



US006989031B2

(12) **United States Patent**
Michelson

(10) **Patent No.:** **US 6,989,031 B2**
(45) **Date of Patent:** **Jan. 24, 2006**

(54) **HEMI-INTERBODY SPINAL IMPLANT
MANUFACTURED FROM A MAJOR LONG
BONE RING OR A BONE COMPOSITE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 22 days.

(21) Appl. No.: **10/112,745**

(22) Filed: **Apr. 2, 2002**

(65) **Prior Publication Data**

US 2002/0161442 A1 Oct. 31, 2002

Related U.S. Application Data

(60) Provisional application No. 60/281,187, filed on Apr. 3, 2001, provisional application No. 60/281,112, filed on Apr. 2, 2001.

(51) **Int. Cl.**
A61F 2/44 (2006.01)

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

(58) **Field of Classification Search** 623/17.11,
623/17.12, 17.13, 17.14, 17.15, 17.16, 23.63,
623/23.61, 23.5, 901; 606/61

See application file for complete search history.

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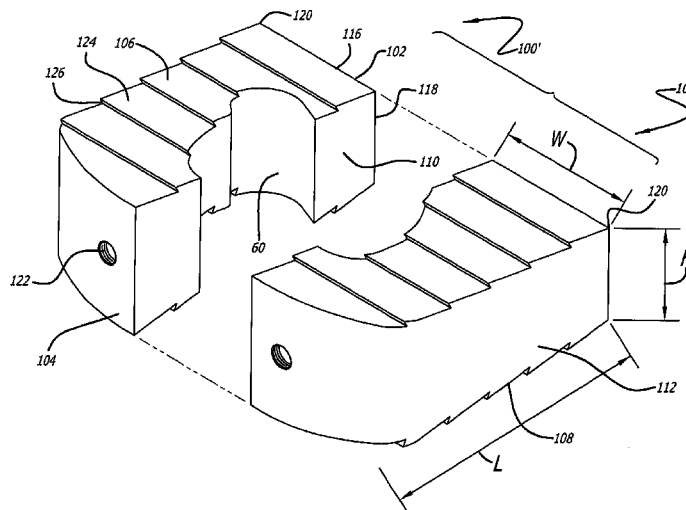
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(57) **ABSTRACT**

An interbody spinal implant comprising cortical bone having a width less than one-half the width of the disc space into which it is adapted to be inserted. The implant has a leading end that is asymmetrical from side to side and/or includes a straight portion adapted to be used in side-by-side pairs.

122 Claims, 7 Drawing Sheets



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FIG. 1
PRIOR ART

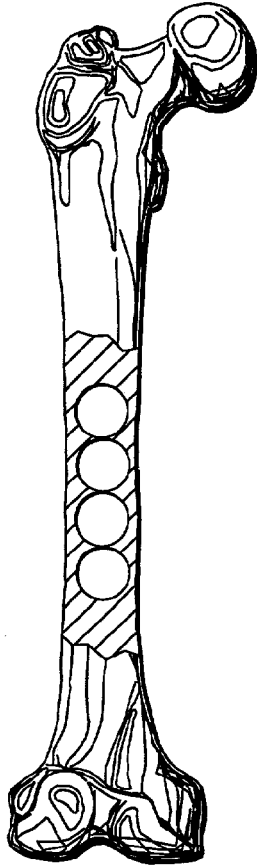


FIG. 2

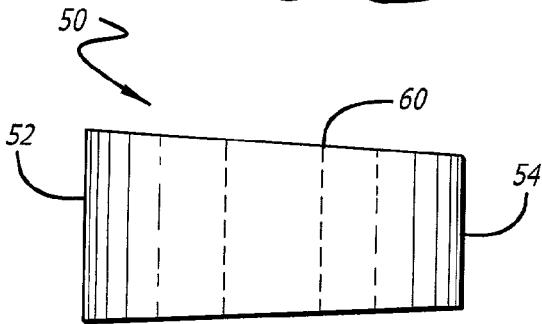
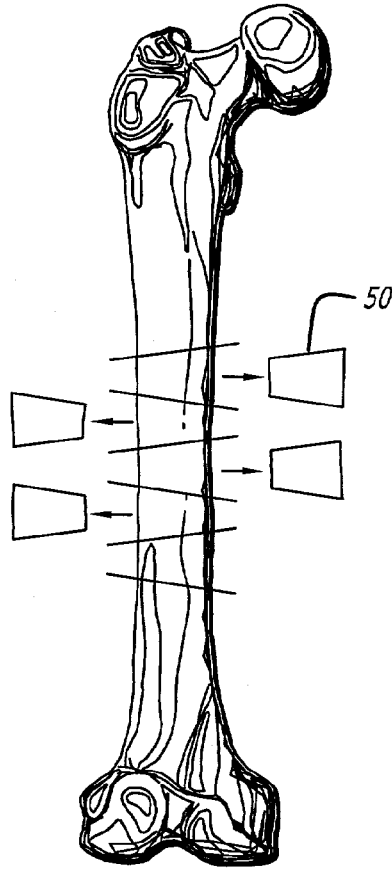


