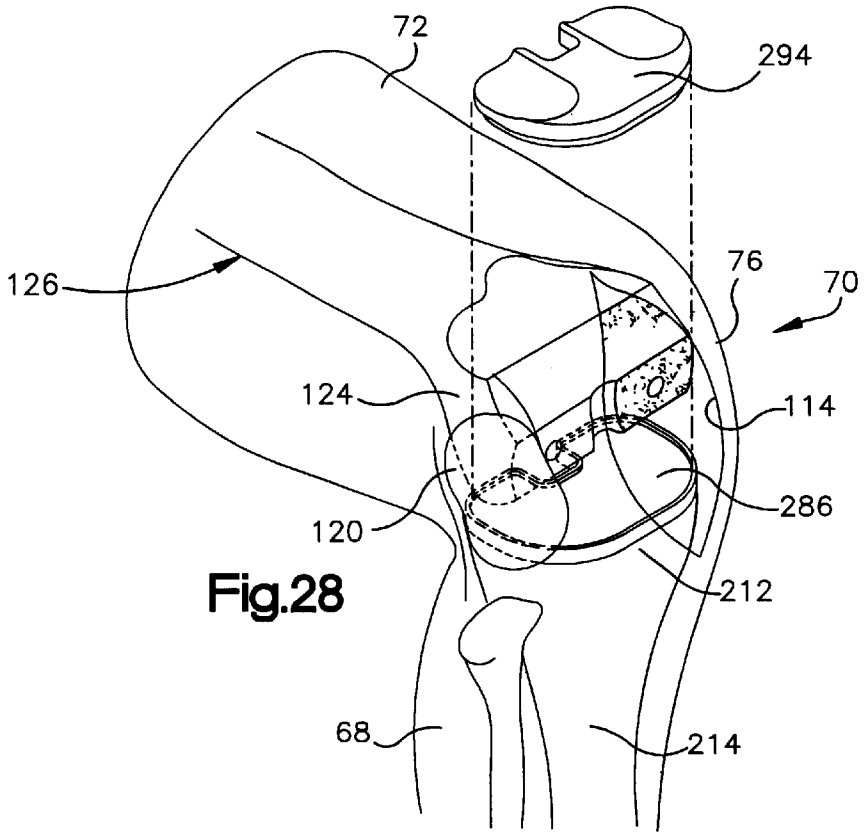
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Fig.28

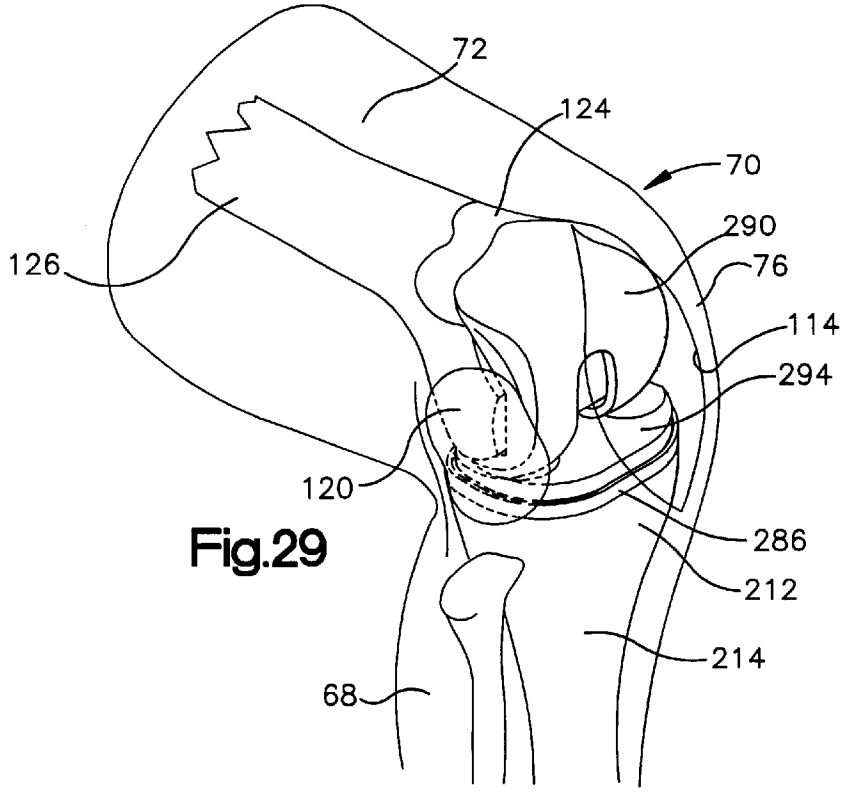
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Fig.29

