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(54) **FEMORAL HIP PROSTHESIS AND METHOD OF IMPLANTATION**

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Related U.S. Application Data

(63) Continuation of application No. 12/429,882, filed on Apr. 24, 2009, now abandoned, which is a continuation of application No. 10/763,314, filed on Jan. 22, 2004, now Pat. No. 7,534,271.

(51) **Int. Cl.**
A61F 2/36 (2006.01)
(52) **U.S. Cl.** **623/23.21**; 623/23.35
(58) **Field of Classification Search** 623/23.21, 623/23.22, 23.24, 23.25, 23.26
See application file for complete search history.

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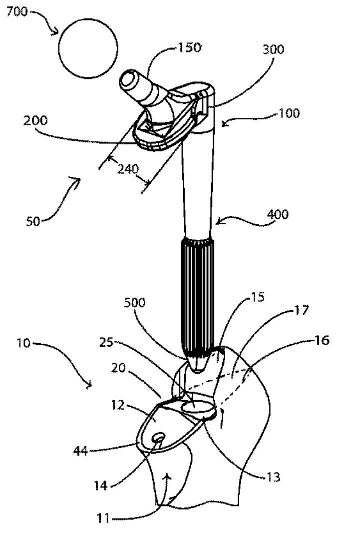
(57) **ABSTRACT**

Implants and methods are presented for surgically repairing a hip joint with a proximal femoral prosthesis that comprises femoral head component and a femoral stem component. The femoral stem component comprises a neck portion, a flange portion, a transitional body region and an elongated stem. The femur is prepared for implantation of the femoral hip prosthesis by resecting the proximal femur and reaming a symmetric intramedullary cavity in the femur. The femoral hip prosthesis is then inserted the on the resected femur and in the intramedullary cavity. The femoral hip prosthesis elastically deforms when loaded during use to apply dynamic compressive loads and displacement to the calcar region of the resected proximal femur.

18 Claims, 8 Drawing Sheets



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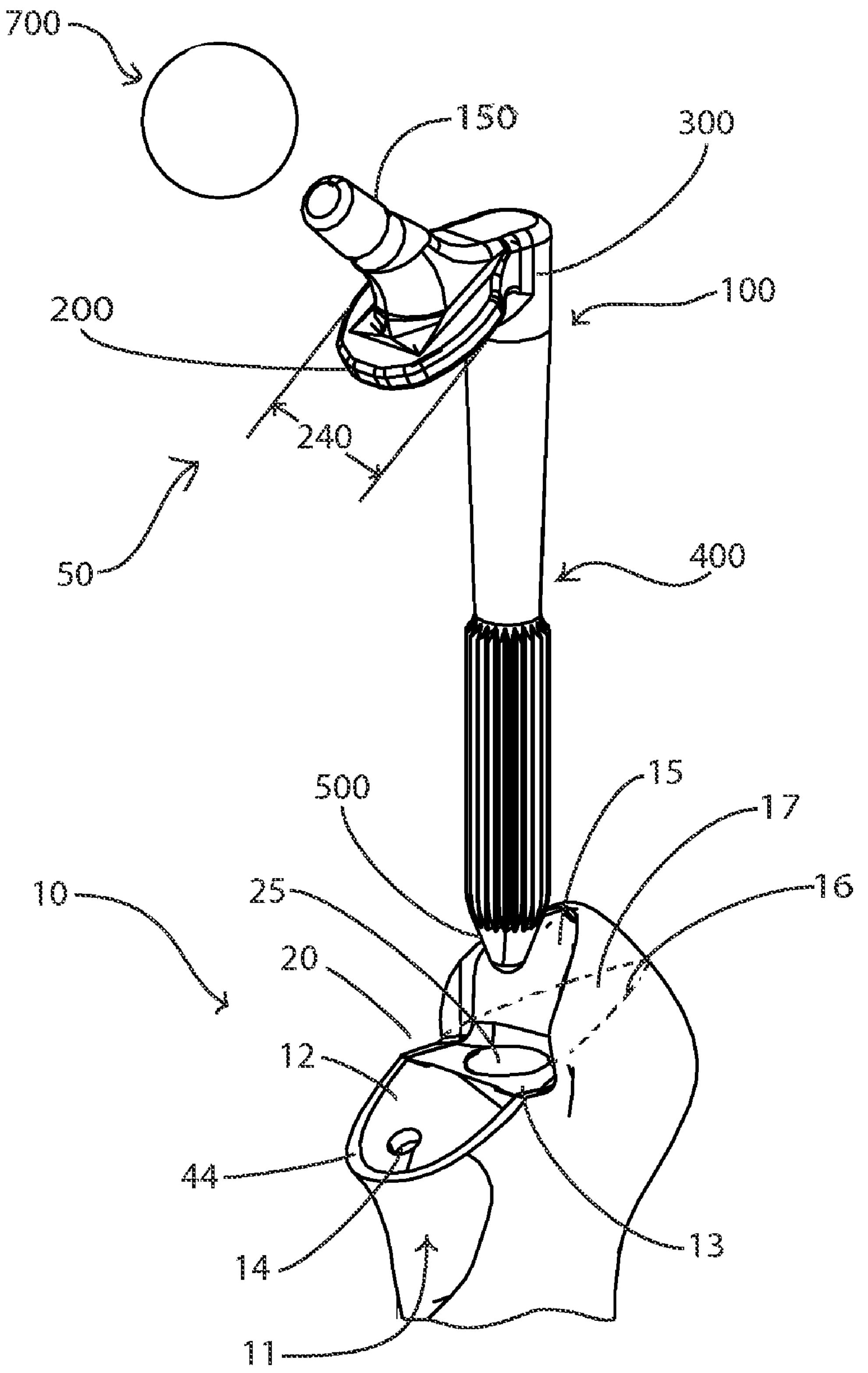