FIG. 3

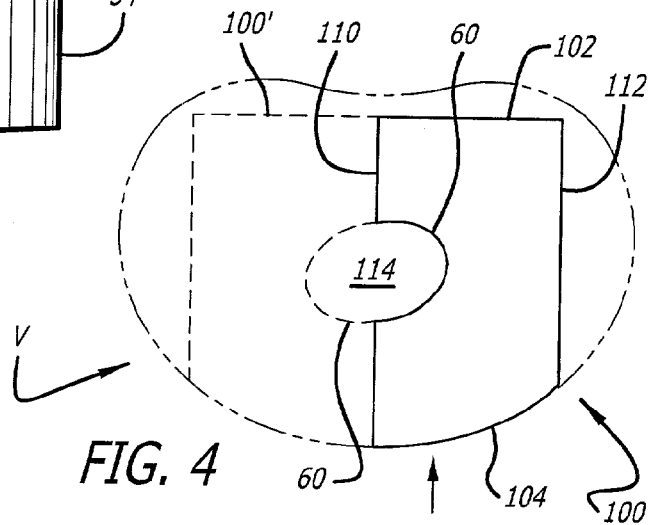


FIG. 4

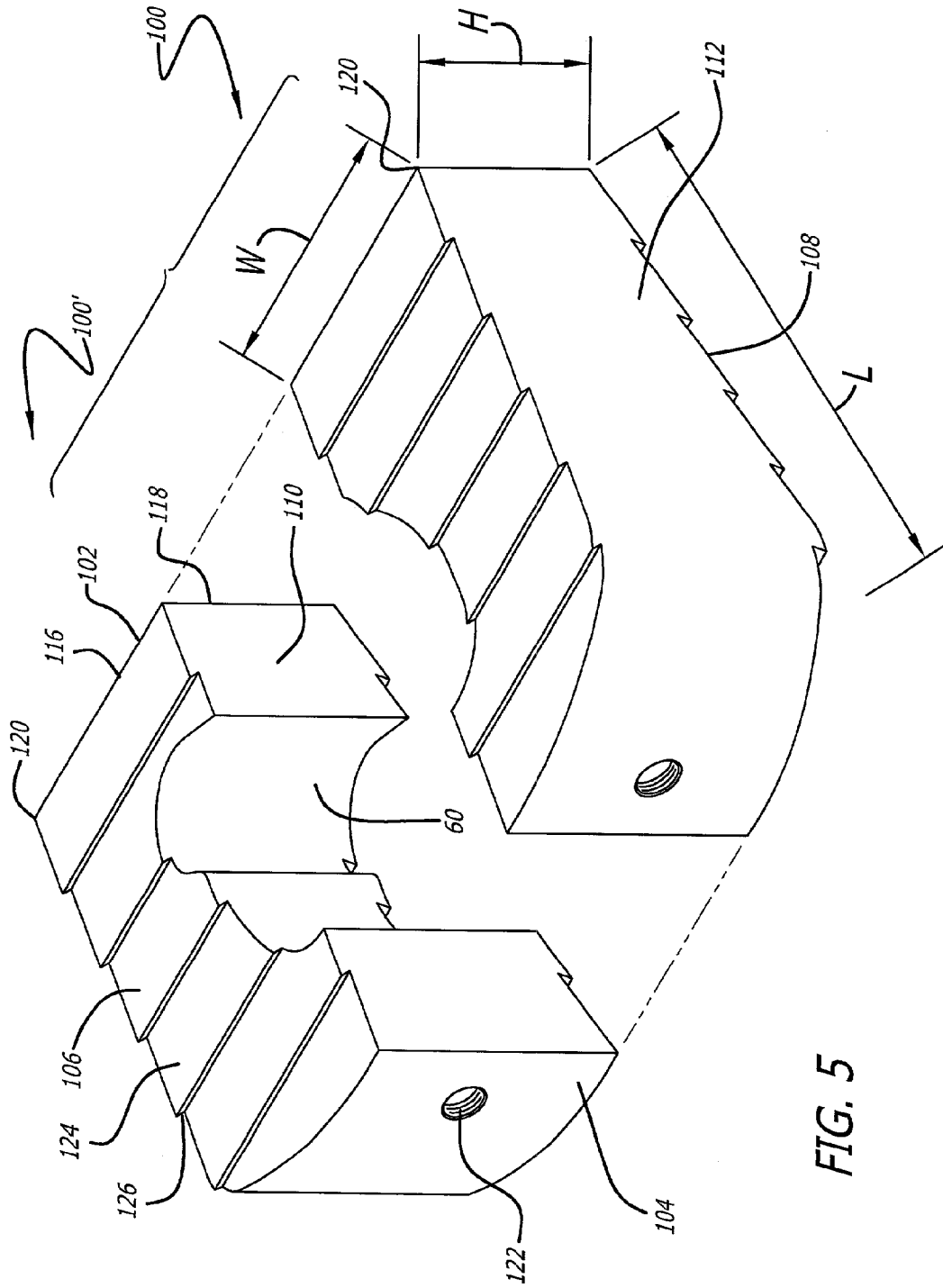
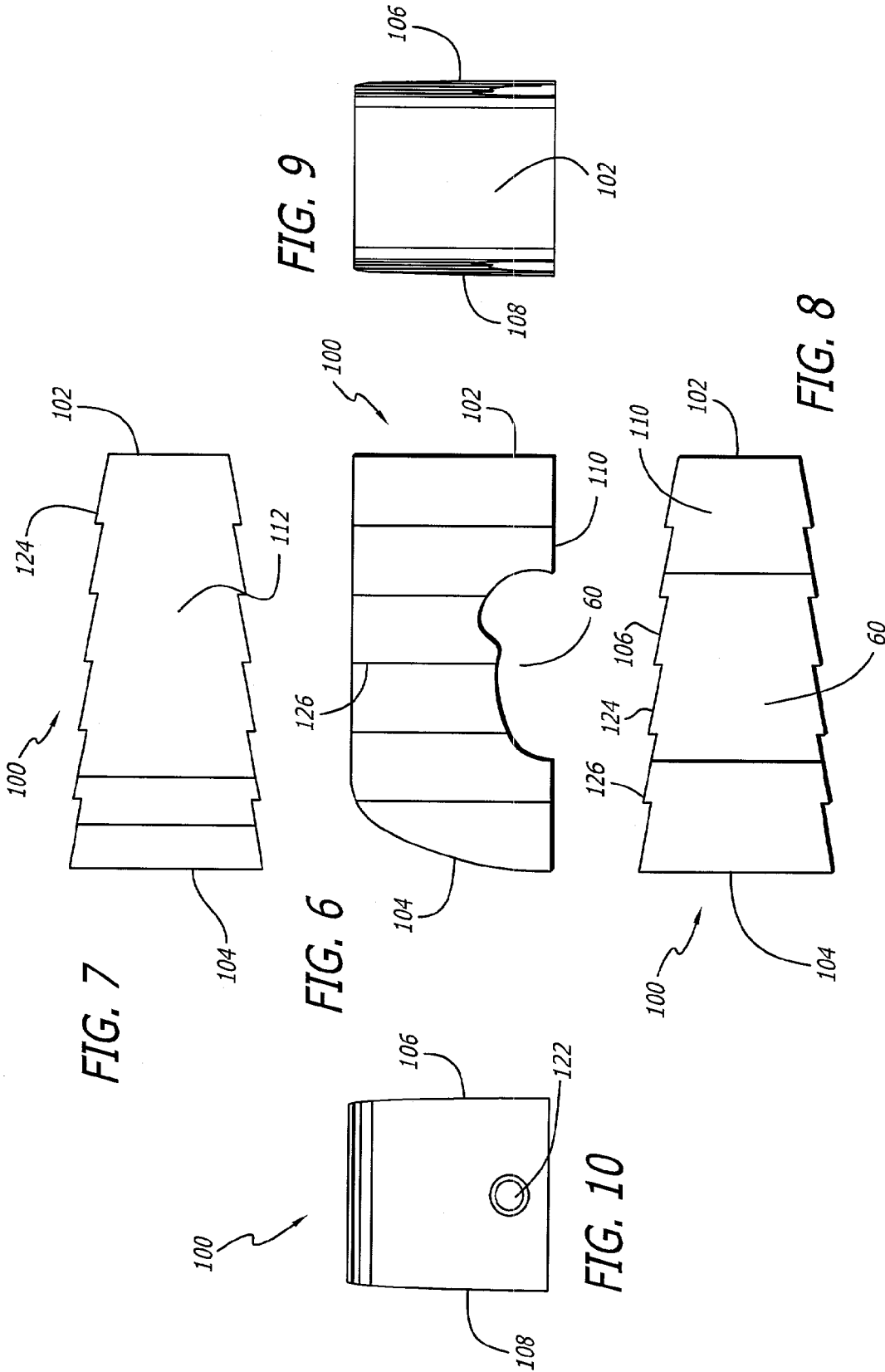
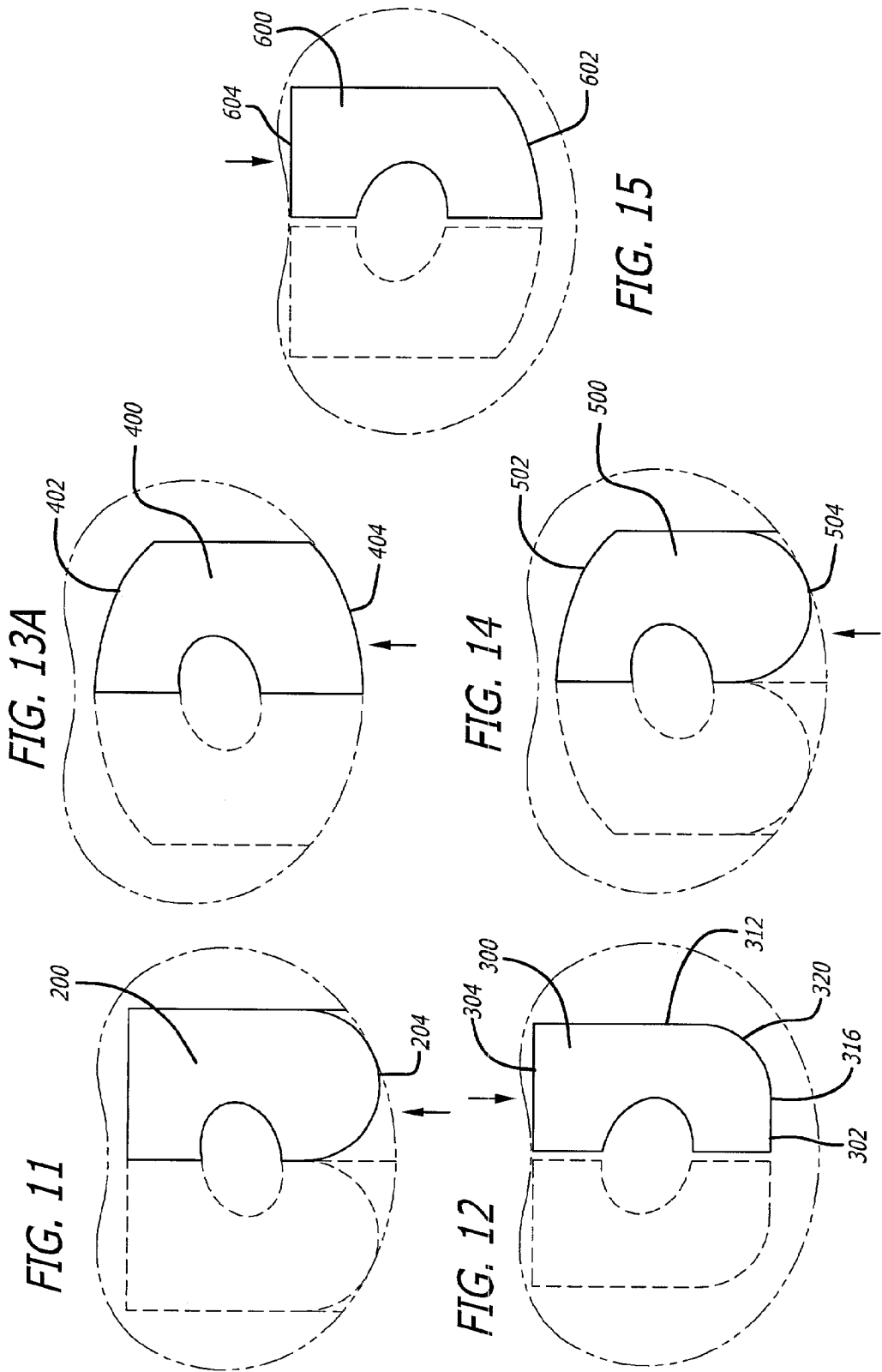