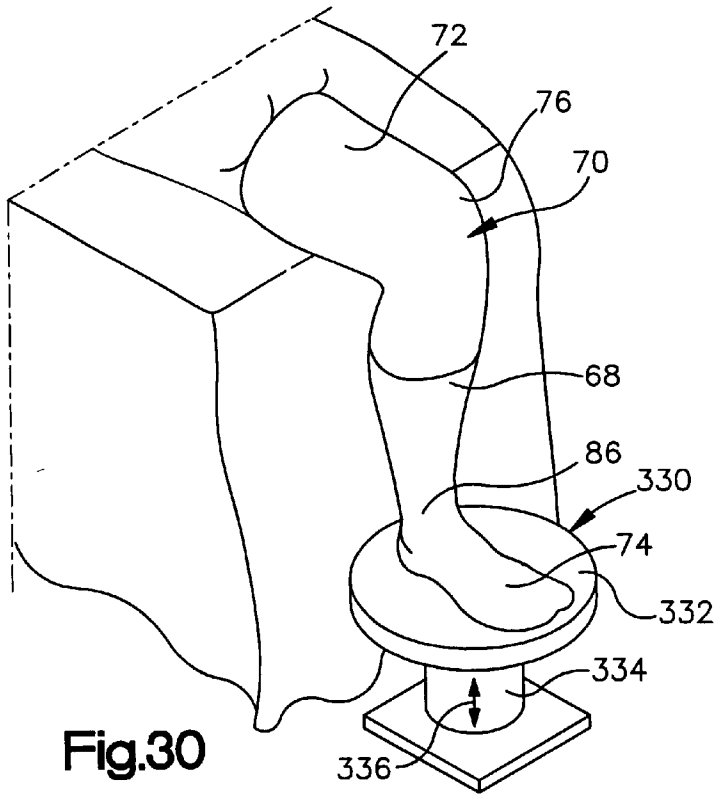

Fig.30

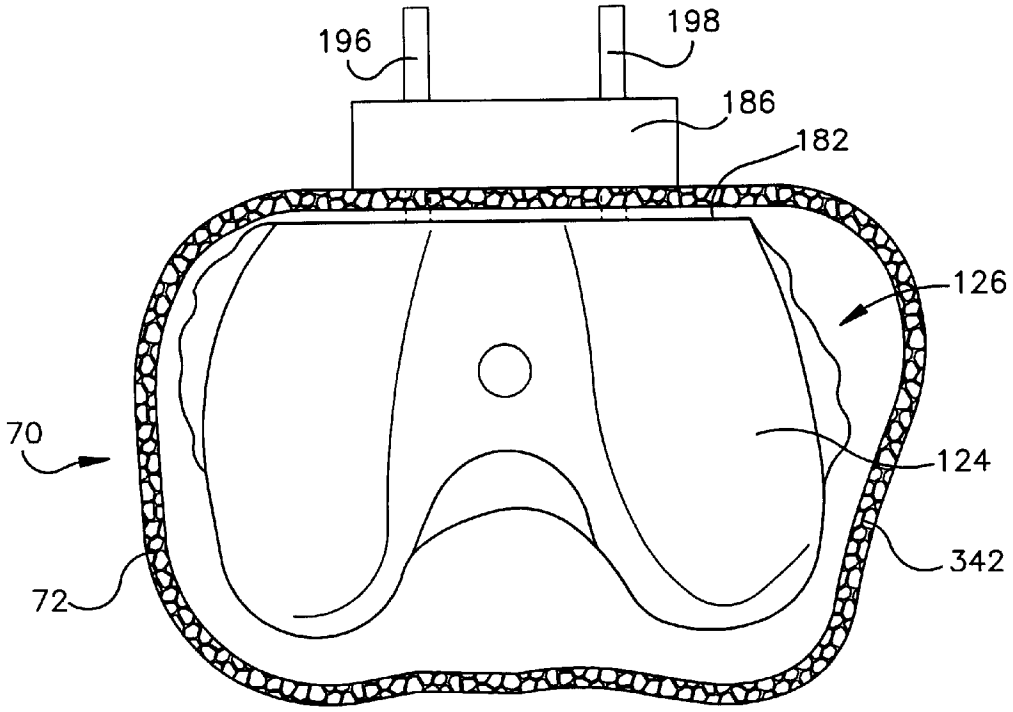

Fig.31

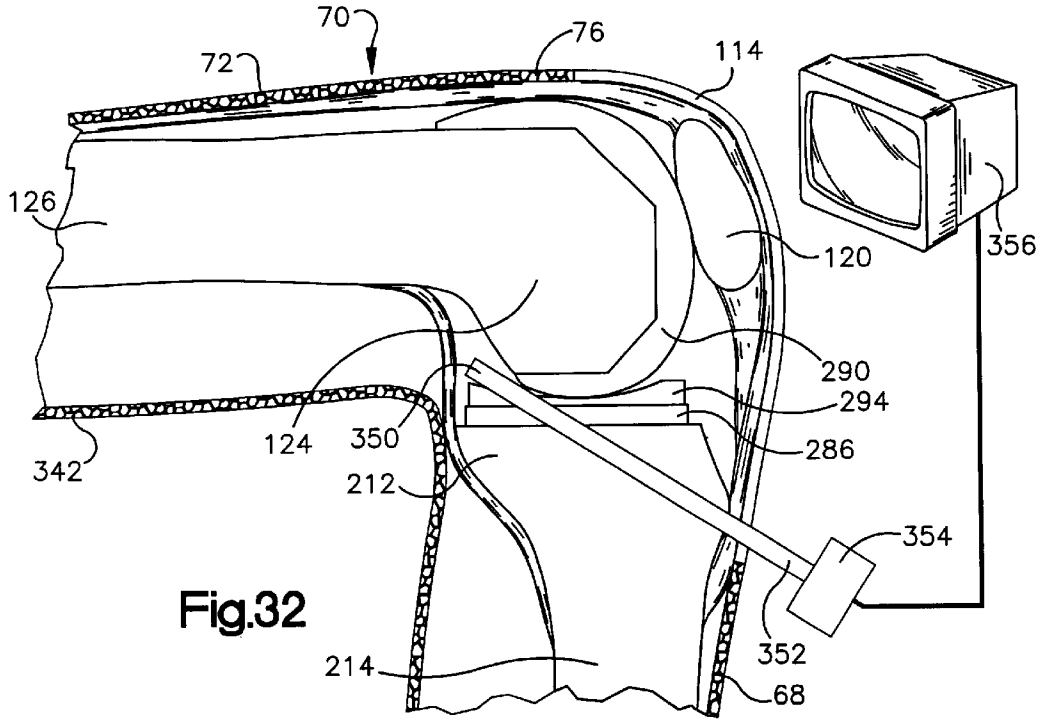
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Fig.32

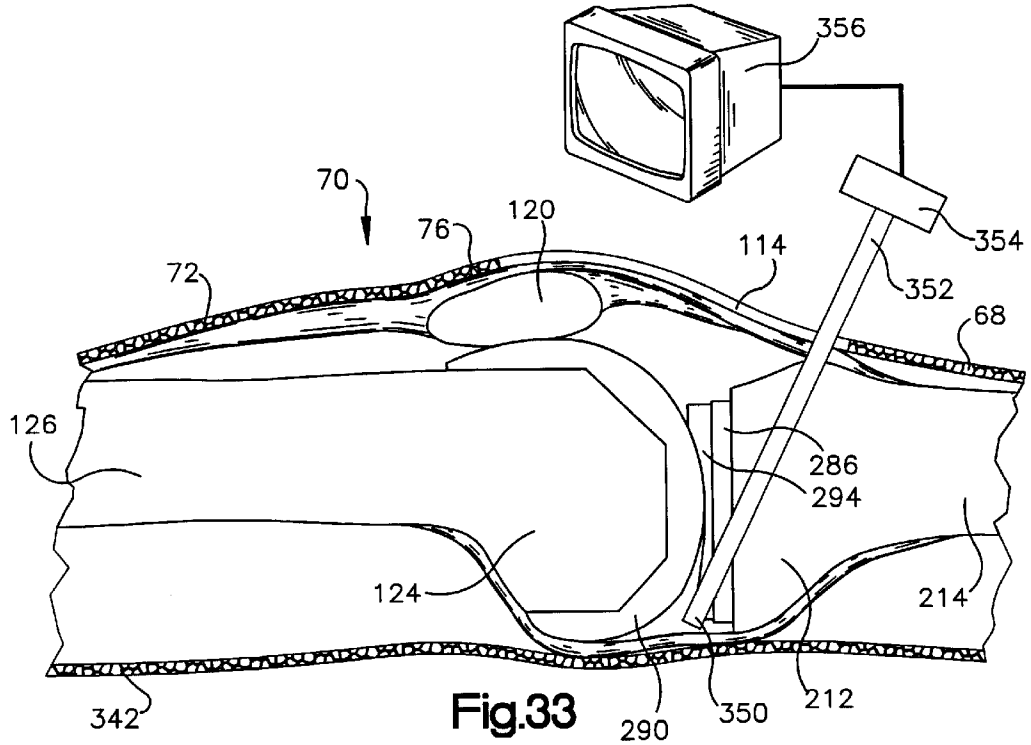
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Fig.33

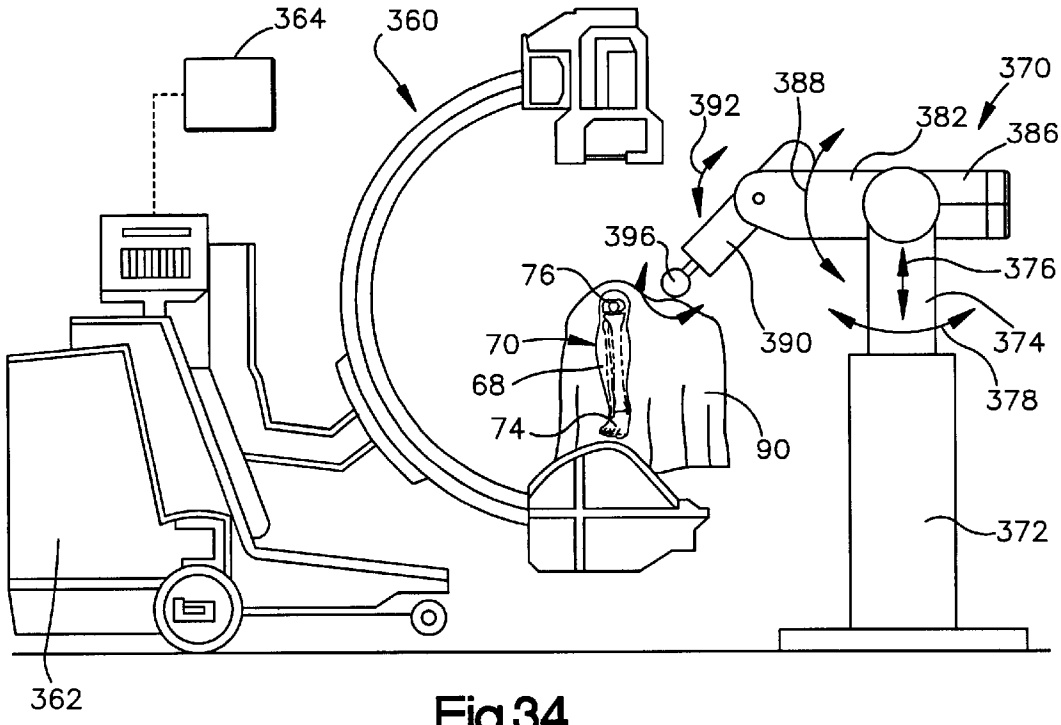
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Fig.34

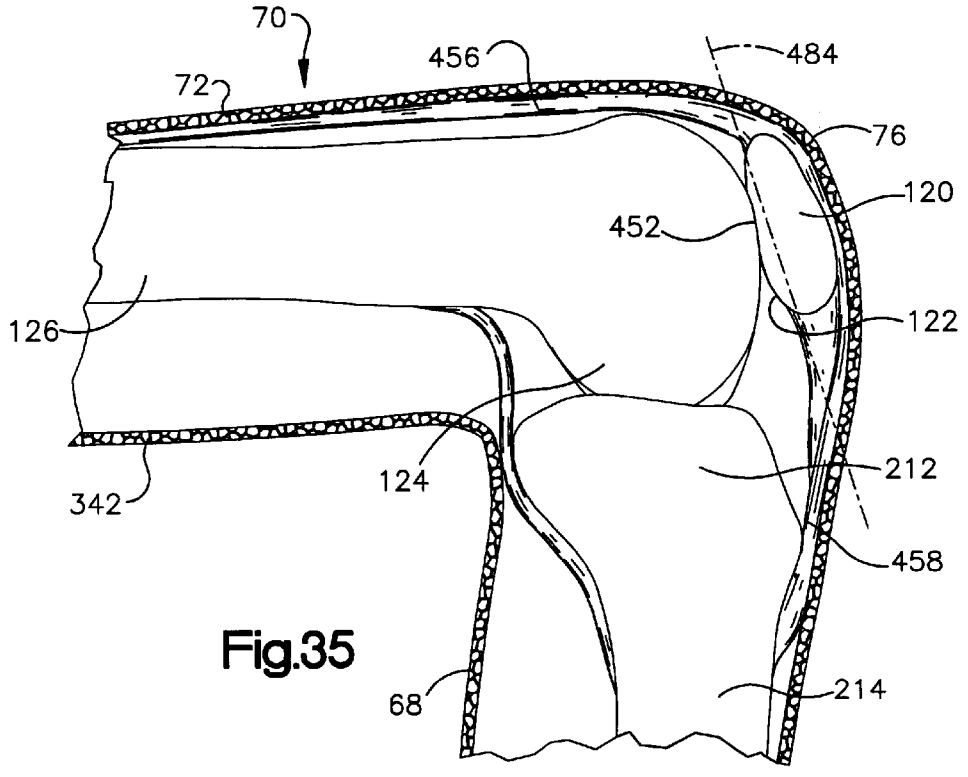
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Fig.35

