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(54) **METHOD FOR FORMING AN INTERVERTEBRAL IMPLANT**

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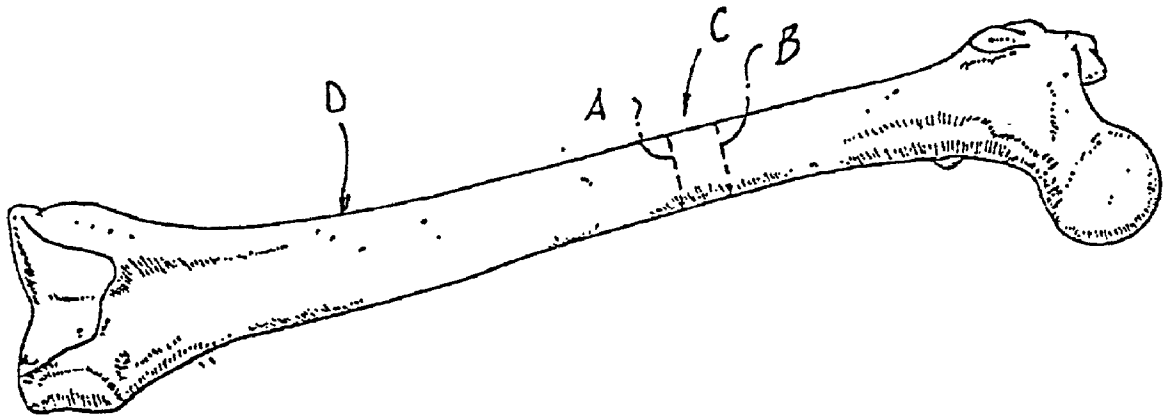
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(52) **U.S. Cl. 623/17.11; 623/23.63**

(57) **ABSTRACT**

An intervertebral implant having a composite wedge/dowel configuration is provided. The intervertebral implant includes a central body portion and a pair of radially extending wings. The radially extending wings can be tapered from a first end of the implant to the second end of the implant along an axis parallel to the longitudinal axis of the central body portion. Alternately, the radially extending wings can be tapered along an axis transverse to the longitudinal axis of the cylindrical body portion or along any other axis between parallel and transverse to the longitudinal axis. A throughbore or plurality of throughbores extend from a top surface of the implant through the implant to a bottom surface of the implant. The implant may be formed from a cortical ring cut from the diaphysis of a long bone by milling the top and bottom surfaces of the cortical ring to form the substantially central body portion and the tapered radially extending wings. The cortical ring is milled such that the intramedullary canal of the cortical ring defines a throughbore in the central body portion of the implant. The sidewalls of the implant may be machined to form a substantially rectangular shape or the implant can be left to have a substantially circular configuration. Alternately, the implant may be formed of any biocompatible material having the requisite strength requirements via any known process, i.e., molding.



