

**(12) PATENT
(19) AUSTRALIAN PATENT OFFICE**

**(11) Application No. AU 200027568 B2
(10) Patent No. 772682**

(54) Title
Highly-mineralized osteogenic sponge compositions, and uses thereof

(51)⁷ International Patent Classification(s)
A61L 027/22 A61L 027/46
A61K 038/18 A61L 027/56

(21) Application No: **200027568** (22) Application Date: **2000.02.04**

(87) WIPO No: **WO00/45871**

(30) Priority Data

(31) Number **60/118615** (32) Date **1999.02.04** (33) Country **US**

(43) Publication Date : **2000.08.25**

(43) Publication Journal Date : **2000.10.26**

(44) Accepted Journal Date : **2004.05.06**

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(56) Related Art
WO 1998/017330
WO 1997/040137

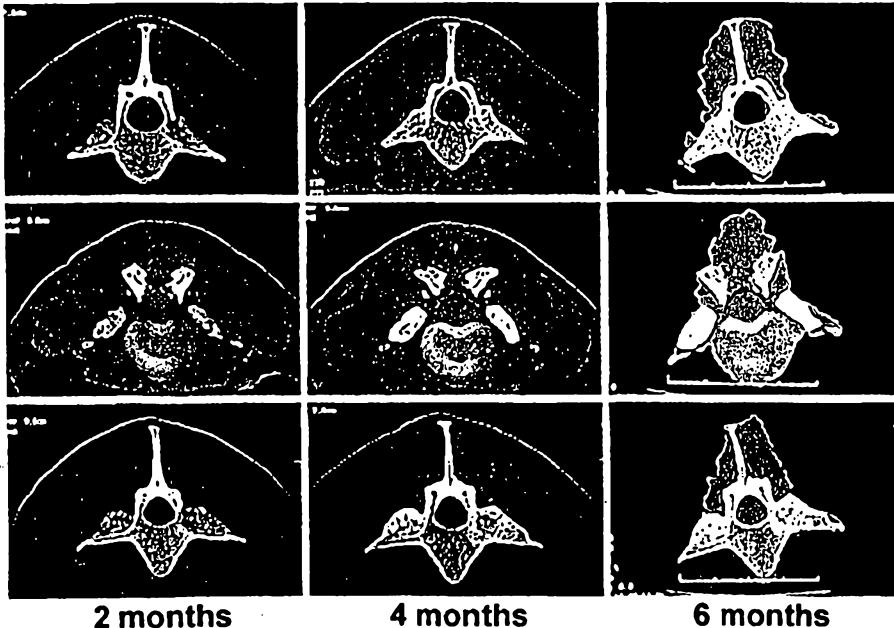


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : A61L 27/22, 27/56, 27/46, A61K 38/18		A1	(11) International Publication Number: WO 00/45871
			(43) International Publication Date: 10 August 2000 (10.08.00)
(21) International Application Number: PCT/US00/03043		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 4 February 2000 (04.02.00)			
(30) Priority Data: 60/118,615 4 February 1999 (04.02.99) US			
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Published*With international search report.**Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

(54) Title: HIGHLY-MINERALIZED OSTEOGENIC SPONGE COMPOSITIONS, AND USES THEREOF



(57) Abstract

Osteogenic sponge compositions having enhanced osteoinductive properties for use in bone repair are described. The compositions include a quickly resorbable porous carrier, a more slowly resorbed mineral scaffold and an osteogenic factor, preferably a bone morphogenetic protein. The compositions enable increased osteoinductive activity while retaining a reliable scaffold for the formation of new bone at an implant site. Methods for therapeutic use of the compositions are also described.

Highly-Mineralized Osteogenic Sponge Compositions, and Uses Thereof

Field of the Invention

5 The present invention relates generally to osteogenic compositions. Specifically, the present invention relates to an osteogenic sponge composition effective for the induction of new bone growth in animals.

Background of the Invention

10 Bone grafting has been commonly used to augment healing in the treatment of a broad range of musculoskeletal disorders. This procedure has several disadvantages. If the bone material is obtained from donors of the same species, such as an allograft, an increased risk of disease transmission and immune reaction exists. Bone material surgically removed from the patient, known as an autograft, is also undesirable because a sufficient amount of autogenous bone may not be available and the additional surgery 15 necessary to obtain the autograft increases the risk of infection.

Due to the need for safer bone graft materials, efforts have been directed to finding bone graft substitutes. Candidate compositions include collagen and a bioceramic, such as hydroxyapatite, as these

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components are the chief structural materials in bone tissue. Bioceramics provide a porous matrix which encourages some new bone growth but, when used in powdered form, give rise to foreign body-giant cell reactions. Other compositions include 5 demineralized bone powder and collagen. The osteogenic potential of these compositions have been found to be less than satisfactory.

The discovery of osteogenic factors and their application to bone graft substitute compositions has increased the effectiveness of the above-mentioned compositions. Although many preparations 10 purport to be effective in bone repair in vertebrates, including higher animals such as primates, most of the experimentation done with the compositions have involved lower animals, such as mice and rats.

In light of this background, there remains a need for improved 15 osteogenic compositions and methods that effectively induce bone growth in higher animals, including primates.

Summary of the Invention

According to a first aspect, the present invention consists in an osteogenic sponge composition useful for the induction of new bone growth in a mammal, comprising:

- 5 a resorbable sponge matrix material;
- an osteogenic factor, said osteogenic factor incorporated in said sponge matrix material in an amount that causes an increased rate of resorption of said sponge matrix material in a mammal; and

10 particulate mineral having an average particle diameter of at least about 0.5 mm embedded in said resorbable sponge matrix material, said particulate mineral present in a weight ratio of at least 4:1 relative to said resorbable sponge matrix material, so as to provide a scaffold for bone ingrowth in the presence of said osteogenic factor.

