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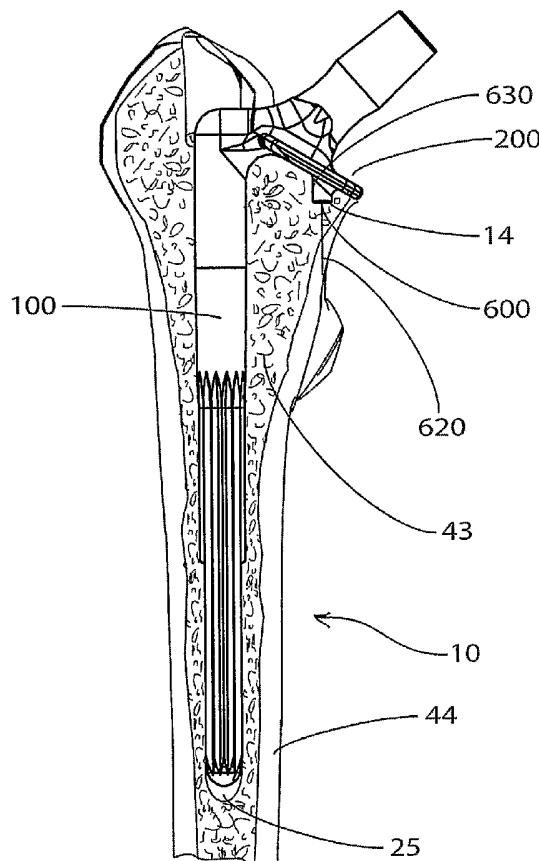
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(54) Title: FEMORAL HIP PROSTHESIS AND METHOD OF IMPLANTATION



(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 comprising 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 into the resected femur and into 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.

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## FEMORAL HIP PROSTHESIS AND METHOD OF IMPLANTATION

## CROSS-REFERENCE TO RELATED APPLICATIONS

[001] Not applicable.

## BACKGROUND OF THE INVENTION

1. The Field of the Invention

[002] 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

[003] 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.

[004] 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 placed strategically at specific locations on their surface to help facilitate long-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.

[005] 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 hemiarthroplasty, or articulates with a corresponding implant replacing the opposite side of the joint in the case of a total joint arthroplasty.

[006] 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. [007] 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

[008] 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

[0009] 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.

[0010] Figure 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;

[0011] Figure 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;

[0012] Figure 3 is a perspective view shown from the posteriorolateral position showing the before it is inserted into the resected proximal femur;

[0013] Figure 4 is an anterior side view of the femoral hip prosthesis shown outside of the femur;

[0014] Figure 4a is an embodiment of a substantially circular cross-section of the elongated stem portion;

[0015] Figure 4b is an embodiment of a substantially square cross-section of the elongated stem portion;

[0016] Figure 4c is an embodiment of a substantially triangular cross-section of the elongated stem portion;

[0017] Figure 4d is an embodiment of a substantially hexagonal cross-section of the elongated stem portion;

[0018] Figure 4e is an embodiment of a substantially star shaped cross-section of the elongated stem portion;

[0019] Figure 5 is an isometric view of the medial side of the femoral stem component as it appears outside of the femur;

[0020] Figure 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;

[0021] Figure 7 is a medial view of the femoral hip prosthesis inside of the proximal femur.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Depicted in Figures 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.

[0023] 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.

[0024] 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 through 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. Figure 1, is a simplified perspective view from the anteromedial 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 figure 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 figure 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.

[0025] 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. Figure 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 figure 2. The second diameter 48 in the embodiment of figure 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 figure 1 and figure 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.

[0026] 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 transversely 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 figure 1. This alternative resection 17 is formed by extending the calcar resection 12 from medial to lateral though the entire proximal femur 10.

[0027] More bone conserving cuts may also be formed in to the proximal femur 10 as shown in figure 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 figure 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 Figure 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.

[0028] 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.

[0029] 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.

**[0030]** 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.

**[0031]** 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.

**[0032]** 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 Figures 1 through Figure 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.

**[0033]** 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 figures 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.

[0034] The flanged portion 200 is less thick than it is wide. As shown in the embodiment of figures 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 amount of bone that must be resected to form the calcar resection 12.

[0035] 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 figure 4, these two planes are shown as lines since this is a side view. In the embodiment of the transitional body portion shown in figure 4, the transitional body portion 300 has a curved fillet 330 on its medial side. Although this is shown as a round fillet in figure 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.

[0036] 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 femur 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.

**[0037]** 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.

**[0038]** 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 470, 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.

**[0039]** As shown in figure 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 spine section 470, 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 figure 4a through figure 4e. Included in these figures are the cross-sectional periphery 902 and the maximum diameter 905 of the cross-sectional periphery 902.

**[0040]** Material may be removed from the elongated stem portion 400 to create 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 figure 4 is substantially cylindrical in shape 910. The cross-section of this cylindrically shaped elongated stem portion is shown in figure 4a. 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 figure 4b; a substantially triangle shape 930, as shown in figure 4c; a substantially hexagonal shape 940, as shown in figure 4c, a substantially star shape 950 as shown in figure 4e, 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.

[0041] 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.

[0042] The elongated stem portion 400 may include a tapered portion 450 along its length. This is shown in figure 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.

[0043] Features such as 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.

[0044] 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.

[0045] 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 figure 3, or spherical as in the embodiment of figure 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.

[0046] 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 figure 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.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] The rotation-restricting boss 600 in the embodiment of the prosthesis 10 shown in figure 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 figure 4, figure 5 and figure 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 figure 6, the corresponding boss cavity 14 is in line with the axis of protrusion 620.

