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(58) Field of search
A5R

(54) **Implantable joint prosthesis**

(57) A prosthesis including a load receiving surface for receiving a load applied to the prosthesis, a first surface provided with interlocking means for interlocking fixation of a first bone portion and for transferring a portion of the applied load to the first bone portion, and a second surface which is smooth to cause an increase in the portion of the applied load applied to the first bone portion to increase the stress produced therein thereby substantially reducing stress shielding in the first bone portion and resorption of bone therein.

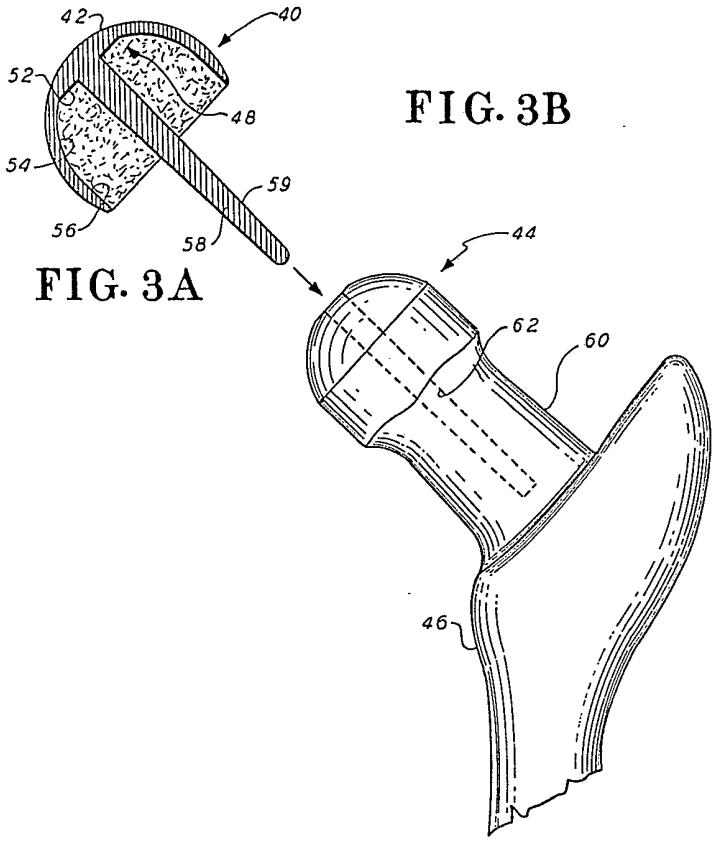


FIG. 3A

FIG. 3B

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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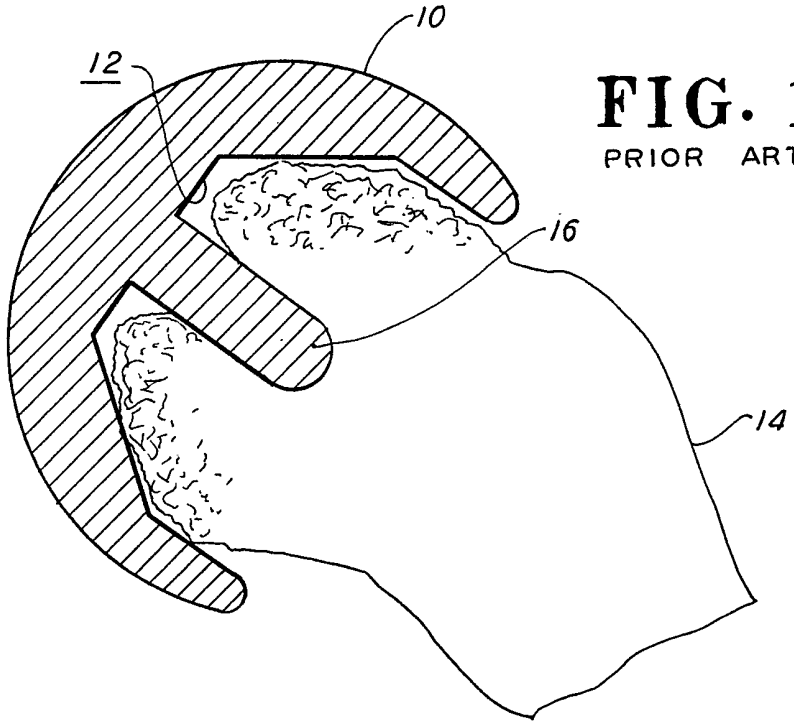