According to a second aspect, the present invention consists in an osteogenic sponge composition effective for the induction of new bone growth in a primate, comprising:

- 15 a resorbable sponge matrix material;
- an osteogenic factor that stimulates osteoblasts and osteoclasts, said osteogenic factor incorporated in said sponge matrix material in an amount that causes an increased rate of resorption of said sponge matrix material in the primate; and

20 particulate mineral having an average particle diameter of at least about 0.5 mm embedded in said resorbable sponge matrix material, said particulate mineral present in a weight ratio of at least 4:1 relative to said resorbable sponge matrix material, so as to provide a mineral scaffold for a duration sufficient for osteoid ingrowth through an area in which said sponge composition is implanted.

According to a third aspect, the present invention consists in a method for inducing
25 bone growth in a primate, comprising:

- a) providing an osteogenic sponge composition comprising:
 - 30 a resorbable sponge matrix material;
 - an osteogenic factor that stimulates osteoblasts and osteoclasts, said osteogenic factor incorporated in said sponge matrix material in an amount that causes an increased rate of resorption of said sponge matrix material in the primate; and
 - particulate mineral having an average particle diameter of at least about 0.5 mm embedded in said resorbable sponge matrix material, said particulate mineral present in a weight ratio of at least 4:1 relative to said resorbable sponge matrix material, so as to

provide a scaffold for bone ingrowth in the presence of said osteogenic factor; and

5 b) implanting said osteogenic sponge composition in an area in which bone growth is desired in the primate, said osteogenic sponge composition providing a scaffold for a duration sufficient for osteoid ingrowth through an area in which said osteogenic sponge composition is implanted.

According to a fourth aspect, the present invention consists in an osteogenic sponge composition for the induction of new bone growth in a primate, comprising:

10 a carrier consisting essentially of a resorbable sponge matrix with particulate mineral embedded in said resorbable sponge matrix, said particulate mineral present in an amount constituting at least about 95% by weight of said carrier; and
an osteogenic factor.

15 According to a fifth aspect, the present invention consists in a highly mineralized sponge implant device consisting essentially of a resorbable sponge matrix formed of collagen and having particulate biocompatible mineral embedded within said matrix, said device comprised 1% to 3% by weight of the collagen and 97% to 99% by weight of the particulate biocompatible mineral.

According to a sixth aspect, the present invention consists in an osteogenic implant, comprising:

20 a resorbable matrix carrier comprised 1% to 3% by weight of collagen in sponge form and 97% to 99% by weight of a particulate biocompatible mineral embedded within said collagen; and
an osteogenic factor.

According to a seventh aspect, the present invention consists in an interbody spinal fusion device, comprising:

25 a load bearing member sized for insertion between adjacent vertebrae; and
a composition according to the first, second, fourth, fifth or sixth aspect retained by said load bearing member.

30 According to an eighth aspect, the present invention consists in a method for interbody spinal fusion in a mammal, comprising implanting between adjacent vertebrae in the mammal an interbody spinal fusion device according to the seventh aspect.

The invention provides in one preferred embodiment an osteogenic sponge composition useful for the induction of new bone growth in a mammal. This composition includes a resorbable sponge matrix material and an osteogenic factor, preferably one that preferably stimulates osteoblasts and osteoclasts, said osteogenic factor incorporated in the sponge matrix material. The resorbable sponge matrix material is desirably a three-

dimensionally stable yet flexible material, facilitating its use as an implant. The osteogenic factor is usually incorporated in an amount that causes an increased rate of resorption of said sponge matrix material in a mammal. The composition also includes a particulate mineral having an average particle diameter of at least about 0.5 mm
5 embedded in the resorbable sponge matrix material, wherein the particulate mineral present in a weight ratio of at least 4:1 relative to the resorbable sponge matrix material so as to provide a scaffold for bone ingrowth in the presence of the osteogenic factor. More preferred compositions are even more highly mineralized, for example wherein the particulate mineral is present in a weight ratio of at least about 10:1 relative to the
10 resorbable sponge matrix material. The particulate mineral is desirably formed of a synthetic calcium phosphate ceramic or of bone, especially cortical bone. The osteogenic factor is most preferably BMP-2 or LMP, or comprises a nucleotide sequence encoding BMP-2 or LMP.

Another embodiment of the present invention provides a method for inducing bone
15 growth in a primate. The method includes a first step of providing an osteogenic sponge composition having a

resorbable sponge matrix material and an osteogenic factor that stimulates osteoblasts and osteoclasts incorporated in the sponge matrix material in an amount that causes an increased rate of resorption of the sponge matrix material in the primate. Particulate 5 mineral having an average particle diameter of at least about 0.5 mm is embedded in said resorbable sponge matrix material and present in a weight ratio of at least 4:1 relative to the resorbable sponge matrix material, so as to provide a scaffold for bone ingrowth in the presence of the osteogenic factor. This osteogenic 10 sponge composition is implanted in the primate in a void in which bone growth is desired, with the osteogenic sponge composition providing a scaffold for a duration sufficient for osteoid ingrowth through the void. Particularly preferred methods involve bone ingrowth to attain spinal fusions in humans.

15

Another preferred embodiment of the invention provides an osteogenic sponge composition effective for the induction of new bone growth in a mammal (especially a primate) that includes

a carrier consisting essentially of a resorbable sponge matrix 20 with particulate mineral embedded in the resorbable sponge matrix, wherein the particulate mineral is present in an amount constituting at least about 95% by weight of the carrier. An osteogenic factor that stimulates osteoblasts and osteoclasts is incorporated in said carrier.