[0051] As shown in figure 6 and figure 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.

[0052] 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.

## CLAIMS

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 comprising:
  - a femoral head component having an external bearing surface and a female friction fit portion;
  - a femoral stem component comprising:
    - a neck portion having a proximal male friction fit portion, reversibly engagable with the female friction fit portion, and a distal neck body;
    - a flange portion distal and adjacent to the neck portion, attached to the distal neck body, having an upper portion and a bottom surface;
    - a transitional body region, adjacent to the bottom surface of the flange portion and extending from the distal neck body;
    - an elongated stem portion extending distally from the transitional body region and having a longitudinal axis that is orientated at an acute angle from the bottom surface of the flange portion; and
    - a distal end tip portion adjacent and distal to the elongated stem portion; wherein the transitional body region has a maximum height of less than thirteen millimeters when measured normal from the bottom surface of the flange to any part of the elongated stem portion.
2. A prosthesis as is claim 1, wherein the elongated stem portion comprises a uniform envelope with a substantially constant cross-sectional peripheral shape and size.
3. A prosthesis as in claim 1, whereby some of the forces applied to the head component during use are converted into displacement of the flanged portion and compressive forces to the calcar region of the femur through the surface on the femur.
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 of the flange, the elongated stem also has a stem axis origin near the bottom of the flange, 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 the longitudinal axis are substantially parallel.
8. A prosthesis as in claim 6, wherein the axis of protrusion and the longitudinal axis are not substantially parallel.
9. A prosthesis as in claim 6, wherein the axis of protrusion is normal to the bottom of the flange portion.
10. A prosthesis as in Claim 1, wherein the elongated stem portion has a distal section with multiple longitudinal flutes, the longitudinal flutes are aligned approximately parallel to the longitudinal axis.

11. A prosthesis as in Claim 1, having a distal section on the opposite end of the distal elongated stem portion; the distal section having a slot transverse to the longitudinal axis.
12. 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.
13. A prosthesis as in Claim 12 wherein the obtuse angle is between 100° and 170°.
14. A prosthesis as in Claim 1 wherein the neck portion has a first end and a second end, the first end is connected to the flange portion and extending proximally therefrom; the second end is shaped to press-fit into a head component.
15. A prosthesis as in Claim 14 wherein at least a portion of the outer surface of the head component is hemispherical.
16. A prosthesis as in claim 1 wherein the acute angle ranges from 15° to 80°.
17. A prosthesis as in claim 2 wherein the uniform envelope has a maximum cross-section area measured on a plane perpendicular to the longitudinal axis.
18. A prosthesis as in claim 1 wherein the elongated stem portion has a length of at least one hundred millimeters as measured along the length of its longitudinal axis.
19. A prosthesis as in claim 2 having a slot in the distal end of the elongated stem portion
20. A prosthesis as in claim 1 having a tapered portion within the elongated stem portion.
21. 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, comprising:  
a femoral head component having an external bearing surface and a male friction fit portion;  
a femoral stem component comprising:  
a neck portion having a proximal male friction fit portion to reversibly engage with the male friction fit portion and a distal neck body;  
a flange portion distal and adjacent to the neck portion attached to the distal neck body having an upper portion and a bottom surface;  
a transitional body region, adjacent to the bottom surface of the flange portion and extending from the distal neck body;  
an elongated stem portion, extending distally from the transitional body region and substantially aligned with a longitudinal axis that is at an acute angle from the bottom surface of the flange portion, the elongated stem portion having a uniform envelope with a maximum cross-section outer periphery dimension; and  
a distal end tip portion adjacent and distal to the uniform envelope;  
wherein the transitional body region has a maximum height, measured normal from the bottom surface of the flange to any part of the transitional body region, the height is less than the diameter of the maximum cross-section outer periphery dimension.
22. A prosthesis as in claim 21, whereby some of the forces applied to the head component during use are converted into compressive forces through the bottom surface of the flanged body.

23. A prosthesis as in claim 21, further comprising a rotation-restricting boss, extending from the bottom surface of the flange portion.
24. A prosthesis as in Claim 23, wherein the rotation restricting boss has an axis of protrusion with a boss axis origin near the bottom of the flange, the elongated stem also has a stem axis origin near the bottom of the flange, 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.
25. A prosthesis as in claim 23, wherein the axis of protrusion and the longitudinal axis are substantially parallel.
26. A prosthesis as in claim 23, wherein the axis of protrusion and the longitudinal axis are not substantially parallel.
27. A prosthesis as in claim 23, wherein the axis of protrusion is normal to the bottom of the flange portion.
28. A prosthesis as in Claim 21, wherein the elongated stem portion has a distal section with multiple longitudinal flutes, the longitudinal flutes are aligned approximately parallel to the longitudinal axis.
29. A prosthesis as in Claim 21, having a distal section on the opposite end of the distal elongated stem portion; the distal section having a slot transverse to the longitudinal axis.
30. A prosthesis as in Claim 21 wherein the neck portion is aligned at an obtuse angle with respect to the bottom surface of the flange portion.
31. A prosthesis as in Claim 30 wherein the obtuse angle is between 100° and 170°.
32. A prosthesis as in Claim 21 wherein the neck portion has a first end and a second end, the first end is connected to the flange portion and extending proximally therefrom; the second end is shaped to press-fit into a head component.
33. A prosthesis as in Claim 32 wherein at least a portion of the outer surface of the head component is hemispherical.
34. A prosthesis as in claim 21 wherein the acute angle ranges from 15° to 80°.
35. A prosthesis as in claim 21 wherein the uniform envelope has a maximum cross-section area measured on a plane perpendicular to the longitudinal axis.
36. A prosthesis as in claim 21 herein the elongated stem portion has a length of at least one hundred millimeters as measured along the length of its longitudinal axis.
37. A prosthesis as in claim 21 further comprising a tapered portion within the elongated stem portion.