FIG. 5





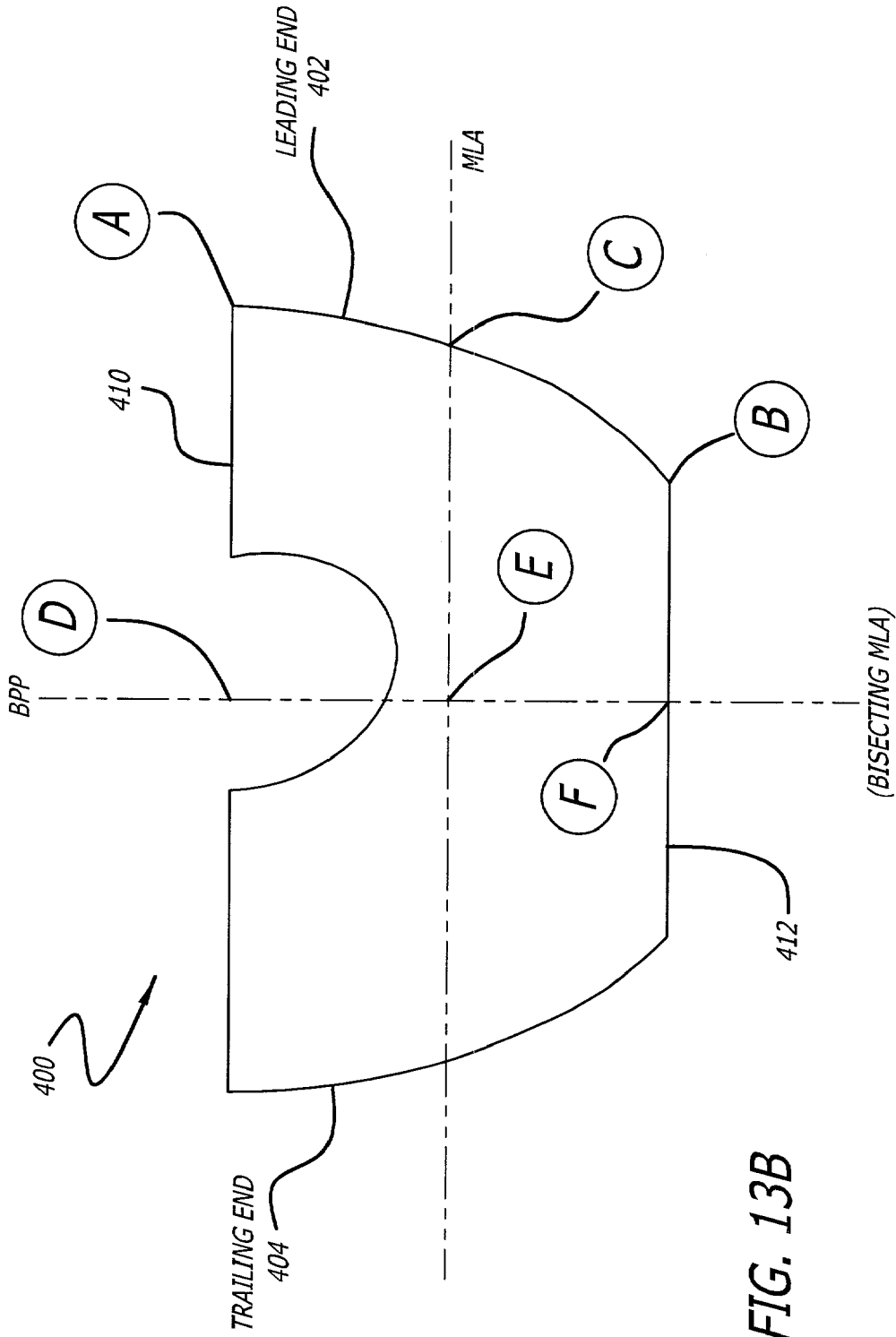


FIG. 13B

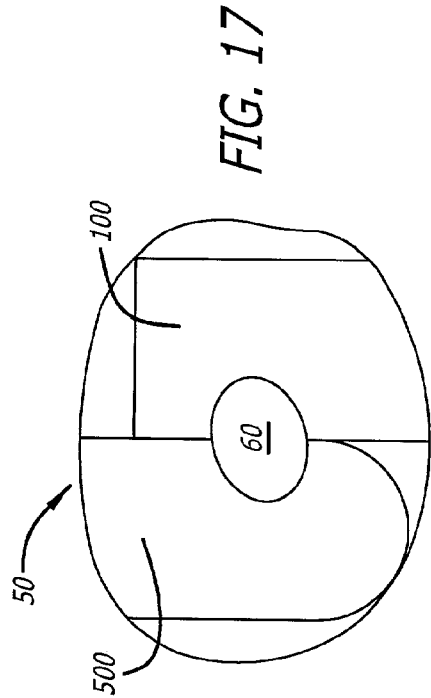


FIG. 17

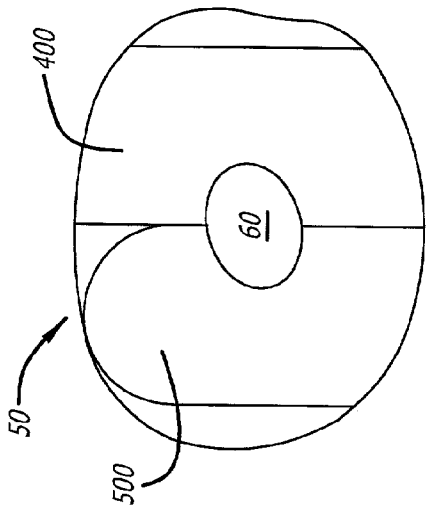


FIG. 16

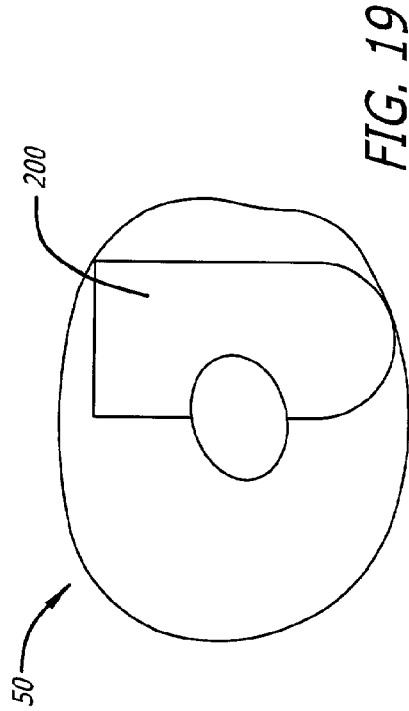


FIG. 19

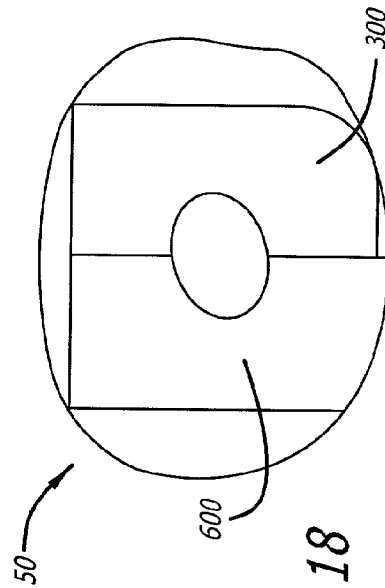


FIG. 18

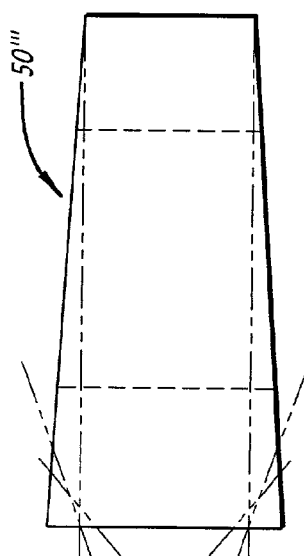
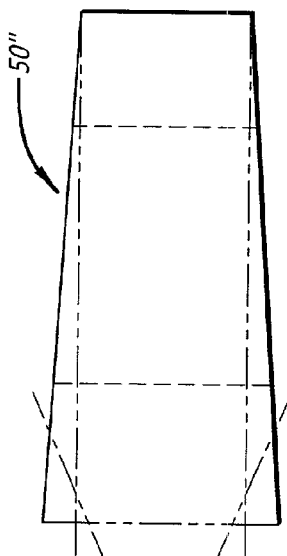
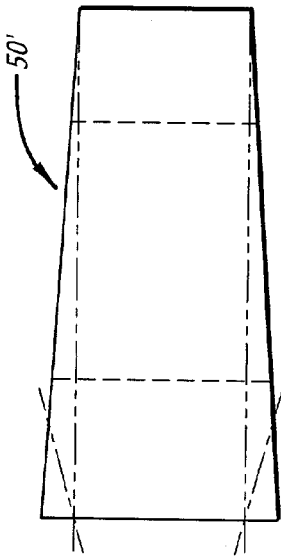
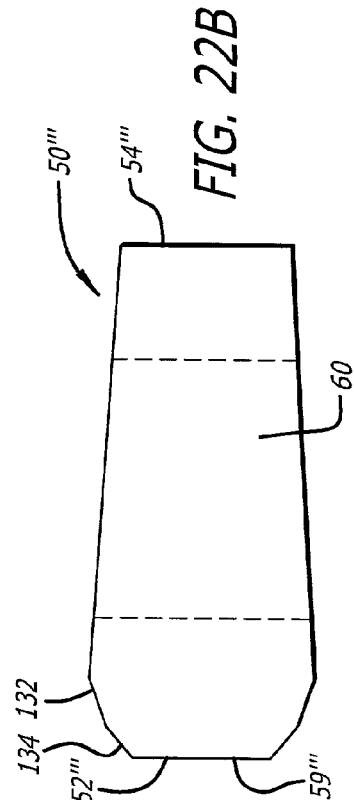
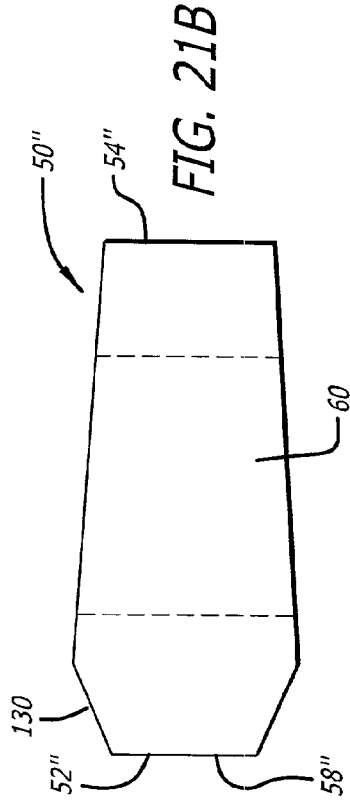
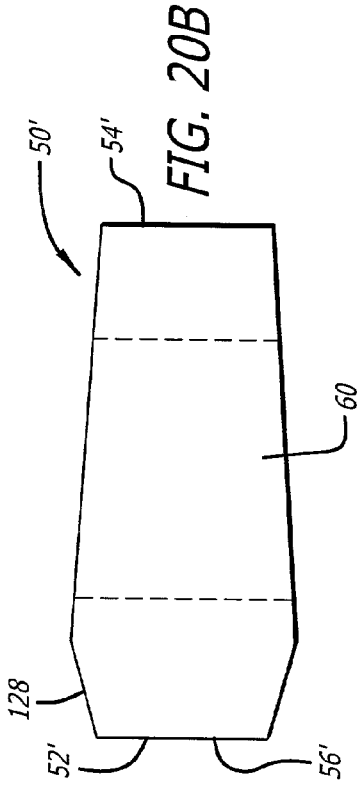