25

A still further aspect of the invention provides a highly mineralized sponge implant device consisting essentially of a resorbable sponge matrix formed of collagen and having particulate biocompatible mineral embedded within said matrix. In this 30 embodiment, the device is comprised 1% to 3% by weight of the

collagen and 97% to 99% by weight of the particulate biocompatible mineral. In another inventive feature, an osteogenic factor can be incorporated in such an implant.

5 A further embodiment of the invention provides an interbody spinal fusion device that includes a load bearing member sized for insertion between adjacent vertebrae and any one of the aforementioned compositions retained by the load bearing member. Such fusion devices can be used in inventive interbody spinal 10 fusion methods mammals, wherein the devices are appropriately implanted to facilitate spinal fusion.

15 A particular feature of the present invention relates to the discovery that the inclusion of an osteogenic factor, especially an osteoblast- and osteoclast-stimulating osteogenic factor, in a resorbable sponge composition causes a substantially accelerated resorption of the sponge. This rapid resorption can diminish or eliminate the capacity of the sponge composition to effectively stimulate and support new bone formation in a void filled with the 20 sponge composition. This is particularly the case in primates, including humans, in which the rate of new bone formation is relatively slow. Objects of the present invention are to provide osteogenic sponge compositions effective for the induction of bone growth in mammals, particularly primates, including humans, and 25 related methods and devices. These and other objects and advantages of the present invention will become apparent upon reading the descriptions herein.

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BRIEF DESCRIPTION OF THE FIGURES

FIGs. 1 and 2 depict a digitized images of computerized tomography (CT) scans of an L4-L5 posterolateral spinal fusions performed on rhesus monkeys as described in Example 5 (top 5 panels, section through superior transverse processes; middle panels, section through disc space; lower panels, section through inferior transverse processes).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to preferred embodiments and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications of the invention, and such further applications of the principles of the invention as illustrated herein, being contemplated as would normally occur to one skilled in the art to which the invention relates.

As described above, the invention relates in certain aspects to osteogenic sponge compositions effective for the induction of new bone growth in mammals and methods for inducing bone growth in mammals. The present invention features osteogenic sponge compositions effective for use in primates, wherein the compositions exhibit high osteoinductive potential and provide a lasting mineral scaffold to support bone ingrowth. Such preferred compositions include a porous, resorbable sponge carrier, such as collagen in sponge form, and an osteogenic factor that stimulates the action of both osteoblasts (which biologically facilitate the formation of bone) and osteoclasts (which biologically facilitate the resorption of bone). In accordance with the present invention, it has been found that the incorporation of an effective inductive amount of an osteogenic factor, such as a bone morphogenetic protein (BMP), stimulates osteoclasts to such a level that a porous resorbable carrier is quickly resorbed and, in the absence of a high mineral component in the composition, causes the performance of the composition to suffer in some cases to the extent that the observation of substantial bone

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ingrowth is sporadic. Although such non-mineralized sponge compositions may be highly effective for repair of bone defects in lower animals, such as mice, that have a faster bone growth rate, they are less effective in large animals such as primates, including 5 humans.

Accordingly, a feature of the present invention is the provision of an osteogenic composition in the form of a sponge that includes a substantial amount of a relatively slowly-resorbed mineral 10 component that remains at the implant site after the carrier has been rapidly resorbed, in order to provide a scaffold for new bone formation that is not prematurely resorbed due to the osteoclastic potentiation by the bone morphogenic protein in the composition. The present invention also provides methods for using such 15 osteogenic compositions in treatment of bone trauma, disease and defects, for artificial arthrodeses and for other treatment where new bone formation is desired, especially in primates, including humans.

The sponge matrix material is preferably collagenous. A wide 20 variety of collagen materials are suitable for the sponge matrix. Naturally occurring collagens may be subclassified into several different types depending on their amino acid sequence, carbohydrate content and presence or absence of disulfide cross-links. Types I and III collagen are two of the most common subtypes 25 of collagen. Type I collagen is present in skin, tendon and bone whereas Type III collagen is found primarily in skin. The collagen in the composition may be obtained from skin, bone, tendon, or cartilage and purified by methods known in the art. Alternatively, the collagen may be purchased commercially. The collagen in the 30 composition is preferably Type I bovine collagen.

The collagen carrier can further be atelopeptide collagen and/or telopeptide collagen. Moreover, both non-fibrillar and fibrillar collagen may be used. Non-fibrillar collagen is collagen that has 5 been solubilized and has not been reconstituted into its native fibrillar form.

The sponge carrier may also be formed of other natural or synthetic polymeric materials, in addition to or as an alternative to 10 collagen. For example, the sponge carrier may be formed of gelatin (e.g. foamed gelatin), in addition collagen or as an alternative to collagen. Other natural and synthetic polymers are also known for the formation of biocompatible sponge materials, and can be used herein.

15

As indicated above, preferred compositions of the invention also include an osteoinductive factor, such as an osteoinductive protein or a nucleotide sequence encoding an osteoinductive protein operably associated with a promoter (e.g. provided in a vector such as a viral 20 vector) which drives expression of the gene in the animal recipient to produce an effective amount of the protein. The osteogenic factor utilized in the present invention can be one that stimulates production or activity of osteoblasts and osteoclasts. The factor is preferably a bone morphogenetic protein (BMP) or a LIM mineralization protein (LMP), or 25 comprises a nucleotide sequence encoding a BMP or LMP. Recombinant human BMPs are preferred, and may be commercially obtained or prepared as described and known in the art, e.g. in U.S. Patent Nos. 5,187,076 to Wozney et al.; 5,366,875 to Wozney et al.; 4,877,864 to Wang et al.; 5,108,932 to Wang et al.; 5,116,738 to Wang et al.; 30 5,013,649 to Wang et al.; 5,106,748 to Wozney et al; and PCT Patent Nos.