Fig. 1

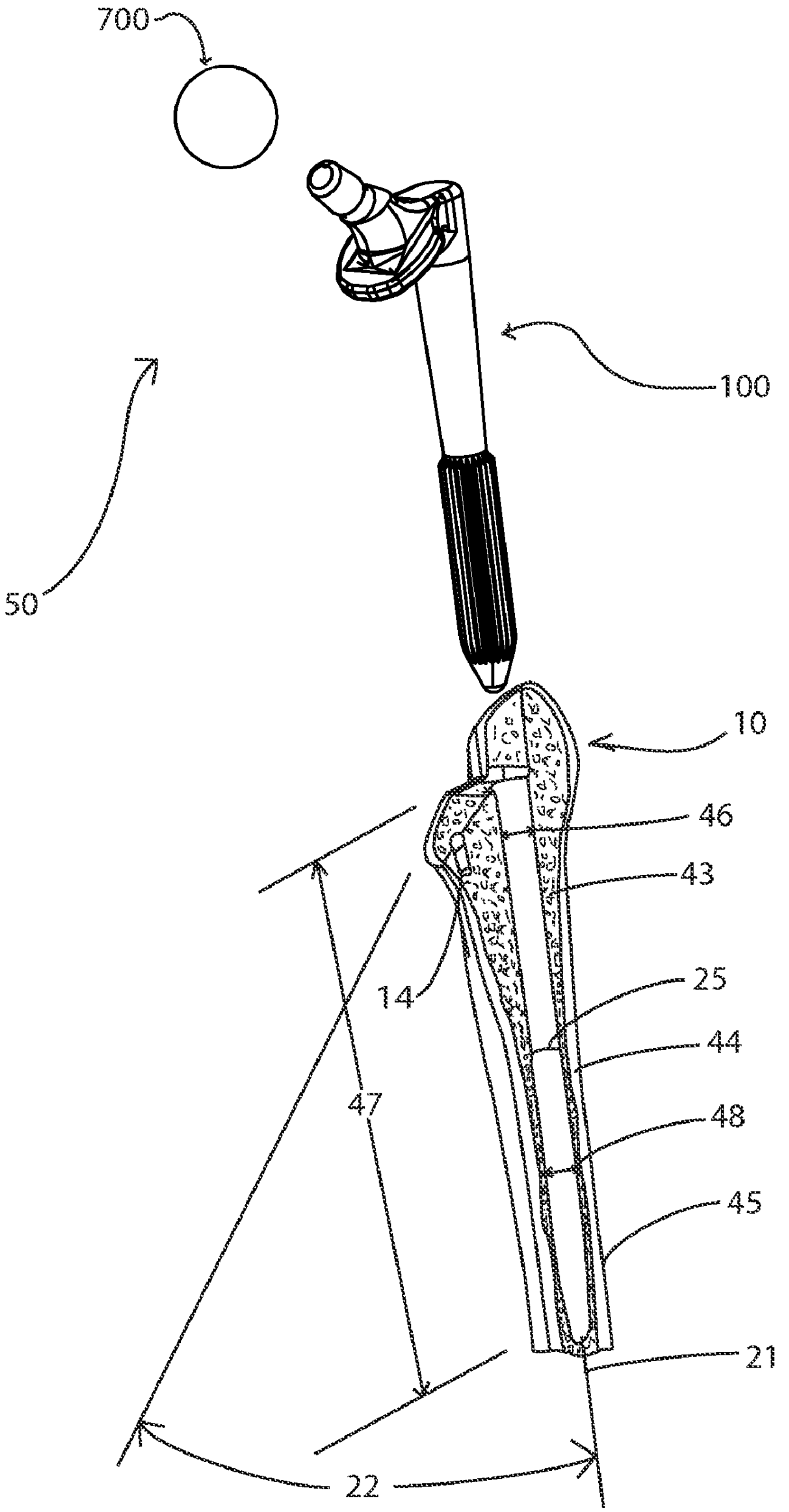

Fig. 2

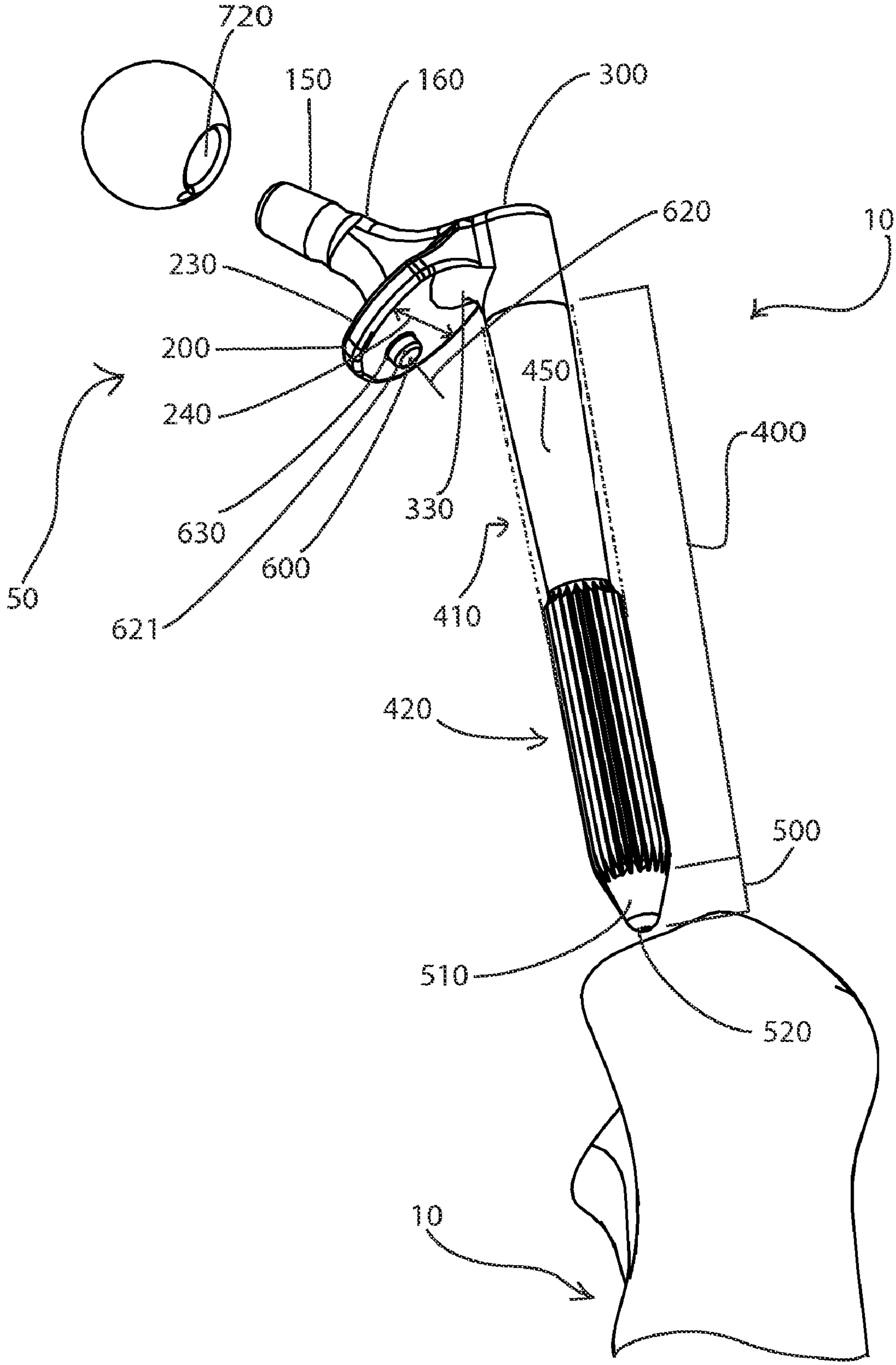
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Fig. 3

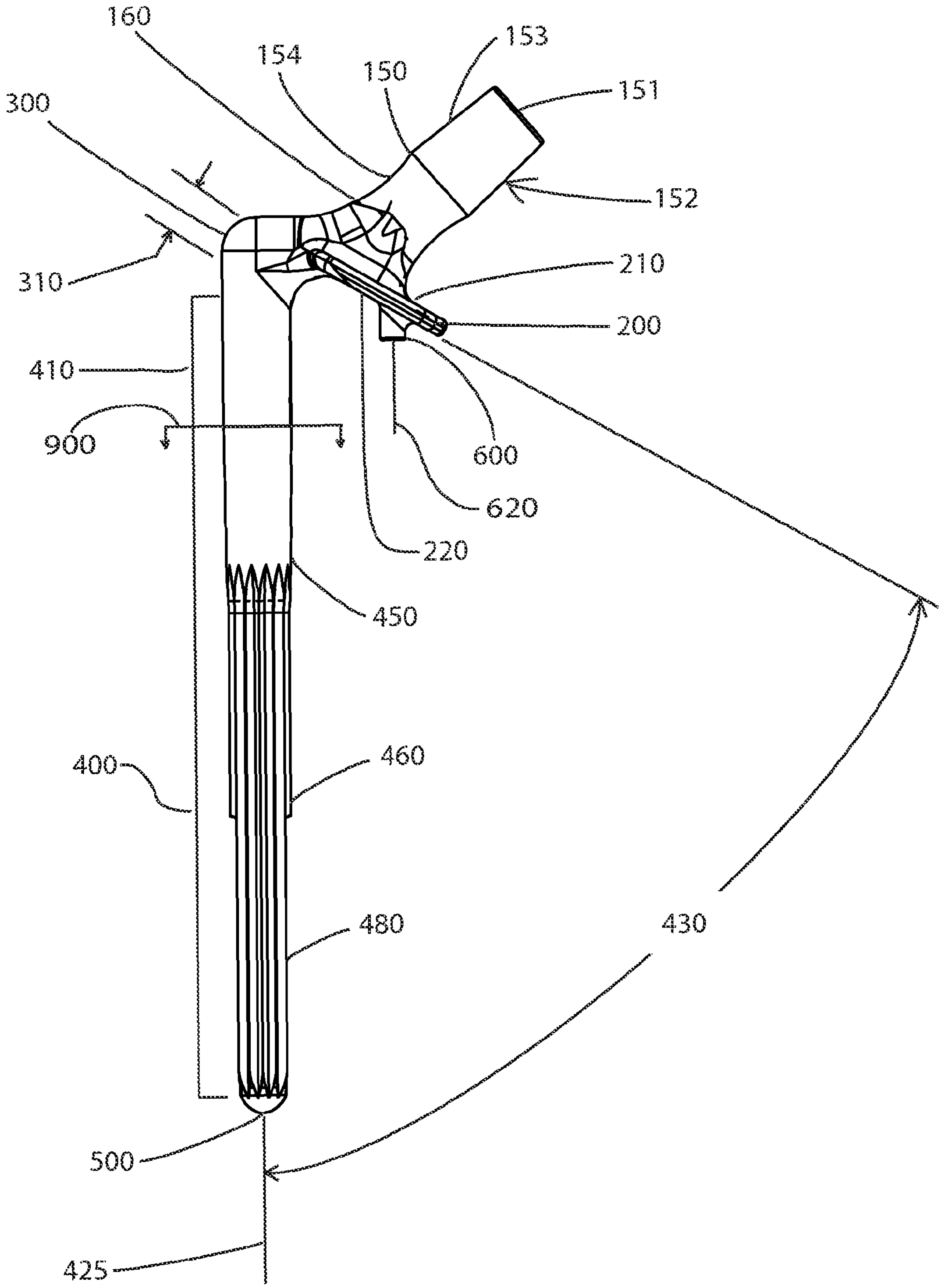
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Fig. 4