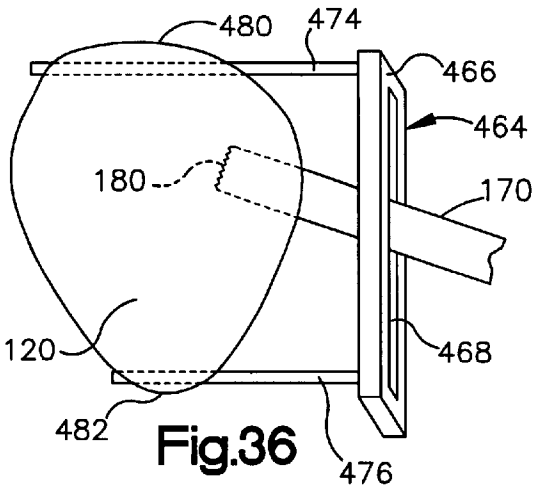

Fig.36

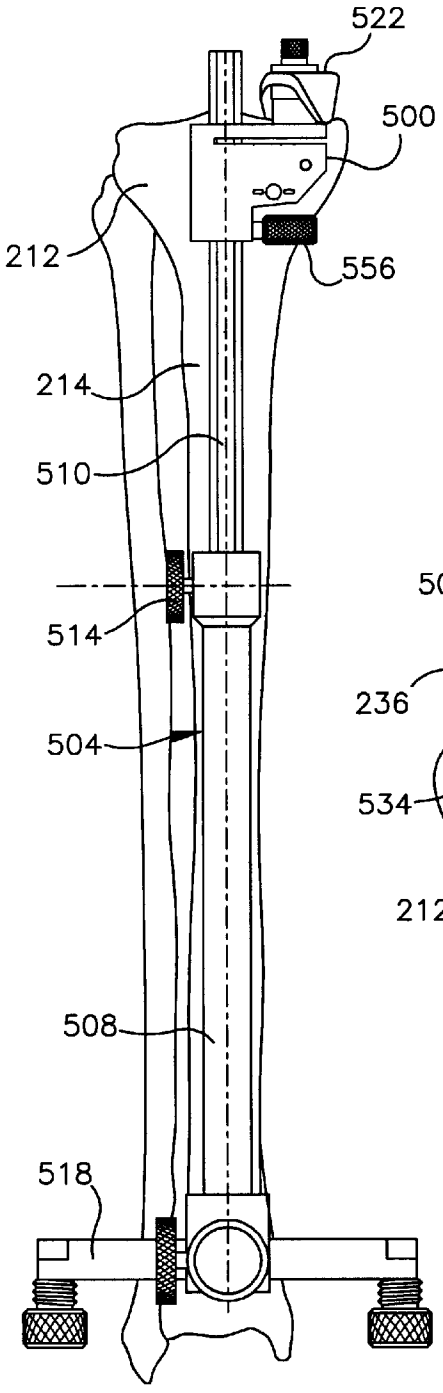

Fig.37

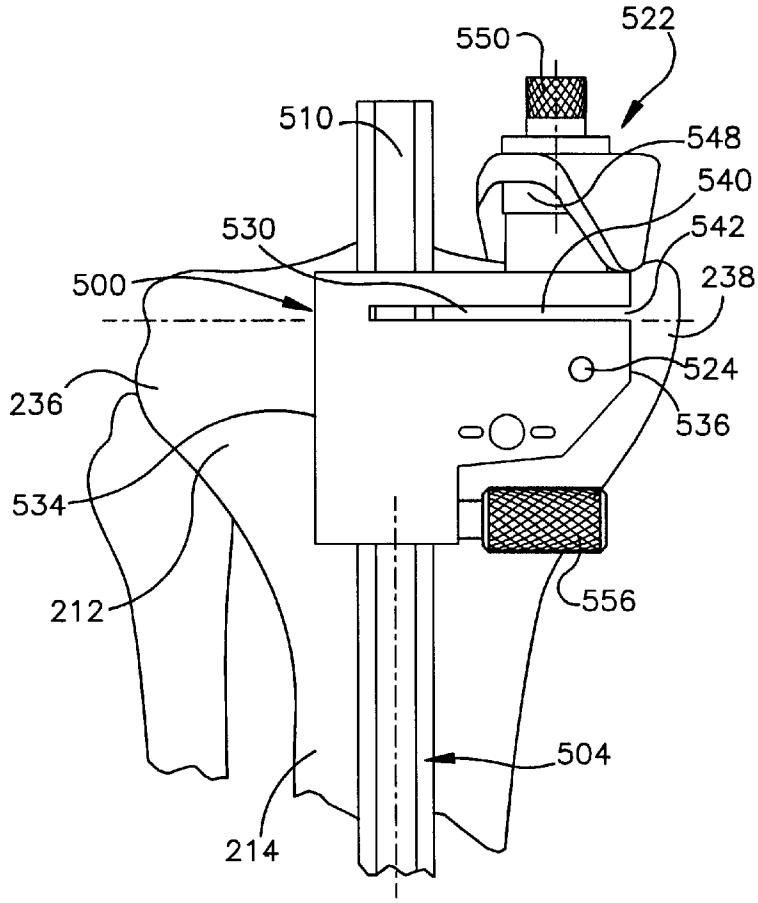

Fig.38

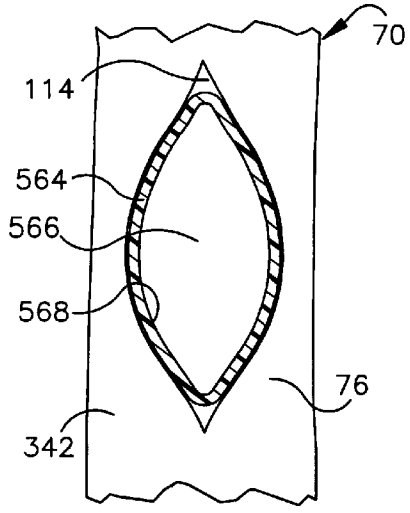

Fig.39

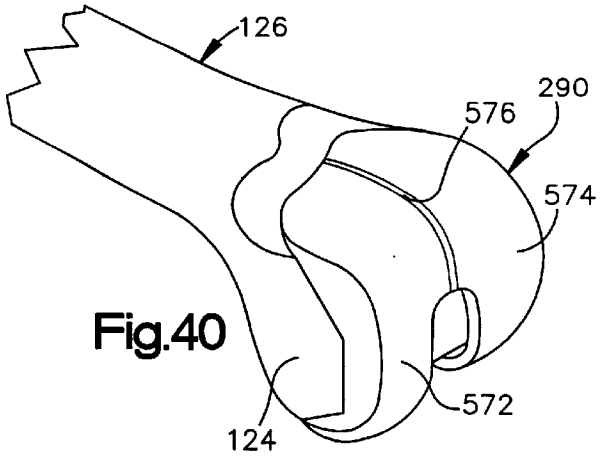

Fig.40

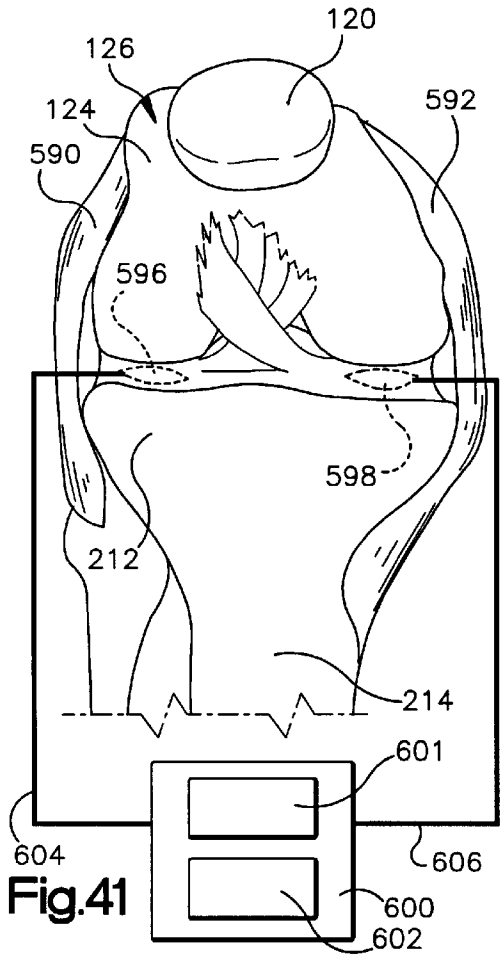

Fig.41

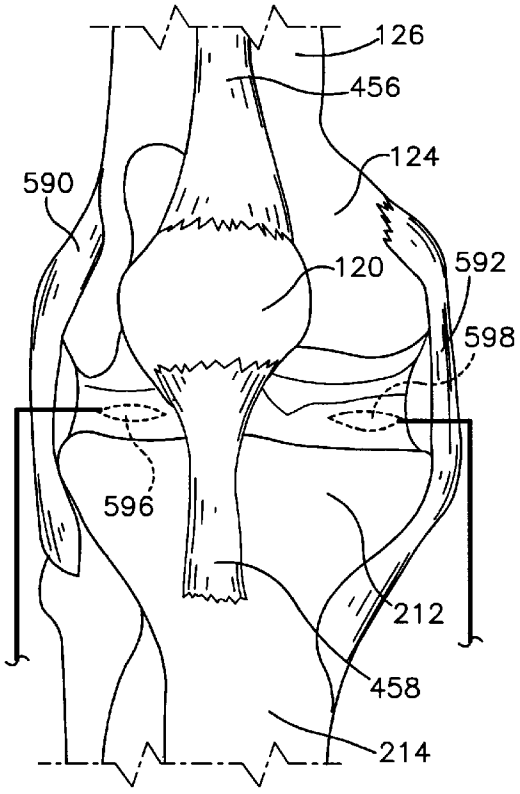

Fig.42