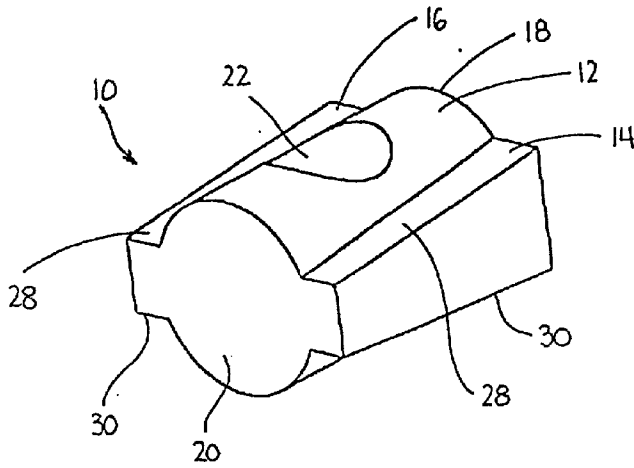


FIG. 1

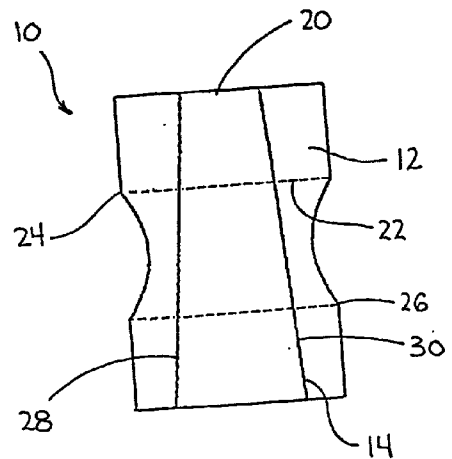


FIG. 2

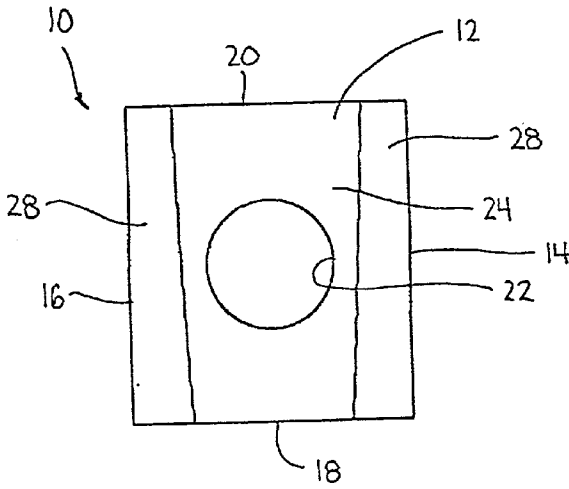


FIG. 3

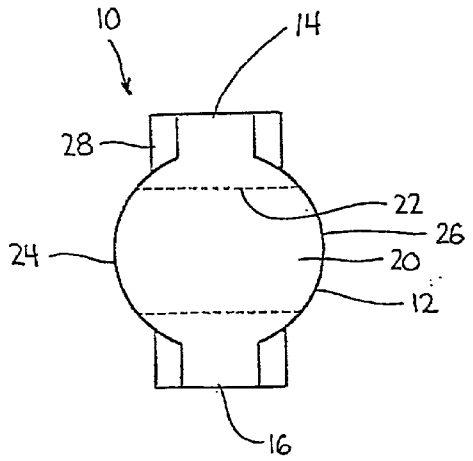


FIG. 4

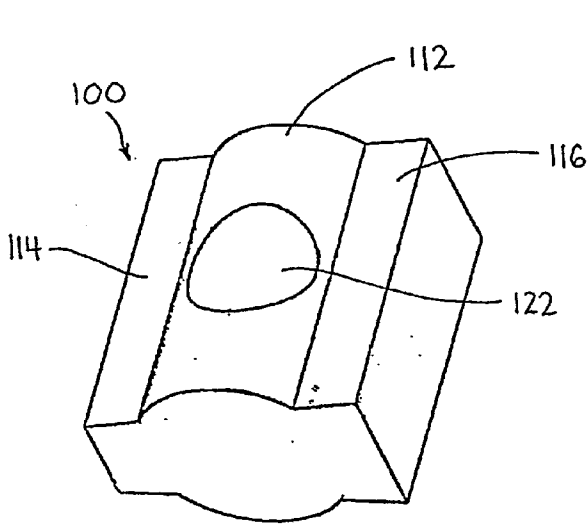


FIG. 5

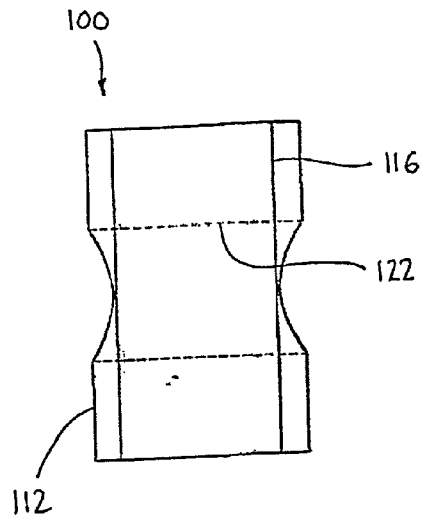


FIG. 6

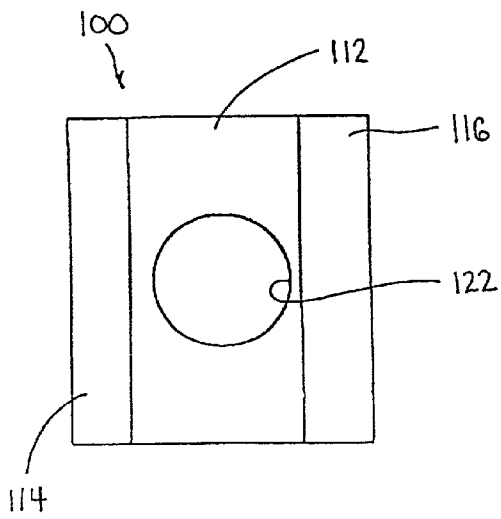


FIG. 7

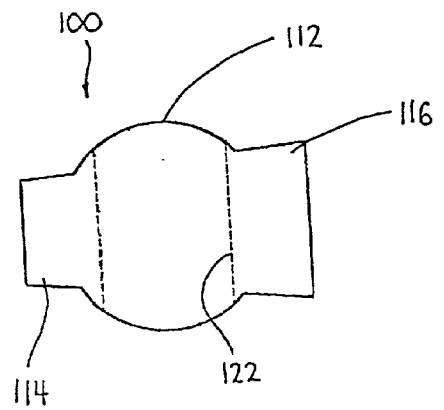


FIG. 8

FIG. 9

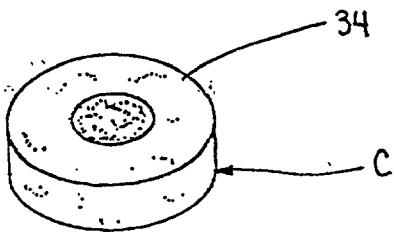
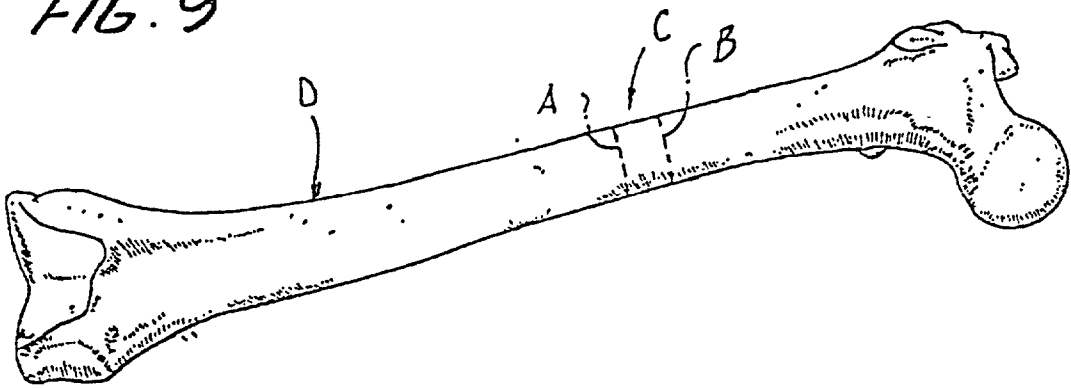


