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(54) **PROSTHESIS WITH COMPRESSIBLE STEM**

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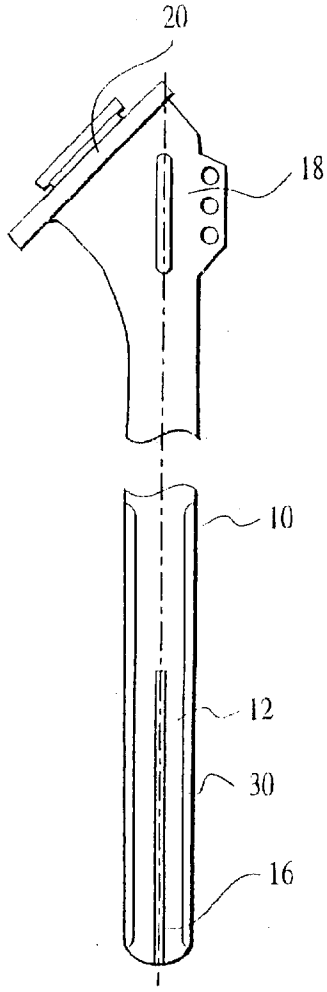
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(57) **ABSTRACT**

A series of humeral stems, each stem including an axial bore and longitudinal slots along the distal end to allow for distal compression. The compression force necessary to compress the distal diameter of each stem varies by stem diameter. Thus, as the stem diameter increases through the series, the compression force decreases. The axial bore and longitudinal slots together form a series of stem segments that assume the shape of the medullary canal, reducing the force exerted upon the canal by the humeral stem.



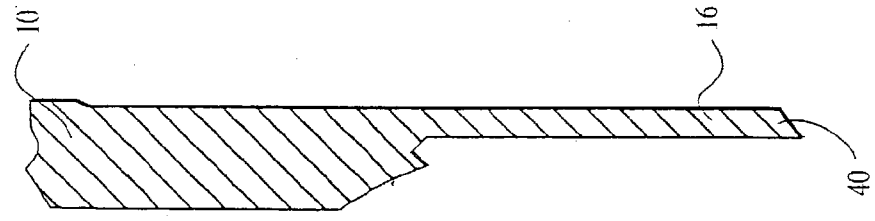


FIG. 4

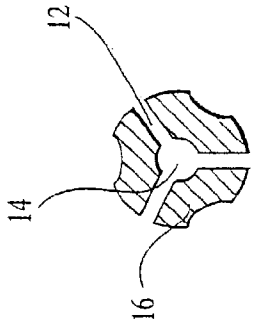


FIG. 3

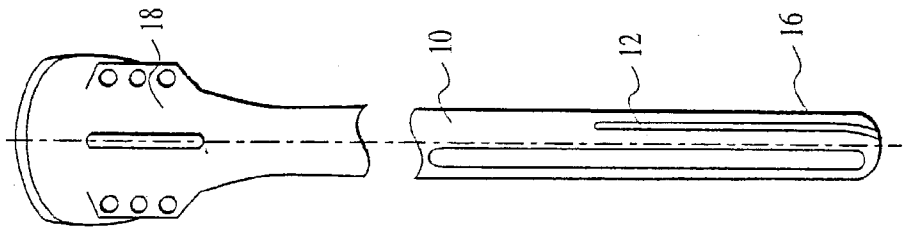


FIG. 2

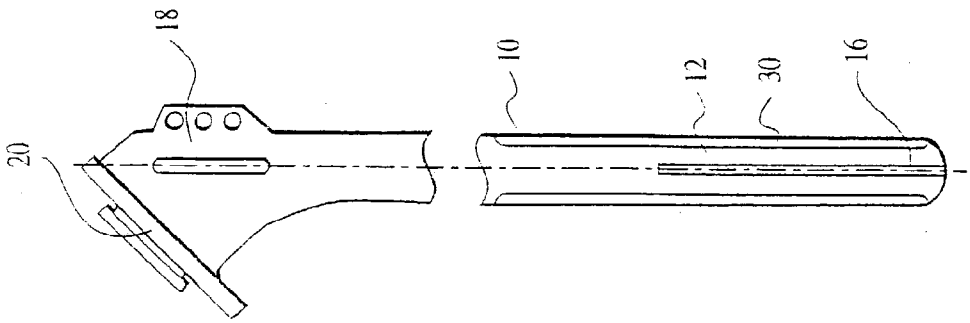


FIG. 1

PROSTHESIS WITH COMPRESSIBLE STEM

FIELD OF THE INVENTION

[0001] The present invention relates to a prosthesis having a compressible stem for insertion into a bone. More particularly, the present invention relates to a humeral stem having an axial bore and plurality of stem segments separated by longitudinal slots along the distal end. The plurality of stem segments allows the stem to assume the shape of the humeral medullary canal, the slots allowing for distal compression. The present invention also provides a series of such stems wherein the compression force necessary to compress the distal diameter of the stem varies by stem diameter. Thus, as the stem diameter increases, the compression force decreases, thereby relieving cortical wall pressure in potentially thinner cortical walls.