FIG. 20A

FIG. 21A

FIG. 22A

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HEMI-INTERBODY SPINAL IMPLANT MANUFACTURED FROM A MAJOR LONG BONE RING OR A BONE COMPOSITE

RELATED APPLICATIONS

This application claims priority to provisional application No. 60/281,187, filed Apr. 3, 2001, and provisional application No. 60/281,112, filed Apr. 2, 2001, both of which are incorporated by reference herein.

BACKGROUND

Description of the Related Art

The diaphysis is the shaft of a major long bone between the epiphyses, the ends of the bone forming the joints. Human cadaveric diaphyseal bone is used to form implants made of bone utilized in interbody spinal fusion surgery.

As show in FIG. 1, interbody spinal implants in the form of bone dowels can be formed by making circular cuts transverse to the long axis of the diaphysis. The circular cuts required to form cylindrical bone dowels create unusable portions of the diaphyseal bone and is not an efficient use of a precious and scarce resource.

As shown in FIG. 2, a diaphyseal ring is formed by making two spaced apart cuts approximately perpendicular to the long axis of the diaphyseal portion of a major long bone with the medullary canal forming an opening through the ring. Such rings are generally harvested from femurs for use in the lumbar spine. Other bones from the arm or leg or other part of the human skeleton may be useful in various regions of the spine.

The cuts are generally spaced apart so as to form a ring of bone having a height corresponding to the restored disc space or slightly greater. Diaphyseal ring bone grafts are placed into the spine within and across the height of the space previously occupied by a spinal disc between adjacent vertebral bodies to achieve interbody fusion of those vertebral bodies through the disc space. The diaphyseal ring bone graft is incorporated into the bony fusion over time.

Interbody spinal fusion with diaphyseal bone rings, however, has had limited success in the past. While all the causes for failure may not yet be appreciated, it is nevertheless believed that a failure to gain congruity at the interfaces of the bone ring implant to the adjacent vertebral bodies, and a failure to achieve stability of the bone ring implant, may be two of the more significant factors subject to the surgeon's control contributing to such failures. Moreover, bone rings are limited to insertion from an anterior approach to the spine and require a relatively large incision for insertion.

Interbody spinal implants that are entirely or almost entirely made of cortical bone or a bone composite material offer the advantages of that material including an appropriate modulus of elasticity and strength for the prescribed use, the capacity to be bioactive, including being osteoconductive, osteoinductive, osteogenic, and to more generally provide a good substrate for the formation of new bone as fusion occurs. Further, by being bioabsorbable the bone material is replaced by the patient's own bone over time, thereby preventing stress shielding and leading to the eventual elimination of any foreign body from the implantation site.

As it is desirable to take advantage of all these benefits, there exists a need for an improved interbody spinal fusion implant made of bone or a bone composite material having a configuration that provides for an improved congruity of

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the implant to the vertebral bodies and improved implant stability, that is adapted for insertion from either an at least in part anterior or posterior approach to the spine, and is adapted to be inserted through a relatively small incision.

SUMMARY OF THE INVENTION

In accordance with the purposes of the present invention, as embodied and broadly described herein, an interbody spinal fusion implant made of cortical bone is provided for insertion at least in part into an implantation space formed across the height of a disc space between adjacent vertebral bodies of a human spine. The implant includes a leading end for insertion first into the disc space, a trailing end opposite the leading end, and a length along a mid-longitudinal axis of the implant. The leading end has a generally straight portion from side to side. The implant also includes opposed upper and lower portions between the leading and trailing ends that are adapted to be placed within the disc space to contact and support the adjacent vertebral bodies. The upper and lower portions are non-arcuate along at least a portion of the length of the implant. The implant also includes an interior facing side, an exterior facing side opposite the interior side, and a maximum width therebetween. The maximum width of the implant is less than approximately one-half of the width of the adjacent vertebral bodies into which the implant is adapted to be inserted. The interior and exterior sides connect the upper and lower portions and the leading and trailing ends. The interior side forms a corner with the generally straight portion of the leading end. The interior side is adapted to be oriented toward an interior side of another implant when inserted within the disc space.

The implant is preferably manufactured from a bone ring obtained from a major long bone of a human having a medullary canal. The interior side of the implant includes at least a portion of the medullary canal so that when the implant is placed side by side another implant having an interior side with at least a portion of a medullary canal, a passage is formed. The passage is adapted to hold bone growth promoting material to permit for the growth of bone from vertebral body to vertebral body through the passage.

In another preferred embodiment, the implant is manufactured from a bone composite material. The interior side includes a recess so that when the implant is placed side by side another implant having an interior side including a recess, a passage is formed. The passage is adapted to hold bone growth promoting material to permit for the growth of bone from vertebral body to vertebral body through the implant.

In accordance with the purposes of another embodiment of the present invention, as embodied and broadly described herein, an interbody spinal fusion implant made of cortical bone is provided for insertion at least in part into an implantation space formed across the height of a disc space between adjacent vertebral bodies of a human spine. The implant has a leading end that is asymmetrical from side to side. The implant is manufactured from a bone ring obtained from a major long bone of a human and includes at least 40 percent of the bone ring from which it is being formed.

In accordance with the purposes of a further embodiment of the present invention, as embodied and broadly described herein, a pair of interbody spinal fusion implants manufactured from a bone composite material is provided for insertion at least in part into an implantation space formed across the height of a disc space between adjacent vertebral bodies of a human spine. Each implant has a length that is greater than one half the depth of the vertebral bodies adjacent the

disc space into which the implant is adapted to be inserted. Each implant has a leading end that is asymmetrical from side to side. Each implant has an interior facing side that includes a recess to form a passage when the implants are placed side by side with the interior sides facing each other. The combined width of the pair of implants is greater than one half the width of the adjacent vertebral bodies into which the implants are adapted to be inserted.

Additional objects and advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation view of a human long bone in partial cross section illustrating the harvesting of cylindrical dowels of diaphyseal bone.

FIG. 2 is a side elevation view of a human long bone illustrating the harvesting of diaphyseal bone rings in accordance with the present invention.

FIG. 3 is a side elevation view of a diaphyseal bone ring in accordance with a preferred embodiment of the present invention.

FIG. 4 is a top plan view of a preferred embodiment of a bone implant in accordance with the present invention and a second bone implant that is a mirror image thereof illustrated in dashed line, both implants being shown implanted from an anterior approach to the spine in a vertebral body illustrated in dashed line.

FIG. 5 is a rear perspective view of the implants of FIG. 4.

FIG. 6 is a top plan view of one of the implants of FIG. 5.

FIG. 7 is an exterior side elevation view of the implant of FIG. 6.

FIG. 8 is an interior side elevation view of the implant of FIG. 6.

FIG. 9 is a leading end view of the implant of FIG. 6.

FIG. 10 is a trailing end view of the implant of FIG. 6.

FIG. 11 is a top plan view of another preferred embodiment of a bone implant in accordance with the present invention and a second bone implant that is a mirror image thereof illustrated in dashed line, both implants being shown implanted from an anterior approach to the spine in a vertebral body illustrated in dashed line.

FIG. 12 is a top plan view of another preferred embodiment of a bone implant in accordance with the present invention and a second bone implant that is a mirror image thereof illustrated in dashed line, both implants being shown implanted from a posterior approach to the spine in a vertebral body illustrated in dashed line.

FIG. 13A is a top plan view of another preferred embodiment of a bone implant in accordance with the present invention and a second bone implant that is a mirror image thereof illustrated in dashed line, both implants being shown implanted from an anterior approach to the spine in a vertebral body illustrated in dashed line.

FIG. 13B is a top plan view of the implant of FIG. 13A illustrating the mid-longitudinal axis and a plane bisecting the mid-longitudinal axis along the length of the implant.

FIG. 14 is a top plan view of another preferred embodiment of a bone implant in accordance with the present invention and a second bone implant that is a mirror image

thereof illustrated in dashed line, both implants being shown implanted from an anterior approach to the spine in a vertebral body illustrated in dashed line.