FIG. 10

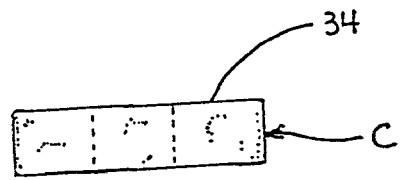


FIG. 11

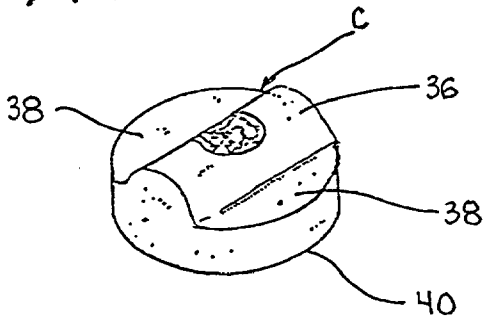


FIG. 12

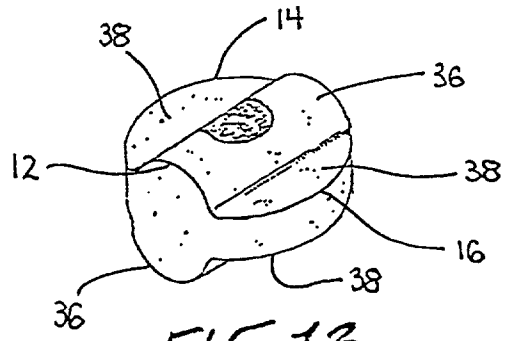


FIG. 13

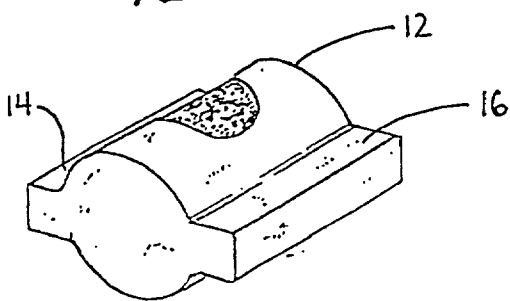


FIG. 14

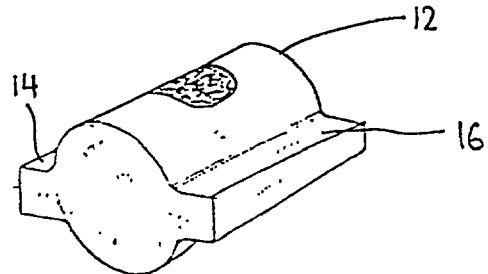


FIG. 15

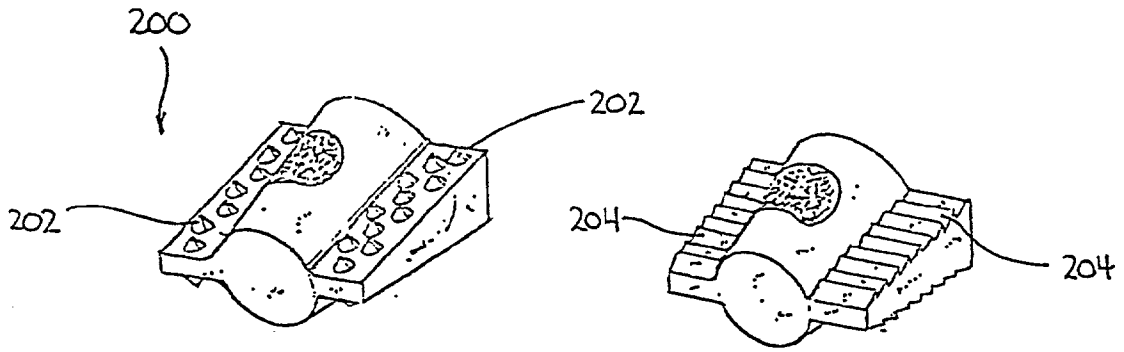


FIG. 16

FIG. 17

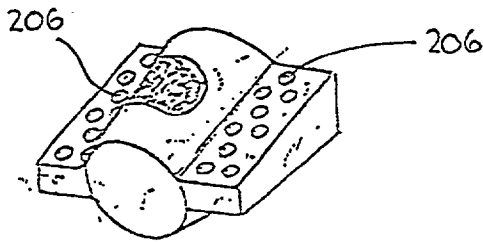


FIG. 18

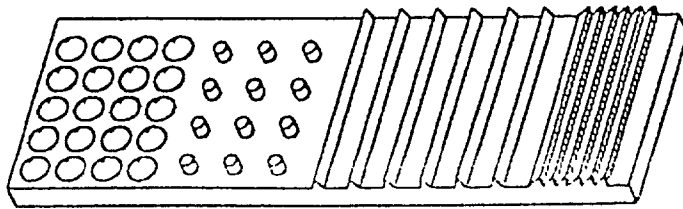


FIG. 18a

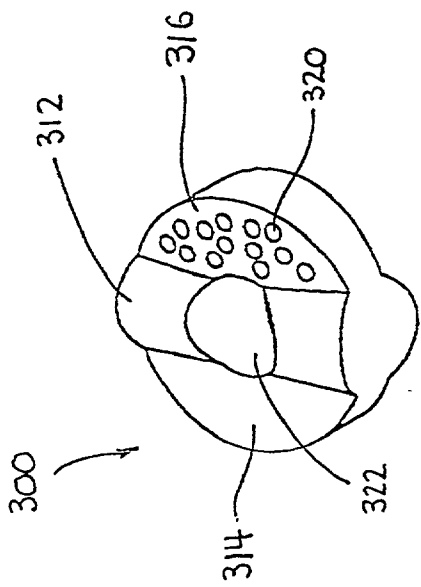


FIG. 19

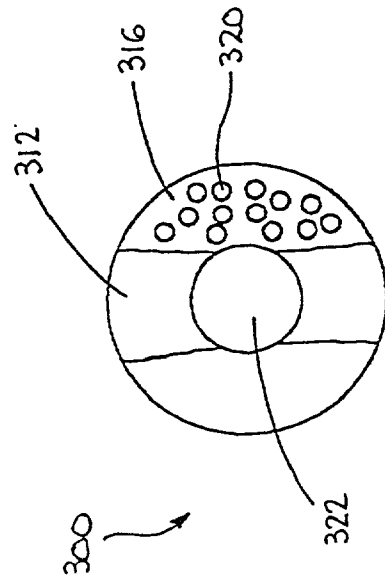


FIG. 21

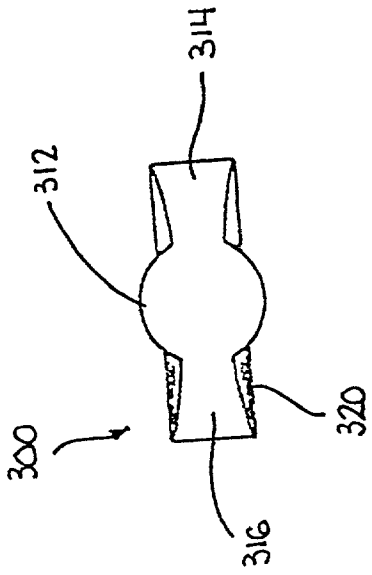


FIG. 20

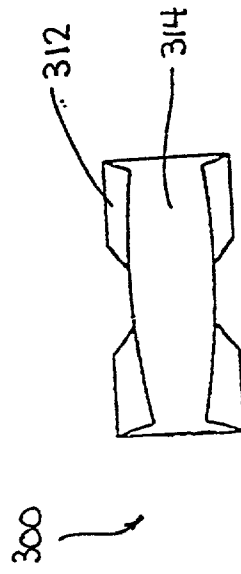


FIG. 22

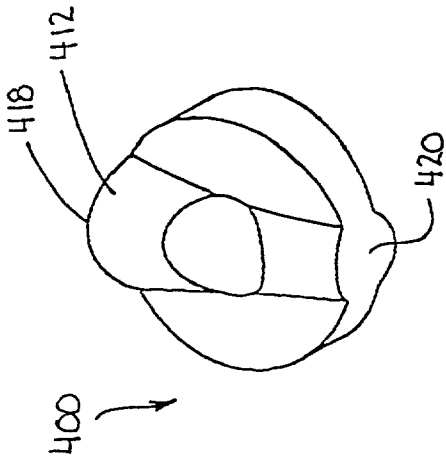


FIG. 23

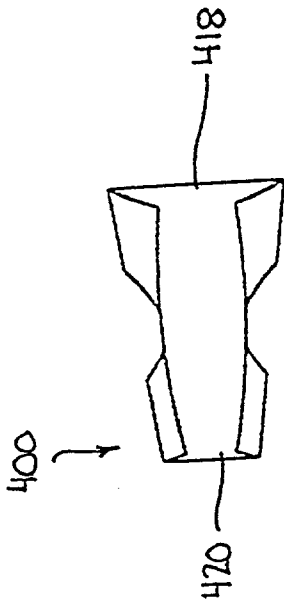


FIG. 24

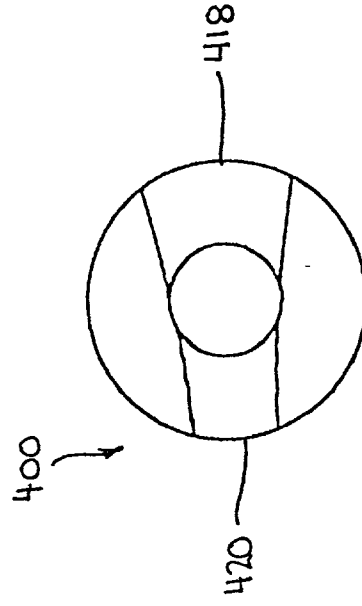


FIG. 26

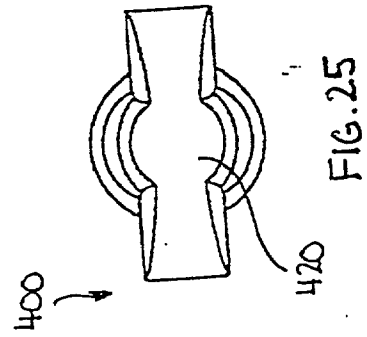


FIG. 25