BACKGROUND OF THE INVENTION

[0002] Shoulder replacement operations involve replacing at least a portion of the proximal section of the humeral shaft with a prosthesis. Typically, the medullary canal of the humerus is reamed or bored at its upper end for receiving the prosthesis. A stem portion of the prosthesis is inserted into the reamed portion of the humerus in a secure position. The stem engages an artificial humeral head for receipt by the glenoid cavity.

[0003] Early shoulder prostheses were typically unitary structures including a stem, to be implanted within the humerus, and a head, to be positioned within the glenoid cavity of the scapula, attempting to directly mimic the unitary structure of the upper portion of the humerus that they were designed to replace.

[0004] Due to several problems with the a conventional unitary shoulder prosthesis, among them the necessity of maintaining a large inventory of differently configured prostheses in order to accommodate the varying morphologies of patients, assorted modular prostheses have been developed. A modular prosthesis generally consists of two parts: a stem that is mounted into the medullary canal of the humerus, and a head connected in some manner to the stem. The head replaces the bearing surface of the scapula to allow the movement of the shoulder. Different stem sizes and head sizes in a modular prosthesis provide the surgeon with some degree of inter-operative flexibility which facilitates reconstruction of the original anatomy of the patient. With a range of stem sizes and a range of head sizes available, the surgeon can choose a particular combination to suit the anatomy of each individual without having to have a large inventory of unitary humeral prostheses.

[0005] While modular prostheses have solved a number of problems prevalent in the prior art, others remain. For example, unitary as well as modular prostheses typically fail to maximize flexibility of the stem portion in order to reduce hoop stress during insertion of the stem.

SUMMARY OF THE INVENTION

[0006] The present invention relates to a humeral stem for use in a shoulder prostheses. In particular, the invention provides a humeral stem having a plurality of stem segments, preferably an odd number of stem segments, allowing the humeral stem to conform to the geometry of the medullary canal. The stem has increased stability and distal flexibility to relieve humeral pain. The invention also provides a series of such humeral stems. Generally, the stems are for use in a modular shoulder prosthesis. However, if desired, a unitary prosthesis could be designed having a stem configured as taught herein. The stem has utility in any prosthesis in which a stem of the prosthesis is to be inserted into the medullary canal of the bone, such as a shoulder, hip, knee, or finger prosthesis.

[0007] A modular humeral prosthesis generally comprises a stem to be fitted to a resected humerus and a head sized and configured to approximate the humeral head. Optionally, one or more connecting members may be used to connect the stem to the head in a variety of configurations. For example, the connecting member could be used to achieve varying degrees of eccentricity (offset) or tilt of the head to the stem. The humeral head has a spherical surface on one side and a flat face on the opposite side. The spherical surface replaces the bearing surface of the normal humeral head to allow movement of the shoulder.

[0008] The humeral stem is shaped for insertion into the reamed portion of the medullary canal of the humerus. The stem includes an axial bore and a plurality of stem segments separated by longitudinal slots around the distal end. The plurality of stem segments allows the stem to assume the shape of the humeral medullary canal, the slots allowing for distal compression. Providing an odd number of stem segments, preferably three, allows the stem segments to conform to the geometry of the medullary canal. The size and length of the bore as well as the length of the stem segments and slots are codependent and determine the compression force necessary to compress the distal diameter of the stems by a predetermined amount. In the series of stems, the bore, stem segments and slots are sized and configured such that the compression force needed to compress each stem decreases as the diameter of the stem increases. Preferably, a series of stems is provided having varying diameters.

[0009] Thus, the stem reduces hoop stress during insertion of the stem. The stem is especially effective in relieving cortical wall pressures in potentially thinner cortical walls.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1 a** side view of one embodiment of the present invention;

[0011] **FIG. 2** is a rear view of one embodiment of the present invention;

[0012] **FIG. 3** is a cross-sectional view of the distal end of one embodiment of the invention;

[0013] **FIG. 4** is a cross-sectional view of one embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] In the drawings, like structures are provided with like reference numerals.

[0015] **FIG. 1** illustrates a side view of a first embodiment of the present invention. Stem **10** generally comprises proximal portion **18** and distal portion **10**. Proximal portion **18** has engagement structure **20** provided thereon for engaging a functional element, for example a joint structure. An axial

bore **14** (**FIG. 3**) extends through distal portion **10**. Slots **12** are provided along distal portion **10** to divide the distal portion **10** into a plurality of stem segments **16**. Preferably, three or more slots are provided, and are equiangularly arranged about the circumference of the stem, to provide three stem segments **16**. While three stem segments **16** are preferred, any number of stem segments (above three) may be provided. Note, however, that there is a possibility of lateral slippage if an even number of stem segments are provided. Thus, it is recommended that an odd number of stem segments be provided. Further, an odd number of stem segments better enables the stem to conform to the geometry of the medullary canal. It is desirable that the stem be manufactured of titanium **6-4**. However, any suitable biocompatible material may be used to manufacture the stem.