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WO93/00432 to Wozney et al.; WO94/2693 to Celeste et al.; and WO94/26892 to Celeste et al. Further, the osteoinductive factor may be isolated from bone. Methods for isolating BMP from bone are described in U.S. Patent no. 4,294,753 to Urist and Urist et al., PNAS 371, 1984.

5 Recombinant human BMP-2 (rhBMP-2), recombinant human BMP-4 (rhBMP-4), recombinant human BMP-7 (rhBMP-7) or heterodimers thereof are most preferred. The osteoinductive factor may also be LIM mineralization protein (LMP) or a suitable vector incorporating a gene encoding the same operably associated with a promotor, as described in

10 WO99/06563 (see also genbank accession No. AF095585). When such vectors are employed as osteogenic factors in accordance with the invention, they are preferably delivered in conjunction with cells, for example autologous cells from the recipient of the implant. Most preferably the vector is delivered in conjunction with autologous white

15 blood cells derived from bone marrow or peripheral blood of the recipient. These cells may be applied to the sponge composition along with the osteogenic factor prior to implantation.

20 The particulate mineral component includes a natural or synthetic mineral that is effective in providing a scaffold for bone ingrowth as the resorbable carrier is resorbed. The mineral may be, for example, bone, especially cortical bone, or a synthetic bioceramic such as a biocompatible calcium phosphate ceramic. Illustrative ceramics include tricalcium phosphate, hydroxyapatite, and 25 biphasic calcium phosphate. These mineral components may be purchased commercially or obtained or synthesized by methods known in the art.

30 Biphasic calcium phosphate is a particularly preferred synthetic ceramic for use in the invention. Desirably, such biphasic

calcium phosphate with have a tricalcium phosphate:hydroxyapatite weight ratio of about 50:50 to about 95:5, more preferably about 70:30 to about 95:5, even more preferably about 80:20 to about 90:10, and most preferably about 85:15.

5

In general, the amount of mineral in the osteogenic sponge composition must be sufficient to provide a scaffold that will remain in the patient for a period of time sufficient for the formation of osteoid in the void for which bone growth is desired. Typically, this 10 period of time will be about 6 to about 8 weeks. The minimum level of mineral that must be present in the composition is also dependent on the activity of the BMP in the composition; the higher the activity of the BMP, the greater the content of the mineral matrix required to counter the osteoclastic potentiation of the BMP. The 15 rate of resorption of the resorbable carrier also increases as the BMP concentration increases.

In preferred aspects of the invention, the particulate mineral:resorbable sponge matrix weight ratio will be at least about 20 4:1, more preferably at least about 10:1. In particularly preferred sponge implants, the particulate mineral will constitute at least 95% by weight of the sponge implant. For example, highly effective sponge carrier devices are provided wherein they comprise about 97% to about 99% by weight particulate mineral and about 1% to 25 about 3% of the collagen or other sponge-forming matrix material. Moreover, it is preferred that the mineral component have an average particle size of at least about 0.5 mm, more preferably about 0.5 mm to about 5 mm, and most preferably about 1 mm to about 3 mm.

30

To make the sponge implant, a collagen slurry may be formed as known and preferably is chilled to increase its viscosity to help suspend the porous particulate mineral component. The porous particulate mineral is dispersed into the collagen slurry and gently 5 mixed. After the porous particulate mineral component is uniformly dispersed in the slurry, the slurry is poured into sterile trays or other forms and freeze dried. The sheets of composite sponge are then removed from the freeze drier and exposed to a gluteraldehyde 10 cross-linking agent. The composite sponge formed is generally three-dimensionally stable and can be sterilized and packaged in accordance with known procedures.

The dimensions of the sponge produced may vary depending on the application. Dimensions of a typical sponge are, for example, 15 about 10 cm (length) x 7.5 cm (width) x 0.35 cm (height).

As one example, BMP or other osteogenic factors may be included in the formed sponge by combining the BMP with a liquid carrier as known in the art and infusing the liquid into the sponge.

20 As further enhancements of the compositions of the present invention, those skilled in the art will readily appreciate that other osteogenic enhancing factors may be incorporated into the composition. Such additional factors include host compatible 25 osteogenic progenitor cells, autographic bone marrow, allographic bone marrow, transforming growth factor- β , fibroblast growth factor, platelet-derived growth factor, insulin-like growth factor, microglobulin- β , antibiotics and steroids.

30 In yet another aspect of the invention, methods for inducing bone

growth in mammals are provided. The methods include providing the above-described osteogenic sponge composition and implanting the composition at a site at which bone growth is desired, e.g., to treat a disease, defect or location of trauma, and/or to promote 5 artificial arthrodesis. The hydrated sponge composition may be rolled up prior to packing the sponge into the implantation site.

Once in place, the osteogenic sponge composition will effectively induce and support ingrowth of bone into the desired area even in a 10 primate such as a human that exhibits a relatively slow rate of bone formation compared to smaller mammals, such as rodents or rabbits. Although the collagen carrier is resorbed relatively quickly, the substantial mineral component remains as a scaffolding to support new bone growth in and through the desired area.

15

The above osteogenic sponge compositions of the present invention are especially advantageous when used in bones or bone portions that exhibit only low to moderate vascularization. Such low to moderate vascularized regions exhibit low rates of bone formation 20 so rapid resorption of a carrier poses a problem. Examples of low to moderate vascularized sites include, for example, transverse processes or other posterior elements of the spine.