FIG. 1
PRIOR ART

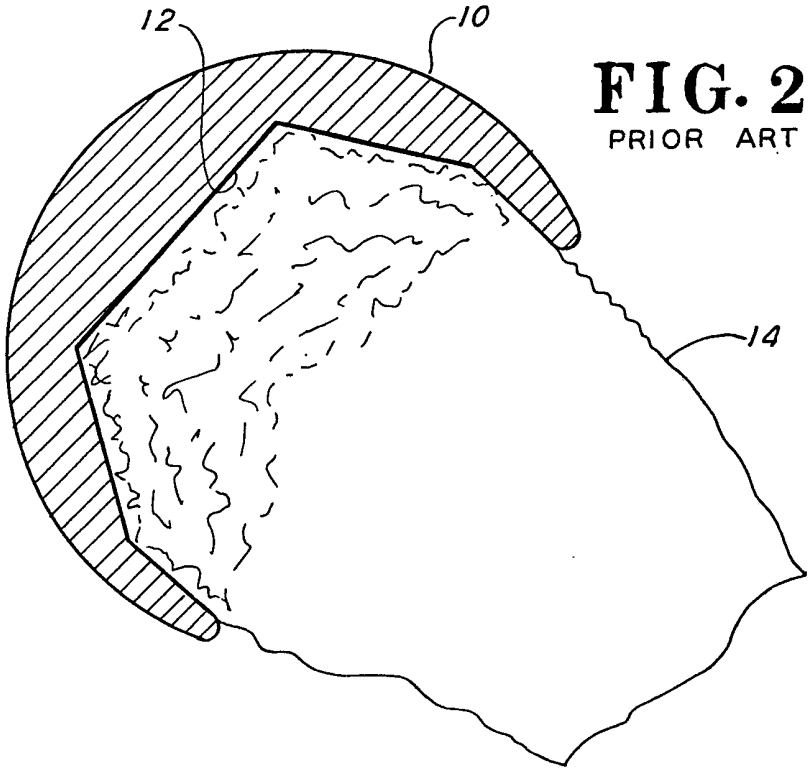


FIG. 2
PRIOR ART

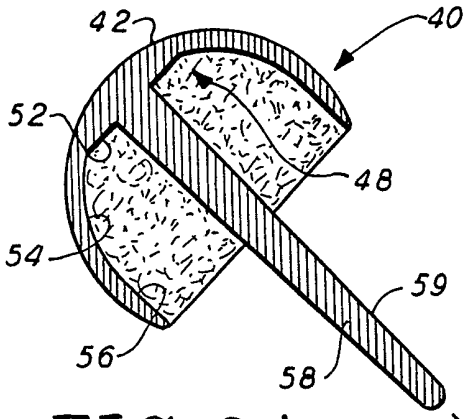


FIG. 3A

FIG. 3B

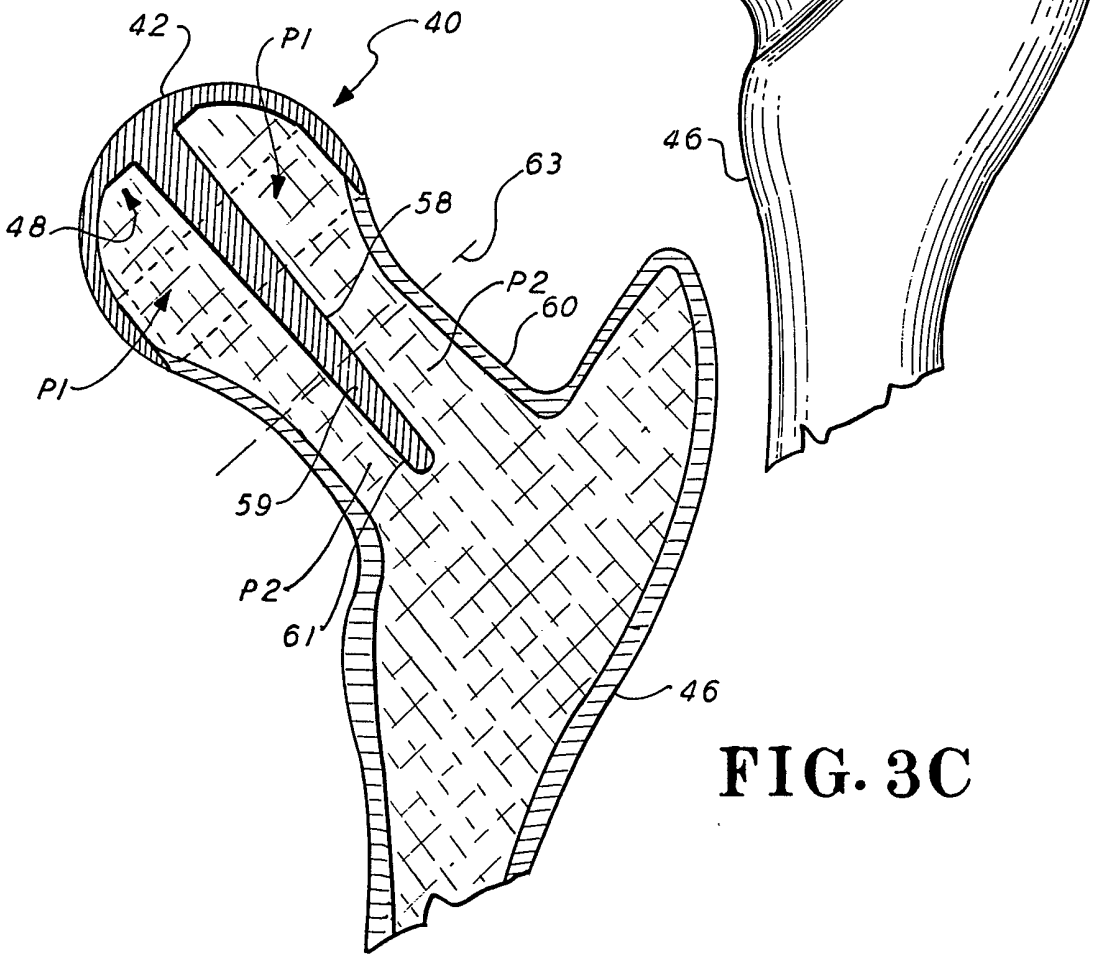