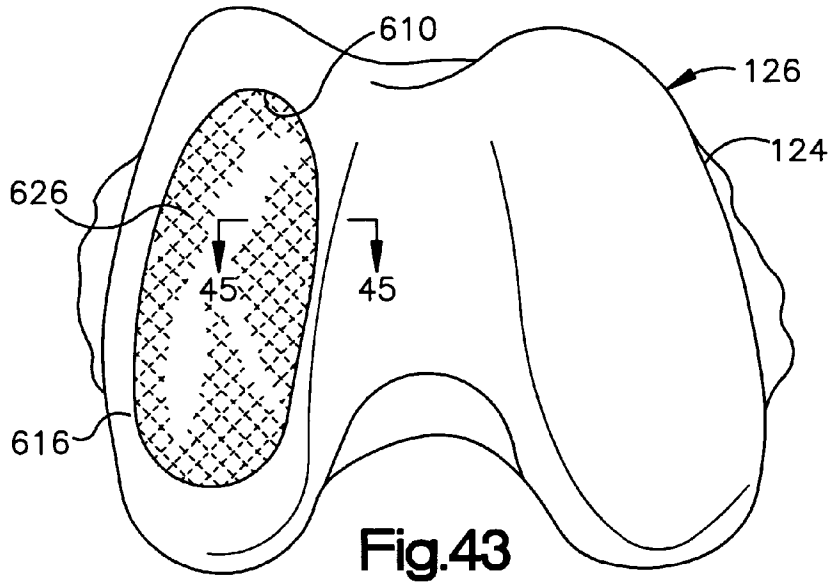

Fig.43

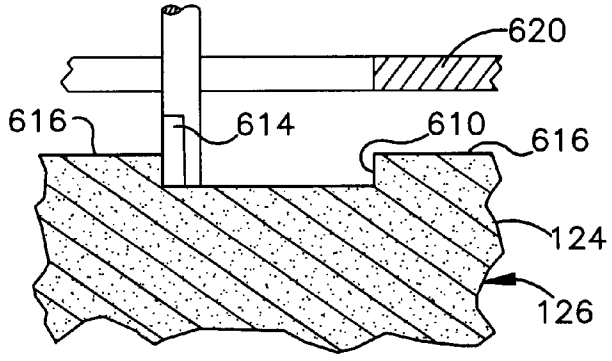

Fig.44

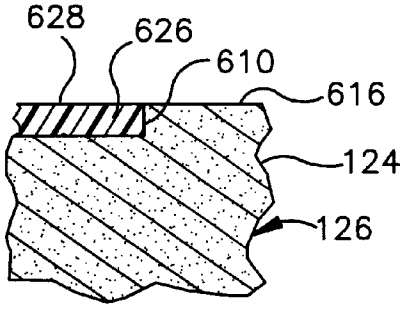

Fig.45

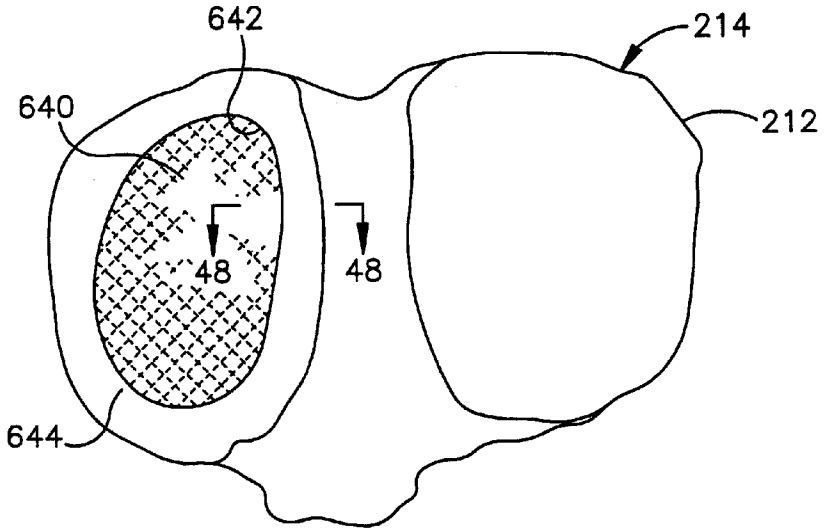

Fig.46

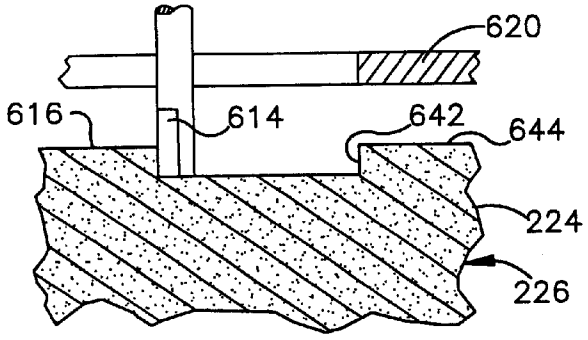

Fig.47

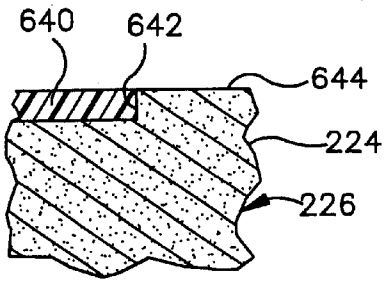

Fig.48

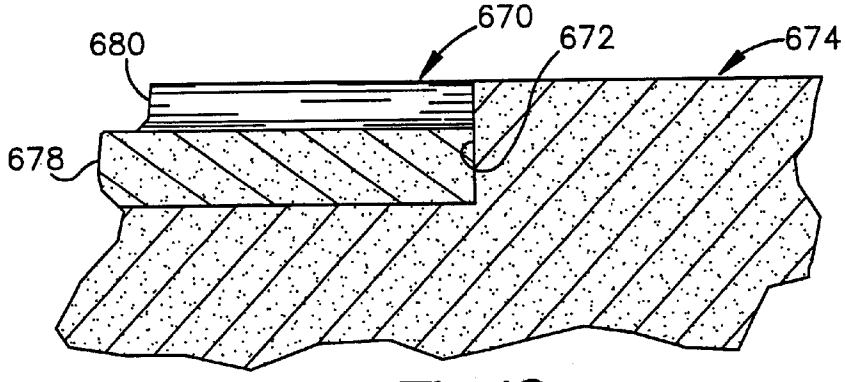

Fig.49