25

An especially preferred use of the sponge compositions of the present invention is as an implant to promote arthrodesis between vertebrae in spinal fusions in humans or other primates, including interbody, posterior and/or posterolateral fusion techniques. Although the rate of bone formation in the primate spine is relatively slow overall and thus will benefit generally from the 30 present invention, the elements to be fused in posterior and

posterolateral fusions exhibit particularly low levels of vascularization and thus fusions of these elements are expected to benefit markedly from the invention.

5 Moreover, the osteogenic sponge compositions can be incorporated with a load-bearing member used in a spinal fusion, including hollow spinal cages, dowels or other devices known in the art having a pocket, chamber or other mechanism for retaining the osteogenic sponge composition. The load-bearing member
10 desirably will have a compressive strength of at least about 10,000 N. Suitable such load bearing members are described, for example in U.S. Patent Nos. 5522899, 5785710, 5776199 and 5814084, each of which is hereby incorporated by reference in its entirety.

15 Reference will now be made to specific examples using the processes described above. It is to be understood that the examples are illustrative and not limiting of the invention.

20 **EXAMPLE 1**
PREPARATION OF COLLAGEN SPONGE/
BONE PARTICLE COMPOSITE

12 grams of deproteinized cortical bone chips, 1-3 mm in size, were added to 12 grams of collagen slurry (0.192 grams of collagen).
25 This composite slurry was poured into a 7.5 cm x 10.0 cm mold, freeze dried, double sterile packaged, and sterilized by ETO gas sterilization.

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EXAMPLE 2
PREPARATION OF COLLAGEN SPONGE/
SYNTHETIC CERAMIC COMPOSITE

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12 grams of biphasic calcium phosphate particles, 1 mm in diameter, were added to 12 grams of collagen slurry (0.192 grams of collagen). This composite slurry was poured into a 7.5 cm x 10.0 cm mold, freeze dried, double sterile packaged, and sterilized by 10 ETO gas sterilization.

EXAMPLE 3
PREPARATION OF COLLAGEN SPONGE/
BONE PARTICLE COMPOSITE

15

12 grams of deproteinized cortical bone chips, 1-3 mm in size, were added to 24 grams of collagen slurry (0.192 grams of collagen). This composite slurry was poured into a 7.5 cm x 10.0 cm mold, freeze dried, double sterile packaged, and sterilized by 20 ETO gas sterilization.

EXAMPLE 4
PREPARATION OF COLLAGEN SPONGE/
SYNTHETIC CERAMIC COMPOSITE

25

12 grams of biphasic calcium phosphate particles, 1 mm in diameter, were added to 24 grams of collagen slurry (0.192 grams of collagen). This composite slurry was poured into a 7.5 cm x 10.0 cm mold, freeze dried, double sterile packaged, and sterilized by 30 ETO gas sterilization.

EXAMPLE 5**L4-L5 POSTEROLATERAL INTERTRANSVERSE PROCESS
SPINAL FUSION STUDY**

5

The present study was performed to determine the effect of the osteogenic sponge compositions of the present invention on spinal fusion.

The experimental group included two adult rhesus monkeys (10 *Macaca mulatta*). The monkeys were anesthetized with 3-5 mg/kg telazol intramuscularly (i.m.). The anesthesia was maintained with 1.5-2.0% isoflurane. After anesthesia was achieved, animals were shaved, prepared with betadine and sterily draped. The surgical site was infiltrated with 10-15 ml of 0.25% marcaine to aid with 15 immediate postoperative analgesia. A midlineposterior skin incision was made over the lumbar spine. The paraspinal muscles were reflected using elevators, exposing the lamina and the transverse processes of the L4 and L5 vertebral bodies. The transverse processes of the two vertebrae to be fused were decorticated with an 20 electric burr.

Composite sponges, having dimension of 3.5 cm x 1.4 cm x 0.35 cm, were prepared using techniques as described in Examples 1 and 2. The sponges included, on a weight basis, 97% biphasic calcium phosphate (15% hydroxyapatite and 85% tricalcium phosphate, 1 mm particle size) and 3% collagen. Recombinant 25 human BMP-2 (rhBMP-2) was prepared at a concentration of 3.0 mg/ml in a buffered solution. Each sponge was infused with 1.5 ml of the rhBMP-2 solution.

The sponges were placed in the paraspinal bed directly on top 30 of and bridging the two adjacent transverse processes. The sponges

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were placed bilaterally, with two sponges (one on top of the other) on each side of the spine, resulting in a total dose of 9 mg rhBMP-2 per implant site. The animals were allowed to recover and move around ad libitum without restrictions during the study period.

5 The spines were manually assessed for fusion upon sacrifice (2, 4 and 6 months) and determined to be fused based upon the absence of motion during attempted bending, and presence of histological bridging bone.

10 The fusions were also evaluated by CT scan at 2, 4 and 6 months after implantation. FIGS. 1 and 2 show the CT scans for each subject studied. FIGS. 1 and 2 demonstrate the sequence of events that occur within the composite sponge carrier loaded with rhBMP-2. On the far left of the figures are three CT sections equally spaced throughout the fusion mass at 2 months post-operative, 15 showing that resorption of the composite sponge is just about complete due to the lack of radiopacity of the ceramic granules. The three middle CT sections show these same three CT sections at four months with increased bone deposition where the carrier once resided. The composite sponge has maintained the space within 20 the soft tissue site for a sufficient enough period of time for the desired volume of new bone deposition to occur. Finally, the far right three CT scans show even further bone deposition, remodeling and maturation with the formation of outer cortices around the periphery of the fusion masses by six months.