FIG. 3C

FIG. 4B

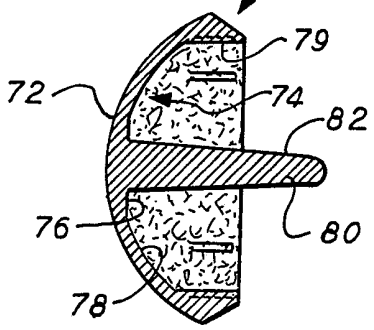


FIG. 4A

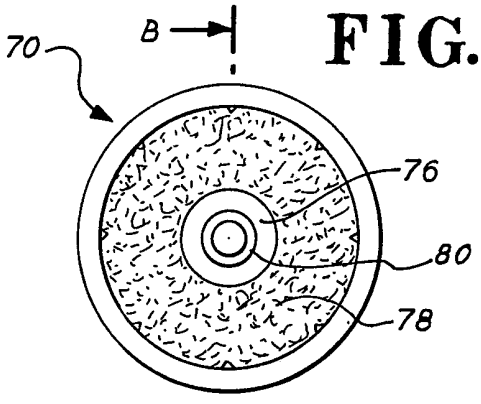
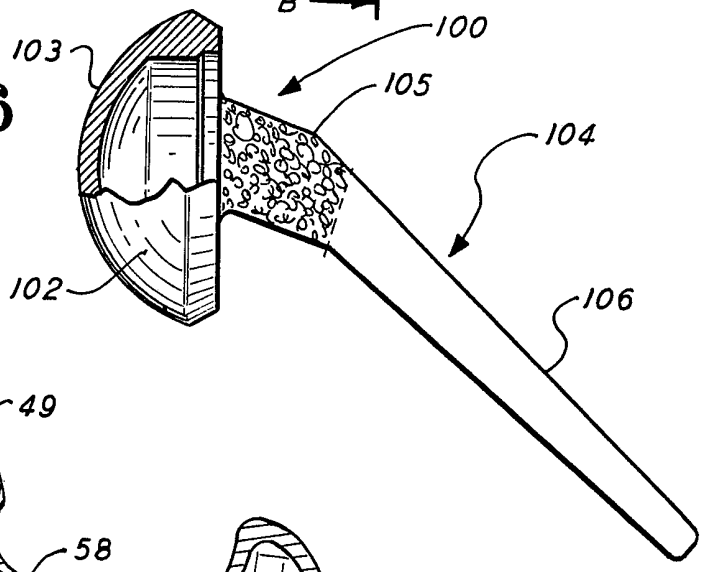