FIG. 15 is a top plan view of another preferred embodiment of a bone implant in accordance with the present invention and a second bone implant that is a mirror image thereof illustrated in dashed line, both implants being shown implanted from a posterior approach to the spine in a vertebral body illustrated in dashed line.

FIG. 16 is a top plan view of a section of diaphyseal bone ring cut across the longitudinal axis of a long bone illustrating the shapes of two implants that can be formed therefrom in accordance with a preferred embodiment of the present invention.

FIG. 17 is a top plan view of a section of diaphyseal bone ring cut across the longitudinal axis of a long bone illustrating the shapes of two implants that can be formed therefrom in accordance with another preferred embodiment of the present invention.

FIG. 18 is a top plan view of a section of diaphyseal bone ring cut across the longitudinal axis of a long bone illustrating the shapes of two implants that can be formed therefrom in accordance with another preferred embodiment of the present invention.

FIG. 19 is a top plan view of a section of diaphyseal bone ring cut across the longitudinal axis of a long bone illustrating the shape of an implant that can be formed therefrom in accordance with another preferred embodiment of the present invention.

FIG. 20A is a side elevation view of a section of diaphyseal bone cut across the longitudinal axis of a long bone illustrating a method of forming a shape of an implant in accordance with a preferred embodiment of the present invention.

FIG. 20B is a side elevation view of an implant in accordance with a preferred embodiment of the present invention formed by the method of FIG. 20A.

FIG. 21A is a side elevation view of a section of diaphyseal bone cut across the longitudinal axis of a long bone illustrating a method of forming a shape of an implant in accordance with another preferred embodiment of the present invention.

FIG. 21B is a side elevation view of an implant in accordance with another preferred embodiment of the present invention formed by the method of FIG. 21A.

FIG. 22A is a side elevation view of a section of diaphyseal bone cut across the longitudinal axis of a long bone illustrating a method of forming a shape of an implant in accordance with another preferred embodiment of the present invention.

FIG. 22B is a side elevation view of an implant in accordance with another preferred embodiment of the present invention formed by the method of FIG. 22A.

DETAILED DESCRIPTION OF THE DRAWINGS

The following description is intended to be representative only and not limiting and many variations can be anticipated according to these teachings, which are included within the scope of this inventive teaching. Reference will now be made in detail to the preferred embodiments of this invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

FIGS. 2 and 3 show a preferred method for obtaining a diaphyseal bone ring 50 from a major long bone used to

form certain of the implants of the present invention. Bone ring **50** is formed by making two spaced apart cuts approximately perpendicular to the long axis of the diaphyseal portion of a major long bone with a portion of the medullary canal forming an opening through the ring. Such rings are generally harvested from femurs for use in the lumbar spine. Other bones from the arm or leg or other part of the human skeleton may be useful in various regions of the spine. The cuts may be made into the long bone generally perpendicular to or at other angles transverse to the long axis of the diaphyseal bone to form bone ring **50** having upper and lower surfaces. Making the cuts at an angle to each other creates a bone ring with upper and lower surfaces that are angled relative to each other. The angular relationship of the upper and lower surface of the bone ring, when subsequently formed into an implant and implanted into the spine, positions the adjacent vertebral bodies in angular relationship to each other to restore the natural curvature of the spine, such as lordosis for example.

As shown in FIG. **3**, bone ring **50** has an end **52** with a height that is greater than the height at an end **54**. Bone ring **50** also has a medullary canal **60** therethrough, shown in outline.

Where it is desired to form two implants from a bone ring, bone ring **50** may be cut into two parts, each part including at least a portion of the medullary canal. Thereafter, the parts are machined to form a desired shape suitable for their intended use as an interbody spinal implant. Examples of tools which may be used to machine the implant include, but are not limited to, burrs, reamers, mills, saws, trephines, chisels, and the like. Each part of the bone may be machined to form an implant having a leading end. For example only, the leading end may be shaped to be asymmetrical from side to side and/or may have a straight portion from side to side at the leading end. The interior side includes at least a portion of the medullary canal and may be machined to be at least in part straight. The exterior side also may be machined to have a straight portion. The trailing end of each part may be machined to any desired shape suitable for the intended purpose and may be shaped to conform to the anatomical contour of the adjacent vertebral bodies between which the implant is adapted to be inserted. Where it is appropriate, it may be desirable to preserve at least a portion of the natural curvature of the perimeter of the bone ring as part of the configuration of the implant shape.

FIGS. **4-10** show an implant **100** in accordance with a preferred embodiment of the present invention adapted for use from an anterior approach to the spine. Implant **100** has a leading end **102** for insertion first into the disc space between two adjacent vertebral bodies and a trailing end **104** opposite leading end **102**. Implant **100** has an upper portion **106**, a lower portion **108**, an interior side **110**, and an exterior facing side **112** opposite interior facing side **110**. As used herein, the phrase "interior side" describes the side of the implant adapted to be orientated toward the interior side of another implant when a pair of implants are inserted side by side into the disc space. Interior side **110** includes at least a portion of the medullary canal of the bone ring.

FIG. **4** shows a top plan view of a vertebral body **V** and implants **100** and **100'**, respectively, inserted from an anterior approach to the spine. Implant **100'** is preferably, but need not be, a mirror image of implant **100**. The description of implant **100** is equally applicable to implant **100'**. Implant **100** is placed side by side with implant **100'** so that the portions of the medullary canal of interior sides **110** of each implant are positioned adjacent one another to form a passage **114** therethrough. Preferably passage **114** is adapted

to hold bone growth promoting material to permit for the growth of bone from vertebral body to vertebral body through passage **114**. Preferably, the combined width of both implants is greater than one-half the width of the adjacent vertebral bodies into which the implants are adapted to be inserted.

In a preferred embodiment of the present invention, leading end **102** and opposed sides **110**, **112** are machined to have various configurations. Leading end **102** can be machined to have a generally planar configuration across at least a portion of its width from side to side. For example, leading end **102** is preferably machined to have a generally straight portion **116** from side to side that is preferably oriented at approximately 90° to the mid-longitudinal axis of the implant. Where the implantation space is prepared into the vertebral bodies to have a lip or ridge that is at least in part flat, straight portion **116** may be adapted to abut that portion of the implantation space. Interior side **110** is preferably machined to form a corner **118** with generally straight portion **116** of leading end **102**. Exterior side **112** may be machined to form a corner **120** with generally straight portion **116** of leading end **102** or implant **100** may be machined to have a curved transition from straight portion **116** of leading end **102** to exterior side **112**. In a preferred embodiment, corners **118**, **120** can be machined so either or both of sides **110**, **112** are at a 90° angle to straight portion **116** of leading end **102** to produce at least in part straight portions outwardly facing and at least in part generally parallel to each other, that can be aligned or offset from each other along sides **110**, **112**. One or both of sides **110**, **112** may also be formed to be at least in part oriented generally parallel to the mid-longitudinal axis of implant **100**. Forming the implant to have a leading end with a straight portion and an interior facing side with a straight portion permits the implant to be placed in proximity to another implant to achieve a better fill of the implantation space. Further, leading end **102** may be tapered to facilitate insertion of implant **100** between the two adjacent vertebral bodies.

An example of an implantation space adapted to receive at least a portion of implant **100** may be preferably formed with the apparatus and method described by Michelson in U.S. Pat. Nos. 6,159,214 and 6,224,607, the disclosures of which are incorporated herein by reference. The instruments and method are not the subject matter of this application. It is understood that the preparation of the implantation space shown therein are a preferred instrument and method of preparing the implantation spaces and that any method and instrumentation suitable for the purpose may be utilized to prepare the desired implantation space.

In a preferred embodiment of implant **100**, trailing end **104** preferably has an asymmetrical curvature from side to side, at least a portion of which is preferably adapted to conform to at least a portion of the peripheral contour of the anterior aspect of the vertebral bodies adjacent the disc space into which the implant is inserted.

FIGS. **5** and **10** show that implant **100** preferably has a driver opening **122** at trailing end **104** for cooperatively engaging an instrument for installing implant **100** into the implantation space. Driver opening **122** is preferably configured for threaded engagement with an insertion instrument.

FIGS. **5**, **7**, and **8** show at least a portion of upper and lower surfaces **106**, **108** in an angular relationship to each other from trailing end **104** to leading end **102** for allowing for angulation of the adjacent vertebral bodies relative to each other. Preferably, upper and lower surfaces **106**, **108** are non-arcuate in a direction along the longitudinal axis of

implant **100**. In addition to passage **114**, upper and lower surfaces **106**, **108** may include at least one opening in communication with one another to permit for the growth of bone from vertebral body to vertebral body through implant **100**, though the invention is not so limited. Upper and lower surfaces **106**, **108** may also be porous and may include a bone ingrowth surface.

As shown in FIGS. **5–8**, the implants described herein may include a bone-engaging surface **124**. Bone engaging surface **124** preferably has forward facing ratchets **126** facing leading end **102** of implant **100**. Forward facing ratchets **126** resist motion of implant **100** in a direction opposite to the direction of insertion. Other preferred embodiments of bone-engaging surfaces may include the surfaces of the implant being roughened, knurled, splined, or may include at least one protrusion to penetrably engage the bone of the vertebral bodies. By way of example only, the implants of the present invention may include the surface configuration taught by Michelson in U.S. patent application Ser. No. 09/457,228, entitled “Spinal Implant Surface Configuration,” the disclosure of which is incorporated by reference herein.