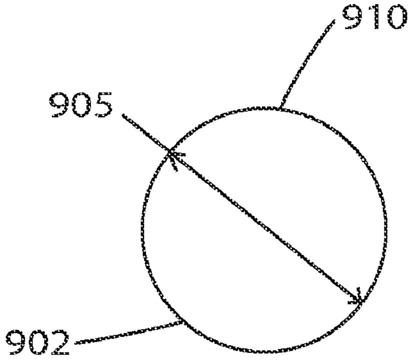

Fig. 4a

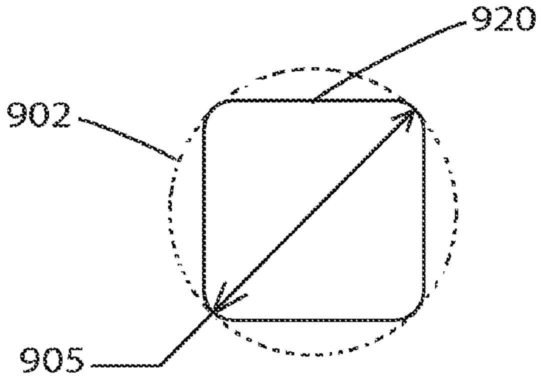

Fig. 4b

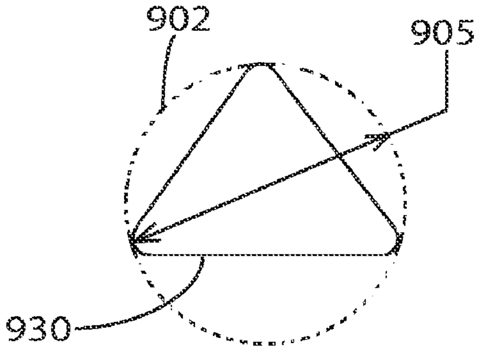

Fig. 4c

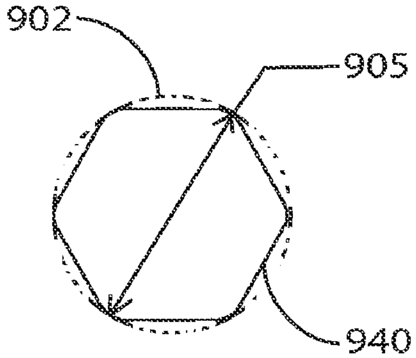

Fig. 4d

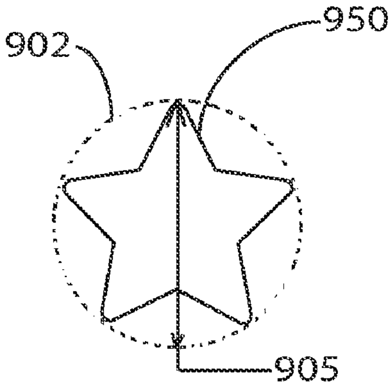

Fig. 4e

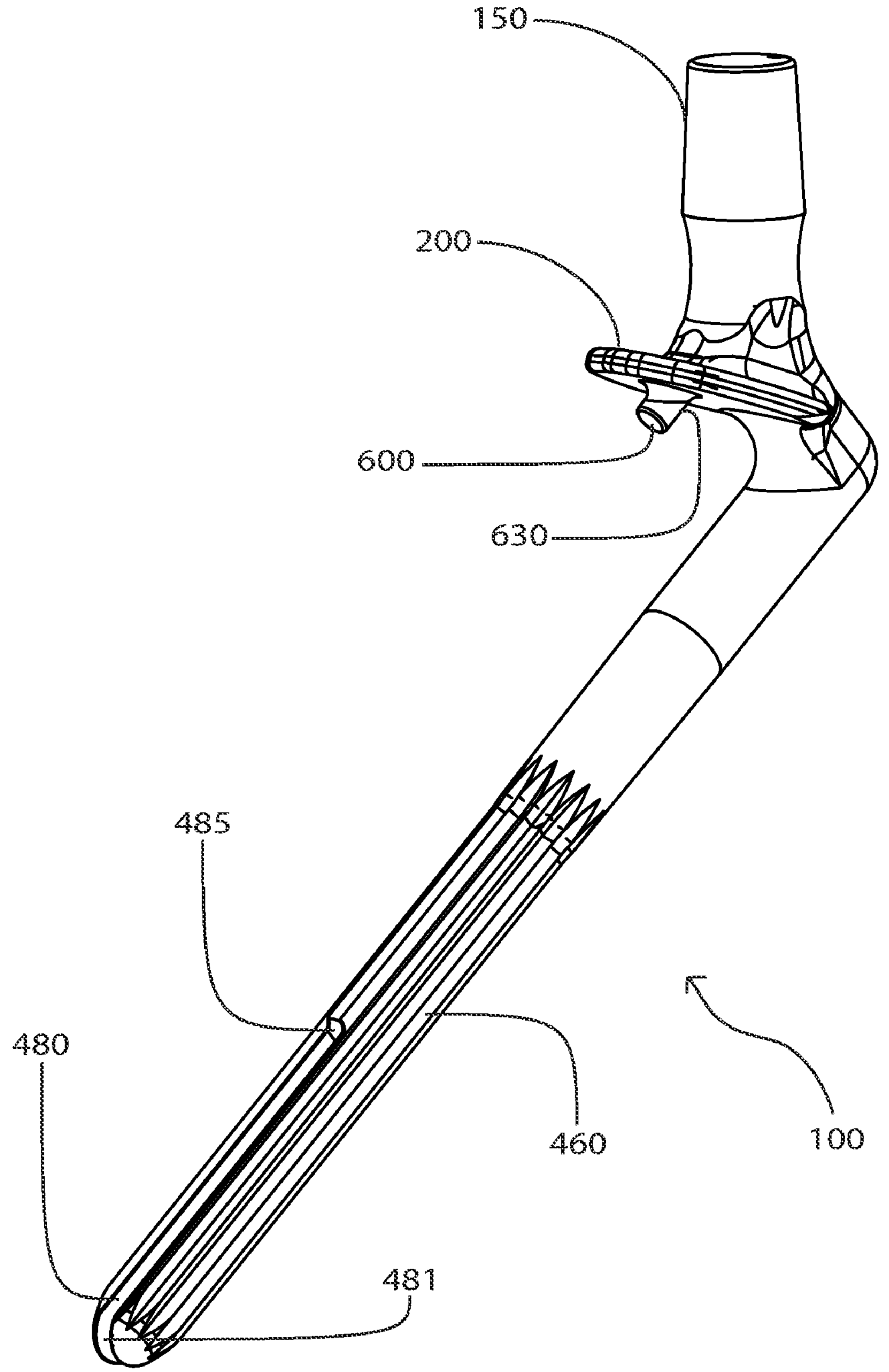

Fig. 5

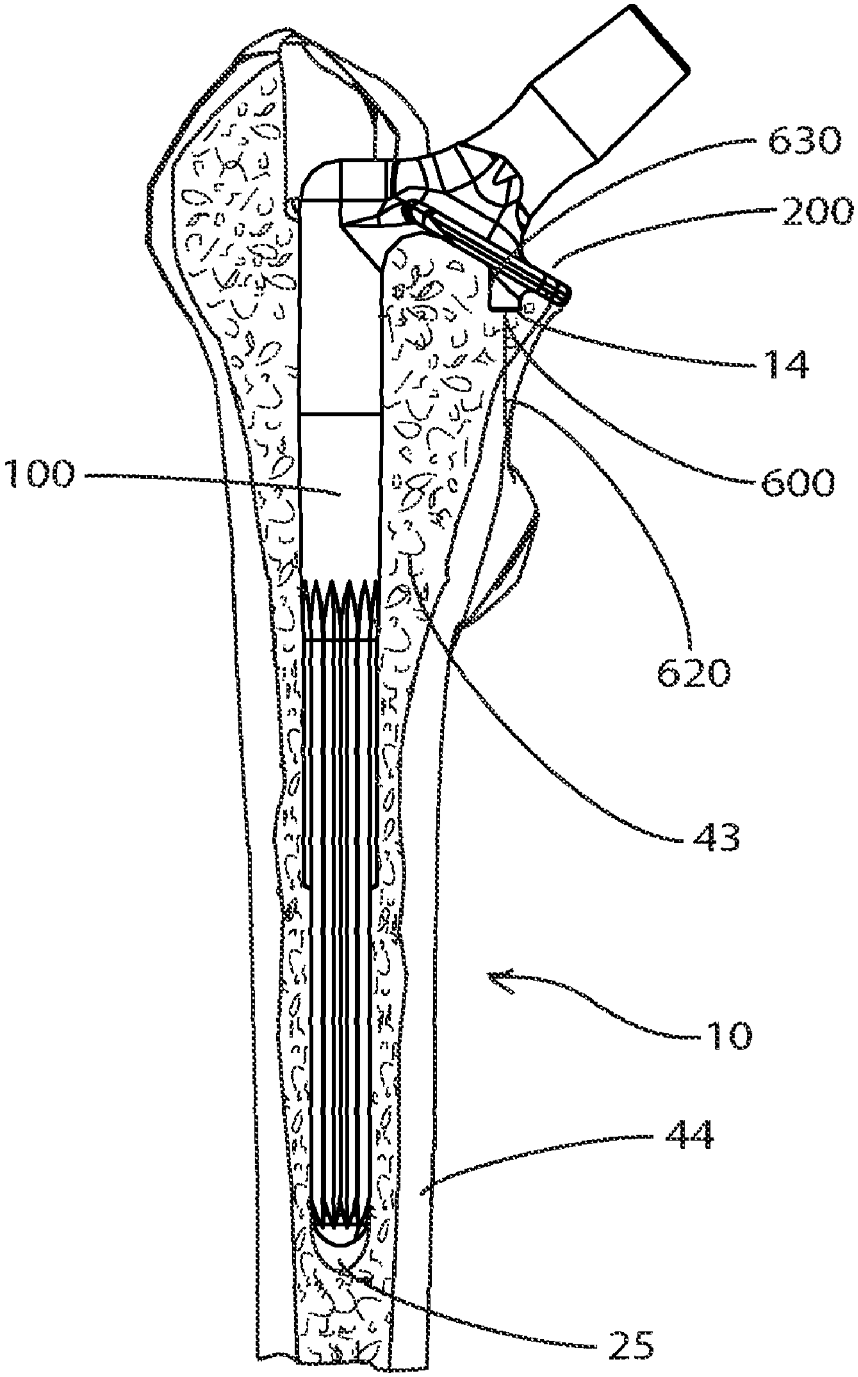

Fig. 6

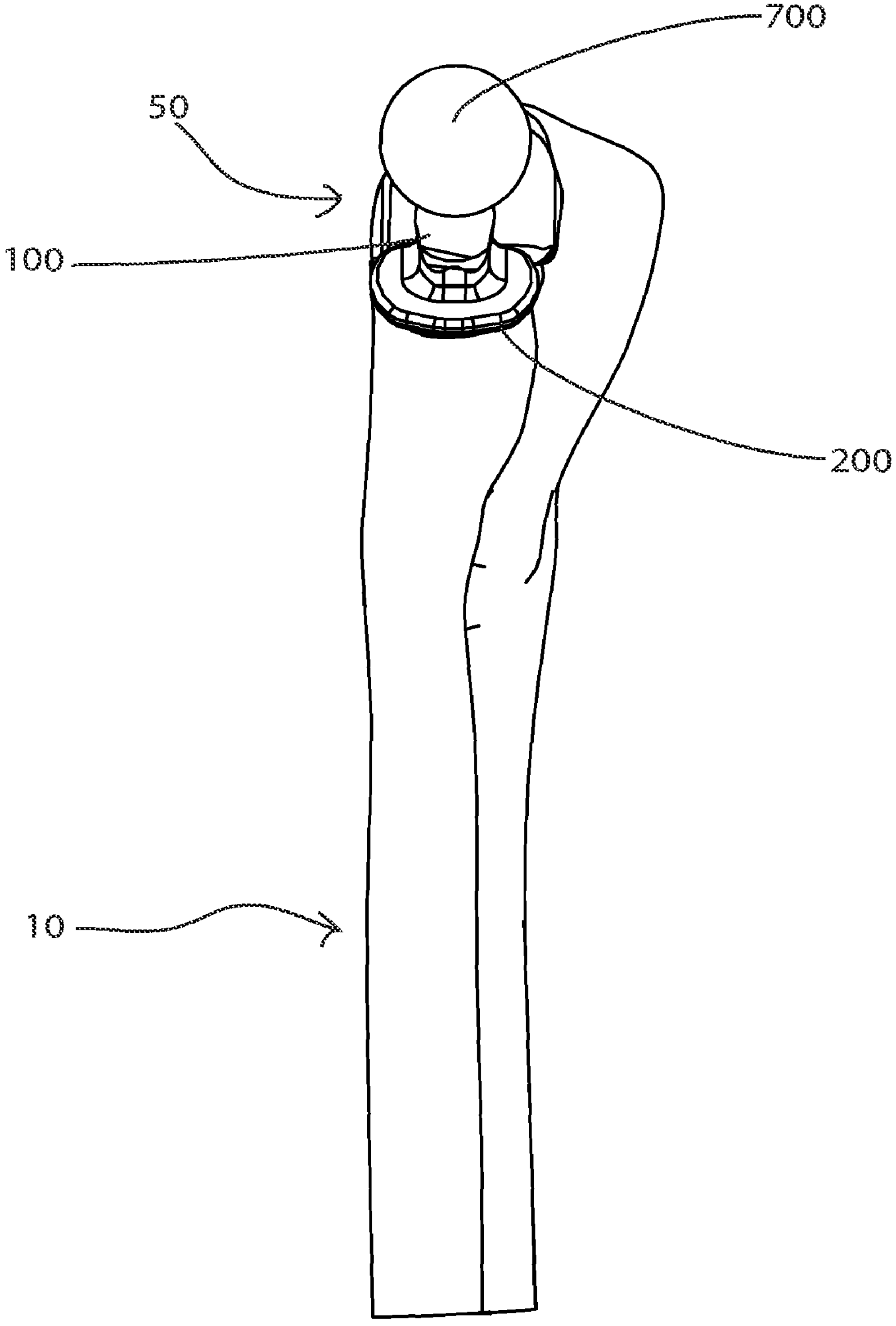

Fig. 7

FEMORAL HIP PROSTHESIS AND METHOD OF IMPLANTATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of the following, which is herein incorporated by reference:

U.S. patent application Ser. No. 12/429,882 filed Apr. 29, 2009, and is entitled FEMORAL HIP PROSTHESIS AND METHOD OF IMPLANTATION, which is a continuation of the following:

U.S. patent application Ser. No. 10/763,314 filed Jan. 22, 2004, now U.S. Pat. No. 7,534,271, and is entitled FEMORAL HIP PROSTHESIS AND METHOD OF IMPLANTATION.

BACKGROUND OF THE INVENTION

1. The Field of the Invention

The present invention relates to a femoral hip prosthesis for replacing a portion of proximal femoral bone during hip replacement and the methods of assembly and use thereof.

2. The Relevant Technology

Total hip arthroplasty using a metallic hip prosthesis has been successfully performed since the early 1960's and is now a routine procedure to address orthopedic diseases such as osteoarthritis, fracture, dislocations, rheumatic arthritis, and aseptic or avascular bone necrosis. During this procedure, the bone is prepared for the prosthesis by removing the damaged articulating end of the bone by resecting a portion of the bone including the femoral head. This exposes the inside, of the metaphaseal region of the intramedullary canal in the proximal femur. The surgeon then drills or reams a cavity in the femur approximately in line with the intramedullary canal. This cavity is used to align other tools such as reamers, broaches and other bone tissue removal instruments to create a roughly funnel shaped bone cavity that is smaller in cross-section as it extends down from the bone resection at the proximal end of the femur into the distal intramedullary canal. This funnel shaped cavity is typically also eccentric with more bone material removed from the medial calcar region of the proximal femur than the region on the lateral side of the canal.

Oftentimes a grouting agent commonly referred to as bone cement is then added to the funnel shaped cavity. Once the prosthesis is inserted into the cavity, this creates a bone cement mantle between the prosthesis and the bone. Sometimes the shape of the cavity is prepared to closely match the shape of the external surface of the prosthesis, and the prosthesis is press fit into the cavity without the use of bone cement. These press-fit prostheses typically have a textured bone-ingrowth surfaces place strategically at specific locations on their surface to help facilitate lone-term bone tissue growth into the prosthesis. This bone ingrowth into the porous structure on the implant creates a long lasting secure bond between the prosthesis and the proximal femur.