FIG. 6



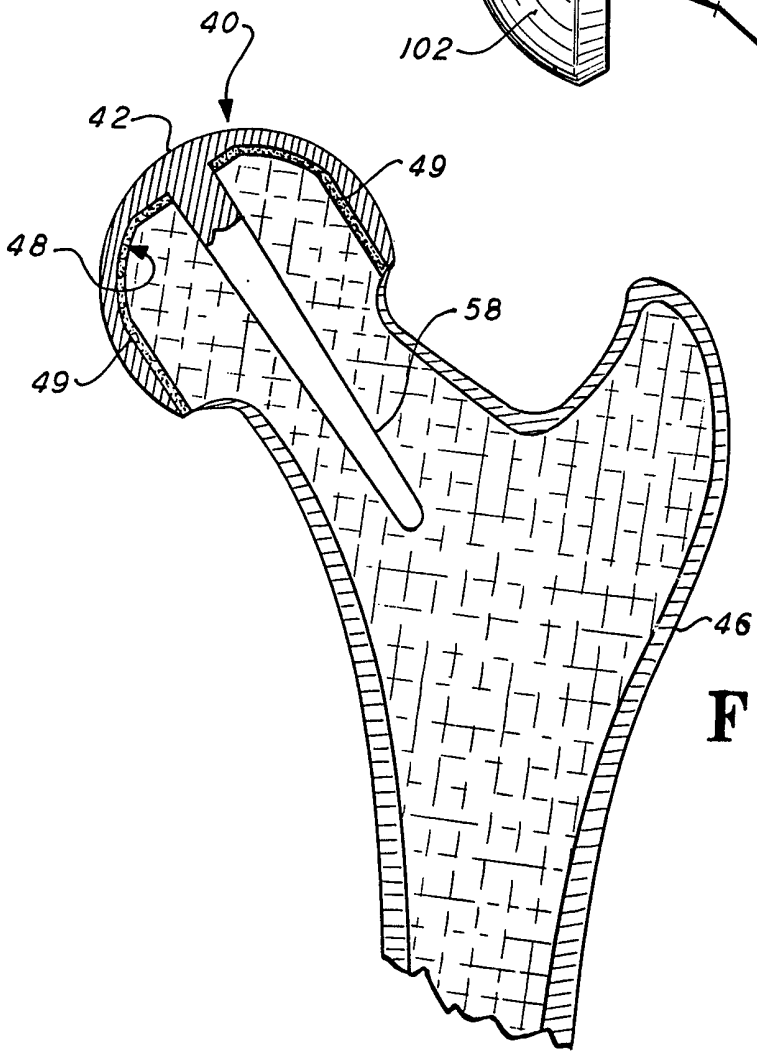


FIG. 8

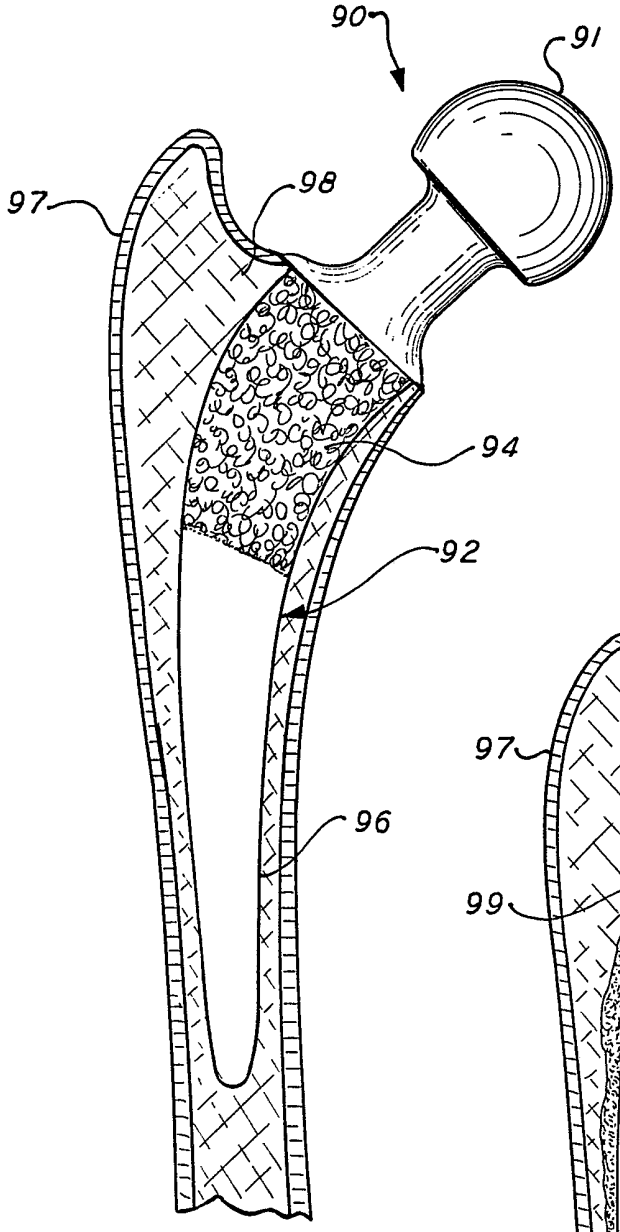
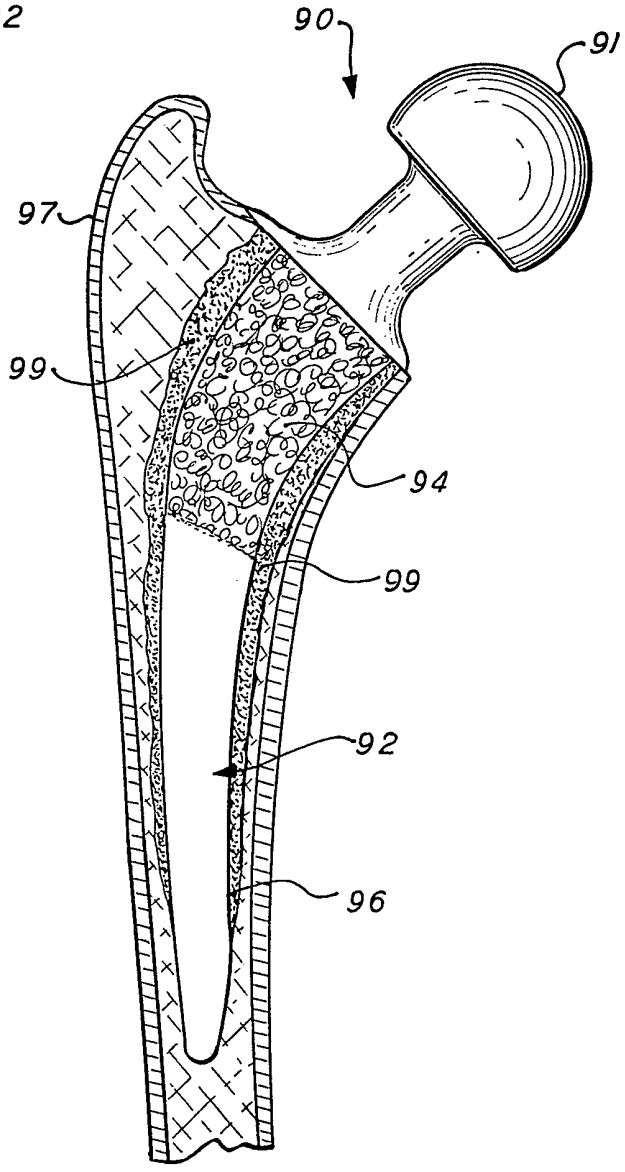


FIG. 5

FIG. 7



SPECIFICATION

Prosthesis with interlocking fixation and providing reduction of stress shielding

This invention relates generally to a partially porous coated prosthesis with interlocking fixation and the provision of stress shielding reduction.