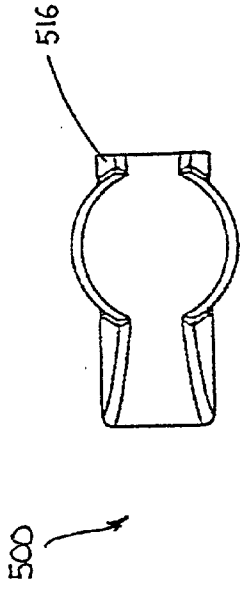


FIG. 28

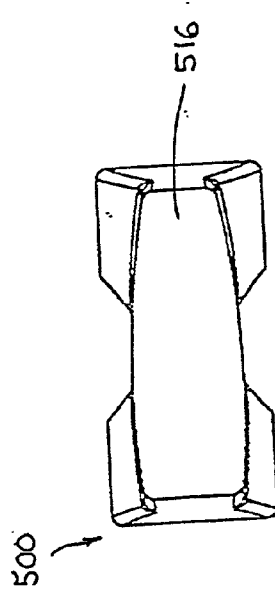


FIG. 30

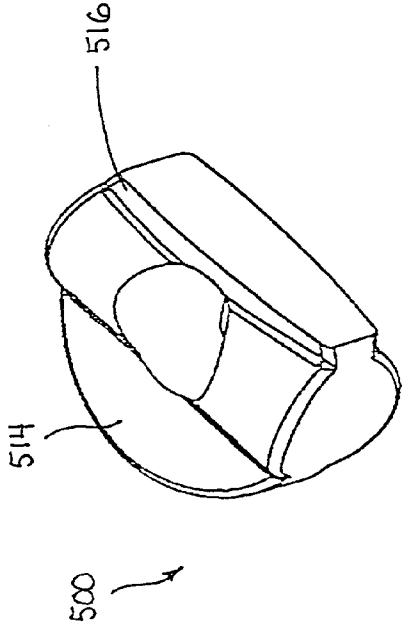


FIG. 27

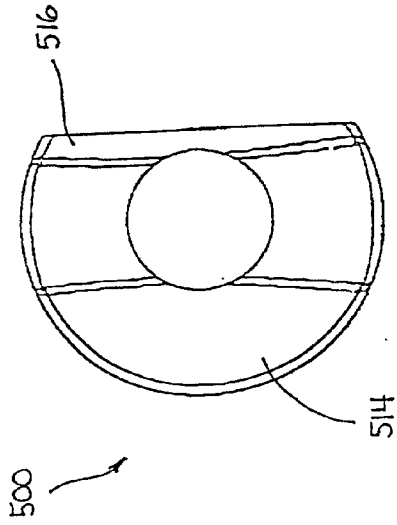


FIG. 29

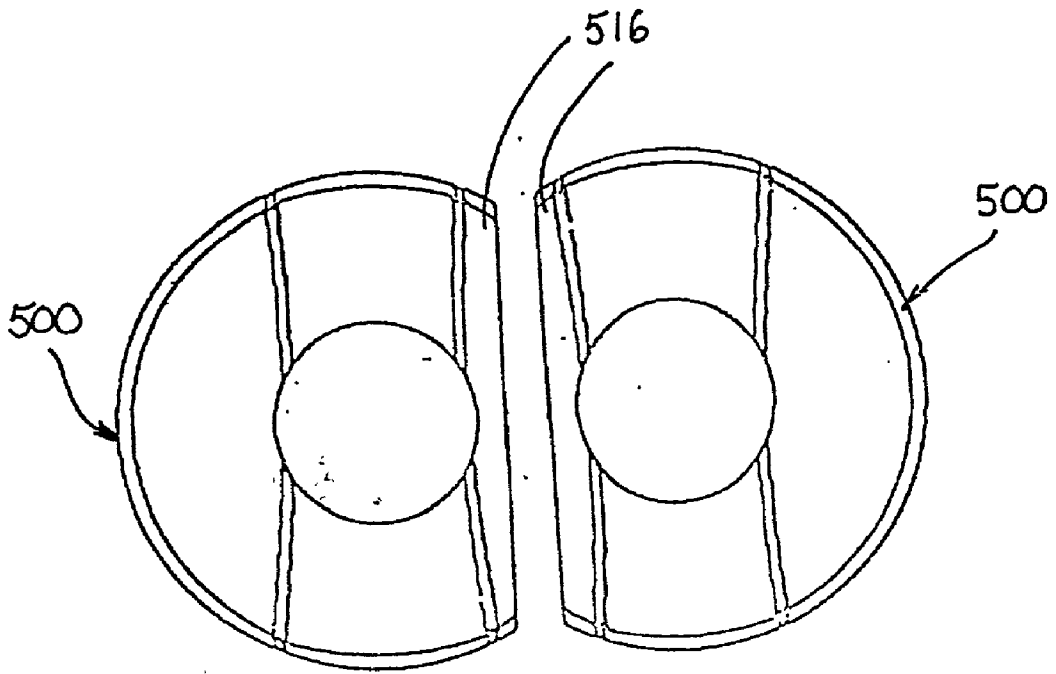


FIG. 31

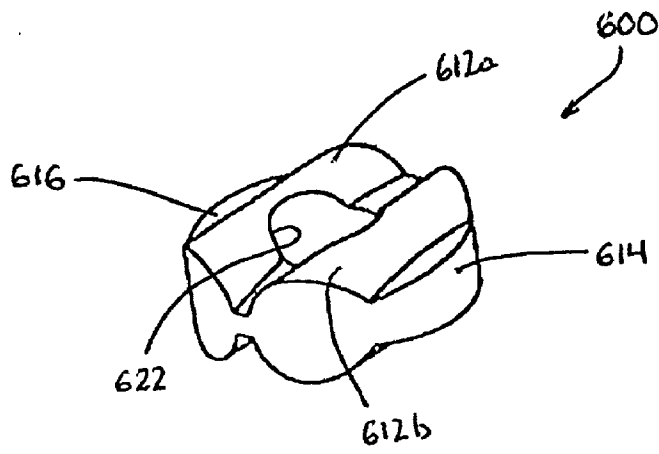


FIG. 32

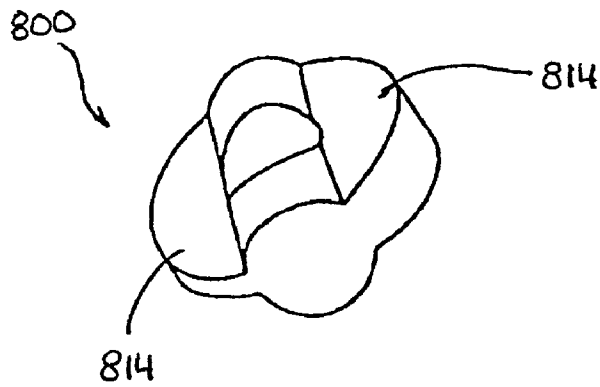


FIG. 37

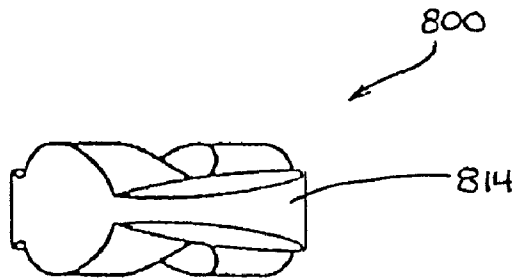


FIG. 38

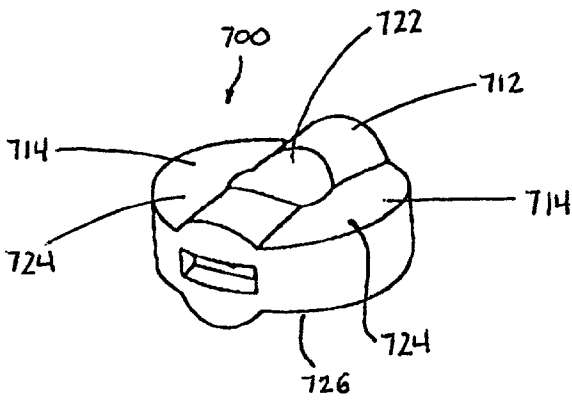


FIG. 33

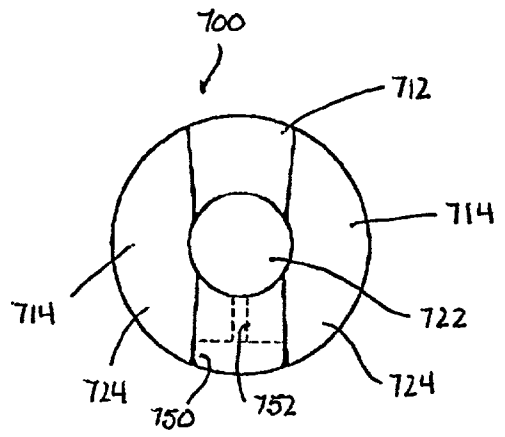


FIG. 34

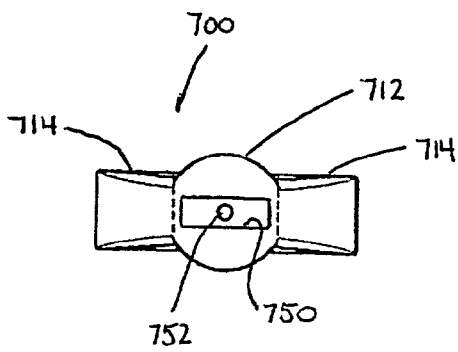


FIG. 35

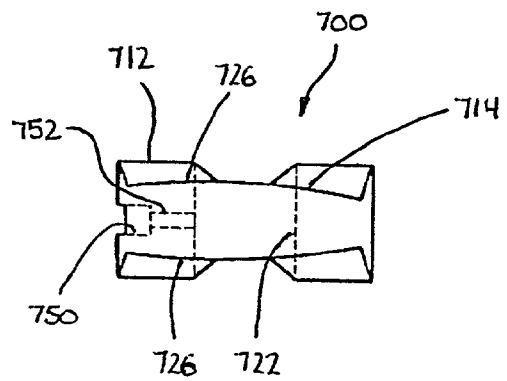


FIG. 36

METHOD FOR FORMING AN INTERVERTEBRAL IMPLANT

[0001] This application is a divisional of U.S. application Ser. No. 09/328,283 filed Jun. 8, 1999, which claims priority from U.S. provisional application Ser. No. 60/116,852, filed Jan. 22, 1999, both of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Technical Field

[0003] The present disclosure relates generally to intervertebral implants and, more particularly, to an intervertebral implant having a composite wedge/dowel configuration suitable for interbody spinal fusion.

[0004] 2. Background of Related Art

[0005] Intervertebral implants for fusing together adjacent vertebrae of a spinal column are well known in the surgical arts. Typically, a surgical procedure for implanting an intervertebral implant between adjacent vertebrae is performed to treat back pain in patients with ruptured or degenerated intervertebral discs, spondylolisthesis or other pathologies. A variety of different types of intervertebral implants have been developed for such a procedure including intervertebral wedge implants, spinal fusion cages and cylindrical threaded bone dowels.