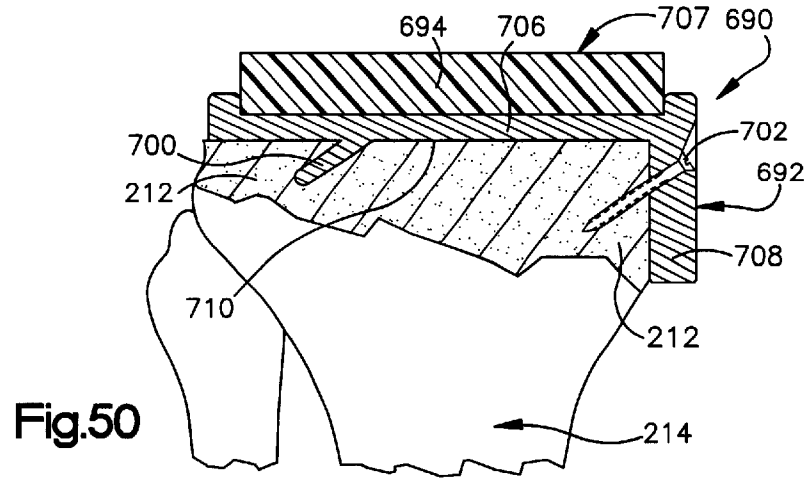

Fig.50

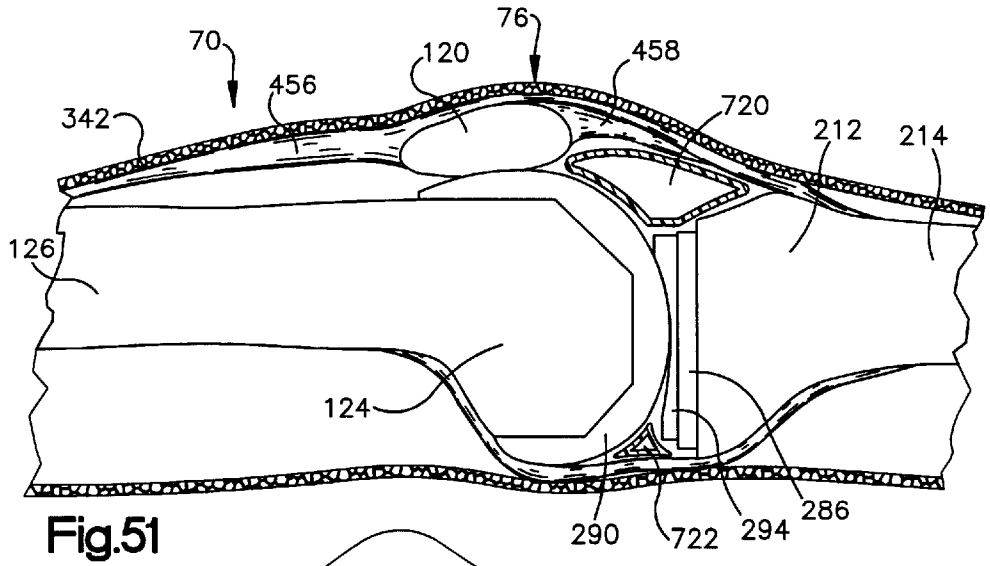

Fig.51

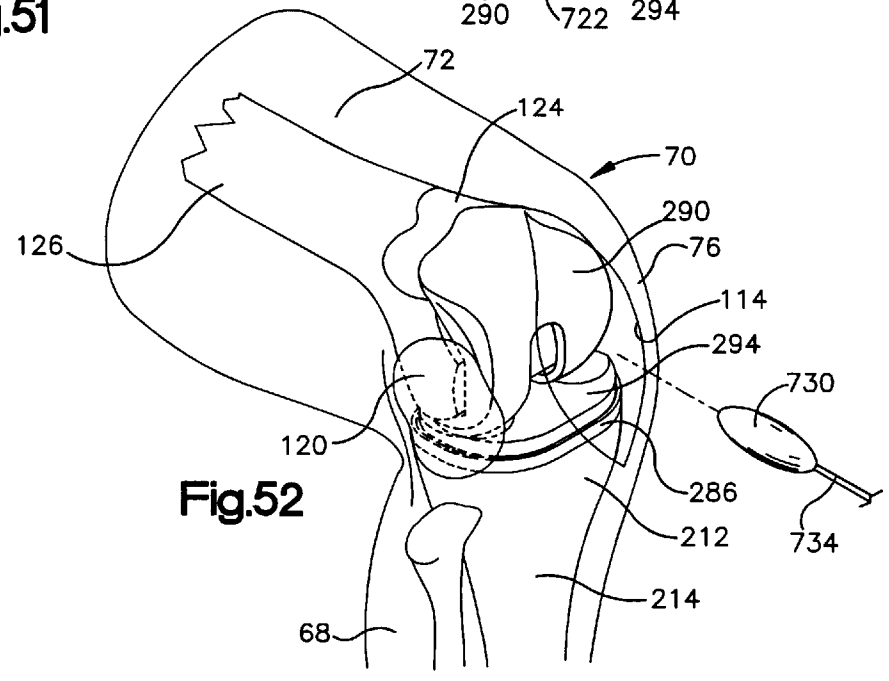

Fig.52

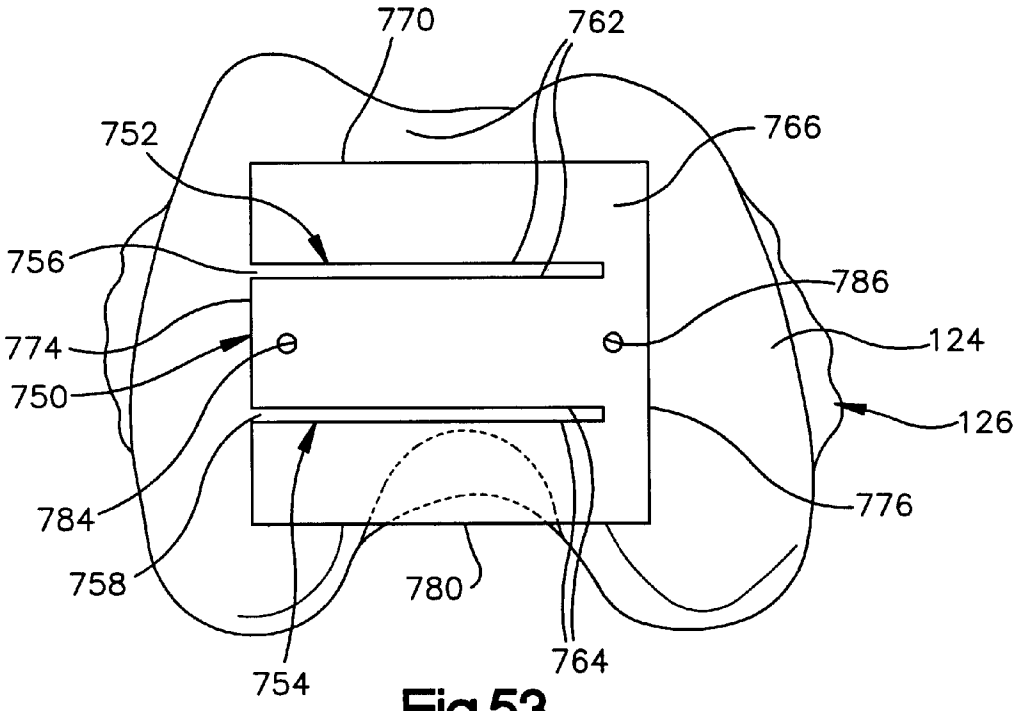
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Fig.53

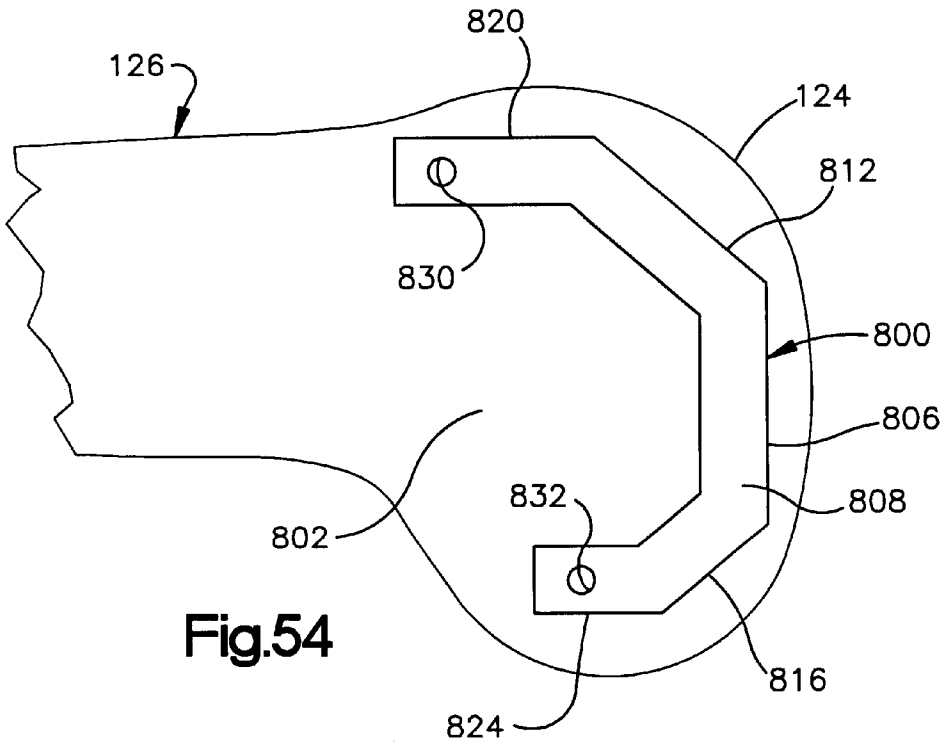
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Fig.54