Prosthesis fixation by growth of bone into porous-coated implants is well known in the art as an alternative fixation means to the use and known limitations of various other fixation means, for example screws, spikes, acrylic cement, etc. As is further known in the art with regard to such porous-coated implants, bone has been shown to grow into the voids of porous coated prostheses producing a mechanically effective biological bond. The interlocking of viable bone with the porous prosthetic surface has been found to provide a three-dimensional fixation which resists both tensile and shear stress at the implant-bone interface.

A porous coating can also be employed to improve the bonding ability of bone cement. Where cement is used in apposition to a smooth prosthetic surface, as is often the case, one obtains a relatively weak bond at the prosthesis-cement interface. Properly applied bone cement, however, produces a strong cement to bone interface wherein the cement is forced into the interstices of the bone. The strength of fixation is limited by the strength of the relatively weak prosthesis to cement interface and does not utilize effectively the strength of the bone to cement interface. The use of a porous surface prosthesis, however, produces interlocking at both the cement-bone and prosthesis-cement interfaces thus producing three-dimensional fixation which is resistant to both tensile and shearing loads.

Stress shielding is a problem that it is also known in the porous-coated implant art which stress-shielding is taught in detail in an article entitled, "POROUS INGROWTH FIXATION OF THE FEMORAL COMPONENT IN A CANINE SURFACE REPLACEMENT OF THE HIP," by Anthony K. Hedley et al., published March 1982, No. 163, Clinical Orthopaedics & Related Research. As taught in detail in the Hedley el al. article, and as shown diagrammatically in Figure 1 of the drawings, which Figure is taken from Figure 4 of the Hedley article, it is known and illustrated that upon the entire interior surface 12 of a femoral hip surface replacement component 10 being porous-coated, and upon the prosthesis being implanted in the head of the femur 14, bone ingrowth will occur at the interface between the bone and the porous coated prosthesis stem 16 providing good fixation but it has been found, as illustrated, that the load or stress will be transferred to this interface and the interface between the head of the femur and the interior surface 12 of the prosthesis will be shielded from the load or stress which is transferred to the interface between the bone and the porous coated stem 16 and this stress-shielding has been found to cause resorption and hypertrophy at the head of the bone causing the shown void between the head of the femur 14 and the interior surface 12 of the prosthesis 10. As is further known to those skilled in the art, interior wall fixation and bone ingrowth between the head of the femur 14 and the interior surface 12 of the prosthesis 10 is more desirable than fixation and bone ingrowth between the femur 14 and porous-coated surface of the stem 16 because it provides a more uniform loading between the prosthesis and the femur and a more uniform transfer of stress from the prosthesis to the resected femoral head. As is also taught in the Hedley et al. article, in Figure 6 thereof, and as shown in Figure 2 of the drawings taken from such Figure 6, the stress-shielding problem associated with the porous coating of the surface of the stem 16 of the prosthesis 10 of Figure 1 can be eliminated by eliminating the stem thereby producing direct bone ingrowth between the resected head of the femur 14 and the entire interior surface 12 of the prosthesis 10 achieving the above-noted preferable fixation between the bone and the interior wall of the prosthesis with its attendant uniform loading and stress transfer.

Although the use of a stem is not necessary for the purpose of providing axial fixation in a bone capping type prosthesis as described in Hedley, in other applications a stem is important in providing initial fixation in order to provide fixation means while bone ingrowth occurs in order to minimize patient or joint immobilization for an undesirably lengthy period of time or to help prevent motion between the bone and prosthesis interfaces which can occur as a result of patient movement wherein such motion can prevent ingrowth by repeated rupture of early bone ingrowth with resultant fixation failure.

The use of stems also can provide alignment capabilities improving the positional accuracy of placement of the prosthesis. Further, stems can provide fixation which augments resistance to the joint reaction loads and can be useful in preventing possible fractures.

Stress shielding can also occur with cemented prostheses where the cement provides the strong interlocking between implant and bone. This phenomenon has been seen clinically on well fixtured hip stem prostheses in cases where there is excellent distal fixation of the stem. This situation produces load transfer from prosthesis to bone at the distal aspect of the prosthesis leaving the bone proximal to this region unloaded thereby resulting in stress shielding and resorption of the proximal bone.

The auxiliary stem functions, including alignment, initial fixation fracture prevention, and load augmentation can all be considered as providing secondary fixation since all provide at some time a load transfer function. The alignment function provides load transfer between prosthesis and bone during implantation wherein this loading controls positioning of the component during implantation. Preventing of fracture also involves load transfer preventing overloading of predetermined regions of bone.