Implant **100** is preferably manufactured from a bone ring **50** and includes approximately 40 percent or more of the bone ring from which it is formed. Implant **100** preferably has a length **L** greater than one-half the depth of the vertebral bodies adjacent the disc space into which the implant is adapted to be inserted as measured between the anterior and posterior aspects of the vertebral bodies. Implant **100** also preferably has a maximum width **W** that is less than approximately one-half the width of the adjacent vertebral bodies into which the implant is adapted to be inserted.

For any of the embodiments of the implants of the present invention, instead of being machined from a single bone portion such as bone ring **50**, the implant can be manufactured from a composite bone material which may include at least one of cortical bone fibers, bone filaments, bone particles, or bone dust, and a material which may or may not be bioactive and/or bioresorbable such as a plastic, ceramic, for example. By way of example only and not limitation, bioresorbable materials may include polygalactone. Once formed, the composite implant material may be machined or molded, into the desired shape.

FIG. **11** shows an implant **200** in accordance with another preferred embodiment of the present invention adapted for use from an anterior approach to the spine. Implant **200** is similar to implant **100**, except that it has a trailing end **204** that is curved from side to side. For example, trailing end **204** may be configured in the shape of a half circle from side to side or may be an arc of a circle. Such a configuration of trailing end does not significantly protrude from the disc space between the vertebral bodies and interfere with any delicate neurostructures or vessels that may be present adjacent thereto.

FIG. **12** shows an implant **300** in accordance with another preferred embodiment of the present invention adapted for use from a posterior approach to the spine. Implant **300** is similar to implant **100** and has a curved transition from straight portion **316** of leading end **302** to exterior side **312** to form a rounded portion **320**. Trailing end **304** is at least in part straight and can form a corner with exterior side **312**. Trailing end **304** may have other configurations suitable for its intended purpose.

FIGS. **13A** and **13B** show an implant **400** in accordance with another preferred embodiment of the present invention adapted for use from an anterior approach to the spine.

Implant **400** has a leading end **402** that is asymmetrical from side to side. An example of an implant having an asymmetric leading end is disclosed by Michelson in U.S. Pat. No. 6,350,282, incorporated by reference herein.

As illustrated in FIG. **13B**, implant **400** has a mid-longitudinal axis **MLA** along its length. Mid-longitudinal axis **MLA** is shown bisected by a plane **BPP** perpendicular to and bisecting the length of implant **400** along the mid-longitudinal axis **MLA**. Implant **400** has a first distance as measured from point **C** at leading end **402** to plane **BPP** at point **E** that is greater than a second distance as measured from plane **BPP** at point **F** to the junction of leading end **402** and exterior side **412** at point **B**. Implant **400** has a third distance as measured from point **A** at the junction of leading end **402** and interior side **410** to plane **BPP** at point **D** that is greater than the second distance as measured from at point **F** to point **B**. While in the preferred embodiment as shown in FIG. **13B**, the third distance from points **A** to **D** is illustrated as being longer than the first distance from points **C** to **E**, the third distance can be equal to or less than the first distance. In a preferred embodiment, the first distance measured from points **C** to **E** is greater than the second distance measured from points **B** to **F**; the third distance measured from points **A** to **D** can be less than the first distance measured from points **C** to **E**; and the third distance measured from points **A** to **D** does not equal the second distance measured from points **B** to **F**. Implant **400** preferably has a trailing end **404** that is asymmetrical from side to side. Trailing end **404** may have other configurations suitable for its intended purpose.

FIG. **14** shows an implant **500** in accordance with another preferred embodiment of the present invention adapted for use from an anterior approach to the spine. Implant **500** is similar to implant **400**, except that it has a trailing end **504** that is symmetrical side to side. For example, trailing end **504** may be configured in the shape of a half circle from side to side or may be an arc of a circle.

FIG. **15** shows an implant **600** in accordance with another preferred embodiment of the present invention adapted for use from a posterior approach to the spine. Implant **600** is similar to implant **400** except that trailing end **604** is at least in part straight.

FIGS. **16–19** each show a top plan view of a section of diaphyseal bone ring **50** cut across the longitudinal axis of the long bone shown in FIG. **2** illustrating various shapes of implants that can be formed therefrom. FIG. **16** shows bone ring **50** being capable of being machined into implants **400** and **500** described above. FIG. **17** shows bone ring **50** being capable of being machined into implants **100** and **500** described above. FIG. **18** shows bone ring **50** being capable of being machined into implants **300** and **600**. At least a portion of the medullary canal is preferably included in the interior sides of the implants formed from the bone rings. When possible and where it is desired, at least a portion of the natural curvature of the bone ring is preserved and included in the shape of the implants formed.

While it is preferred to form two implants from each bone ring **50**, the present invention is not so limited. For example, FIG. **19** shows bone ring **50** being capable of being machined into a single implant, such as implant **200**. It is appreciated that other configuration of implants may be formed in addition to those shown herein without departing from the scope of the present invention.

FIGS. **20A–22B** show side elevation views of the diaphyseal bone ring with different configurations of a chamfered tapered end adapted to facilitate the insertion of an implant having a height greater at its a leading end than at

its trailing end from the posterior approach to the spine. FIGS. 20A and 20B show bone ring 50' in accordance with a preferred embodiment of the present invention having a chamfer 128 at end 52' that is configured to provide a portion 56' of end 52' having a reduced height that is generally equal to the height of end 54'. The reduced height facilitates introduction into the disc space.

FIGS. 21A and 21B show bone ring 50" in accordance with another preferred embodiment of the present invention. Bone ring 50" is similar to bone ring 50', except that end 52" has a chamfer 130 that is cut at a steeper angle than chamfer 128 to provide a portion 58" of end 52" that has a height that is generally less than the height of end 54".

FIGS. 22A and 22B show bone ring 50''' in accordance with another preferred embodiment of the present invention. Bone ring 50''' is similar to bone ring 50'', except that end 52''' is created by making two cuts at different angles to a mid-longitudinal axis between ends 52''' and 54'''. A first cut is made to form a first chamfer 132 and a second cut is made to form second chamfer 134. A portion 59''' of end 52''' is formed having a height that is generally less than the height of end 54'''.

In any of the embodiments of the present invention, the implant may include, be made of, treated, coated, filled, used in combination with, or have a hollow or medullary canal for containing artificial or naturally occurring materials and/or substances suitable for implantation in the human spine. These materials and/or substances include any source of osteogenesis, bone growth promoting materials, bone, bone derived substances or products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic proteins, hydroxyapatite, genes coding for the production of bone, and bone including, but not limited to, cortical bone. The implant can include at least in part of materials that are bioabsorbable and/or resorbable in the body such as bone and/or bone growth promoting materials. The implant of the present invention can be formed of a porous material or can be formed of a material that intrinsically participates in the growth of bone from one of adjacent vertebral bodies to the other of adjacent vertebral bodies. Where such implants are for posterior implantation, the trailing ends of such implants may be treated with, coated with, or used in combination with chemical substances to inhibit scar tissue formation in the spinal canal. The implant of the present invention may be modified, or used in combination with materials to make it antibacterial, such as, but not limited to, electroplating or plasma spraying with silver ions or other substance. At least a portion of the implant may be treated to promote bone ingrowth between the implant and the adjacent vertebral bodies. The implant of the present invention may be used in combination with a spinal fixation implant such as any object, regardless of material, that can be inserted into any portion of the spine, such as but not limited to interbody spinal implants, structural bone grafts, mesh, cages, spacers, staples, bone screws, plates, rods, tethers of synthetic cords or wires, or other spinal fixation hardware.

Although various embodiments of the present invention have been disclosed, they are but preferred embodiments for the purpose of illustration by example and not limitation. It should be understood that any modifications of these teachings as would be known to one of ordinary skill in the art are anticipated and within the scope of the present inventive teachings.

What is claim is:

1. An interbody spinal implant made of conical bone for insertion at least in part into an implantation space formed

across the height of a disc space between adjacent vertebral bodies of a human spine, the vertebral bodies having an anterior aspect and a posterior aspect, said implant comprising:

- 5 a leading end for insertion first into the disc space, a trailing end opposite said leading end, said implant having a length along a mid-longitudinal axis of said implant from said leading end to said trailing end;
- opposed upper and lower portions between said leading and trailing ends adapted to be placed at least in part within and across the height of the disc space to contact and support the adjacent vertebral bodies, said upper and lower portions being non-arcuate along at least a portion of the length of said implant;
- 15 an interior facing side, an exterior facing side opposite said interior side, and a maximum width therebetween, said maximum width of said implant being less than approximately one-half of the width of the adjacent vertebral bodies into which said implant is adapted to be inserted, said interior and exterior sides connecting said upper and lower portions and said leading and trailing ends, said leading end having a generally straight portion from side to side, a portion of said exterior side being in a plane generally parallel to the mid-longitudinal axis, said portion of said exterior side intersecting said generally straight portion of said leading end and forming a corner with said generally straight portion of said leading end, said interior side adapted to be oriented toward an interior side of another implant when inserted within the disc space;
- 20 said trailing end being adapted to conform from side to side to at least a portion of the peripheral contour of at least one of the anterior and posterior aspects of the vertebral bodies adjacent a disc space into which said implant is inserted;
- said implant being manufactured from a bone ring obtained from a major long bone of a human having a medullary canal, said interior side of said implant including at least a portion of the medullary canal so that when said implant is placed side by side another implant having an interior side including at least a portion of a medullary canal a passage is formed adapted to hold bone growth promoting material for permitting for the growth of bone from vertebral body to vertebral body through said passage.