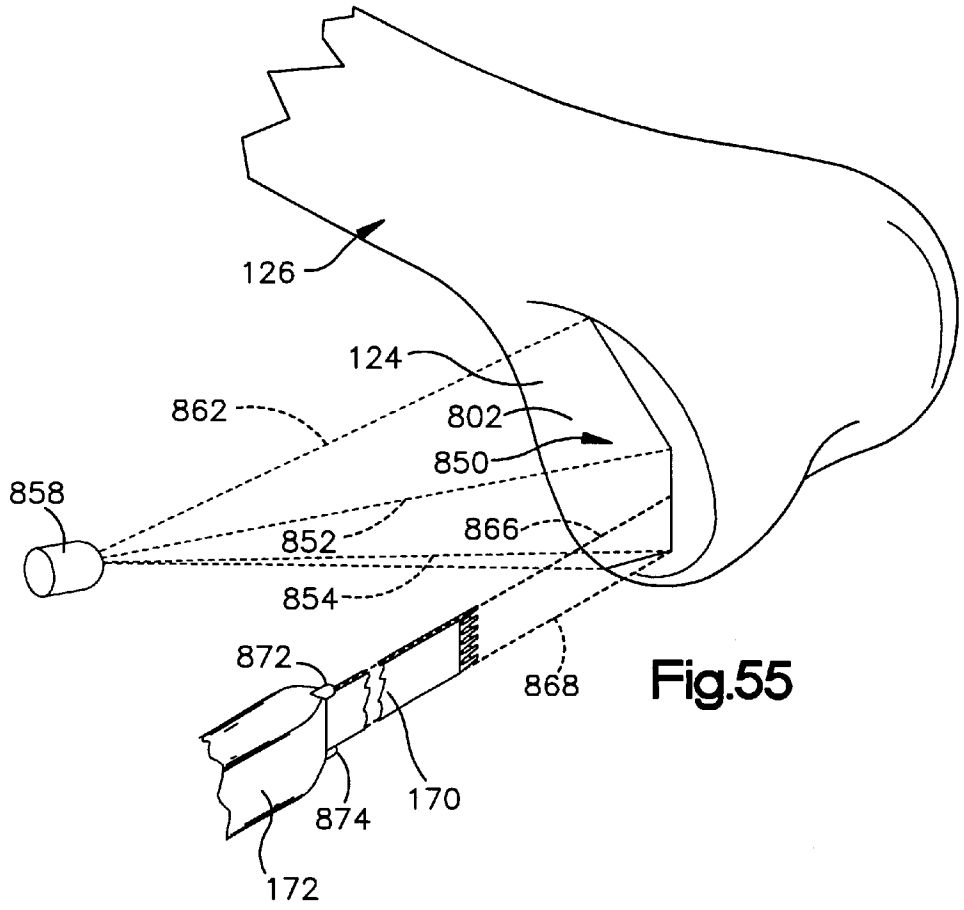
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Fig.55

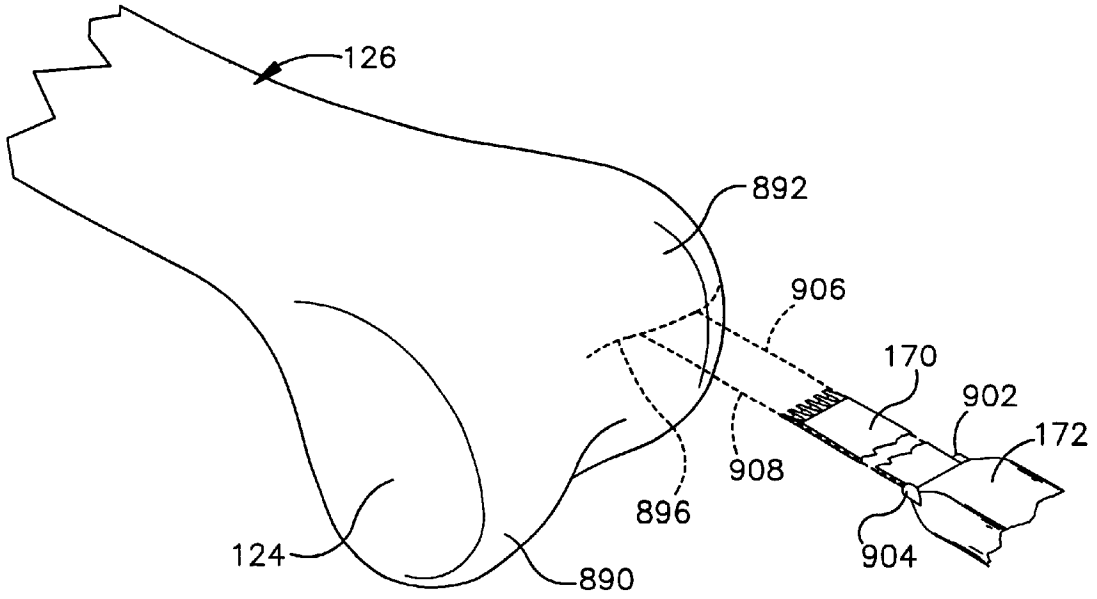
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Fig.56

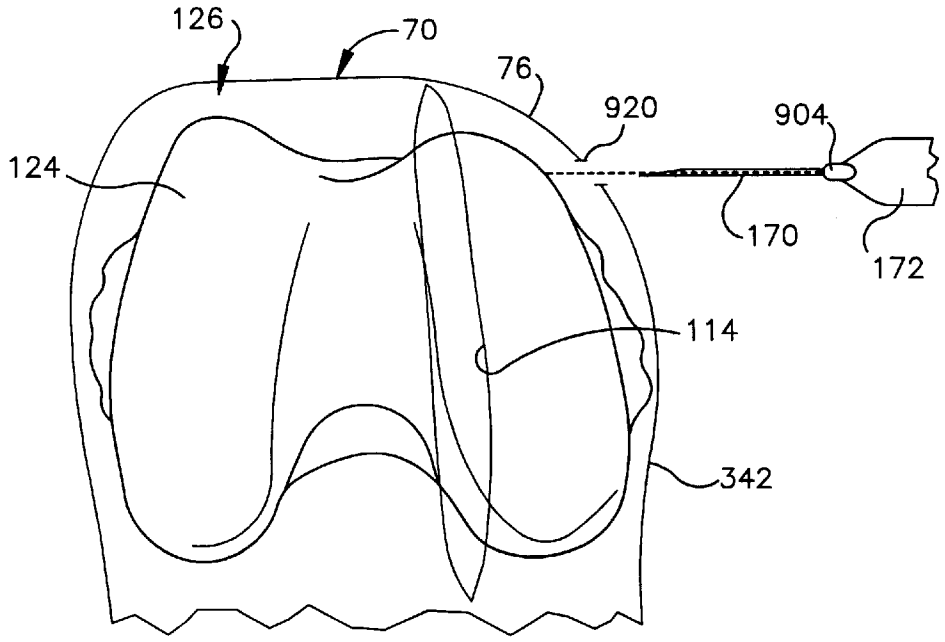
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Fig.57

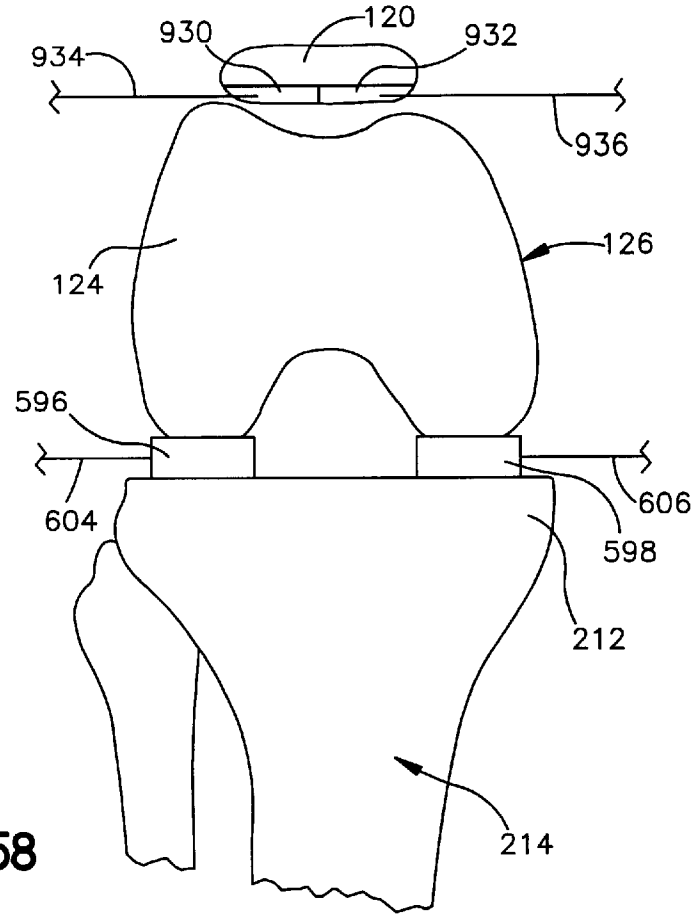
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Fig.58

INSTRUMENTATION FOR MINIMALLY INVASIVE JOINT REPLACEMENT AND METHODS FOR USING SAME

RELATED APPLICATIONS

This application is 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. This application is also a continuation-in-part of U.S. patent application Ser. No. 09/815,405 filed Mar. 22, 2001, now abandoned. This application 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. 6,432,063. This application 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. This application is also a continuation-in-part of U.S. patent application Ser. No. 09/602,743 filed Jun. 23, 2000, now U.S. Pat. No. 6,361,565. This application 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. This application 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. 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.