Once the bone cavity is prepared, the prosthesis is placed into the bone cavity and is supported directly by internal bone tissue in the case of a press fit implant or indirectly by the bone cement mantle in the case of the cemented implant. Then, the prosthesis is aligned such that the articulating end of the implant articulates with the opposite side of the natural joint in the case of a hemiarthoplasty, or articulates with a corresponding implant replacing the opposite side of the joint in the case of a total joint arthroplasty.

Current designs of proximal femur hip prosthesis have eccentric, non-symmetric cone shaped central body portions. The current methods of implant fixation allow for transfer of axial loads to the proximal femur mainly through shear stresses at the eccentric funnel shaped bone-prosthesis interface. The effective transfer of load is significantly dependent on the three-dimensional shape of funnel shaped cavity, the bone-prosthesis or bone-cement-prosthesis interface as well as physiological loading of the proximal end. Partly because of the eccentrically shaped cross-section of the central body portion, these currently available prostheses transmit radial expansion forces on the proximal femoral cavity as the implant is loaded in compression. The funnel shape of the cavity and the matching shape of the implant or bone cement result in circumferential hoop stresses and radial expansion stresses are distributed to the bone as the femoral component is axially loaded. This results in complex axial and shear stresses at the bone-implant interface. Consequently, the distribution of the loads that transmit from the femoral head axially through the proximal femur is altered after THA.

A potential cause of failure of currently used prosthesis is associated with the possible resorption of the bone surrounding the implant. The bone resorption can be the result of an altered distribution of shear stresses on the remaining proximal femoral tissue. In time, the lack of adequate stress transfer from the metal stem to the surrounding bone may cause a loss of bone density, resulting in the increased possibility of bone failure or loosening of the bone-prosthesis interface. The gradual loss of bone support in the calcar region of the eccentric cavity increases the bending load that must be borne by the prosthesis. This increase in bending load on the prosthesis can lead to stress shielding by the prosthesis resulting in prosthesis fatigue and potentially to eventual clinical failure.

SUMMARY

The present invention is directed to a femoral hip prosthesis that satisfies the need for anatomically distributing the dynamic compressive loads on the hip joint to the proximal femoral bone. The femoral hip prosthesis is adapted for implantation against a resected surface on a proximal end of a femur, and also in an intramedullary cavity of the femur. The femoral hip prosthesis comprises femoral head component and a femoral stem component. The femoral stem component comprises a neck portion, a flange portion, a transitional body portion, and an elongated stem portion. The neck portion comprises a proximal male friction fit portion and a distal neck body. The flange portion is distal and adjacent to the neck portion and is attached to the distal neck body. The flange portion comprises an upper portion and a bottom surface. The transitional body region is adjacent to the bottom surface of the flange portion and also extends from the distal neck body. The elongated stem portion extends distally from the transitional body region and is aligned with a longitudinal axis. The longitudinal axis is oriented at an acute angle relative to the bottom surface of the flange portion. The elongated stem portion comprises a uniform envelope that may contain rotation-restricting splines, a tapered portion or a transverse slot. The femoral hip prosthesis may also alternatively contain a rotation-restricting boss that is attached to the bottom of the flange portion. The femoral hip prosthesis also comprises a distal end tip portion on the distal end of the elongated stem portion.

DESCRIPTION OF THE DRAWINGS

Various embodiments of the present invention will now be discussed with reference to the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope.

FIG. **1** is a perspective view of the show from the anteriomedial direction showing the femoral hip prosthesis including the before it is inserted into the resected proximal femur;

FIG. **2** is a perspective view shown form the anterioromedial direction showing the femoral hip prostheses before it is inserted and a cross-sectional view of the resected proximal femur with the intramedullary cavity and the boss cavity prepared;

FIG. **3** is a perspective view shown from the posteriorolateral position showing the before it is inserted into the resected proximal femur;

FIG. **4** is an anterior side view of the femoral hip prosthesis shown outside of the femur;

FIG. **4***a* is an embodiment of a substantially circular cross-section of the elongated stem portion;

FIG. **4***b* is an embodiment of a substantially square cross-section of the elongated stem portion;

FIG. **4***c* is an embodiment of a substantially triangular cross-section of the elongated stem portion;

FIG. **4***d* is an embodiment of a substantially hexagonal cross-section of the elongated stem portion;

FIG. **4***e* is an embodiment of a substantially star shaped cross-section of the elongated stem portion;

FIG. **5** is an isometric view of the medial side of the femoral stem component as it appears outside of the femur;

FIG. **6** is a cross-sectional view of the proximal femur from the anterior side showing the positioning of the femoral stem component inside of the proximal femur;

FIG. **7** is a medial view of the femoral hip prosthesis inside of the proximal femur.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Depicted in FIGS. **1** through **7** are different embodiments of an implantable proximal femoral hip prosthesis **50** and methods of implantation therein. These embodiments of a hip joint replacement procedure and the design of the femoral hip prosthesis **50** that is meant to restore the biomechanical function of the hip joint while maintaining a secure interface with the proximal femur **10** and help to preserve anatomical loading of the remaining bone that surrounds the femoral hip prosthesis **50** once it is implanted. This allows the loads on the hip joint to be distributed optimally to the proximal femur **10**.

The femoral hip prosthesis **50** comprises a femoral head component **700** and a femoral stem component **100**. The femoral stem component **100** comprises a neck portion **150**, a flange portion **200**, a transitional body portion **300**, an elongated stem portion **400**, and a distal tip end **500**. The non-eccentric symmetrical shape of the interface between the elongated stem portion **400** of the femoral stem component **100** and a cavity **25** along with the contact at the interface between a proximal resection **20** and the femoral stem component **100** helps to stabilize the femoral hip prosthesis **50** and transfer more anatomic loads from the prosthesis **50** to the bone efficiently.

To prepare the patient for a proximal femoral hip prosthesis **50**, the surgeon first makes an incision or incisions near the hip joint, then the surgeon cuts though some of the tissue near the articulating joint, and retracts these tissues apart to visualize and access the diseased bone structures that are to be replaced by the hip joint replacement prostheses. FIG. **1**, is a simplified perspective view from the anteriomedial direction showing the proximal femur **10** and the femoral hip prosthesis **50**, showing the femoral head component **700**, the femoral stem component **100**, and the proximal femur **10**. For clarification, all of the other tissues necessary to provide function to the hip joint are not shown in this simplified view. The surgeon aligns bone tissue removal tools, such as drills, reamers, or broaches (not shown) with alignment instrumentation (not shown) to form a substantially non-eccentric, symmetric intramedullary cavity **25** in the cancellous bone **3** of the proximal femur **10** that is in longitudinal alignment with the shaft **45** of the proximal femur **10**. The intramedullary cavity **25** is formed with a cross-sectional shape, such as a diameter **46** as shown in an embodiment of the intramedullary cavity **25** shown in FIG. **2**. The diameter **46** is the measurement of the diameter of the maximum circular periphery that encompasses an envelope that the cross-sectional shape of the intramedullary cavity **25** comprises. The shape of the intramedullary cavity **25** can also be substantially non-eccentric, symmetric, non-circular shapes such as a square (not shown), star shape, (not shown), hexagon (not shown), or other parallelogram shape. Matching non-circular shapes of both the femoral stem component **100** and the intramedullary cavity **25** are potentially more efficient at restricting torsional movement between the femoral stem component **100** and the proximal femur **10** than circular cross-sectional shapes. The intramedullary cavity **25** also is formed to a length **47** as also shown in FIG. **2**. The cross-sectional shape, diameter **46** and length **47** of the intramedullary cavity **25** in the proximal femur **10** is dependent on the morphology, structure, and pathology of the patient anatomy and the anticipated biomechanical in vivo loads resulting from the use of the femoral stem component **100**.