The claims defining the invention are as follows:

1. An osteogenic sponge composition useful for the induction of new bone growth in a mammal, comprising:
 - 5 a resorbable sponge matrix material;
 - an osteogenic factor, said osteogenic factor incorporated in said sponge matrix material in an amount that causes an increased rate of resorption of said sponge matrix material in a mammal; and
 - 10 particulate mineral having an average particle diameter of at least about 0.5 mm embedded in said resorbable sponge matrix material, said particulate mineral present in a weight ratio of at least 4:1 relative to said resorbable sponge matrix material, so as to provide a scaffold for bone ingrowth in the presence of said osteogenic factor.
- 15 2. The osteogenic sponge composition of claim 1, wherein said particulate mineral is present in a weight ratio of at least about 10:1 relative to said resorbable sponge matrix material.
- 20 3. The osteogenic sponge composition of claim 1 or 2, wherein said osteogenic factor comprises a bone morphogenetic protein, a LIM mineralization protein, or a nucleotide sequence encoding a bone morphogenetic protein or a LIM mineralization protein.
- 25 4. The osteogenic sponge composition of claim 1 or 2, wherein said resorbable sponge matrix material includes collagen.
- 30 5. The osteogenic sponge composition of claim 3, wherein said resorbable sponge matrix material includes collagen.

6. The osteogenic sponge composition of any one of claims 1 to 5, wherein said particulate mineral is selected from the group consisting of bone particles and biocompatible synthetic calcium phosphate ceramics.

7. The osteogenic sponge composition of claim 6, wherein said particulate mineral comprises biphasic calcium phosphate.

8. The osteogenic sponge composition of claim 7, wherein said biphasic calcium phosphate has a porosity of at least about 50%.

9. The osteogenic sponge composition of claim 8, wherein said particulate mineral includes bone particles.

10. The osteogenic sponge composition of claim 9, wherein said bone particles are cortical bone particles.

11. The osteogenic sponge composition of any one of claims 1 to 10, which is comprised at least about 95% by weight of said particulate mineral.

12. The osteogenic sponge composition of any one of claims 1 to 11, wherein said particulate mineral has an average particle size in the range of about 0.5 mm to about 5.0 mm.

13. The osteogenic sponge composition of any one of claims 1 to 12, wherein said porous particulate mineral has an average particle size in the range of about 1 to about 2 mm.

20 14. The osteogenic sponge composition of any one of claims 1 to 13, wherein said osteogenic factor is a bone morphogenetic protein.

15. The osteogenic sponge composition of claim 14, wherein said bone morphogenetic protein is a recombinant human protein.

16. The osteogenic sponge composition of claim 15, wherein
5 said bone morphogenetic protein is BMP-2 or BMP-7.

17. The osteogenic sponge composition of claim 16, further comprising an osteogenic enhancing factor selected from the group consisting of autographic bone marrow, allographic bone marrow,
10 transforming growth factor- β , fibroblast growth factor, platelet-derived growth factor, insulin-like growth factor, microglobulin- β , and steroids.

18. An osteogenic sponge composition effective for the
15 induction of new bone growth in a primate, comprising:

a resorbable sponge matrix material;

20 an osteogenic factor that stimulates osteoblasts and osteoclasts, said osteogenic factor incorporated in said sponge matrix material in an amount that causes an increased rate of resorption of said sponge matrix material in the primate; and

25 particulate mineral having an average particle diameter of at least about 0.5 mm embedded in said resorbable sponge matrix material, said particulate mineral present in a weight ratio of at least 4:1 relative to said resorbable sponge matrix material, so as to provide a mineral scaffold for a duration sufficient for osteoid ingrowth through an area in which said sponge composition is implanted.

19. The sponge composition of claim 18 wherein the primate
30 is a human.

- 21 -

20. A method for inducing bone growth in a primate, comprising:

(a) providing an osteogenic sponge composition comprising:
5 a resorbable sponge matrix material;
an osteogenic factor that stimulates osteoblasts and osteoclasts, said osteogenic factor incorporated in said sponge matrix material in an amount that causes an increased rate of resorption of said sponge matrix material in the primate; and
10 particulate mineral having an average particle diameter of at least about 0.5 mm embedded in said resorbable sponge matrix material, said particulate mineral present in a weight ratio of at least 4:1 relative to said resorbable sponge matrix material, so as to provide a scaffold for bone ingrowth in the presence of said
15 osteogenic factor; and
20 (b) implanting said osteogenic sponge composition in an area in which bone growth is desired in the primate, said osteogenic sponge composition providing a scaffold for a duration sufficient for osteoid ingrowth through an area in which said osteogenic sponge composition is implanted.

21. The method of claim 20, wherein said particulate mineral is present in a weight ratio of at least 10:1 relative to said resorbable sponge matrix material.

25
22. The method of claim 21, wherein said osteogenic factor comprises a bone morphogenetic protein, a LIM mineralization protein, or a nucleotide sequence encoding a bone morphogenetic protein or LIM mineralization protein.

30

23. The method of claim 20 or 21, wherein said resorbable sponge matrix material includes collagen.

24. The method of claim 22, wherein said resorbable sponge matrix material includes collagen.

5 25. The method of any one of claims 20 to 24, wherein said particulate mineral is selected from the group consisting of bone, a synthetic biocompatible calcium phosphate ceramic, or a mixture thereof.

26. The method of claim 25, wherein said porous particulate mineral comprises biphasic calcium phosphate.

10 27. The method of claim 26, wherein said biphasic calcium phosphate has a porosity of at least about 50%.

28. The method of any one of claims 20 to 27, wherein said particulate mineral includes bone particles.

15 29. The method of claim 28, wherein said bone particles are cortical bone particles.