[0006] A variety of different types of intervertebral implants have been developed to perform this function including spinal fusion cages, threaded bone dowels and stepped bone dowels. Exemplary implants are disclosed in U.S. patent applications filed on even date herewith, under Certificate of Express Mail Label Nos. EL260888076US and Intervertebral Dowel", respectively, the entire disclosures of which are incorporated herein by reference.

[0007] One fusion cage described in U.S. Pat. No. 5,015,247 includes a cylindrical implant constructed from titanium having one closed end, one open end and a series of macro-sized openings formed through a side wall of the implant. The open end of the cylindrical implant is internally threaded and configured to receive a cap. A series of external threads are formed about the circumference of the cylindrical implant. Prior to use, a bone graft of cancellous bone taken from a patient's iliac crest is placed in a press and forced into the hollow body of the cylindrical implant such that cancellous bone extends through the macro-sized openings. The cap is then screwed onto the internally threaded end of the implant. Subsequently, the cylindrical implant is screwed into a previously prepared receiving bed between two adjacent vertebrae.

[0008] Because of their simplicity, spinal fusion cages are widely accepted. However, spinal fusion cages suffer from several drawbacks. For example, the cylindrical loading surface area of spinal fusion cages is small, thus two spinal fusion cages are typically required during a surgical procedure. Secondly, spinal fusion cages are made primarily from metal, most notably titanium. This material does not remodel but remains in a patient forever or until it is removed. Since vertebral bodies eventually fuse with the cancellous bone or other bone growth material positioned within the fusion cage, if removal is required, it can be very difficult and dangerous to the patient. Thirdly, spinal fusion

cages do not maintain lordosis, thus the natural curvature of the spine is altered. Finally, it is difficult to insert a spinal fusion cage and achieve equal purchase with the adjacent vertebrae. A spinal fusion cage will often tend to engage one vertebrae more securely than the other.

[0009] Wedge implants also suffer from several drawbacks. Although wedge implants have a greater load bearing surface area and are configured to maintain lordosis, wedge implants are more difficult to secure in place since they are not threaded into the vertebrae. Moreover, wedge implants have limited ability to prevent rotational forces between the two vertebrae that are intended to be fused.

[0010] Threaded bone dowels also suffer from some of the same drawbacks as spinal fusion cages. Threaded bone dowels have a small loading surface area and they do not maintain lordosis. Furthermore, threaded bone dowels are typically cut from bone with a hollow drill bit and subsequently are threaded. The hollow drill bit is positioned to cut transversely through the bone and the intramedullary canal during the cut. If the distance between the outer surface of the cut dowel and the intramedullary canal does not exceed a predetermined thickness, the dowel must be rejected. Since there is little bone to spare during such a transverse cut, a high percentage of bone dowels cut may be rejected due to anatomical variability between donors.

[0011] Accordingly, a need exists for an improved intervertebral implant which maintains simplicity for consistent surgical implantation, creates an improved biomechanical construct when implanted, maintains lordosis, conforms to vertebral endplates, spares the endplates in the load bearing region while perforating them in other areas to gain access to cells in cancellous bone; when produced from bone, can remodel into bone, can be easily manufactured and addresses other problems associated with current spinal fusion implants.

SUMMARY

[0012] In accordance with the present disclosure, an intervertebral implant having a composite wedge/dowel configuration is provided. The intervertebral implant includes a central body portion and a pair of radially extending wings. The radially extending wings can be tapered from a first end of the implant to the second end of the implant along an axis parallel to the longitudinal axis of the cylindrical body portion for anterior or posterior insertion. Alternately, the radially extending wings can be tapered along an axis perpendicular to the longitudinal axis of the cylindrical body portion for lateral insertion or the wings can be tapered along any axis between axis parallel and perpendicular to the longitudinal axis of the implant. A throughbore or a plurality of throughbores extend from a top surface of the implant to a bottom surface of the implant providing a space for boney bridging to occur between the vertebrae which are intended to be fused. The throughbore(s) is dimensioned to receive growth factors including autograft, allograft, DBM, etc., to stimulate bone healing.

[0013] In a preferred embodiment, the implant is formed from a cortical ring allograft cut from the diaphysis or metaphysis of a long bone. The implant can be formed by milling the top and bottom surfaces of the cortical ring to form the central body portion and the tapered radially extending wings. The implant is milled such that the

intramedullary canal of the cortical ring defines a through-bore in the central body portion of the implant. Thereafter, the sidewalls of the implant may be machined to form a substantially rectangular shape or be maintained in an essentially semi-circular configuration. Alternately, the implant may be formed of any biocompatible material having the requisite strength requirements via any known process, i.e., molding, casting, machining, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Various preferred embodiments are described herein with reference to the drawings wherein:

[0015] FIG. 1 is a perspective view of one embodiment of the presently disclosed intervertebral implant;

[0016] FIG. 2 is a side view of the intervertebral implant shown in FIG. 1;

[0017] FIG. 3 is a top view of the intervertebral implant shown in FIG. 1;

[0018] FIG. 4 is a front view of the intervertebral implant shown in FIG. 1;

[0019] FIG. 5 is a perspective view of another embodiment of the presently disclosed intervertebral implant;

[0020] FIG. 6 is a side view of the intervertebral implant shown in FIG. 5;

[0021] FIG. 7 is a top view of the intervertebral implant shown in FIG. 5;

[0022] FIG. 8 is a front view of the intervertebral implant shown in FIG. 5;

[0023] FIG. 9 is a side view of a long bone;

[0024] FIG. 10 is a perspective view of a cortical ring cut from the long bone shown in FIG. 9;

[0025] FIG. 11 is a side view of the cortical ring shown in FIG. 10;

[0026] FIG. 12 is a perspective view of the cortical ring after the top surface has been milled;

[0027] FIG. 13 is a perspective view of the cortical ring after the bottom surface has been milled;

[0028] FIG. 14 is a perspective view of the cortical ring after the sidewalls have been machined;

[0029] FIG. 15 is a perspective view of the cortical ring after the radially extending wings have been tapered;

[0030] FIG. 16 is a perspective view of a third embodiment of the presently disclosed intervertebral implant;

[0031] FIG. 17 is a perspective view of a fourth embodiment of the presently disclosed intervertebral implant;

[0032] FIG. 18 is a perspective view of a fifth embodiment of the presently disclosed intervertebral implant;

[0033] FIG. 18a is a perspective view of a variety of different shaped protrusions;

[0034] FIG. 19 is a perspective view of a sixth embodiment of the presently disclosed intervertebral implant;

[0035] FIG. 20 is a front view of the intervertebral implant shown in FIG. 19;

[0036] FIG. 21 is a top view of the intervertebral implant shown in FIG. 19;