The intramedullary cavity **25** may have a multiple diameters, or in the case of non-circular cross-sectionally shaped cavities multiple sizes, to approximately match the shape of the femoral stem component **100**. FIG. **2**, which illustrates a cross-sectional view of the proximal femur **10**, shows that both a first diameter **46** and a second diameter **48** can form an intramedullary cavity **25** is shown in FIG. **2**. The second diameter **48** in the embodiment of FIG. **2** is smaller than the first diameter **46**. Additionally, a third, forth, fifth, or more diameters (all not shown) can form the intramedullary cavity **25**. For the purposes of clarity of illustration, the cross-section of the intramedullary cavity on FIG. **1** and FIG. **2** are circular, resulting in a substantially cylindrical opening. Correspondingly different size or shaped tissue removal tools (not shown) are used to prepare an intramedullary cavity **25** with more than one size diameter **46**. The surgeon may also find it advantageous to form different or alternating shapes of cross-sections in the symmetric, non-eccentric intramedullary cavity **25**. For example, the cavity may be first diameter circular, and then square, then a second diameter circle, then a star shape, then cone shaped, then finally spherically shaped at its deepest, most distal end.

After the basic intramedullary cavity **25** is formed, instrumentation (not shown) is used to align cutting guides for bone cutting instruments (not shown) to form a proximal resection **20** on the proximal femur **10**. The proximal resection **20** may have different surfaces such as a calcar resection surface **12** that is formed when the femoral calcar **11** is transverely cut through the proximal femur **10**. The calcar resection surface **12** is cut at an acute angle **22** with respect to the longitudinal axis **21** of the proximal femur **10**. This acute angle is typically between 10° and 80°. Although the proximal resection **20** may be simply one continuous transverse cut that passes from the medial to the lateral side of the proximal femur in the direction and plane defined by a the plane outlined by the dashed line **16** shown in FIG. **1**. This alternative resection **17** is formed by extending the calcar resection **12** from medial to lateral though the entire proximal femur **10**.

More bone conserving cuts may also be formed in to the proximal femur **10** as shown in FIG. **1**. These cuts may include a formed concentric region **15** that is larger in size but concentric to or aligned with the intramedullary cavity **25**. These cuts may also include a transverse resection **13** that is cut relatively perpendicular to the intramedullary cavity **25**. To simplify the surgical procedure, the resections shown in FIG. **1** can all be formed by a single reamer (not shown). This reamer has a cutting surface formed in the shape of the combined profile of all of the resection cuts. It can be rotated or oscillated about the longitudinal axis **21** of the intramedullary canal **25**, until the desire bone tissue is removed. As shown in FIG. **2**, the various cuts that together form the proximal resection **20** pass through portions of both the relatively dense cortical bone **44** and the more porous cancellous bone **3**. Thus, the cutting surfaces of the tissue removal tools are designed to cut both dense cortical bone **44** and less dense cancellous bone **3**.

After the intramedullary cavity **25** and the proximal resection **20**, including the calcar resection **12** and when applicable other bone tissue removal cuts are formed, the femoral stem component **100** can be inserted to mate with the exposed bone surfaces. The femoral stem component **100** comprises a proximal male friction fit portion **150**, a distal neck body **160**, a flange portion **200**, a transitional body portion **300**, an elongated stem portion **400**, and a distal end tip portion **500**. These portions will be discussed in detail below.

The femoral stem component **100** has a proximal male friction fit portion **150** on its most proximal end that is shaped to accept partially hemispherical femoral head component **700**. One shape of the proximal male friction fit portion **150** is a cylindrical taper shape with the smaller diameter on the male friction fit portion proximal section **151**, a tapered male friction fit portion **152** distal to the male friction fit portion proximal section **151**, and a larger diameter male friction fit portion taper maximum cross-section bottom end **153** on the distal end of the male friction fit portion **152**. The proximal male friction fit portion **150** could also be a straight cylindrical shape without a taper, or a series of successively larger diameter cylindrical shapes.

A femoral head component **700** has a male cavity **720** that is dimensioned to fit over and mate with the friction fit portion **152** of the proximal male friction fit portion **150** when the femoral head component **700** is assembled on the proximal male friction fit portion **150**. The femoral head prosthesis **700** has an external bearing surface portion **710** on its external surface that is substantially on its proximal side when implanted. The external bearing surface portion **710** of the femoral head prosthesis **700** is substantially hemispherical shaped on a portion of its load bearing external bearing surface. This hemispherical shape is designed to mate with either an artificial prosthetic acetabular cup surface (not shown) as is the case for a total hip arthroplasty or a natural acetabular surface as is the case for a hip femoral hemiplasty.

The proximal male friction fit portion **150** has a male friction fit portion neck **154** that is distal to the male friction fit portion portion **152** and adjacent to the male friction fit portion taper bottom end **153**. This male friction fit portion neck **154** functions as an undercut relief for the femoral head component **700** when assembled. Because the male friction fit portion neck **154** is smaller in diameter than the male friction fit portion portion **152**, the femoral head component **700** can be pressed onto the proximal male friction fit portion **150** with the only direct contact between the two on the friction fit portion **152** of the femoral stem component **100** and the male friction fit portion **720** of the femoral head component **700**.

The male friction fit portion neck **154** is proximal to and attached directly to a more bulky distal neck body **160**. The distal neck body **160** is shaped to distribute the loads transmitted through the proximal male friction fit portion **150** from the femoral head component **700** through a flange portion **200** and a transitional body portion **300**. The shape of the distal neck body **160** transitions from a simple symmetric shape similar to the cross-section of the male friction fit portion neck **154** to a more complex asymmetric shape that is similar to the combined shape of the flange portion **200** and the transitional body portion **300**. In the embodiment shown in FIG. **1** through FIG. **7**, the cross-sectional shape of the distal neck body **160** at the proximal section is round because the male friction fit portion is a conical tapered and the male friction fit portion neck **154** is a cylindrical hourglass shape. However, the shape of the distal neck body **160** at the proximal section can be other shape to correspond with the shape of the proximal male friction fit portion **150**.

The flange portion **200** has an upper portion **210** on its proximal side that contacts at least a part of the distal neck body **160**. In the embodiments shown in FIGS. **1**, **2**, **3**, **6** and **7** the flange portion is angled to match the at the same angle as the calcar resection **12** made by the surgeon on the proximal femur **10**. The angle and the size of the flange portion **200** are dependent on the anatomy of the patient and the morphology of the calcar resection **12**. The flange portion **200** has an anterior-posterior flange portion width **240** that is wide enough to cover at least a portion of the cortical bone tissue **44** that has been resected. The cortical bone tissue **44** is more rigid than the cancellous bone tissue **3**. In a healthy hip joint, the compressive loads are transmitted through both the cancellous bone tissue and the cortical bone tissue **44** of the proximal femur **10**. Because the cortical bone tissue **44** is more dense and rigid, and can sustain a higher load per square unit area without fracture than the cancellous bone tissue **3**, cortical bone tissue **44** is a more efficient distributor of compressive loads than cancellous bone tissue **3**. Thus, the flanged portion **200** is shaped to cover both the resected cancellous bone **3** and the resected cortical bone **44** so that the compressive loads transmitted through the flange portion **200** are distributed as anatomically close as possible to how they were distributed when the proximal femur **10** was healthy and intact.

The flanged portion **200** is less thick than it is wide. As shown in the embodiment of FIG. **4**, the flange portion thickness **221** is between 0.5 millimeters and 12 millimeters. The flange portion **200** is substantially thick enough to transmit loads from the hip joint to the calcar resection surface **12** of both the cancellous bone tissue **3** and the cortical bone tissue **44**. The flange portion **200** is also thin enough to limit the about of bone that must be resected to form the calcar resection **12**.

The transitional body region **300** is the portion of the femoral stem component **100** that transitions from the distal neck body **160** and the flange portion **200** to the distal elongated stem portion **400**. The transitional body region **300** is adjacent to both the distal neck body **160** and the flange portion **200** on its proximal side and adjacent to the elongated stem portion **400** on its distal side. The transitional body portion **300** has a maximum height **310** that is the linear distance measured between a plane tangent to the bottom surface **220** of the flange portion **200** and a plane through the most distal part of the transitional body portion **300**. In FIG. **4**, these two planes are shown as lines since this is a side view. In the embodiment of the transitional body portion shown in FIG. **4**, the transitional body portion **300** has a curved fillet **330** its medial side. Although this is shown as a round fillet in FIG. **4**, the medial side of the transitional body portion **300** can be a chamfered fillet, a stepped fillet, or any other non-linear or linear shape that transitions from the shape of the elongated stem portion **400** to the shape of portions of the distal neck body **160** or the flange portion **200**. The maximum height **310** of the majority of the transitional body region **300**, when measured normal from the bottom surface **220** of the flange portion **200** to any part of the elongated stem portion **400** is less than thirteen millimeters or less. Both the physical structure of the femoral hip prosthesis **50**, and the mechanical properties of the material from which the prosthesis is fabricated, function together to determine the functional strength and elasticity of the femoral stem component **100**.