38. A method of surgically repairing a hip joint comprising;  
providing a femoral hip prosthesis comprising a femoral head component and a femoral stem component, the femoral stem component comprising a neck portion with a proximal male friction fit portion and a distal neck body, a flange portion distal and adjacent to the neck portion attached to the distal neck body having an upper portion and a bottom surface, a transitional body region, adjacent to the bottom surface of the flange portion and extending from the distal neck body, an elongated stem portion, extending distally from the transitional body region and aligned with an longitudinal axis that is aligned at an acute angle from the bottom surface of the flange portion;  
reaming an intramedullary cavity in the proximal femur with a reamer;  
resecting the bone tissue on the proximal femur to form a resected proximal femur;  
reaming a boss cavity in the proximal femur;  
inserting the elongated stem portion of the femoral hip prosthesis in the intramedullary cavity,  
placing at least part of the flange portion on the resected proximal femur; and  
inserting at least a portion of a rotation-restricting boss into the boss cavity.

39. A method of surgically repairing a hip joint comprising;  
providing a femoral hip prosthesis comprising a femoral head component and a femoral stem component; the femoral stem component comprising a neck portion with a proximal male friction fit portion and a distal neck body, a flange portion distal and adjacent to the neck portion attached to the distal neck body having an upper portion and a bottom surface, a transitional body region, adjacent to the bottom surface of the flange portion and extending from the distal neck body, an elongated stem portion, extending distally from the transitional body region and aligned with an longitudinal axis that is aligned at an acute angle from the bottom surface of the flange portion;  
resecting the bone tissue on the proximal femur to form a resected proximal femur;  
preparing a non-eccentric, symmetric intramedullary cavity in the proximal femur;  
reaming a boss cavity in the proximal femur;  
inserting a portion of the elongated stem portion of the femoral hip prosthesis in the intramedullary cavity,  
inserting at least a portion of a rotation-restricting boss into the boss cavity, and  
placing at least part of the flange portion on the resected proximal femur.

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

- a femoral head component having an external bearing surface and a female friction fit portion;
- a femoral stem component comprising:
- a neck portion extending substantially outside the cavity of the femur and having a proximal male friction fit portion, reversibly engagable with the female friction fit portion, and a neck body extending distal and lateral to the male friction fit portion;
- a flange portion medially and distally projecting from the neck body having an upper portion and a bottom surface;
- an elongated stem portion extending substantially inside the cavity of the femur and extending distally from the neck body and having a longitudinal axis that is orientated at an acute angle from the bottom surface of the flange portion; and
- a distal tip portion adjacent and distal to the elongated stem portion;
- wherein the elongated stem portion has an outer surface that is substantially circumscribed by a surface of revolution.

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

- a femoral head component having an external bearing surface and a female friction fit portion;
- a femoral stem component comprising:
- a neck portion extending substantially outside the cavity of the femur and having a proximal male friction fit portion, reversibly engagable with the female friction fit portion, and a neck body extending distal and lateral to the male friction fit portion;
- a flange portion medially and distally projecting from the neck body having an upper portion and a bottom surface;
- an elongated stem portion extending substantially inside the cavity of the femur and extending distally from the neck body and having a longitudinal axis that is orientated at an acute angle from the bottom surface of the flange portion; and
- a distal tip portion adjacent and distal to the elongated stem portion;
- wherein the elongated stem portion has an outer surface that is substantially circumscribed by a surface with a substantially uniform cross section.

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

- a femoral head component having an external bearing surface and a female friction fit portion;
- a femoral stem component comprising:
- a neck portion extending substantially outside the cavity of the femur and having a proximal male friction fit portion, reversibly engagable with the female friction fit portion, and a neck body extending distal and lateral to the male friction fit portion;
- a flange portion medially and distally projecting from the neck body having an upper portion and a bottom surface;

an elongated stem portion extending substantially inside the cavity of the femur and extending distally from the neck body and having a longitudinal axis that is orientated at an acute angle from the bottom surface of the flange portion; and a distal tip portion adjacent and distal to the elongated stem portion; wherein the elongated stem portion does not vary in its maximum cross sectional width by more than ten percent.