[0037] FIG. 22 is a side view of the intervertebral implant shown in FIG. 19;

[0038] FIG. 23 is a perspective view of a seventh embodiment of the presently disclosed intervertebral implant;

[0039] FIG. 24 is a side view of the intervertebral implant shown in FIG. 23;

[0040] FIG. 25 is a front view of the intervertebral implant shown in FIG. 23;

[0041] FIG. 26 is a top view of the intervertebral implant shown in FIG. 23;

[0042] FIG. 27 is a perspective view of an eighth embodiment of the presently disclosed intervertebral implant;

[0043] FIG. 28 is a side view of the intervertebral implant shown in FIG. 27;

[0044] FIG. 29 is a top view of the intervertebral implant shown in FIG. 27;

[0045] FIG. 30 is a side view of the intervertebral implant shown in FIG. 27;

[0046] FIG. 31 is a top view of a pair of the intervertebral implants shown in FIG. 27 in their implanted positions;

[0047] FIG. 32 is a perspective view of another embodiment of the intervertebral implant;

[0048] FIG. 33 is a perspective view of another embodiment of the intervertebral implant;

[0049] FIG. 34 is a top view of the intervertebral implant shown in FIG. 33;

[0050] FIG. 35 is a front view of the intervertebral implant shown in FIG. 33;

[0051] FIG. 36 is a side view of the intervertebral implant shown in FIG. 33;

[0052] FIG. 37 is a front perspective view of another embodiment of the intervertebral implant; and

[0053] FIG. 38 is a side perspective view of the intervertebral implant shown in FIG. 37.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0054] Preferred embodiments of the presently disclosed intervertebral implant will now be described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views.

[0055] FIGS. 1-4 illustrate one preferred embodiment of the presently disclosed intervertebral implant shown generally as 10. Briefly, intervertebral implant 10 includes a substantially cylindrical body portion 12 having a pair of radially extending wings 14 and 16. Cylindrical body portion 12 has a first end 18 and a second end 20. Each of radially extending wings 14 and 16 has a trapezoidal shape as viewed from the side of intervertebral implant 10.

[0056] Cylindrical body portion 10 includes a throughbore 22 which extends from a top surface 24 of body portion 12

to a bottom surface **26** of body portion **12**. Throughbore **22** has a central axis which is perpendicular to the longitudinal axis of radially extending wings **14** and **16** and cylindrical body portion **10**. Throughbore **22** is dimensioned to receive bone growth material including bone particles and/or a biocompatible osteoinductive or osteoconductive material. These materials may include cancellous bone, cancellous bone particles, ceramics, polymers, composites, BMP, etc. Although not shown, additional bores may be formed through wings **14** and **16**. These bores may also be packed with bone growth material.

[**0057**] Radially extending wings **14** and **16** each include an upper surface **28** and a lower surface **30**. Surfaces **28** and **30** are tapered to converge toward each other from first end **18** of cylindrical body portion **12** to second end **20** of cylindrical body portion **12**, i.e., the height of the wings decreases from the first end to the second end of the implant. The wings are shaped in such a fashion as to conform to the vertebral end plates located above and below the implant. Implant **10** is suitable for anterior and posterior insertion. Alternately, surfaces **28** and **30** may be parallel to each other.

[**0058**] Intervertebral implant **10** can be constructed from a broad range of biocompatible materials, such as surgical stainless steel, titanium, ceramic hydroxyapatite, polymers, carbon fiber tantalum, etc., but is preferably constructed from cadaveric human or animal bone or bone composites. Such composites may include those discussed in U.S. Pat. No. 5,899,939 to Boyce et al. and in U.S. patent application Ser. No. 09/256,447 to Boyce et al., the entire disclosures of which are incorporated herein by reference. Intervertebral implant **10** can be used in cervical, thoracic and lumbar spinal fusion procedures. For cervical spinal fusion procedures, in which implants are typically between 8-15 mm in length and 10-14 mm in diameter, bone is preferably obtained from the fibula, radius, ulna or humerus. For thoracic and lumbar spinal fusion procedures in which implants are typically 10-30 mm in diameter and about 14-20 mm in height, bone is preferably obtained from the humerus, femur or tibia. Alternately, as discussed above, intervertebral implant **10** can be molded or machined from other biocompatible materials including composites made of bone.

[**0059**] Referring to FIGS. 9-15 above, in one preferred embodiment, intervertebral implant **10** is manufactured from a cortical ring C formed by making transverse cuts through a long bone D, along lines A and B as illustrated in FIG. 9. Next, the top **34** of cortical ring C is machined using a milling device (not shown) having a dome or crown configuration to shape one side of cortical ring C to have a semi-cylindrical portion **36** with two radially extending flats **38** (FIG. 12). Cortical ring C is flipped over and the same milling procedure is performed on the bottom surface **40** to form radially extending wings **14** and **16** and cylindrical body portion **12**. Next, the front and side surfaces are machined to reconfigure cortical ring C to have a rectangular configuration (FIG. 14). Alternately, this step may be deleted and the implant can retain its original profile which will vary depending on the type of bone being cut. Finally, wings **14** and **16** are machined further to provide the taper required to maintain lordosis of the spine (FIG. 15). Each of the milling steps may be performed independently using any known milling device. However, one or more of the steps may be combined into a single milling procedure using a computer controlled three dimensional milling machine. For

example, radially extending wings **14** and **16** can be tapered during milling of the top and bottom surfaces of the cortical ring.

[**0060**] Preferably, before long bone D is cut, the bone is partially demineralized by placing the long bone in a 0.6NHC1 solution. By demineralizing the bone in this fashion, only the walls of the intramedullary canal and the circumferential surfaces of the bone may be demineralized. The strength imparting surfaces of the radially extending wings and the radial surface of the implant will not be compromised. Moreover, the bone may be treated using a variety of bone healing enhancing technologies. For example, bone growth factors may be infused into the natural porosity of the bone and/or the bone may be infused with acid to further demineralize the bone. Both these bone treatments may be performed using the pressure flow system disclosed in U.S. Pat. No. 5,846,484 which is incorporated herein by reference.

[**0061**] As discussed above, intervertebral implant **10** need not be formed from human cadaveric or animal bone but rather may be formed from any biocompatible material. As such, other known processes, such as molding, casting or machining techniques, may be used to manufacture the implant.