Conventional orthopedic alloys such as cobalt chrome, titanium and stainless steel alloys and orthopedic composite materials have proven to provide reasonable strength and rigidity to orthopedic implants and may also be used to fabricate the femoral stem component **100**. However, when conventional orthopedic alloys or composites are fabricated into the eccentric conical shape of a typical femoral stem component **100**, the resulting implant is more rigid than the proximal femoral **10** that the femoral stem component **100** is replacing. Flexibility of the stem component **100** is necessary to allow the flex and compliance desired to dynamically anatomically load the proximal femur **10** bone during biomechanical loading. The relatively small shape of the transitional body portion **300** allows for more flexion of the flange portion **200** when the proximal male friction fit portion **150** is loaded than is seen with the bulkier conventional eccentric cone shaped femoral prosthesis. The unique shape of the femoral stem component **100** allows for flexibility of the prosthesis even when fabricated from rigid orthopedic alloys such as such as cobalt chrome, titanium and stainless steel alloys.

This dynamic flexibility within the transitional portion **300** is desired since it allows the flange portion **200** of the femoral stem component **100** to transmit loads and displacements to the femoral calcar region **11** of the proximal femur **10**. When bone is loaded and allowed to deform, a piezoelectric effect within the tissue simulate the bone cells into further production. This phenomenon, sometimes called Wolfs Law, coupled with other physiologic and biochemical principles, helps to keep the bone surrounding the femoral hip prosthesis **50** healthy and vibrant. The femoral stem component **100** is designed to optimize the effects that a flexible, yet strong femoral hip prosthesis **50** will have on the surrounding loaded bone tissue. As the hip joint is loaded during clinical use, loads are transmitted through the male friction fit portion **154** and distal neck body **160** to the flange portion **200** and the transitional body portion **300** to the stem. Since the transitional body portion **300** is relatively flexible and not as bulky and rigid as a conventional femoral hip prosthesis, the transitional body portion **300** allows the femoral stem component **100** to flex and transmit the compressive load to the bone in the calcar region **11** of the proximal femur **10**. These loads on the bone may allow the dynamization necessary to keep the tissue surrounding the femoral stem component **100** healthy and help prevent bone resorption in the calcar region **11** of the proximal femur **10**.

Distal and adjacent to the transitional body portion **300** is the elongated stem portion **400**. The elongated stem portion **400** comprises some or all of the following portions and features; a tapered portion **450**, a splined section **420**, and transverse slot **480**. The elongated stem portion is encompassed within a cylindrically shaped envelope referred to as uniform envelope **410**. The cross-sectional shape and the area of the uniform envelope **410** remains substantially uniform throughout the longitudinal length of the elongated body. The uniform envelope **410** has a circular uniform cross-sectional periphery **902** that is defined by the maximum cross-sectional peripheral diameter **905** of the elongated stem portion **400**. The uniform envelope **410** is the same length as the elongated stem portion. The elongated stem portion is adjacent to the transitional body portion **300** on its proximal end and adjacent to a distal tip portion **500** on its distal end.

As shown in FIG. **4**, the elongated stem portion **400** is longitudinally aligned with a longitudinal axis **425**. When the femoral stem component **100** is implanted in the proximal femur **10**, the longitudinal axis **425** is approximately in alignment with the longitudinal axis **21** of the intramedullary cavity **25**. All the possible features or portions of the elongated stem portion **400**, including the tapered portion **450**, the splined section **420**, and the transverse slot **480** have cross-sections perpendicular to the longitudinal axis **425** and are contained within a maximum diameter **905** of a cross-sectional periphery **902** that defines the cross-section of the uniform envelope **410**. Representative shapes of cross-sectional areas viewed from a cross-sectional view cut plane **900** are shown in FIG. **4***a* through FIG. **4***e*. Included in these figures are the cross-sectional periphery **902** and the maximum diameter **905** of the cross-sectional periphery **902**.

Material may be removed from the elongated stem portion **400** to created features such as taper portions **450**, splines **460** or the transverse slots **480**. However, the basic substantial shape of the external periphery of the cross-section of the elongated stem portion **400** remains uniform and circular. Thus, the elongated stem portion and the uniform envelope **410** are both substantially symmetric and non-eccentric. The embodiment of the elongated stem portion **400** shown in FIG. **4** is substantially cylindrical in shape **910**. The cross-section of this cylindrically shaped elongated stem portion is shown in FIG. **4***a*. However, for other embodiments of the femoral stem component **100**, the cross-sectional shape of the elongated stem portion **400** can be also non-circular shapes such as substantially square shape **920**, as shown in FIG. **4***b*; a substantially triangle shape **930**, as shown in FIG. **4***c*; a substantially hexagonal shape **940**, as shown in FIG. **4***c*, a substantially star shape **950** as shown in FIG. **4***e*, or any other substantially non-eccentric, symmetric shape such as a tube (not shown) that can functionally form the cross-section of the elongated stem portion **400**.

In the embodiments shown, the longitudinal axis **425** of the elongated stem portion **400** is a substantially straight axis throughout the length of the elongated stem portion **400**. However, to better match the anatomy of the proximal femur **10**, the longitudinal axis **425** can also be curved. The curve may be in the anterior-posterior plane, the medial-lateral plane or a compound curve that is seen in both the anterior-posterior plane and the medial-lateral plane. A flexible reamer (not shown) could be used to form the curved intramedullary cavity before the prosthesis **10** with a curved longitudinal axis **425** is implanted.

The elongated stem portion **400** may include a tapered portion **450** along its length. This is shown in FIG. **2**. This tapered portion **450** may also include splines **460** or transverse slots **480** cut into it. The cross-sectional area of the tapered portion **450** in the embodiments shown decreases linearly along the longitudinal length of the tapered portion **450** as the tapered portion **450** transitions down the length of the elongated stem portion **400** from proximal to distal. The direction of the tapered portion **450** may also be in the opposite direction. The tapered area in the elongated portion **400** allows for greater flexibility in bending along the tapered portion **450** due to the reduced cross-sectional area and reduced cross-sectional bending moment of inertia. The tapered portion **450** also allows for an interference tapered wedge fit between the elongated stem portion **400** and the intramedullary cavity **25** in the proximal femur **10** when the cross-sectional size of the intramedullary canal **25** is less than the maximum diameter **905** of the periphery **902**.

Features such the splines **460** are cut into the elongated stem portion **400** for various structural and functional reasons such as to provide additional torsional resistance to the femoral stem component **100**. In the embodiments shown, the splines **460** are evenly spaced around the periphery **902** of the distal elongated stem portion **400**. The splines **460** are cut longitudinal around the periphery **902** of the elongated stem portion **400**. This allows the splines **460** to resist axial rotation between the femoral stem component **100** and the intramedullary cavity **25**. The splines **460** may also provide additional structural flexibility to the distal end of the femoral stem component **100**.

At the distal end of the femoral stem component **100**, an optional longitudinal transverse slot **480** may be cut transversely into the elongated stem portion **400** to provide additional flexibility and potentially additional torsional resistance to the femoral stem component **100**. The embodiment of the slot **480** that is shown is substantially uniform in cross-sectional and in shape though its length. The cross-sectional shape of the slot **480** may also be non-uniform. The cross-sections shape of the slot **480** may also change. For example the sides of the slot **481** may change from parallel planar surfaces to non-parallel or non-planar surfaces as the slot transitions from distal to proximal. The slot **480** also has a fillet **485** that takes the form of a rounded radius shape at its most proximal end. The shape of this fillet **485** may be other shapes that allow a relatively smooth transition from the slot **480** to the non-slotted cross-section. For example the slot **480** may be keyhole shaped.

Adjacent and distal to the elongated stem portion is the distal end tip portion **500**. The distal end tip portion **500** has a lead-in section **510** that reduces in cross-sectional area from proximal to distal. The lead-in section may be tapered as in the embodiment of FIG. **3**, or spherical as in the embodiment of FIG. **4**, or any shape that is successively smaller in cross-sectional area from proximal to distal. The distal end tip portion **500** helps to guide the femoral stem component **100** into the intramedullary canal **25**. The relatively smooth shape of the distal end tip portion **500** also functions to reduce the stress on the proximal femoral bone associated with discontinuity of terminating a rigid prosthesis in the intramedullary canal **25**.