Title: Femoral Hip Prosthesis and Method of Implantation  
Inventor: Michael D. Ries, et al.  
Docket No. MLI 10  
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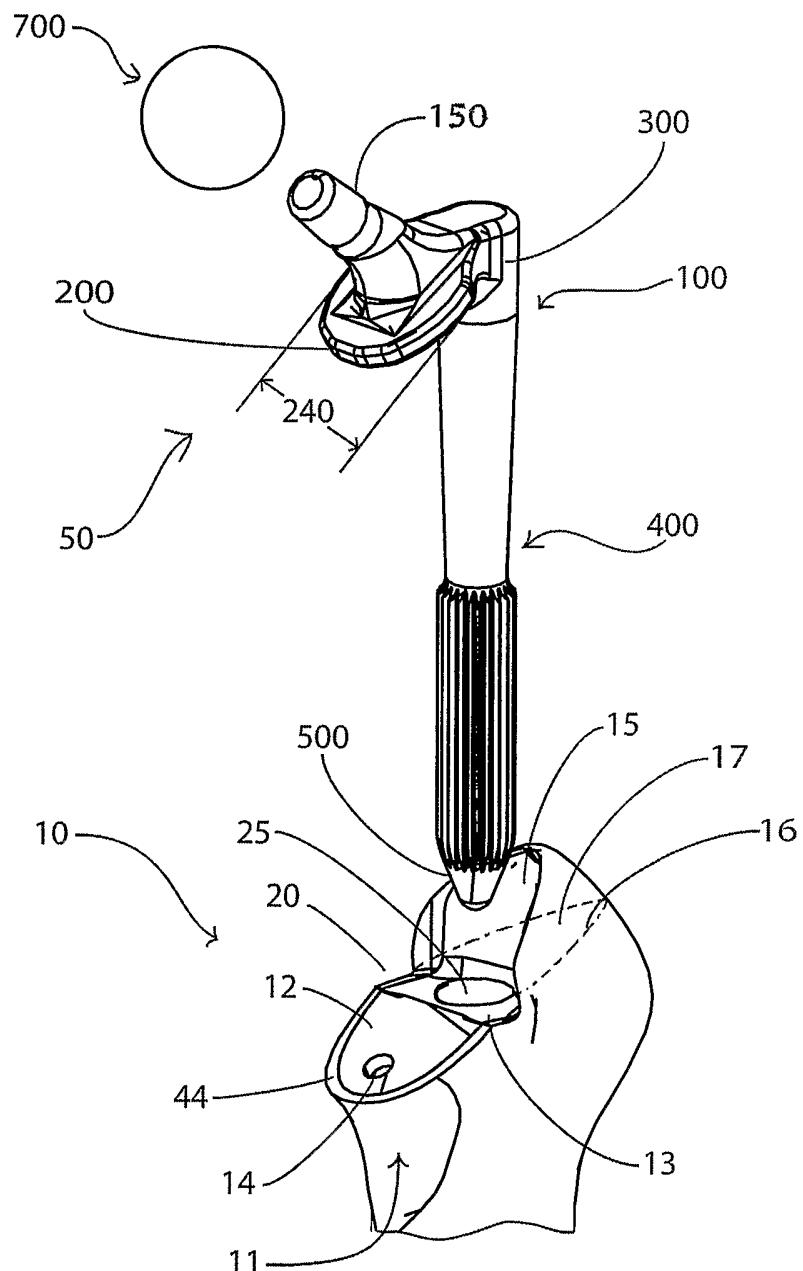


Fig. 1

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Inventor: Michael D. Ries, et al.  
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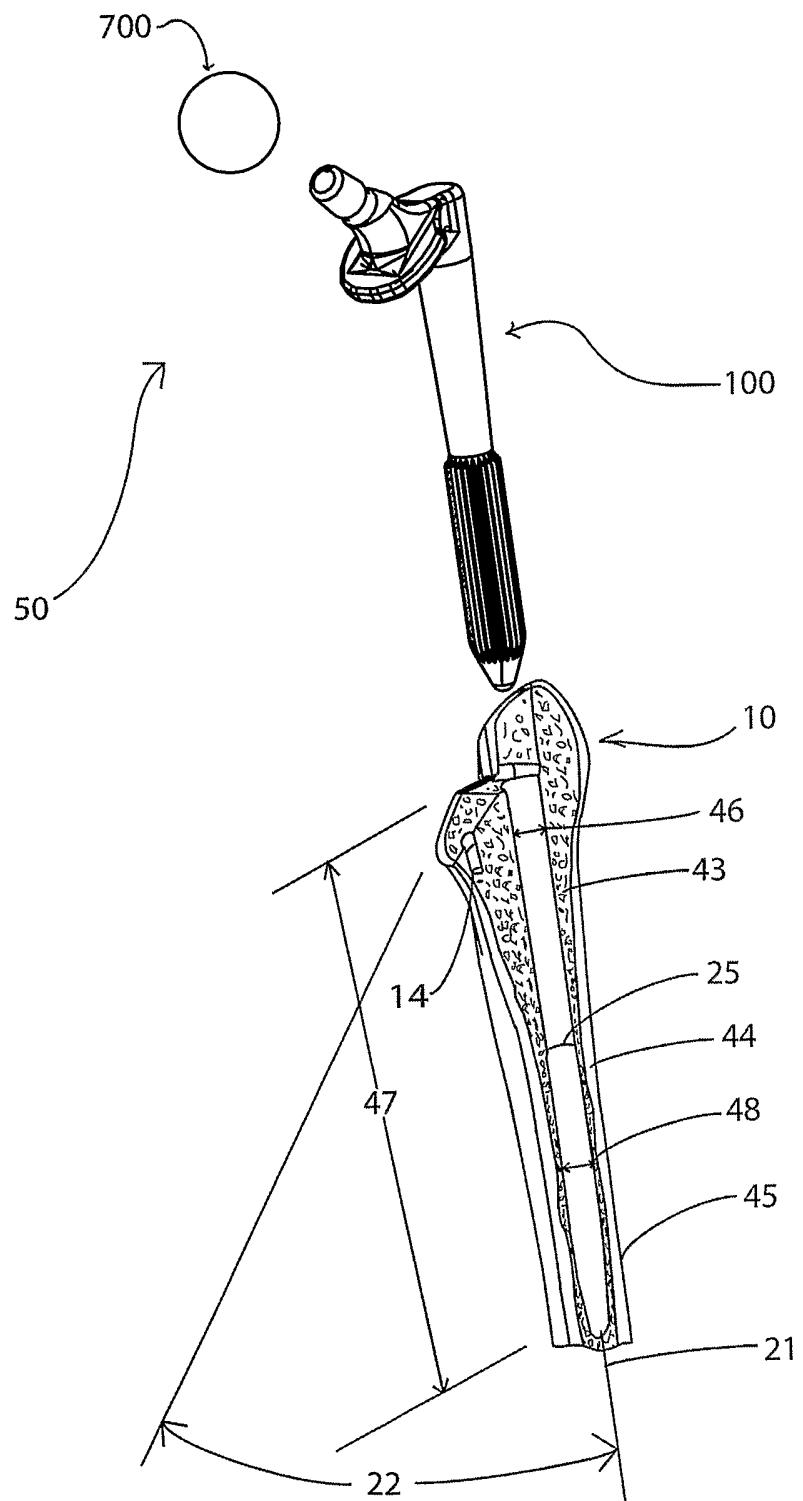