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 or 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 can not 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.

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 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 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 devises 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.

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**; and

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**.

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 (ostified), 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 will be 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** is 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. No. 4,373,709 or U.S. Pat. No. 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**.

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 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**.

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.

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.

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.

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**.

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 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** 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**.

Femoral Procedure

Expansion of the incision **114** with the known 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 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** is 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** was 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** was 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**.

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** is 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.

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.

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** is

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** are 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** is 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 too. 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 is 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 is 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 is 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

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 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** is 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**) are 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**). 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 is 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** is 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.

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**.

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**. 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 surgeons knee **252** (FIG. **23**) 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.

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.

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 were 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 were 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**, 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** are 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.

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 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 computer navigation systems could be pinned 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**.

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 is 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 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. **32**, 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 was to 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. **32**). Pins, corresponding to the pins **196** and **198** of FIG. **32**, 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** is inserted through the incision **114** and moved to the posterior of the knee portion **76**. 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** 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. 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.

It should 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, 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 is 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.

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 while the patient's leg is 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** while the patient's leg **70** is 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. 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** (PIG. **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** bends 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** is 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**).

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 indicated 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 osteoclasts. 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 phosporus 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-inflamatories and/or immuno suppressants. Collagen, fribin, osteoindctive 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 row **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**.

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 is **15** 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** maybe 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 patients 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 tough 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** 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 visocelastic 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 expand-

able 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 laminer 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** is in the orientation illustrated in FIGS. **2**, **3** and **25**. The drapery system **100** was 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-gage 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** are 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**.

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.

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.

Having described the invention, the following is claimed:

1. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, moving a guide member having opposite ends which are spaced apart by a distance which is less than two thirds (⅔) of a distance between tips of lateral and medial epicondyles on a femur in an upper portion of the one leg of the patient into the incision, positioning the guide member on the femur in the one leg of the patient with opposite ends of the guide member substantially aligned with an axis through the lateral and medial epicondyles on the femur in the one leg of the patient, moving a cutting tool through the incision into engagement with a guide surface on the guide member, cutting the femur in the one leg of the patient with the cutting tool, said step of cutting the femur includes moving the cutting tool along the guide surface on the guide member, and positioning an implant in engagement with the femur in the one leg of the patient, wherein the implant has a transverse length that is larger than the guide surface length.

2. A method as set forth in claim **1** further including the step of moving a patella in the knee portion of the one leg of the patient from a normal position of the patella to an offset position with an inner side of the patella facing inward.

3. A method as set forth in claim **1** wherein said step of making an incision includes making an incision which has a length of between about seven and about thirteen centimeters.

4. A method as set forth in claim **1** further including the step of expanding the incision by applying force against opposite edges of the incision, said step of moving a guide member into the incision is at least partially performed while the incision is expanded.

5. A method as set forth in claim **1** further including the step of moving an endoscope through the incision to a portion of the knee portion opposite from the incision and inspecting the portion of the knee portion opposite from the incision through the endoscope.

6. A method as set forth in claim **5** wherein said step of inspecting the portion of the knee portion opposite from the endoscope includes viewing the implant through the endoscope.

7. A method as set forth in claim **5** wherein said step of inspecting a portion of the knee portion opposite from the incision is at least partially performed prior to performance of said step of positioning an implant in engagement with the femur in the one leg of the patient.

8. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, moving a guide member having opposite ends which are spaced apart by a distance which is less than two thirds (⅔) of a distance between tips of lateral and medial epicondyles on a femur in an upper portion of the one leg of the patient into the incision, positioning the guide member on the femur in the one leg of the patient with opposite ends of the guide member substantially aligned with an axis through the lateral and medial epicondyles on the femur in the one leg of the patient, moving a cutting tool through the incision into engagement with a guide surface on the guide member, cutting the femur in the one leg of the patient with the cutting tool, said step of cutting the femur includes moving the cutting tool along the guide surface on the guide member, and positioning an implant in engagement with the femur in the one leg of the patient, wherein said steps of making an incision in a knee portion of the one leg of the patient, moving a guide member into the incision, positioning the guide member on the femur, cutting the femur, and positioning an implant in engagement with the femur are performed with a lower portion of the one leg of the patient extending downward from an upper portion of the one leg and with a foot connected with the lower portion of the one leg of the patient below the support surface.

9. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, moving a guide member having opposite ends which are spaced apart by a distance which is less than two thirds (⅔) of a distance between tips of lateral and medial epicondyles on a femur in an upper portion of the one leg of the patient into the incision, positioning the guide member on the femur in the one leg of the patient with opposite ends of the guide member substantially aligned with an axis through the lateral and medial epicondyles on the femur in the one leg of the patient, moving a cutting tool through the incision into engagement with a guide surface on the guide member, cutting the femur in the one leg of the patient with the cutting tool, said step of cutting the femur includes moving the cutting tool along the guide surface on the guide member, and positioning an implant in engagement with the femur in the one leg of the patient wherein said step of cutting the femur includes forming a surface on the femur which has a dimension in a direction parallel to a central axis of the guide surface which is greater than the distance between the opposite ends of the guide member.

10. A method of performing surgery on a joint in a patient's body, said method comprising the steps of flexing the joint, making an incision in body tissue which extends around the joint while the joint is flexed, said step of making an incision includes making an incision which has a length of less than thirteen centimeters, moving a guide member through the incision, said guide member having opposite ends which are spaced apart by a distance which is less than two thirds (⅔) of a distance across an end portion of at least one bone at a location where the distance across the end portion of the one bone is a maximum, positioning the guide member on the end portion of the one bone while the joint is flexed, moving a cutting tool through the incision into engagement with the one bone at the joint while the joint is flexed, cutting the one bone at the joint with the cutting tool while the joint is flexed, said step of cutting the one bone at the joint includes moving the cutting tool along a guide surface on the guide member and cutting bone to form a cut surface which extends across the end portion of the one bone and has a dimension extending parallel to a longitudinal central axis of the guide surface which is greater than the length of the guide surface, and positioning an implant in engagement with the one bone while the joint is flexed.

11. A method as set forth in claim **10** further including the step of inserting at least one retractor into the incision while the joint is flexed and holding back a margin of the incision with the one retractor to increase exposure of the one bone at the joint while the joint is flexed.

12. A method as set forth in claim **10** further including the steps of inserting a first retractor into the incision while the joint is flexed, inserting a second retractor into the incision while the joint is flexed, and expanding the incision while the joint is flexed by separating opposite margins of the incision under the influence of force applied to opposite margins of the incision by the first and second retractors.

13. A method as set forth in claim **12** further including the step of cutting the one bone at the joint with the cutting tool while the joint is flexed is at least partially performed while performing said step of expanding the incision.

14. A method as set forth in claim **10** further including the steps of rotating a first portion of the patient extending in a first direction from the joint about an axis extending along the first portion of the patient while the joint is flexed and after having performed said step of cutting the one bone at the joint.

15. A method as set forth in claim **10** further including the steps of positioning a guide member relative to the one bone while the joint is flexed, said step of cutting the one bone includes utilizing a guide surface on the member to position the cutting tool during making of an initial portion of a cut in the one bone, and completing the cut in the one bone while guiding the cutting tool with a surface formed during making of the initial portion of the cut in the one bone.

16. A method of performing surgery on a joint in a patient's body, said method comprising the steps of flexing the joint, making an incision in body tissue which extends around the joint while the joint is flexed, said step of making an incision includes making an incision which has a length of less than thirteen centimeters, moving a cutting tool through the incision into engagement with at least one bone at the joint while the joint is flexed, cutting the one bone at the joint with the cutting tool while the joint is flexed, pivoting a first portion of the patient extending in a first direction from the joint sidewardly in a direction transverse to normal movement of the first portion of the patient during flexion and extension of the joint while the joint is flexed and after having performed said step of cutting the one bone at the joint, and positioning an implant in engagement with the one bone while the joint is flexed.

17. A method as set forth in claim **16** wherein the step of pivoting a first portion of the patient sidewardly is performed with the first portion of the patient suspended from a second portion of the patient which extends in a second direction from the joint.

18. A method of performing surgery on a joint in a patient's body, said method comprising the steps of flexing the joint, making an incision in body tissue which extends around the joint while the joint is flexed, said step of making an incision includes making an incision which has a length of less than thirteen centimeters, moving a cutting tool through the incision into engagement with at least one bone at the joint while the joint is flexed, cutting the one bone at the joint with the cutting tool while the joint is flexed, and positioning an implant in engagement with the one bone while the joint is flexed, wherein said step of positioning an implant in engagement with the one bone includes providing

an implant having first and second portions which are separate from each other, moving the first portion of the implant through the incision into engagement with the one bone, moving the second portion of the implant through the incision into engagement with the one bone, and interconnecting the first and second portions of the implant while they are disposed in engagement with the one bone.

19. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, said step of supporting the patient on a support surface includes supporting an upper portion of one leg of the patient above the support surface with a leg support having a surface which is disposed beneath a posterior surface area on the upper portion of the one leg with a lower portion of one leg of the patient extending downward from the upper portion of the one leg so that a foot connected with the one leg of the patient is below the support surface, making an incision in a knee portion of the one leg of the patient while the upper portion of the one leg is supported above the support surface by the leg support and the foot connected with the one leg of the patient is below the support surface, said step of making an incision in the knee portion of the one leg includes making an incision having a length of less than about thirteen centimeters, said step of making an incision includes making an incision adjacent to an edge portion of the patella in the knee portion of the one leg of the patient, moving the patella from its normal position to an offset position with an inner side of the patella facing inward, moving a guide member having opposite ends which are spaced apart by a distance which is less than a distance between lateral and medial epicondyles on a femur in the upper portion of the one leg of the patient into the incision, positioning the guide member on the femur in the one leg of the patient with opposite ends of the guide member substantially aligned with an axis through the lateral and medial epicondyles on the femur while the upper portion of the one leg is supported above the support surface by the leg support and the foot connected with the one leg of the patient is below the support surface, moving a cutting tool into engagement with the femur in the upper portion of the one leg of the patient, cutting the femur in the upper portion of the one leg of the patient with the cutting tool, said step of cutting the femur with the cutting tool includes moving the cutting tool along a guide surface on the guide member while the patella is offset from its normal position relative to the femur with the inner side of the patella facing inward, said step of cutting the femur with the cutting tool is performed with the upper portion of the one leg of the patient supported above the support surface by the leg support and with the foot connected with the one leg of the patient below the support surface, moving the cutting tool away from the femur, moving the guide member away from the femur, positioning an implant in engagement with the femur, and closing the incision while the upper portion of the one leg is supported above the support surface by the leg support and the foot connected with the one leg is below the support surface.

20. A method as set forth in claim **19** wherein the lower portion of the one leg of the patient is suspended from the upper portion of the one leg of the patient during performance of said steps of making an incision in the knee portion of the one leg of the patient, cutting the femur with the cutting tool, and closing the incision.

21. A method as set forth in claim **19** further including the step of expanding the incision by applying force against opposite edge portions of the incision while the upper portion of the one leg is supported above the support surface by the leg support and the foot connected with the one leg of the patient is below the support surface.

22. A method as set forth in claim **19** further including the steps of bending the knee portion of the one leg of the patient, and generating images of the knee portion of the one leg of the patient after performing said step of making an incision in the knee portion of the one leg of the patient and prior to performing said step of closing the incision.

23. A method as set forth in claim **19** further including the steps of moving a leading end portion of an endoscope through the incision, and visually inspecting a posterior portion of the knee portion of the one leg of the patient through the endoscope.

24. A method as set forth in claim **19** wherein said step of positioning an implant in engagement with the femur includes providing an implant having first and second portions which are separate from each other, moving the first portion of the implant through the incision into engagement with the femur, and interconnecting the first and second portions of the implant while they are disposed in engagement with the femur.

25. A method as set forth in claim **19** wherein said step of cutting the femur in the upper portion of the one leg of the patient includes utilizing the guide surface on the guide member to position the cutting tool during making of an initial portion of a cut in the femur, and completing the cut in the femur while guiding the cutting tool with a surface formed during making of the initial portion of the cut in the femur.

26. A method as set forth in claim **19** further including the step of effecting relative movement between the incision and bones in the one leg of the patient by moving the lower portion of the one leg of the patient relative to the upper portion of the one leg of the patient while the upper portion of the one leg of the patient is supported above the support surface by the leg support and the foot connected with the one leg of the patient is below the support surface.

27. A method as set forth in claim **19** further including the step of providing an output signal which is a function of tension in a ligament extending between the femur and bones in a lower portion of the one leg of the patient.

28. A method as set forth in claim **19** further including the step of moving the lower portion of the one leg of the patient between a first position in which an ankle portion of the one leg of the patient is disposed on a first side of a reference plane and a second positioning which the ankle portion of the one leg of the patient is disposed on a second side of the reference plane while the upper portion of the one leg is supported above the support surface by the leg support and the foot connected with the one leg of the patient is below the support surface, the reference plane extends through the knee portion of the one leg of the patient and extends perpendicular to a longitudinal central axis of the upper portion of the patient's one leg.

29. A method as set forth in claim **19** further including the step of cutting the patella in the knee portion of the one leg of the patient while the patella is disposed in the normal position relative to the knee portion of the one leg with an inner side of the patella facing inward.

30. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, connecting a guide member with at least one bone in the one leg of the patient, moving a cutting tool through the incision into engagement with the one bone in the one leg of the patient, moving the cutting tool along a guide surface on the guide member during making of an

initial portion of a cut in the one bone, completing the cut in the one bone while guiding the cutting tool with a surface formed during making of the initial portion of the cut, and positioning an implant in engagement with the one bone in the one leg of the patient, wherein the implant has a transverse length that is larger than the guide surface length.

31. A method as set forth in claim **30** further including the steps of bending the knee portion of the one leg of the patient, and generating images of the knee portion of the one leg of the patient after performing said step of making an incision in the knee portion of the one leg of the patient and prior to closing the incision.

32. A method as set forth in claim **30** further including the steps of moving a leading end portion of an endoscope through the incision, and visually inspecting a portion of the knee portion of the one leg of the patient through the endoscope.

33. A method as set forth in claim **30** further including the step of effecting relative movement between the incision and bones in the one leg of the patient by moving the lower portion of the one leg of the patient relative to the upper portion of the one leg of the patient while a foot connected with the one leg of the patient is below the support surface.

34. A method as set forth in claim **30** further including the step of providing an output signal which is a function of tension in a ligament extending between bones in the one leg of the patient.

35. A method as set forth in claim **30** further including the step of moving a lower portion of the one leg of the patient between a first position in which an ankle portion of the one leg of the patient is disposed on a first side of a reference plane and a second position in which the ankle portion of the one leg of the patient is disposed on a second side of the reference plane while a foot connected with the one leg of the patient is below the support surface, the reference plane extends through the knee portion of the one leg of the patient and extends perpendicular to a longitudinal central axis of the upper portion of the patient's one leg.

36. A method as set forth in claim **30** further including the step of cutting the patella in the knee portion of the one leg of the patient while the patella is disposed in a normal position relative to the knee portion of the one leg with an inner side of the patella facing inward.

37. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, connecting a guide member with at least one bone in the one leg of the patient, moving a cutting tool through the incision into engagement with the one bone in the one leg of the patient, moving the cutting tool along a guide surface on the guide member during making of an initial portion of a cut in the one bone, completing the cut in the one bone while guiding the cutting tool with a surface formed during making of the initial portion of the cut, and positioning an implant in engagement with the one bone in the one leg of the patient, wherein a lower portion of the one leg of the patient is suspended from an upper portion of the one leg during performance of said steps of making an incision in the knee portion of the one leg of the patient, and cutting the one bone with the cutting tool.

38. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, expanding the incision by applying force against opposite edge portions of the incision while a foot connected with the one leg of the patient is below the support surface, connecting a guide member with at least one bone in the one leg of the patient, moving a cutting tool through the incision into engagement with the one bone in the one leg of the patient, moving the cutting tool along a guide surface on the guide member during making of an initial portion of a cut in the one bone, completing the cut in the one bone while guiding the cutting tool with a surface formed during making of the initial portion of the cut, and positioning an implant in engagement with the one bone in the one leg of the patient.

39. A method of performing surgery on a patient's knee, said method comprising the steps of supporting the patient on a support surface, making an incision in a knee portion of one leg of the patient, connecting a guide member with at least one bone in the one leg of the patient, moving a cutting tool through the incision into engagement with the one bone in the one leg of the patent, moving the cutting tool alone a guide surface on the guide member during making of an initial portion of a cut in the one bone, completing the cut in the one bone while guiding the cutting tool with a surface formed during making of the initial portion of the cut, and positioning an implant in engagement with the one bone in the one leg of the patient, wherein said step of positioning an implant in engagement with the one bone in the one leg of the patient includes providing an implant having first and second portions which are separate from each other, moving the first portion of the implant through the incision into engagement with the one bone, and interconnecting the first and second portions of the implant while they are disposed in engagement with the one bone.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

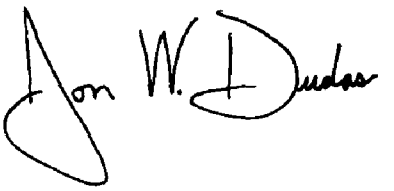
PATENT NO. : 6,702,821 B2
DATED : March 9, 2004
INVENTOR(S) : Peter M. Bonutti

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 82,
Line 34, change "patent" to -- patient --
Line 34, change "alone" to -- along --

Signed and Sealed this

Twenty-ninth Day of June, 2004



JON W. DUDAS
Acting Director of the United States Patent and Trademark Office