2. The implant of claim 1, wherein said straight portion of said leading end is generally oriented at 90 degrees to the mid-longitudinal axis of said implant.

3. The implant of claim 1, wherein at least a portion of said leading end has a reduced height to facilitate insertion of said implant between the two adjacent vertebral bodies.

4. The implant of claim 1, wherein said trailing end is at least in part straight from side to side.

5. The implant of claim 1, wherein said trailing end is configured in the shape of a half circle from side to side.

6. The implant of claim 1, wherein said trailing end is asymmetrical side to side.

7. The implant of claim 1, wherein said interior side is at least in part straight.

8. The implant of claim 1, wherein said interior side is at least in part oriented generally parallel to the mid-longitudinal axis of said implant.

9. The implant of claim 1, wherein said interior and exterior sides are at least in part generally parallel one another.

10. The implant of claim 1, wherein at least a portion of said upper and lower surfaces are in an angular relationship

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to each other from trailing end to leading end for allowing angulation of the adjacent vertebral bodies relative to each other.

11. The implant of claim 1, wherein said upper and lower surfaces include at least one opening in communication with one another to permit for the growth of bone from vertebral body to vertebral body through said implant.

12. The implant of claim 1, wherein said implant has a maximum length less than and approximating the posterior to anterior depth of the vertebral bodies.

13. The implant of claim 1, further comprising a bone engaging surface formed on the exterior of at least said upper and lower portions for engaging the adjacent vertebral bodies, said bone engaging surface including at least one of a protrusion, a ratchet, a spike, a spline, surface roughenings, and knurling.

14. The implant of claim 1, wherein said implant comprises at least in part of a bone growth promoting material.

15. The implant of claim 14, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

16. The implant of claim 1, in combination with a bone growth promoting material.

17. The implant of claim 16, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

18. The implant of claim 1, wherein said implant is treated with a bone growth promoting substance.

19. The implant of claim 1, wherein said implant is at least in part resorbable.

20. The implant of claim 1, in combination with a chemical substance adapted to inhibit scar formation.

21. The implant of claim 1, in combination with an antimicrobial material.

22. The implant of claim 1, wherein at least a portion of said implant is treated to promote bone ingrowth between said implant and said adjacent vertebral bodies.

23. The implant of claim 1, further in combination with at least one spinal fixation implant.

24. The implant of claim 1, wherein said trailing end is curved from side to side along a majority of the width of said implant.

25. The implant of claim 1, wherein said implant has a maximum length greater than the maximum width of said implant.

26. The implant of claim 13, wherein said bone engaging surface includes a plurality of ratchets, said ratchets being at least in part forward-facing.

27. The implant of claim 1, wherein said implant has a horizontal mid-longitudinal plane, each of said upper and lower surfaces being in angular relationship relative to the horizontal mid-longitudinal plane of said implant to allow for angulation of the adjacent vertebral bodies relative to each other.

28. An interbody spinal implant made of cortical bone for insertion at least in part across the height of a disc space between adjacent vertebral bodies of a human spine, the vertebral bodies having an anterior aspect and a posterior aspect, said implant comprising:

a leading end for insertion first into the disc space, a trailing end opposite said leading end, said implant

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having a length along a mid-longitudinal axis of said implant from said leading end to said trailing end;

opposed upper and lower portions between said leading and trailing ends adapted to be placed at least in part within and across the height of the disc space to contact and support the adjacent vertebral bodies;

an interior side, an exterior side opposite said interior side, and a maximum width therebetween, said maximum width of said implant being less than one-half of the width of the adjacent vertebral bodies into which said implant is adapted to be inserted, said interior and exterior sides connecting said upper and lower portions and said leading and trailing ends, said leading end having a shape that is asymmetrical from side to side, said trailing end having a shape from side to side different than the shape of said leading end, said interior side adapted to be oriented toward an interior side of another implant when inserted within the disc space, said upper and lower portions being non-arcuate from side to side;

said implant being manufactured from a bone ring obtained from a major long bone of a human having a medullary canal, said interior side of said implant including at least a portion of the medullary canal so that when said implant is placed side by side another implant having an interior side including at least a portion of a medullary canal a passage is formed adapted to hold bone growth promoting material for permitting for the growth of bone from vertebral body to vertebral body through said passage.

29. The implant of claim 28, wherein said leading end includes a generally straight portion from side to side.

30. The implant of claim 29, wherein said straight portion of said leading end is generally oriented at 90 degrees to the mid-longitudinal axis of said implant.

31. The implant of claim 28, wherein at least a portion of said leading end has a reduced height to facilitate insertion of said implant between the two adjacent vertebral bodies.

32. The implant of claim 28, wherein said trailing end is at least in part straight from side to side.

33. The implant of claim 28, wherein said trailing end is configured in the shape of a half circle from side to side.

34. The implant of claim 28, wherein said trailing end is asymmetrical side to side.

35. The implant of claim 28, wherein the trailing end is adapted to conform from side to side to at least a portion of the peripheral contour of at least one of the anterior and posterior aspects of the vertebral bodies adjacent a disc space into which said implant is inserted.

36. The implant of claim 28, wherein said at least one of said interior and exterior sides is at least in part straight.

37. The implant of claim 28, wherein at least one of said interior and exterior sides is at least in part oriented generally parallel to the mid-longitudinal axis of said implant.

38. The implant of claim 28, wherein said interior and exterior sides are at least in part generally parallel one another.

39. The implant of claim 28, wherein at least a portion of said upper and lower surfaces are in an angular relationship to each other from trailing end to leading end for allowing angulation of the adjacent vertebral bodies relative to each other.

40. The implant of claim 28, wherein said upper and lower surfaces include at least one opening in communication with one another to permit for the growth of bone from vertebral body to vertebral body through said implant.

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41. The implant of claim 28, wherein said implant has a maximum length less than and approximating the posterior to anterior depth of the vertebral bodies.

42. The implant of claim 28, further comprising a bone engaging surface formed on the exterior of at least said upper and lower portions for engaging the adjacent vertebral bodies, said bone engaging surface including at least one of a protrusion, a ratchet, a spike, a spline, surface roughenings, and knurling.

43. The implant of claim 28, wherein said implant comprises at least in part of a bone growth promoting material.

44. The implant of claim 43, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

45. The implant of claim 28, in combination with a bone growth promoting material.

46. The implant of claim 45, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

47. The implant of claim 28, wherein said implant is treated with a bone growth promoting substance.

48. The implant of claim 28, wherein said implant is at least in part resorbable.

49. The implant of claim 28, in combination with a chemical substance adapted to inhibit scar formation.

50. The implant of claim 28, in combination with an antimicrobial material.

51. The implant of claim 28, wherein at least a portion of said implant is treated to promote bone ingrowth between said implant and said adjacent vertebral bodies.

52. The implant of claim 28, further in combination with at least one of a spinal fixation implant.

53. The implant of claim 28, wherein said trailing end is curved from side to side along a majority of the width of said implant.

54. The implant of claim 28, wherein said implant has a maximum length greater than the maximum width of said implant.

55. The implant of claim 42, wherein said bone engaging surface includes a plurality of ratchets, said ratchets being at least in part forward-facing.

56. The implant of claim 28, wherein said implant has a horizontal mid-longitudinal plane, each of said upper and lower surfaces being in angular relationship relative to the horizontal mid-longitudinal plane of said implant to allow for angulation of the adjacent vertebral bodies relative to each other.

57. The implant of claim 28, wherein said implant includes at least 40 percent of the bone ring from which it is being formed.

58. The implant of claim 29, wherein each of said leading end and said trailing end is at least in part curved from side to side, the curve of said leading end having a radius of curvature different than the radius of curvature of said trailing end.

59. An interbody spinal implant made of bone composite material for insertion at least in part into an implantation space formed across the height of a disc space between adjacent vertebral bodies of a human spine, the vertebral bodies having an anterior aspect and a posterior aspect, said implant comprising:

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a leading end for insertion first into the disc space, a trailing end opposite said leading end, said implant having a length along a mid-longitudinal axis of said implant from said leading end to said trailing end;

opposed upper and lower portions between said leading and trailing ends adapted to be placed within the disc space to contact and support the adjacent vertebral bodies, said upper and lower portions being non-arcuate along at least a portion of the length of said implant; an interior side, an exterior side opposite said interior side, and a maximum width therebetween, said maximum width of said implant being less than approximately one-half of the width of the adjacent vertebral bodies into which said implant is adapted to be inserted, said interior and exterior sides connecting said upper and lower portions and said leading and trailing ends, said leading end having a generally straight portion from side to side, a portion of said exterior side being in a plane generally parallel to the mid-longitudinal axis, said portion of said exterior side intersecting said generally straight portion of said leading end and forming a corner with said generally straight portion of said leading end, said interior side adapted to be oriented toward an interior side of another implant when inserted within the disc space;

said trailing end being adapted to conform from side to side to at least a portion of the peripheral contour of at least one of the anterior and posterior aspects of the vertebral bodies adjacent a disc space into which said implant is inserted;

said implant being manufactured from a bone composite material, said interior side of said implant including a recess so that when said implant is placed side by side another implant having an interior side including a recess a passage is formed adapted to hold bone growth promoting material for permitting for the growth of bone from vertebral body to vertebral body through said passage.

60. The implant of claim 59, wherein said bone composite material includes at least one of cortical bone fibers, bone filaments, bone particles and bone dust.