Fig. 2

Title: Femoral Hip Prosthesis and Method of Implantation

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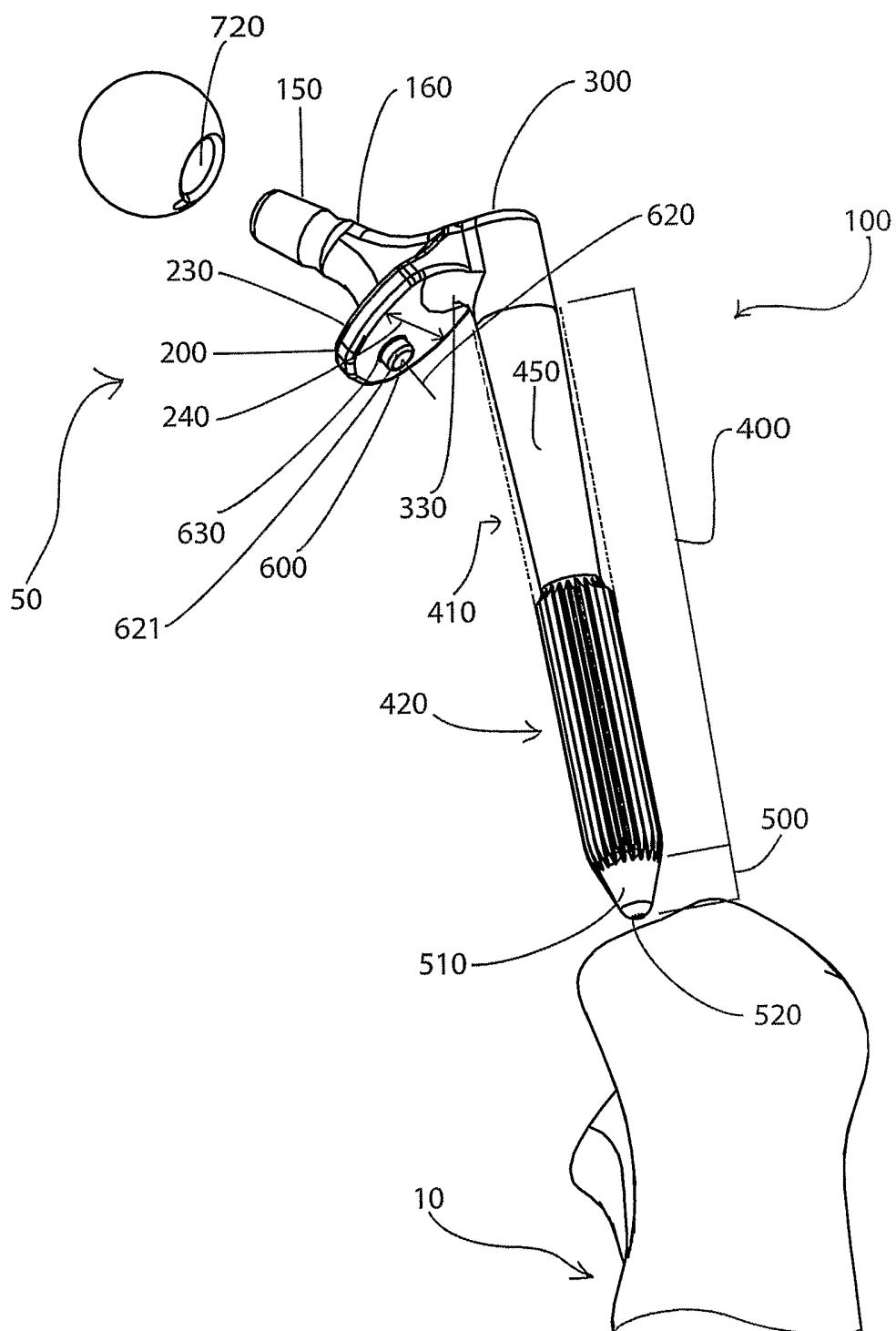


Fig. 3

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Inventor: Michael D. Ries, et al.