For a prosthesis made of material, such as metal or ceramic, substantially stiffer than bone, and where firm fixation and substantial load transfer occurs in bony regions remote from the load application surface, loading of the bony regions nearer the load applicaton surface is substantially reduced

shielding the nearer bone against stress. On the other hand, if firm fixation and substantial load transfer occurs in bony regions near the load application surface, loading of bone further from the load application surface is not substantially reduced and therefore such bone is not substantially protected against stress. Thus, for relatively stiff protheses it is desirable to design fixation so as to minimize load transfer regions of bone away from the load application surface in order to minimize bone resorption of bone nearer the load application surface.

Accordingly, it is a primary object of the present invention to provide an improved prosthesis providing interlocking fixation between the prosthesis and a bone and reducing the above-noted stress shielding problem.

Summary of the invention

The present invention overcomes the above-noted stress shielding problem by providing a prosthesis including a load receiving surface for receiving a load applied to the prosthesis, a first surface provided with interlocking means for interlocking fixation of a first bone portion and for transferring a portion of the applied load to the first bone portion, and a second surface which is smooth to cause an increase in the portion of the applied load applied to the first bone portion to increase the stress produced therein thereby substantially reducing stress shielding in the first bone portion and resorption of bone therein.

A surface is said to be smooth in the context of the present invention if the strength of the bond obtainable between such a surface and material adjacent to it is substantially less than that obtainable between an interlocking surface and a similar adjacent material.

In a preferred embodiment of the present invention, the first surface is a porous coating for either direct bone ingrowth interlocking fixation or for engaging cement for securing the prosthesis to the bone.

Description of the drawings

Figures 1 and 2 are diagrammatical illustrations of stress shielding from the prior art as noted above;

Figures 3A, 3B, and *3C* are diagrammatical illustrations of a femoral hip surface replacement prosthesis embodying the present invention, with the prosthesis of Figures 3A and 3C shown in cross-section;

Figures 4A and *4B* show a humeral surface replacement prosthesis embodying the present invention, with Figure 4B being a cross-sectional view taken substantially along the plane B-B in the direction of the arrows in Figure 4A;

Figure 5 is an illustration of a femoral stem prosthesis embodying the present invention and using a porous coating for direct bone ingrowth interlocking fixation;

Figure 6 is a view, in partial cross-section, of a humeral stem prosthesis embodying the present invention;

Figure 7 is a view of a femoral prosthesis embodying the present invention and illustrating a porous coating for use in conjunction with cement; and

Figure 8 is a femoral surface replacement prosthesis, similar to the one illustrated in Figure 3A, but showing the prosthesis used in conjunction with cement.

Description of the preferred embodiments

Referring now to Figures 3A, 3B and 3C, there is shown a hip surface replacement prosthesis 40 emboying the present invention and including a smooth, highly polished, spherical outer applied load receiving surface 42, a porous-coated interior primary surface indicated by general numerical designation 48, and a longitudinally extending stem 58 extending centrally from the interior of the prosthesis. The prosthesis 40 is for being implanted in the resected head 44 of the femur 46 with the stem 58 being driven into a prepared hole 62 formed in the neck 60 of the femur 46 and with the resected femur head 44 being prepared, in a manner known to those skilled in the prosthesis implantation art, to be complementary in shape to the interior surface of the prosthesis 40. The outer applied load receiving surface 42 of the prosthesis 40 is for replacing the articular surface of the head of the femur and for receiving the load applied to the prosthesis during articulation. The porous-coated interior surface 48 is defined by a flat central portion 52 continuing into a spherical intermediate portion 54 and continuing into a cylindrical interior surface 56; the interior surface 48 is for interlocking fixation with the femur head 44 and for providing primary transfer of the applied load to the femoral head. The porous-coated interior surface 48 provides interlocking fixation between the prosthesis 40 and the resected head of the femur by direct bone ingrowth, over a period of time, of the resected femoral head into the porous-coated interior surface 48 if cement is not used therebetween or, if cement is so used, the interior surface 48 provides the interlocking fixation with the resected femoral head 44 through the intermediate cement.

The stem 58 is provided with a smooth secondary outer surface 59 and provides secondary functions such as: alignment since the stem engages the prepared hole 62 in the femoral neck and this engagement guides the implant onto the resected femoral head thereby improving accuracy of implantation of the prosthesis; initial fixation by the stem 50 being wedged into the hole 62; secondary transfer of the applied load to the femur; and resistance against fracture of the neck 60 which fracture often occurs in the region where the femoral neck joins the head with such fracture being a common complication of hip surface replacement surgery. Since the surface 59 of the stem 58 is smooth, e.g. not porous-coated, no direct bone ingrowth will occur between the femur 46 and the stem 58 and, where cement is used therebetween, the connection between the smooth stem surface 59 and the femur will be weak due to the smoothness of the surface. Consider the load transfer by the region of the secondary stem surface 59 adjacent to the portion P2-P2 of the femoral neck downwardly of the

dashed line 63 in Figure 3C. If the region 61 is smooth load transfer to bone portion P2-P2 will be reduced. Similarly, if the entire stem is smooth stress protection in the head and neck will be further reduced and hence unlike the prior art prosthesis illustrated in Figure 1, any tendency of the bone portion P1-P1 to resorb will be substantially reduced.

It will be understood by those skilled in the art that the teaching with regard to the identification of bone portions P1-P1 and P2-P2 with regard to Figures 3A, 3B and 3C is diagrammatical and that in actuality such bone portions are not specifically delineatable and that the teaching of the invention is merely by way of illustration particularly with regard to the diagrammatical, not actual, illustration of Figure 3C.