61. The implant of claim 59, further comprising a binding material.

62. The implant of claim 61, wherein said binding material is at least one of bioactive and bioresorbable.

63. The implant of claim 59, wherein said straight portion of said leading end is generally oriented at 90 degrees to the mid-longitudinal axis of said implant.

64. The implant of claim 59, wherein at least a portion of said leading end has a reduced height to facilitate insertion of said implant between the two adjacent vertebral bodies.

65. The implant of claim 59, wherein said trailing end is at least in part straight from side to side.

66. The implant of claim 59, wherein said trailing end is configured in the shape of a half circle from side to side.

67. The implant of claim 59, wherein said trailing end is asymmetrical side to side.

68. The implant of claim 59, wherein said interior side is at least in part straight.

69. The implant of claim 59, wherein said interior side is at least in part oriented generally parallel to the mid-longitudinal axis of said implant.

70. The implant of claim 59, wherein said interior and exterior sides are at least in part generally parallel one another.

71. The implant of claim 59, wherein at least a portion of said upper and lower surfaces are in an angular relationship

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to each other from trailing end to leading end for allowing angulation of the adjacent vertebral bodies relative to each other.

72. The implant of claim 59, wherein said upper and lower surfaces include at least one opening in communication with one another to permit for the growth of bone from vertebral body to vertebral body through said implant.

73. The implant of claim 59, wherein said implant has a maximum length less than and approximating the posterior to anterior depth of the vertebral bodies.

74. The implant of claim 59, further comprising a bone engaging surface formed on the exterior of at least said upper and lower portions for engaging the adjacent vertebral bodies, said bone engaging surface including at least one of a protrusion, a ratchet, a spike, a spline, surface roughenings, and knurling.

75. The implant of claim 59, wherein said implant comprises at least in part of a bone growth promoting material.

76. The implant of claim 75, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

77. The implant of claim 59, in combination with a bone growth promoting material.

78. The implant of claim 77, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

79. The implant of claim 59, wherein said implant is treated with a bone growth promoting substance.

80. The implant of claim 59, wherein said implant is at least in part resorbable.

81. The implant of claim 59, in combination with a chemical substance adapted to inhibit scar formation.

82. The implant of claim 59, in combination with an antimicrobial material.

83. The implant of claim 59, wherein at least a portion of said implant is treated to promote bone ingrowth between said implant and said adjacent vertebral bodies.

84. The implant of claim 59, further in combination with at least one spinal fixation implant.

85. The implant of claim 59, wherein said trailing end is curved from side to side along a majority of the width of said implant.

86. The implant of claim 59, wherein said implant has a maximum length greater than the maximum width of said implant.

87. The implant of claim 74, wherein said bone engaging surface includes a plurality of ratchets, said ratchets being at least in part forward-facing.

88. The implant of claim 59, wherein said implant has a horizontal mid-longitudinal plane, each of said upper and lower surfaces being in angular relationship relative to the horizontal mid-longitudinal plane of said implant to allow for angulation of the adjacent vertebral bodies relative to each other.

89. A pair of interbody spinal implants made of a bone composite material for insertion at least in part across the height of a disc space between adjacent vertebral bodies of a human spine, the vertebral bodies having an anterior aspect, a posterior aspect, and a depth therebetween, each of said implants comprising:

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a leading end for insertion first into the disc space, a trailing end opposite said leading end, said implant having a length along a mid-longitudinal axis of said implant from said leading end to said trailing end, said length of said implant being greater than one half the depth of the vertebral bodies adjacent the disc space into which said implant is adapted to be inserted;

opposed upper and lower portions between said leading and trailing ends adapted to be placed at least in part within and across the height of the disc space to contact and support the adjacent vertebral bodies;

an interior side, an exterior side opposite said interior side, and a maximum width therebetween, said maximum width of said implant being less than approximately one-half of the width of the adjacent vertebral bodies into which said implant is adapted to be inserted, said interior and exterior sides connecting said upper and lower portions and said leading and trailing ends, said leading end having a shape that is asymmetrical from side to side, said trailing end having a shape from side to side different than the shape of said leading end, said interior side adapted to be oriented toward an interior side of another implant when inserted within the disc space, said upper and lower portions being non-arcuate from side to side; and

said implant being manufactured from a bone composite material, said interior side of said implant including a recess so that when said implant is placed side by side another implant having an interior side including a recess a passage is formed adapted to hold bone growth promoting material for permitting for the growth of bone from vertebral body to vertebral body through said passage; and

the combined width of said pair of said implants being greater than one half the width of the adjacent vertebral bodies into which said implants are adapted to be inserted.

90. The implant of claim 89, wherein said bone composite material includes at least one of cortical bone fibers, bone filaments, bone particles and bone dust.

91. The implant of claim 89, further comprising a binding material.

92. The implant of claim 91, wherein said binding material is at least one of bioactive and bioresorbable.

93. The implant of claim 89, wherein said leading end includes a generally straight portion from side to side.

94. The implant of claim 93, wherein said straight portion of said leading end is generally oriented at 90 degrees to the mid-longitudinal axis of said implant.

95. The implant of claim 89, wherein at least a portion of said leading end has a reduced height to facilitate insertion of said implant between the two adjacent vertebral bodies.

96. The implant of claim 89, wherein said trailing end is at least in part straight from side to side.

97. The implant of claim 89, wherein said trailing end is configured in the shape of a half circle from side to side.

98. The implant of claim 89, wherein said trailing end is asymmetrical side to side.

99. The implant of claim 89, wherein the trailing end is adapted to conform from side to side to at least a portion of the peripheral contour of at least one of the anterior and posterior aspects of the vertebral bodies adjacent a disc space into which said implant is inserted.

100. The implant of claim 89, wherein said at least one of said interior and exterior sides is at least in part straight.

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101. The implant of claim **89**, wherein at least one of said interior and exterior sides is at least in part oriented generally parallel to the mid-longitudinal axis of said implant.

102. The implant of claim **89**, wherein said interior and exterior sides are at least in part generally parallel one 5 to another.

103. The implant of claim **89**, wherein at least a portion of said upper and lower surfaces are in an angular relationship to each other from trailing end to leading end for allowing angulation of the adjacent vertebral bodies relative 10 to each other.

104. The implant of claim **89**, wherein said upper and lower surfaces include at least one opening in communication with one another to permit for the growth of bone from vertebral body to vertebral body through said implant. 15

105. The implant of claim **89**, wherein said implant has a maximum length less than and approximating the posterior to anterior depth of the vertebral bodies.

106. The implant of claim **89**, further comprising a bone engaging surface formed on the exterior of at least said 20 upper and lower portions for engaging the adjacent vertebral bodies, said bone engaging surface including at least one of a protrusion, a ratchet, a spike, a spline, surface roughenings, and knurling.

107. The implant of claim **89**, wherein said implant 25 comprises at least in part of a bone growth promoting material.

108. The implant of claim **107**, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing 30 proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

109. The implant of claim **89**, in combination with a bone growth promoting material. 35

110. The implant of claim **109**, wherein said bone growth promoting material is selected from one of bone, bone derived products, demineralized bone matrix, mineralizing 40 proteins, ossifying proteins, bone morphogenetic protein, hydroxyapatite, and genes coding for the production of bone.

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111. The implant of claim **89**, wherein said implant is treated with a bone growth promoting substance.

112. The implant of claim **89**, wherein said implant is at least in part resorbable.

113. The implant of claim **89**, in combination with a chemical substance adapted to inhibit scar formation.

114. The implant of claim **89**, in combination with an antimicrobial material.

115. The implant of claim **89**, wherein at least a portion of said implant is treated to promote bone ingrowth between said implant and said adjacent vertebral bodies.

116. The implant of claim **89**, further in combination with at least one spinal fixation implant.

117. The implant of claim **89**, wherein said trailing end is curved from side to side along a majority of the width of said implant.

118. The implant of claim **89**, wherein said implant has a maximum length greater than the maximum width of said implant.

119. The implant of claim **106**, wherein said bone engaging surface includes a plurality of ratchets, said ratchets being at least in part forward-facing.

120. The implant of claim **89**, wherein said implant has a horizontal mid-longitudinal plane, each of said upper and lower surfaces being in angular relationship relative to the horizontal mid-longitudinal plane of said implant to allow for angulation of the adjacent vertebral bodies relative to each other.

121. The implant of claim **89**, wherein said implant includes at least 40 percent of the bone ring from which it is being formed.

122. The implant of claim **89**, wherein each of said leading end and said trailing end is at least in part curved from side to side, the curve of said leading end having a radius of curvature different than the radius of curvature of said trailing end.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,989,031 B2
DATED : January 24, 2006
INVENTOR(S) : Gary K. Michelson

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page.

Item [56], **References Cited**, FOREIGN PATENT DOCUMENTS, change
“WO 98/08964” to -- WO 95/08964 --; and after “WO 01/28465” insert:

-- WO	WO 01/62191	8/2001
WO	WO 01/68004	9/2001
WO	WO 01/68005	4/2001 --.

Column 9.

Line 66, change “conical” to -- cortical --.

Column 10.

Line 20, change “Interior” to -- interior --.

Column 11.

Line 4, change “ower” to -- lower --.

Column 13.

Line 57, change “claim 28” to -- claim 29 --.

Signed and Sealed this

Eleventh Day of April, 2006



JON W. DUDAS

Director of the United States Patent and Trademark Office