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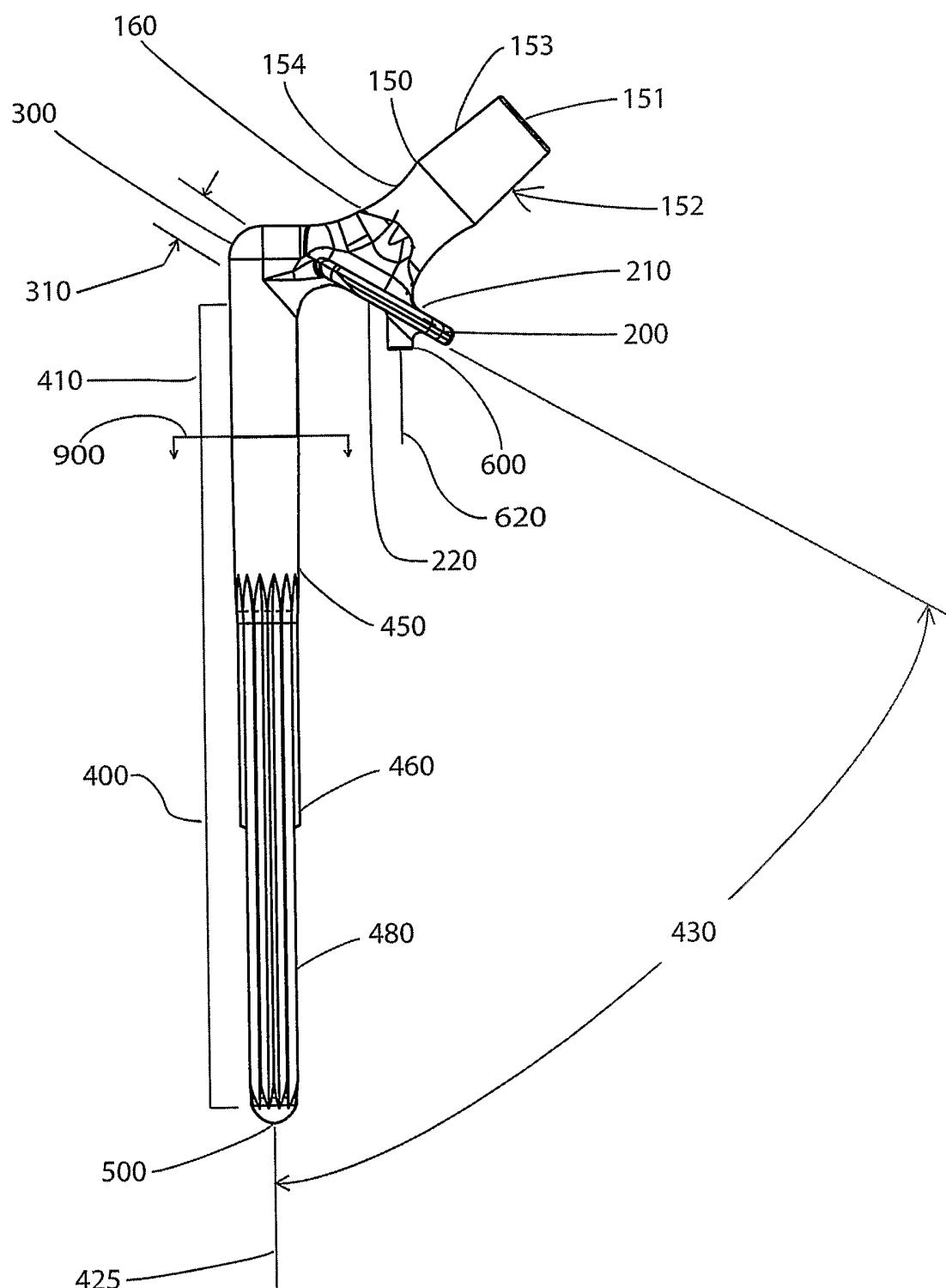


Fig. 4

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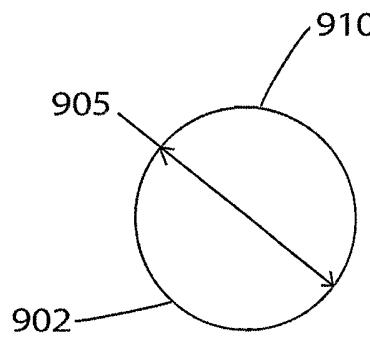


Fig. 4a

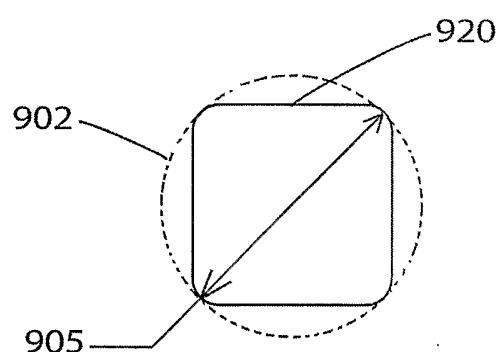


Fig. 4b

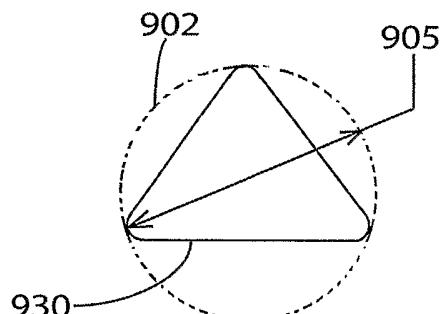


Fig. 4c

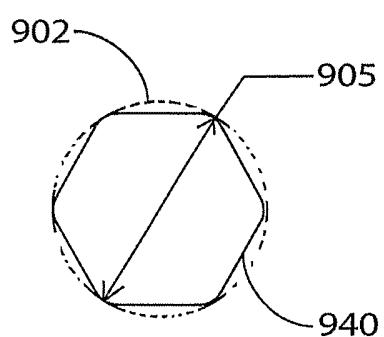


Fig. 4d

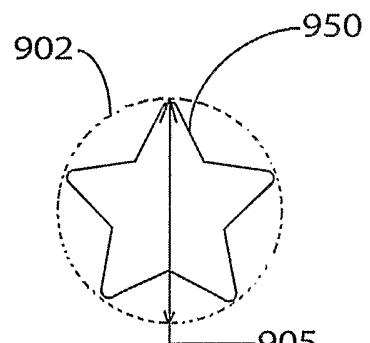


Fig. 4e

Title: Femoral Hip Prosthesis and Method of Implantation

Inventor: Michael D. Ries, et al.