Referring now to Figures 4A and 4B, there is shown a humeral surface replacement prosthesis 70 embodying the present invention and for being implanted in the head of a humerus (not shown) to replace the articular surface of the humeral head. The prosthesis 70 is provided with a smooth, highly polished spherical outer load receiving surface 72 for replacing the articular surface of the humeral head and is further provided with a porous-coated primary load transfer interior surface indicated by general numerical designation 74 defined by a flat central portion 76 continuing into a spherical portion 78 continuing into a cylindrical portion 79. Further the prosthesis 70 is provided with a stem 80 having a smooth outer surface 82 comprising the secondary surface, which outer surface 82 is smooth and non-porous coated and which stem is generally longitudinally extending from the interior of the prosthesis and perpendicular to the flat central interior surface 76. It will be understood by those skilled in the art that the humeral surface replacement prosthesis 70 is the structural and functional equivalent of the femoral surface replacement prosthesis 40 described above and that the reduction in stress shielding provided in this embodiment is accomplished in the same manner that the stress shielding reduction was provided in the femoral prosthesis 40 embodiment of Figures 3A, 3B, 3C.

Shown in Figure 5 is a femoral stem prosthesis embodying the present invention and indicated by general numerical designation 90. The prosthesis includes a smooth, highly polished load receiving spherical head 91 for replacing the articular surface of the femoral head and a stem indicated by general numerical designation 92 having a porous-coated primary load transfer upper portion 94 and a smooth or non-porous coated secondary load transfer lower portion 96.

The porous-coated upper portion 94 of the stem 92 experiences direct ingrowth from the femur and hence places the prosthesis in interlocking fixation with the femur; the non-porous coated lower portion 96 of the stem 92 provides initial and secondary fixation of the prosthesis into the femur and by being smooth or non-porous coated, provides, in combination with the porous-coated upper portion 97, substantial increase in loading and reduction of stress shielding of the portion of the femur adjacent the porous-coated upper portion 94 of the prosthesis 90 in the same manner as taught above with regard to the combination of the porous-coated interior surface 48 and smooth outer surface 59 of the stem 58 of the femoral prosthesis 40.

The humeral stem prosthesis shown in Figure 6 also embodies the present invention and is indicated by general numerical designation 100. This prosthesis is for being implanted in the head of the humerus (not shown) and is provided with a spherical head 102 at its upper portion for replacing the articular surface of the humerus with the outer surface 103 of the spherical head providing the load receiving surface for loads applied to the humerus. The humeral stem prosthesis 100 is further provided with a generally downwardly extending stem 104 for implantation in the humerus; the upper portion of the stem 105 is the primary load transfer surface and is porous-coated for either direct bone ingrowth interlocking fixation with the humerus or for use in conjunction with cement for such interlocking fixation between the prosthesis and the humerus. The lower portion 106 of the stem 104 is a smooth, e.g. non-porous-coated, secondary surface providing the above-noted secondary functions and for preventing interlocking fixation between the prosthesis and the humerus. The smooth secondary stem surface portion 106 provides the same reduction of stress shielding function as indicated above with regard to the smooth secondary surface 59 of the stem 58 of the femoral prosthesis of Figures 3A, 3B, and 3C.

Figure 7 shows the femoral stem prosthesis 90 of Figure 9 wherein the porous-coated primary load transfer upper portion 94 of the stem is used not for direct bone ingrowth interlocking fixation but instead is used in conjunction with cement 99, shown on either side of the porous coating 94, for securing the prosthesis to the femur 97 thereby providing the interlocking fixation between the prosthesis and the femur. The smooth secondary femoral stem surface portion 96 provides in combination with the primary load transfer porous-coated stem surface portion 94 the same increased loading and stress shielding reduction function as described above with regard to the teachings of the embodiment of Figure 5.

Similarly, the femoral surface replacement prosthesis shown in Figure 8 is the same as the femoral surface replacement prosthesis 40 of Figures 3A, 3B and 3C but is shown in Figure 8 for use in conjunction with cement 49 for providing the interlocking fixation between the prosthesis 40 and the femur 46; otherwise, the prosthesis 40 of Figure 8 performs the same stress shielding reduction functions as taught above with regard to the prosthesis 40 of Figures 3A, 3B and 3C.

The prostheses shown may be made of Co-Cr-Mo surgical alloy of Ti-4A1-6Va alloy or commercially pure titanium. The porous coating material may or may not be the same as the substrate metal, and may be of a polymeric material or ceramic. For example, one may use Ti-4A1-6Va substrate wth commercially pure titanium porous coating or one may use a Co-Cr-Mo alloy coating on a Co-Cr-Mo alloy substrate. Alternately, stainless steel substrate may be used with a bonded ultra-high molecular weight polyethylene porous surface. A further alternate is a Co-Cr-Mo alloy substrate with a porous

ceramic coating. Other combinatons of materials and coatings are possible and will reveal themselves to one of ordinary skill in the art.

It will be understood by those skilled in the art that the present invention may be embodied in various other prostheses other than those shown in Figures 3-8, for example finger, toe, an elbow prosthesis, and the preferred embodiments illustrated in the drawings are merely illustrative and not limiting of the present invention.