30. The method of any one of claims 20 to 29, wherein said osteoinductive sponge composition is comprised at least about 95% by weight of said particulate mineral.

20 31. The method of any one of claims 20 to 30, wherein said particulate mineral has an average particle size of about 0.5 mm to about 5.0 mm.

32. The method of any one of claims 20 to 31, wherein said porous particulate mineral has an average particle size of about 1 to about 2 mm.

33. The method of any one of claims 20 to 32, wherein said osteogenic factor is a bone morphogenetic protein.

25 34. The method of claim 33, wherein said bone morphogenetic protein is a recombinant human protein.

35. The method of claim 33, wherein said bone morphogenetic protein is BMP-2 or BMP-7.

36. The method of any one of claims 20 to 35, wherein the primate is a human.

30 37. The method of any one of claims 20 to 36, wherein the area is in the spine of said primate.

38. The method of claim 37, wherein the bone growth is induced to attain a spinal fusion.

39. The method of claim 38, wherein the spinal fusion is an interbody spinal fusion.

40. The method of claim 38, wherein the spinal fusion is a posterolateral spinal fusion.

41. The method of claim 38, wherein the spinal fusion includes a fusion between transverse processes of adjacent vertebrae.

5 42. An osteogenic sponge composition for the induction of new bone growth in a primate, comprising:

a carrier consisting essentially of a resorbable sponge matrix with particulate mineral embedded in said resorbable sponge matrix, said particulate mineral present in an amount constituting at least about 95% by weight of said carrier; and

10 an osteogenic factor.

43. A highly mineralized sponge implant device consisting essentially of a resorbable sponge matrix formed of collagen and having particulate biocompatible mineral embedded within said matrix, said device comprised 1% to 3% by weight of the collagen and 97% to 99% by weight of the particulate biocompatible mineral.

15 44. The device of claim 42 wherein the particulate mineral comprises bone particles.

45. The device of claim 42 wherein the particulate mineral includes a synthetic ceramic.

20 46. The device of claim 45 wherein the ceramic material includes a calcium phosphate ceramic.

47. The device of claim 46 wherein the calcium phosphate ceramic is biphasic calcium phosphate.

48. An osteogenic implant, comprising:

25 a resorbable matrix carrier comprised 1% to 3% by weight of collagen in sponge form and 97% to 99% by weight of a particulate biocompatible mineral embedded within said collagen; and

an osteogenic factor.

49. An interbody spinal fusion device, comprising:

a load bearing member sized for insertion between adjacent vertebrae; and

30 a composition according to any one of claims 1-19 and 42-48 retained by said load bearing member.

50. A method for interbody spinal fusion in a mammal, comprising implanting between adjacent vertebrae in the mammal an interbody spinal fusion device according to claim 49.

51. An osteogenic sponge composition, substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

52. A method for preparing an osteogenic sponge composition, said method substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

53. An osteogenic sponge composition prepared by the method of claim 52.

54. A method for inducing bone growth in a primate, said method substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

10 55. A highly mineralized sponge implant device, substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

15 56. A method for preparing a highly mineralized sponge implant device, said method substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

57. A highly mineralized sponge implant device prepared by the method of claim 56.

20 58. An osteogenic implant, substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

59. A method for preparing an osteogenic implant, said method substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

60. An osteogenic implant prepared by a method of claim 59.

25 61. An interbody spinal fusion device, substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

62. An interbody spinal fusion device, comprising:
a load bearing member sized for insertion between adjacent vertebrae; and
a composition according to any one of claims 51, 53, 55, 57, 58 or 60 retained by said load bearing member.

30 63. A method of preparing an interbody spinal fusion device, said method substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

64. An interbody spinal fusion device prepared by the method of claim 63.

65. A method for interbody spinal fusion in a mammal, said method substantially as hereinbefore described with reference to any one of the examples and/or any one of the accompanying drawings.

66. A method for interbody spinal fusion in a mammal comprising implanting between adjacent vertebrae in the mammal an interbody spinal fusion device according to claim 61, 62 or 64.

67. An osteogenic composition according to any one of claims 1 to 19, 42 to 48, 51, 53, 55, 57, 58, 60, 61, 62 or 64 when used for the induction of new bone growth in a mammal.