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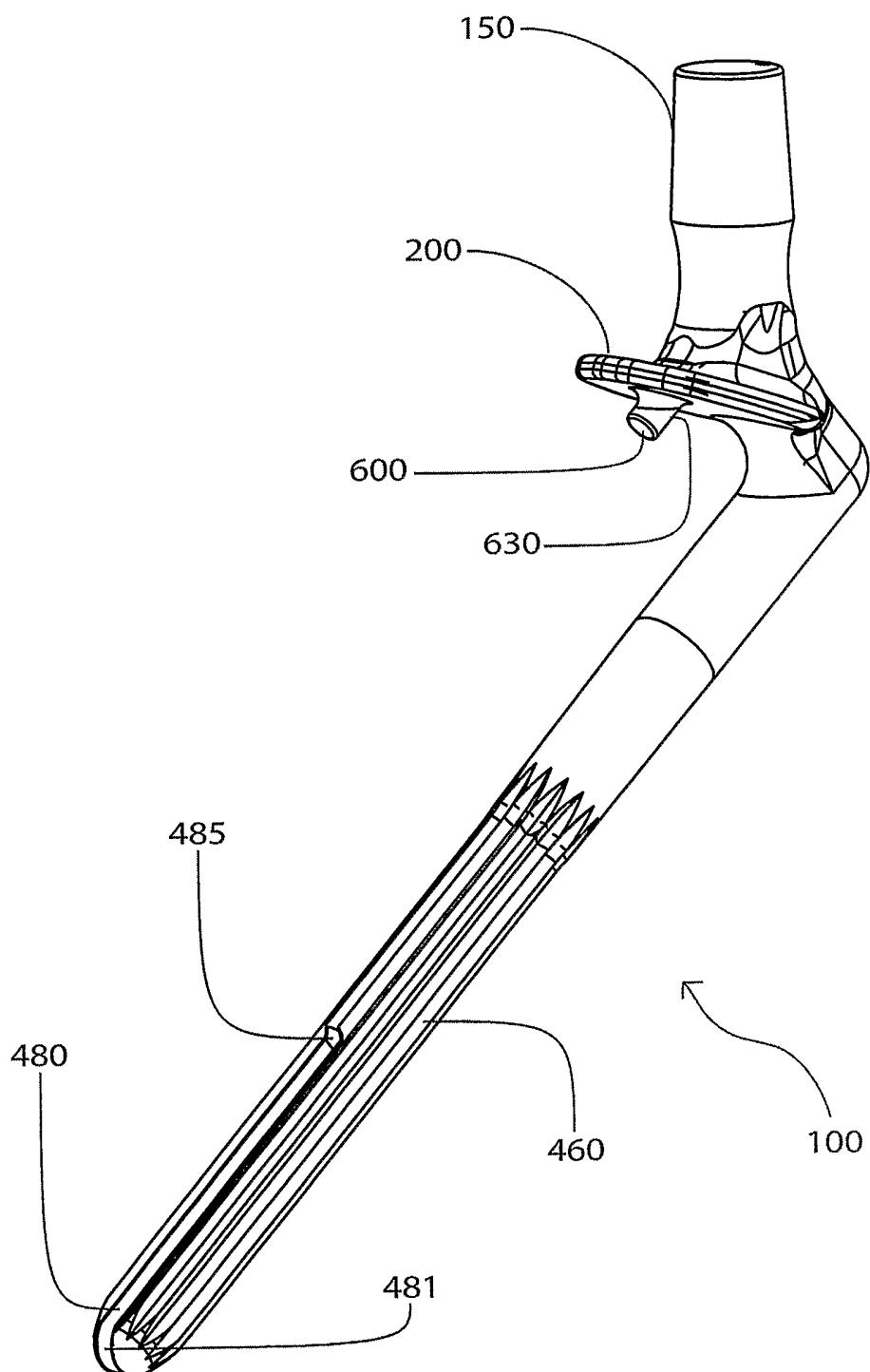


Fig. 5

Title: Femoral Hip Prosthesis and Method of Implantation

Inventor: Michael D. Ries, et al.