[**0062**] FIGS. 5-8 illustrate another embodiment of the intervertebral implant shown generally as **100**. Intervertebral implant **100** is similar to intervertebral implant **10** in that it includes a cylindrical body portion **112**, a pair of radially extending wings **114** and **116** and a throughbore **122** having a central axis which is perpendicular to the longitudinal axis of the radially extending wings and cylindrical body portion. However, radially extending wings **114** and **116** are tapered transversely such that wing **116** has greater height than wing **114**. Implant **100** is suitable for lateral intervertebral insertion.

[**0063**] Intervertebral implant **100** may be manufactured using the same procedure as discussed above with respect to intervertebral implant **10** with slight variation in the milling step for forming the taper on the radially extending wings. Alternately, intervertebral implant **100** may be formed from a biocompatible material having the requisite strength requirements via any known process, i.e., molding, casting or machining.

[**0064**] Referring to FIGS. 16-18, intervertebral implants **10** and **100** may include retaining structure for preventing the implant from migrating from an implanted position after implantation. For example, intervertebral implant **200** (FIG. 16) includes a plurality of triangular protrusions **202** formed on the tapered surfaces of the radially extending wings. Protrusions **202** engage the adjoining vertebrae and prevent the implant from movement in relation thereto. Alternately, the protrusions may assume a variety of different configurations. For example, ridge-shaped protrusions **204** (FIG. 17) or spherically-shaped protrusions **206** (FIG. 18) may also be provided. Perforations (not shown) for receiving bone growth material may also be provided on the outer surface of the implant. It is noted that such protrusions or perforations may also be provided on the cylindrical body portion of the intervertebral implant.

[**0065**] FIG. 18a illustrates a variety of different protrusions which may be formed anywhere on the implant to prevent the implant from migrating from its implanted position in the intervertebral space.

[**0066**] FIGS. 19-22 illustrate an alternate embodiment of the presently disclosed intervertebral implant shown gener-

ally as **300**. Intervertebral implant **300** includes a substantially cylindrical body portion **312** having a pair of radially extending wings **314** and **316**. Radially extending wings **314** and **316** have a substantially semi-circular shape and have a height which decreases from a first end to a second end of the implant. A series of holes **320** are formed in wing **316** and a throughbore **322** extends through cylindrical body portion **312**. Each of holes **320** and throughbore **322** is configured to receive bone growth material, as discussed above. Alternately, holes **320** may be formed in both radially extending wings **314** and **316**.

[**0067**] Referring to FIGS. **23-26**, the intervertebral implant, shown generally as **400**, may include a substantially conical body portion **412**. See also FIGS. **16-18**. Conical body portion **412** decreases in height from first end **418** to second end **420** of the implant.

[**0068**] Referring to FIGS. **27-31**, the intervertebral implant, shown generally as **500**, may include only one radially extending wing **514**. The other radially extending wing **516** can be either partially or completely eliminated. As illustrated in FIGS. **27-30**, radially extending wing **516** has been truncated. During a surgical procedure in which two intervertebral implants are implanted between adjoining vertebrae, the side of each implant having the truncated wing (or the side from which the implant has been eliminated) is positioned adjacent to the truncated wing of the other implant. See FIG. **31**.

[**0069**] FIG. **32** illustrates another embodiment of the intervertebral implant shown generally as **600**. Intervertebral implant **600** includes a pair of cylindrical body portions **612a** and **612b**, a pair of radially extending wings **614** and **616**, a central body portion **618** and a throughbore **622**. Throughbore **622** is centrally located in implant **600** and extends through a portion of both cylindrical body portions **612a** and **612b**. A single implant **600** can be used in surgical procedures which typically required two intervertebral implants such as that shown in FIG. **31**.

[**0070**] FIGS. **33-36** illustrate another embodiment of the intervertebral implant shown generally as **700**. Implant **700** includes a substantially cylindrical body portion **712** having a pair of radially extending semi-circular wings **714** and a throughbore **722**. The top and bottom surfaces **724** and **726** of wings **714** are convex to conform to the anatomical shape of the vertebral end plates. Alternately, the top and bottom surfaces of the wings may assume other shapes which conform to the shape of the vertebral endplates. Implant **700** further includes a slot **750** and a threaded bore **752**. Threaded bore **752** extends from slot **750** into throughbore **722**. Slot **750** and threaded bore **752** are configured to engage an implant insertion tool (not shown) to facilitate insertion of the implant into the intervertebral space. Although the slot and threaded bore are not shown in combination with the other implants disclosed in this application, it is contemplated that each of the implants disclosed herein may include such insertion tool engaging structure.

[**0071**] It will be understood that various modifications may be made to the embodiments disclosed herein. For example, radially extending wings have been described as being tapered or angled along axis both parallel and transverse to the longitudinal axis of the implant. Alternately, radially extending wings can be tapered along any axis between the parallel and transverse axis. For example, radially extending wings **814** of implant **800** are tapered

along an axis which forms an angle of about 45° with respect to the longitudinal axis of the cylindrical body portion **812**. See FIGS. **37** and **38**. Moreover, the taper of the radially extending wings may be different than that shown but should be such as to maintain the natural alignment of the vertebrae. Alternately, radially extending wings need not be tapered. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A method for forming an intervertebral implant from the diaphysis or metaphysis of a long bone comprising the following steps:

- a. making a transverse cut across a long bone to form a cortical ring;
- b. milling the top surface of the cortical ring to form a first longitudinally extending crown having two upper radially extending flats; and
- c. milling the bottom surface of the cortical ring to form a second longitudinally extending crown having two lower radially extending flats, the upper and lower flats forming a pair of radially extending wings.

2. A method according to claim **24**, wherein the first and second crowns are milled to form a substantially cylindrical body portion.

3. A method according to claim **25**, wherein the first and second crowns are milled such that the intramedullary canal of the long bone extends through the substantially cylindrical body portion.

4. A method according to claim **26**, further including the steps of:

milling the side surfaces of the cortical ring to form a substantially rectangular implant.

5. A method according to claim **25**, further including the step of milling the upper and lower radially extending flats to vary the angle of the flats in a direction parallel to the longitudinally extending axis of the substantially cylindrical body portion.

6. A method according to claim **25**, further including the step of milling the upper and lower radially extending flats to vary the angle of the flats in a direction transverse to the longitudinal axis of the cylindrical body portion.

7. A method according to claim **24**, further including the following step:

d. forming protrusions on the intervertebral implant.

8. A method according to claim **30**, wherein the protrusions are formed on the radially extending wings.

9. A method according to claim **24**, wherein the first and second crowns are milled to form a substantially conical body portion.

10. A method according to claim **24**, further including the step of forming at least one hole in at least one of the radially extending wings.

11. A method according to claim **24**, wherein at least one of the upper and lower flats defining each of the radially extending wings is convex.

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