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Dated 3 September, 2003

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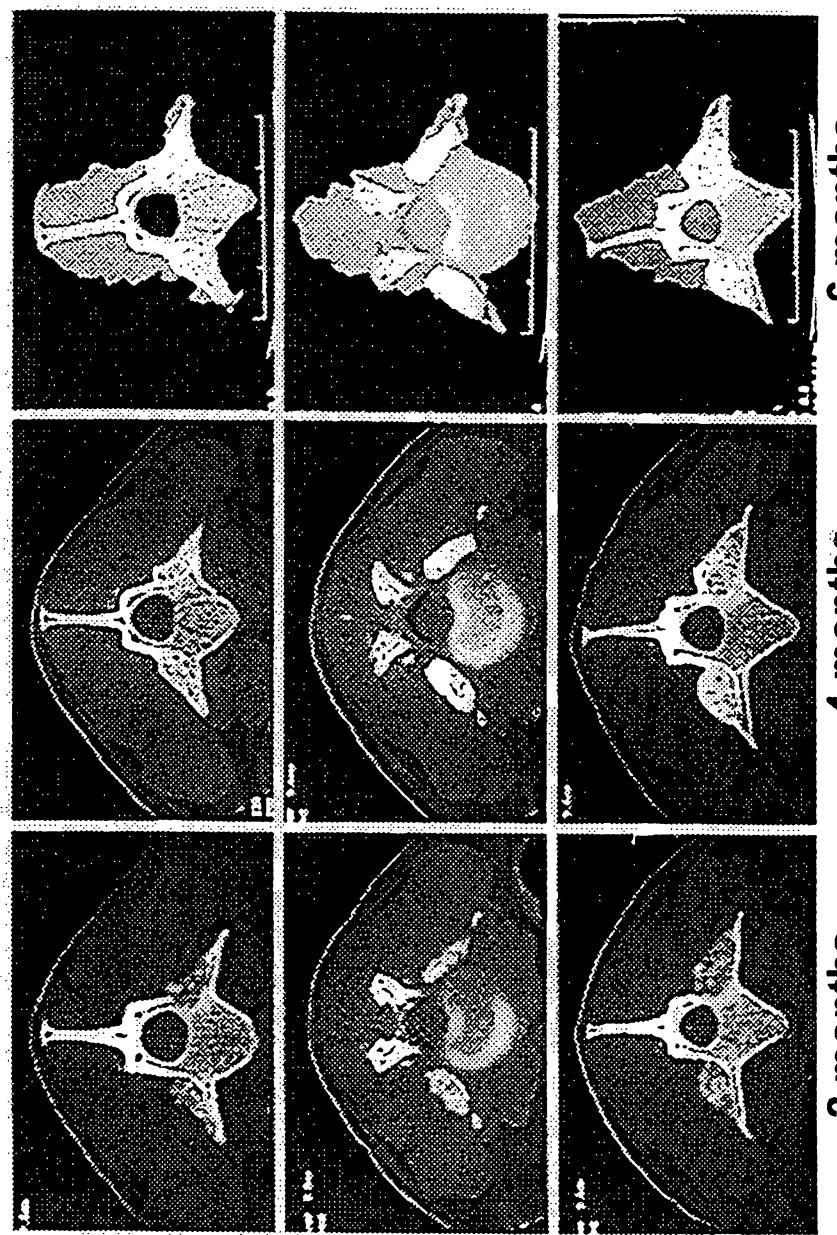


Fig. 1

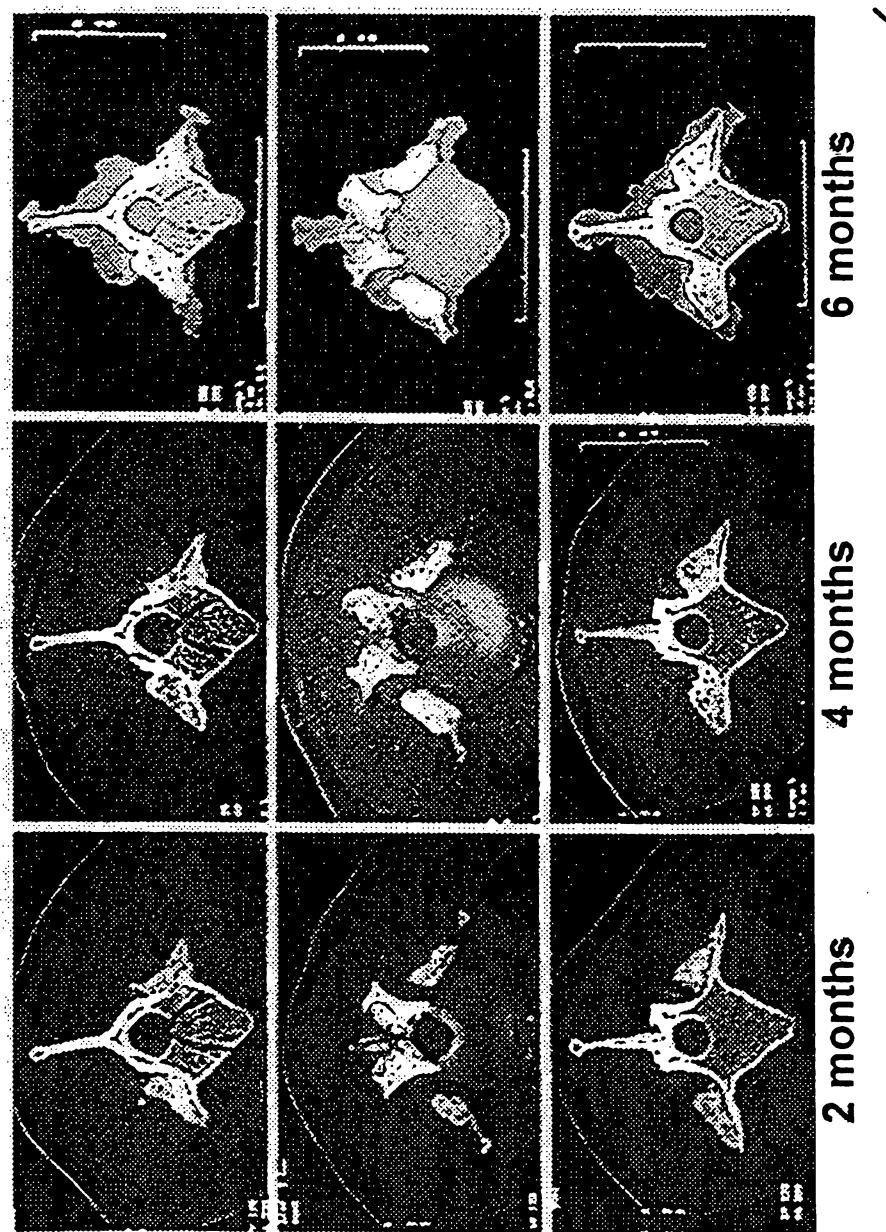


Fig. 2