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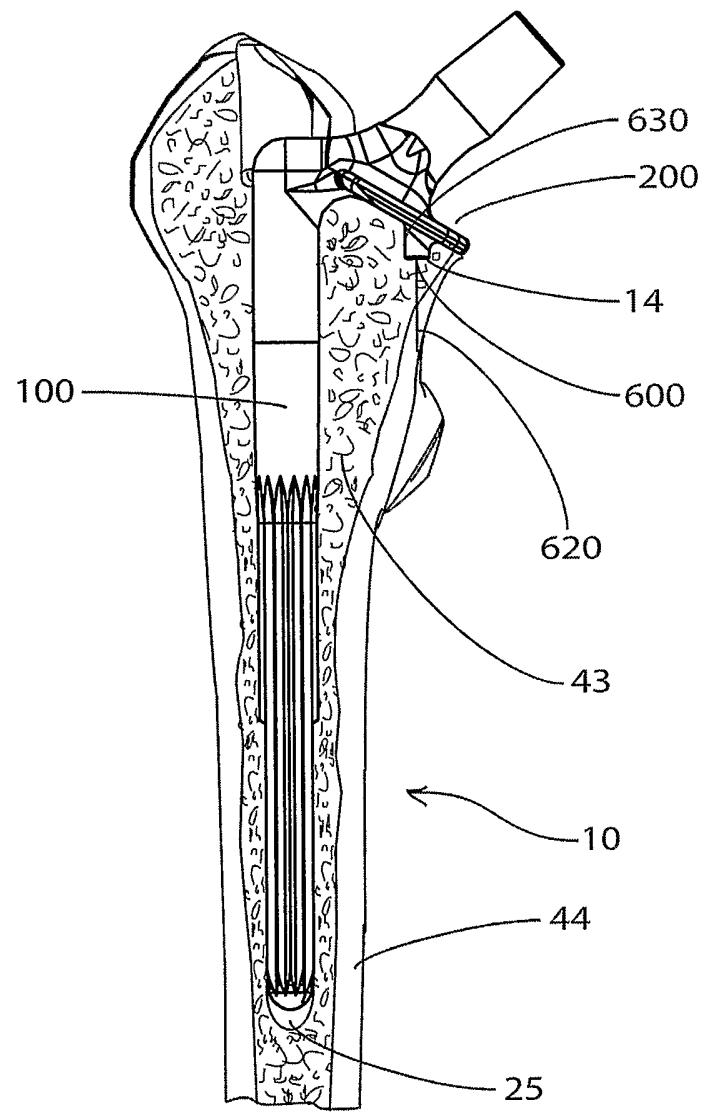


Fig. 6

Title: Femoral Hip Prosthesis and Method of Implantation

Inventor: Michael D. Ries, et al.

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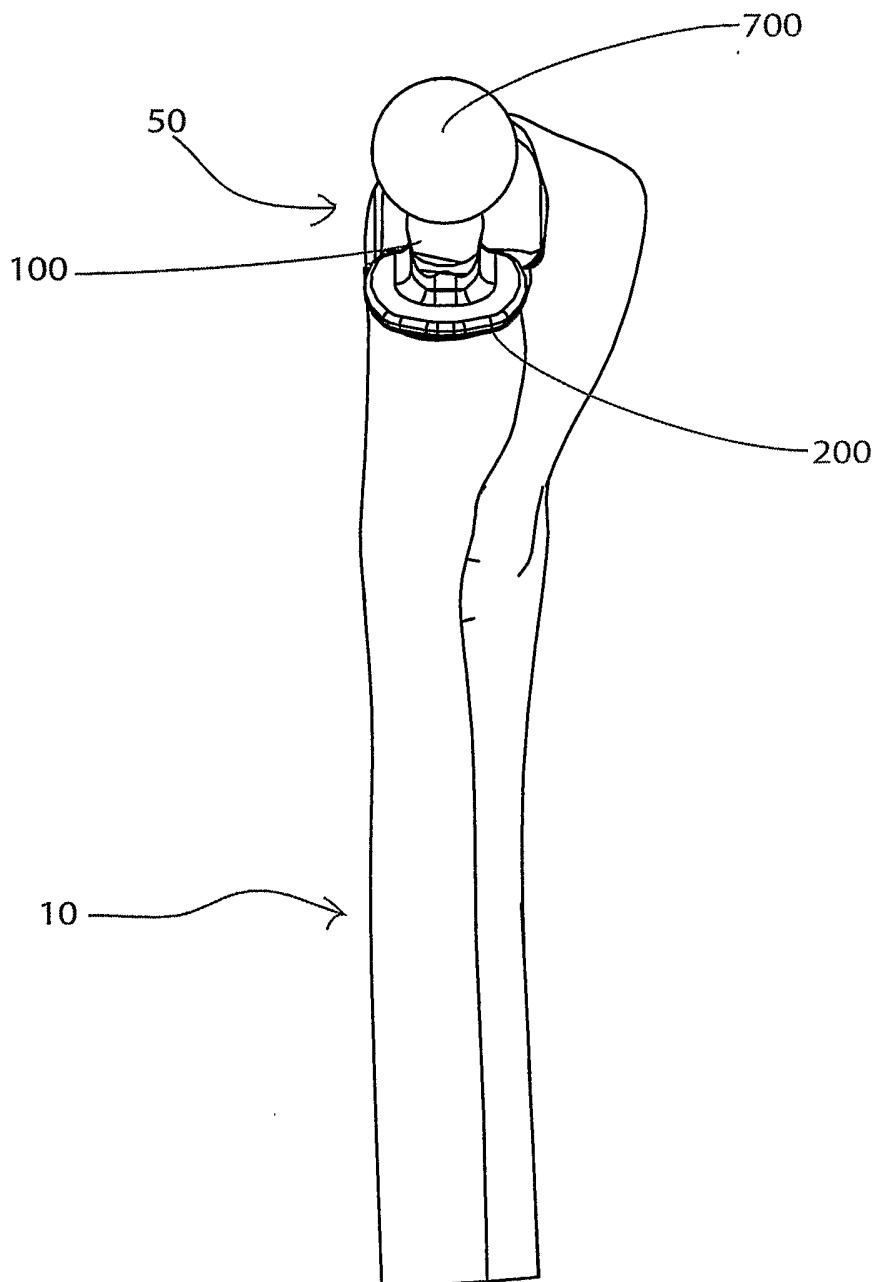


Fig. 7