The load distribution on the proximal femur **10** of an intact hip joint can be essentially resolved into an axial component, a bending moment in the medial and lateral direction, a bending moment in the anterior posterior direction, and a torsional moment with a rotational axis approximately in line with the longitudinal axis **21** of the proximal femur. The distribution of the magnitude and direction of these force components depend upon complex combinations of biomechanical factors such as leg stance, patient weight distribution, and patient gait. The femoral stem component **100** is designed to translate these forces to anatomic loads on the proximal femur **10**. As described above, the flange portion **200** helps to translate the compressive loads to the cancellous bone **3** and cortical bone **4** in the calcar region **11**. The elongated stem portion **400** helps to transmit the bending and torsional moments to the intramedullary canal **25**. In addition, a rotation-restricting boss **600** helps to transmit some of the torsional moments to the bone in the calcar region **11** of the proximal femur **10**. As shown in FIG. **6**, the boss periphery **630** of the rotation-restricting boss **600** interfaces with the bone surrounding the boss cavity **14**. This structural interference between the femoral stem component **100** and the proximal femur **10** helps to restrict rotation, caused by the above-described resultant torsional moment with approximately in line with the longitudinal axis **21** of the proximal femur **10**, between the femoral stem component **100** and the intramedullary cavity **25**.

The size and location of the rotation-restricting boss **600** are factors that affect the amount that the rotation-restricting boss **600** restricts rotational movement of the femoral stem component **100**. Due to greater resistance from a rotation-restricting boss with a larger resultant moment arm, the further that the rotation-restricting boss **600** is located from the longitudinal axis **425** of the elongated stem portion **400**, the more effective it is in transmitting rotational loads and restricting rotational movement of the femoral stem component **100** to the proximal femur **10**. Also, the larger the cross-sectional area of the rotation-restricting boss **600**, the more effective it is in distributing torsion and restricting rotational movement of the femoral stem component **100**.

The embodiments of the rotation-restricting boss **600** that are shown by example are circular in cross-section resulting in a cylindrical shaped boss. However, other cross-sectional shapes such as square, rectangular, triangular or diamond shapes may be more practical to machine or may be better at distributing torsional loads from the femoral hip prosthesis **50** to the proximal femur **10** than the shown cylindrically shaped rotation-restricting boss **600**. The optimized shape of the rotation-restricting boss **600** may be more fin shaped than cylindrical shaped or longer than it is wide. This shape is partially dependent on the mechanical characteristics of the bone tissue where the rotation-restricting boss **600** is inserted.

The rotation restricting boss **600** has an axis of protrusion **620** with origin **621** substantially on a plane tangent or coincident with the bottom surface **220** of the flange portion **200**. The boss axis of protrusion origin **621** and the stem portion longitudinal axis **425** are spaced apart by a length this is more than the maximum length **905** of the cross-section of the periphery **902** of the uniform envelope **410** of the elongated stem portion **400**.

The rotation-restricting boss **600** in the embodiment of the prosthesis **10** shown in FIG. **3** has an axis of protrusion that is substantially normal to the bottom surface **220** of the flange portion **200**. The rotation-restricting boss in the embodiment of the prosthesis **10** shown in FIG. **4**, FIG. **5** and FIG. **6** has an axis of protrusion **620** that is substantially parallel with the longitudinal axis **425** of the elongated stem portion **400**. As shown in cross-section of the proximal femur illustrated in FIG. **6**, the corresponding boss cavity **14** is in line with the axis of protrusion **620**.

As shown in FIG. **6** and FIG. **7**, after the femoral stem component **100** is implanted in the proximal femur **10**, the flange portion **200** is pressed against a resected surface **20** on the proximal femur **10**, and the elongated stem portion **400** is pressed in the intramedullary cavity **25** aligned with the long axis of the proximal femur **10**. As the femoral head **700** is loaded by the hip joint, a substantial component of the axial compressive force is transmitted to the cancellous **3** and cortical **4** bone in the calar region **11** from the flange portion **200**. The principle torsional loads are transmitted to the splines **460**, slot **480** and rotational-restricting boss **600** and the principle bending loads are transmitted to the intramedullary canal **25** through the elongated stem portion **400**. Collectively, these feature and portions of the femoral hip prosthesis **10** contribute to distribute anatomical loads from hip joint to the remaining proximal femoral bone tissue.

While the present invention has been disclosed in its preferred form, the specific embodiments thereof as disclosed and illustrated herein are not to be considered in a limiting sense, as numerous variations are possible. The invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. No single feature, function, element or property of the disclosed embodiments is essential. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. The following claims define certain combinations and subcombinations that are regarded as novel and non-obvious. Other combinations and subcombinations of features, functions, elements and/or properties may be claimed through amendment of the present claims or presentation of new claims in this or related applications. Such claims, whether they are broader, narrower or equal in scope to the original claims, are also regarded as included within the subject matter of applicant's invention. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A prosthesis adapted for implantation against a resected surface on a proximal end of a femur and inside of an intramedullary cavity of the femur, the prosthesis comprising:

a femoral head component comprising an external bearing surface;

a femoral stem component comprising:

a neck portion comprising a proximal portion re-engageable with the femoral head component, and a distal neck body;

a flange portion distal and adjacent to the neck portion, the flange portion having a planar bottom surface with a maximum anterior-posterior width which protrudes anteriorly and posteriorly beyond the neck portion, the flange portion shaped to cover at least a portion of resected cortical bone;

a transitional body region adjacent to the bottom surface of the flange portion and extending from the distal neck body; and

an elongated stem portion extending distally from the transitional body region, and wherein the elongated stem portion is at least partially encompassed within a uniform envelope;

wherein the transitional body region is shaped to flex such that, during a normal gait cycle, the flange portion exerts a significant compressive load on the resected surface of the femur.

2. A prosthesis as in claim **1**, wherein the uniform envelope comprises a substantially constant cross-sectional peripheral shape and size and the uniform envelope is substantially the same length as the elongated stem portion.

3. A prosthesis as in claim **1**, wherein the elongated stem portion comprises a proximal section having a cross sectional shape that is substantially consistent along a longitudinal length of the proximal section, wherein a minimum displacement between the bottom surface of the flange portion and the proximal section, measured normal to the bottom surface, is less than thirteen millimeters.

4. A prosthesis as in claim **1**, further comprising a rotation-restricting boss, extending from the bottom of the flange portion.

5. A prosthesis as in claim **2**, further comprising a rotation-restricting boss, extending from the bottom of the flange portion.

6. A prosthesis as in claim **5**, wherein the rotation restricting boss has an axis of protrusion with a boss axis origin near the bottom surface of the flange portion, the elongated stem also has a stem axis origin near the bottom of the flange portion, the boss axis origin and the stem axis origin are spaced apart by a length more than the maximum cross-section of the elongated stem portion.

7. A prosthesis as in claim **6**, wherein the axis of protrusion and a longitudinal axis oriented at an acute angle from the bottom surface of the flange portion are substantially parallel.

8. A prosthesis as in claim **7**, wherein the acute angle ranges from 15° to 80°.

9. A prosthesis as in claim **6**, wherein the axis of protrusion and a longitudinal axis oriented at an acute angle from the bottom surface of the flange portion are not substantially parallel.

10. A prosthesis as in claim **9**, wherein the axis of protrusion is normal to the bottom surface of the flange portion.

11. A prosthesis as in claim **10**, wherein the acute angle ranges from 15° to 80°.

12. A prosthesis as in claim **1**, wherein the elongated stem portion has a distal section with multiple longitudinal splines, wherein the longitudinal splines are aligned approximately parallel to a longitudinal axis oriented at an acute angle from the bottom surface of the flange portion.

13. A prosthesis as in claim **1** wherein the neck portion is aligned at an obtuse angle with respect to the bottom surface of the flange portion.

14. A prosthesis as in claim **13**, wherein the obtuse angle is between 100° and 170°.

15. A prosthesis as in claim **1**, wherein the neck portion has a first end and a second end, wherein the first end is connected to the flange portion and extends proximally therefrom and the second end is shaped to press-fit into the femoral head component.

16. A prosthesis as in claim **15**, wherein at least a portion of the outer surface of the femoral head component is hemispherical.

17. A prosthesis as in claim **2**, wherein the uniform envelope has a maximum cross-section area measured on a plane perpendicular to a longitudinal axis oriented at an acute angle from the bottom surface of the flange portion.

18. A prosthesis as in claim **1**, wherein the elongated stem portion comprises a proximal section having a cross sectional shape that is substantially consistent along a longitudinal length of the proximal section, wherein a minimum displacement between the bottom surface of the flange portion and the proximal section, measured normal to the bottom surface, is less than a maximum cross sectional width of the elongated stem portion, measured perpendicular to the longitudinal axis.

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