[**0016**] The axial bore and slots **12** define a plurality of elongated, axially extending stem segments **16**. The stem segments **16** are capable of being radially compressed upon insertion into the medullary canal of a bone. Upon placement into the medullary canal, the stem segments **16** compress toward each other to assume the shape of the canal, thereby conforming to the geometry of the canal and reducing the pressure exerted on the canal by the stem. This is especially beneficial in the humeral medullary canal which is generally elliptical. A stem with three stem segments **16** readily assumes a generally oval shape within the medullary canal.

[**0017**] In a series of stems, the bore and slots **12** are sized and configured for differently sized stems in a series of stems such that as the stem diameter increases, the compressive force needed to compress the distal portion of the stem decreases. Grooves **30** are provided along stem segments **16** to for receiving cement to fix the stem in the intramedullary canal. Preferably, the bore, stem segments and slots are sized to enable a movement of at least 1 mm for each stem segment at its distal end. The length and diameter of the axial bore are cooperatively adjusted to dictate the compressive force required.

[**0018**] As one example, the length and diameter of the axial bore of a series of stems may be such as to provide the following values for 1 mm compression at the distal end of each stem segment:

DISTAL STEM DIAMETER (MM)	COMPRESSION FORCE (LBS)
10	20
12	16
14	12
16	10

[**0019**] A finite element analysis may be performed by bringing the stem segments towards the center of the axial bore until they contact one another, and measuring the compression force used in order to determine optimal configurations. Alternatively, a pressure gage may be inserted into the bore to measure the pressure applied, or a force gage may be used to indicate the radial force applied.

[**0020**] **FIG. 2** shows a rear view of one embodiment of the stem of the present invention. The stem is of approximately equal diameter along distal portion **10**, widening at the upper section of proximal portion **18**. The axial bore, stem segments **16** and slots **12** are provided along a length of distal portion **10** sufficient to allow for a desired amount of compression upon application of a compressive force, the diameter of the stem being measured along the stem length having the slots.

[**0021**] As seen in **FIG. 3**, showing a cross-sectional view of the distal end of the stem, axial bore **14** and slots **12** define a plurality of elongated, axially extending stem segments **16**. The size and configuration of bore **14** and slots **12** determine the compressive force necessary to compress the distal portion of the stem. Compressive force applied to the stem, by insertion of the stem into the medullary canal of a bone, for example, causes the stem segments **16** to be radially compressed. Grooves **30** are provided along the stem segments **16** to for receiving cement to fix the stem in the intramedullary canal.

[**0022**] **FIG. 4** depicts a cross-sectional view of a stem segment. Stem segment **16** extends along the longitudinal axis of distal portion **10** of the stem framing the axial bore. Stem segment **16** is rounded distally at end **40** to allow for smooth insertion into the medullary canal.

[**0023**] While various embodiments in accordance with the present invention have been shown and described, it is understood that the invention is not limited thereto, and is susceptible to numerous changes and modifications as known to those skilled in the art. Therefore, this invention is not limited to the details shown and described herein, and includes all such changes and modifications as encompassed by the scope of the appended claims.

What is claimed is:

1. A prosthesis having a stem for insertion in the intramedullary canal of a bone, the stem having a distal end portion with an axial bore formed therein and a plurality of slots formed in the stem and extending generally parallel to the bore axis and extending generally radially therefrom to define a plurality of stem segments, each stem segment being capable of radial compression upon application of a compression force, the stem segments being odd in number to restrain segments on opposite sides of the bore from slipping past each other when compressed together.

2. The prosthesis of claim 1, wherein the stem segments are positioned equiangularly about the bore axis.

3. The prosthesis of claim 1, wherein the stem is manufactured of titanium.

4. The prosthesis of claim 1, further comprising a groove provided along each stem segment for receiving adhesive.

5. A stem for insertion in the intramedullary canal of a bone, the stem comprising:

a proximal end portion having an engagement structure provided thereon; and

a distal end portion having an axial bore and an odd number of slots extending proximally therefrom, at least three slots being provided,

a plurality of elongated, axially extending stem segments being defined by the slots in the distal end portion, the stem segments being configured to enable the stem to conform to the shape of the intramedullary canal of the bone;

each stem segment being capable of radial compression upon application of a compression force.

6. The stem of claim 5, wherein the stem is manufactured of titanium.

7. The stem of claim 5, further comprising a groove provided along each stem segment for receiving adhesive.

8. A series of sized stems for insertion in the intramedullary canal of a bone, each stem comprising:

a proximal end portion having an engagement structure provided thereon; and

a distal end portion having an axial bore and an odd number of slots extending proximally therefrom, at least three slots being provided,

a plurality of elongated, axially extending stem segments being defined by the slots in the distal end portion, the stem segments being configured to enable the stem to conform to the shape of the intramedullary canal of the bone;

each stem of the series having a diameter, the diameter of the stems varying between stems;

each stem segment being capable of radial compression upon application of a compression force, the bore and slots of the series being sized and configured such that the compressive force needed to compress each of the segments decreases as the diameter of the stems increase.

9. The series of claim 8, wherein the stems are manufactured of titanium.

10. The series of claim 8, further comprising a groove provided along each stem segment for receiving adhesive.

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