It will still be further understood by those skilled in the art that many variations and modifications may be made in the present invention without departing from the spirit and scope thereof.

CLAIMS

1. In a prosthesis for interlocking fixation to a bone, wherein the prosthesis includes a load receiving surface for having a load applied thereto, a first predetermined surface in interlocking fixation with a first bone portion and for transferring a first portion of said load to said first bone portion producing stress therein, a second predetermined surface in interlocking fixation with a second bone portion and for transferring a second portion of said load to said second bone portion, said first predetermined surface and said first bone portion respectively near said load receiving surface and said second predetermined surface and said second bone portion, whereby stress shielding is produced in said first bone portion due to said interlocking fixation between said second pre-determined surface and said second bone portion which reduces said first portion of said load transferred to said first bone portion by said first predetermined surface,
WHEREIN THE IMPROVEMENT COMPRISES:
said second predetermined surface being smooth to substantially eliminate said interlocking fixation between said second predetermined surface and said second bone portion thereby reducing the portion of said applied load transferred to said second bone portion by said second predetermined surface thereby increasing the portion of said applied load transferred to said first bone portion by said first predetermined surface thereby increasing said stress produced in said first bone portion to substantially reduce said stress shielding therein and resorption of said first bone portion.

2. A prosthesis according to Claim 1 wherein said prosthesis is a surface replacement prosthesis and wherein said load receiving surface is an exterior surface for replacing an articular surface of the bone, and wherein said first predetermined surface is a porous coated upper interior prosthetic surface of predetermined shape for direct bone ingrowth interlocking fixation of said prosthesis to said bone and wherein said second predetermined surface is the smooth outer surface of a member extending outwardly from said interior surface and which smooth outer surface is for preventing interlocking fixation between said prosthesis and said bone, said member also for providing initial and secondary fixation of said prosthesis to said bone, for aligning said prosthesis with said bone and for providing fracture resistance of said bone across said member.

3. A prosthesis according according to Claim 5 wherein said surface replacement prosthesis is a hip surface replacement prosthesis, wherein said exterior surface is smooth and spherical and wherein said porous-coated upper interior surface is defined by a flat central portion continuing into a spherical portion concentric with said smooth spherical exterior surface and continuing into a cylindrical portion and wherein said member is a longitudinally extending stem extending from said interior surface perpendicular to said flat central portion.

4. A prosthesis according to Claim 5 wherein said prosthesis is a humeral surface replacement prosthesis wherein said exterior surface is spherical and smooth and wherein said interior surface is defined by a flat central portion continuing into a spherical portion concentric with said smooth spherical exterior surface and continuing into a cylindrical portion and wherein said member is a longitudinally extending stem extending from the interior of the prosthesis perpendicular to said flat central portion.

5. A prosthesis according to Claim 1 wherein said prosthesis is a femoral stem prosthesis having a spherical head at its upper portion for replacing the articular surface of the femur and said spherical head providing said load receiving surface, said femoral stem prosthesis having a downwardly extending stem for implantation to the intramedullary canal of the femur, wherein said first predetermined surface is a porous coated upper portion of said stem for direct bone ingrowth interlocking fixation between said prosthesis and said femur and wherein said second predetermined surface is a smooth lower portion of said stem for preventing interlocking fixation between said prosthesis and said bone.

6. A prosthesis according to Claim 1 wherein said prosthes is a humeral stem prosthesis having a spherical head at its upper portion for replacing the articular surface of the humerus and said spherical head providing said load receiving surface, said humeral stem prosthesis having a downwardly extending stem for implantation to the intramedullary canal of the humerus, wherein said first predetermined surface is a porous coated upper portion of said stem for direct bone ingrowth interlocking fixation between said prosthesis and said humerus and wherein said second predetermined surface is a smooth lower portion of said stem for preventing interlocking fixation between said prosthesis and said bone.

7. A prosthesis for implantation into a bone, comprising:
a first portion and a stem, said first porion providing a cavity and said stem being tapered for driving implantation into the bone to wedge a bone portion into the cavity to provide at least initial fixation of the prosthesis to the bone and to place the wedged bone portion in a state of compression, said stem being smooth to substantially prevent interlocking fixation between said stem and said bone which in combination with said bone portion being in said state of compression substantially eliminates stress shielding thereof.

8. A prosthesis according to Claim 7 wherein said bone is provided with a hole, wherein said first portion is provided with a generally concave interior surface, wherein said tapered stem extends generally centrally from said concave interior surface, wherein said cavity is generally annular and resides between the upper portion of the tapered wedge and said concave interior surface, said tapered wedge being larger in diameter than said bone hole.

9. A prosthesis according to Claim 8 wherein said first portion is generally cap shaped having a generally spherical outer surface.

10. A prosthesis according to Claim 9 wherein said prosthesis is a femoral surface replacement prosthesis.

11. A prosthesis according to Claim 9 wherein said prosthesis is a humeral surface replacement prosthesis.

12. A prosthesis substantially as herein described with reference to Figures 3A, 3B and 3C, Figures 4A and 4B, Figure 5, Figure 6, Figure 7, or Figure 8 of the accompanying drawings.

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